AN AFRICAN REVERSE LOGISTICS MODEL FOR PLASTIC SOLID WASTES

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A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTORATE OF PHILOSOPIAE IN ENGINEERING MANAGEMENT IN THE FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT AT THE UNIVERSITY OF JOHANNESBURG

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DATE: 27 FEBRUARY, 2018

Declaration

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I hereby declare that *AN AFRICAN REVERSE LOGISTICS MODEL FOR PLASTIC SOLID WASTES is* as a result of my own personal effort and the sources utilized or quoted have been referenced and acknowledged.

This work is not being concurrently submitted for any degree and has never been accepted for any degree at any recognized educational institution.

Signed

Date: 27 February, 2018

Dedications

This thesis is dedicated to my mother **Rhoda Nyundo Chishimba**. Thank you for being there for me.

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Abstract

Plastic packaged products manufacture continues to increase as a result of the favorable properties possessed by plastic materials. This results in a proportional increase in the amount of Plastic Solid Wastes (PSWs) generated. The concept of Reverse Logistics (RL) is used to recover the PSWs for the purposes of recycling. Numerous studies on RL and recycling have been conducted in developed economies. In developing economies such as in Africa, few studies exist on RL and recycling. This research reveals the research gap and aims to examine the flow of recyclable post-consumer plastic packaged products with the intent of designing a levers' driven RL model for the Zambian context. The research objectives focus on; studying the current sustainable models used in developed economies for the recovery and recycling of PSWs, to examine the Solid Waste Management (SWM) system in Zambia paying special attention to PSWs management, to ascertain the major stakeholders in the recovery and recycling of PSWs. Consequently, to develop instruments for extracting data relating to significance and the levers. To develop a RL model for Zambia and test the influence of the explored levers. Finally, to recommend strategies that can optimize the recovery and recycling of PSWs from the stakeholders' perspective.

A pragmatic research approach is considered appropriate for this research. Based on this philosophical stance, concurrent mixed method strategy is conducted. Four types of stakeholders are considered relevant for this research; households, plastic manufacturing and recycling companies; Informal Waste Collectors (IWCs) and Formal Waste Collectors (FWCs). Three types of survey questionnaires are designed and a set of structured interview questions are drawn. A total of 445 questionnaires are distributed to the households, 60 questionnaires to the IWCs and 30 questionnaires to the plastic manufacturing and recycling companies. 20 interviews are considered for the case study. Concurrent triangulation is used to merge the quantitative and qualitative research findings. Descriptive statistics, Factor Analysis (FA) and inference statistics are drawn and used in analyzing the data

Literature review, questionnaire surveys and interviews reveal that, application of RL for the recovery of PSWs for recycling purposes is still at its infancy in Zambia. The flow of PSWs shows that, the 3Rs concept is applied as well as unsustainable disposal methods (burying or burning). Illegal and legal disposal of PSWs exist. The results reveal that 80.2% of the households do not participate in PSWs recovery and recycling programs while 45.5% of the plastic manufacturing and recycling companies recycle PSWs. Majority of PSWs recoveries involve the IWCs and 43% are dump-sites pickers.

The research outlines the key levers and stakeholders to consider when designing and implementing RL for PSWs in Zambia as well as other countries of similar context. Strategies for developing and implementing sustainable recovery and recycling systems for PSWs are provided to the waste convertors, the community, government, policy makers and other parties across the entire supply-chain. Finally, an optimization RL model driven by levers that influence the stakeholders to participate in the recovery and recycling programs is proposed for the plastic manufacturing and recycling industries for practice and implementation. The proposed RL is validated by using scenario analysis and the 'standard deviation plus 1' scenario is found to recover and recycle the highest amount of PSWs.

Key Words: African, Assessment, Levers, Plastic Solid Wastes, Reverse Logistics, Recycling, Sustainability, Waste Management

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Glossary of Terms

Buy-Back Recycling Centers: Establishments where participants can deliver materials/recyclables in return for a cash payment

Developing Economies: Consists of countries in which citizens have a lower standard of living and few developed industries than other countries.

Deposit System (Returnable Container Legislation): Any law that requires collection of a monetary deposit on beverages and/or other reusable packaging at the point of sale.

Drivers: Mechanisms that significantly influence development in solid waste management.

Drop-off Collection System: A collection system that requires residents to deliver recyclable materials to a designated depositing point

Dumpsite Pickers: Involves waste pickers who recover useful materials prior to it being covered at the landfill/dumpsite whenever trucks full of solid wastes arrives at the open dump/landfill.

Extended Producer Responsibility System: A system that imposes a certain quota for recycling wastes from packaging materials or products on the manufacturer of the products or the manufacturer of products that use the packaging materials.

Household Waste Collectors: Involves individuals or groups moving from door to door collecting recyclable or reusable wastes (from households, institutions or functions etc.)

Informal Waste Collectors: consists of waste pickers such as dump-site picks, household waste collectors, itinerant waste pickers, street pickers and intermediate dealers.

Itinerant Waste Buyers: Involves individuals or groups that move from door to door of households, institutions and commercial centers collecting, trading or purchasing recyclable materials that people consider invaluable.

Kerbside Collection System: A waste collection service provided to urban and suburban households by the municipality or private waste collectors.

Levers: Ideas or actions used to influence people to do what you want them to do.

Middlemen (Intermediate Dealers): Constitutes of primary and secondary dealers, recycling SMEs, junk shops, intermediate processors, brokers and wholesalers.

Model: An example of something planned for implementation.

Municipal Solid Wastes: waste generated from different parts of a society for example commercial institutions, public places, households, health and educational institutions etc.

Post-Consumer Plastic Solid Wastes: End-of-life or end-of-use packaging plastic wastes originating from all fields of applications.

Recovery: Involves processes of recapturing materials considered waste for the purposes of reuse, recycling, composting and/or incineration.

Reverse Logistics: Operations that involve movement of products or end-of-life products from final destinations in order to recapture value or ensure proper disposal.

Recycling: Involves recapturing and processing materials considered waste by turning them into useful new products.

Solid Waste: Any discarded solid material or item unwanted by the owner or not fit for a process.

Solid Waste Management: Processes involving collection and treatment of solid wastes.

Street Waste Pickers: Involves individuals or groups that gather secondary raw materials from mixed wastes in the garbage bins, drains, markets and transfer stations all over the urban areas.

Sustainability: Focuses on resource management to ensure quality future generation resource availability.

Sustainable Development: An organizing principle for achieving human development goals.

Sustainable Solid Waste Management: An approach that aims to address long term pressures through the recovery, recycling and reuse of resources and minimization of wastes streams.

Waste: Any material, solid, liquid or gas that is unvalued and/or unwanted and discarded or discharged by its owner.

Zambia: This is a democratic republic country consisting of 10 provinces in southern Africa. It is considered a developing economy.

List of Acronyms

ANOVA – Analysis of Variance

CLM – Council of Logistics Management

CWG - Collaborative Working Group on Solid Waste Management in Low and Middle-Income Countries

EAPs – Environmental Action Plans

EC - European Commission

ECZ - Environmental Council of Zambia

EM – Engineering Management

EoU – End-of-Use

EoL – End-of Life

EPR- Extended Producer Responsibility

FA – Factor Analysis

FWCs – Formal Waste Collectors

GTZ - German Technical Cooperation

ISWM - Integrated Solid Waste Management

IWB - Itinerant Waste Buyers

IWCs - Informal Waste Collectors

IWS - Informal Waste Sector

MILP- Mixed Integer Linear Programming

MSWs- Municipal Solid Wastes

MSWM- Municipal Solid Waste Management

NAPOR- National Association for PET Container Resources

OECD – Organization for Economic Co-operation and Development

PACRA- Patent and Company Registration Association

PE - Polyethylene

PET- Polyethylene Terephthalate (PET)

PP - Polypropylene (PP)

PPW- Package and Package Waste

PS - Polystyrene

PSWs- Plastic Solid Wastes

PVC - Polyvinyl chloride

RCRA – Resource Conservation and Recovery Act

RL - Reverse Logistics

STATKON – Statistical Consultation Services

SW- Solid Waste

SWM- Solid Waste Management

SSWM- Sustainable Solid Waste Management

WM- Waste Management

WMH - Waste Management Hierarchy

WMU – Waste Management Unit

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Chapter One: Introductory Chapter

1. Introduction

Since the first industrial scale production, plastic waste consumption, production and generation has continued to increase (Al-Salem et al., 2009). The increase is as a result of the multi- purposes for which plastics are used. Plastics are used in applications such as packaging, covers, containers, wiring and coating and films. Hopewell et al (2009) affirms that, approximately 50% are used for disposable single-use applications such as packaging while 20-25% are for long term infrastructure. The substantial properties possessed by plastics has attributed to multi applications (Thompson et al., 2009a; Andrady and Neal 2009). Consequently, it is not surprising to find, a reasonable constitute of Plastic Solid Wastes (PSWs) in Municipal Solid Wastes (MSWs) final waste stream.

In developing economies, the rapid increase in population, urbanization and economic development means the rate at which PSWs is being generated is alarmingly increasing in rates (Okot-Okumu and Nyenje, 2011). This implies, authorities charged with the responsibility of managing waste are facing a number of challenges and this places excessive pressure on the authorities to provide efficient and effective services (Imam et al., 2008; Zhen-shan et al., 2009). Further these challenges are attributed by the complexity of the systems and lack of resource organization (Zhang et al., 2010; Al-Khatib et al., 2010). A lack of organized systems such as Reverse Logistics (RL) has contributed to the challenges of managing PSWs. According to Coelho et al (2011), in Brazil the acceptability of recycled PET products has not prevented the shortage of this end-of-life product by most industries, the damaged reverse supply has prevented.

In Zambia, like most developing economies, there exist no structured plans to solve PSWs management challenges. A number of discussions have been held on how to manage PSWs in the country but the challenges continues. The poor management of PSWs contributes to a number of health and sanitation related problems in the country. The Daily Monitor News (2014) indicates that, Zambia should develop a sustainable and holistic Solid Waste Management (SWM) system, which should dispose of garbage efficiently. For PSWs, the major challenge is on the recovery of this waste type for reuse and recycling purposes.

This chapter presents the following; background of the research, research problem, research aim and objectives, model objectives, research questions, research scope, justification of the research and structure of the thesis

1.1 Background of the Research

SWM has evolved into a significant area of research that combines social, technical, environmental and economic issues. Technical and economic problems emerge as urban development continues to raise resulting in increased population and consequentially declining suitable disposal sites. Environmental and social issues have emerged as the generated waste contaminate ground water, strain the environment and release methane from landfills resulting in a number of concerns from people on risks associated with inhabiting lands near waste facilities.

Several human activities generate waste and the way it is stored, handled, collected and disposed of poses risks to public health and the environment (Zhul et al., 2008). Unscientific disposal of waste causes adverse impacts on human health and all environmental components (Jha et al., 2003; Rathi, 2006). In many developing economies, serious public health issues are caused by uncollected Solid Waste (SW) which directly effects child health and indirectly affect by blocking drains.

In most developing economies, increased economic developments contributes to better income levels for several individuals in urban areas and this has resulted in higher purchasing power (Kinobe et al., 2015). Rapid urbanization and population growth in developing economies has changed life styles by increasing the per capita generation of MSWs (Agdag, 2008; Suocheng et al., 2001). Currently in developing economies, the per capita waste generation is estimated around 0.3 to 0.6 kg/day (Ojok et al., 2013). Worldwide, the total annual SW generation is approximately 17 billion tons and by 2050 is expected to reach 27 billion (Karak et al., 2012). Further, 2.2 billion tons of MSW generation is anticipated by 2025 from low and medium income economies (Hoornweg and Bhada-Tata, 2012). These anticipated increases in MSW have not come with projected solutions as most organizations charged with the responsibility of managing SW are facing challenges. The local authorities and the government in many developing economies are responsible for managing SW systems from collection to final processing but many of these organizations are facing challenges and failing to provide a good service (Kassim and Ali, 2006). Al-Khatib et al (2010) affirms that, a number of Sub-Saharan African economies have no technical expertise required for managing SW and usually on many municipal strategic plans it is not included. These SWM obstacles contribute to lack of systematic and strategic approaches resulting in less attention paid to the management and recovery of SW including PSWs.

PSWs recovery is a challenge in developing economies because a number of RL systems in developing economies consist of informal recoveries which lack organized and structured systems (Kinobe et al., 2015). Majority of PSWs recovery is performed by the informal sector with less skill and capacities (Wilson et al., 2009; Hoornweg and Bhada-Tata, 2012). The Informal Waste Collectors (IWCs) are not organized and depend on recyclables collected from trucks delivering waste to landfills or from temporary garbage dumpsites (Matter et al., 2012).

1.2 Research Problem

In most developing economies such as Zambia, PSWs recovery and recycling challenges have not been resolved. This is because most of the burdens of managing PSWs and other wastes is entirely perceived the local authorities' responsibility. Local authorities have a number of challenges that prevent placing WM as a top priority. From an Engineering Management (EM) perspective; lack of structured and holistic RL systems for recovering and recycling PSWs designed in the context of developing economies have contributed to PSWs management challenges. Holistic RL systems that address the factors that influence stakeholders to participate in recovery and recycling programs are not considered in most developing economies. Nevertheless, numerous studies on RL and recycling have been conducted (Simpson et al, 2012; Kurdve et al., 2012; Song et al., 2015; Ohnishi et al., 2012; Ding et al., 2013; Demiral et al., 2016; Murakami et al., 2015; Ravi, 2012; Long and Poon, 2012; Blengini et al., 2012; Binnemans et al., 2013). None of the above studies were conducted in the African context. Few of the studies above paid attention to the RL of PSWs. Other studies have focused attention on RL and cost or profit optimization (Demirel et al., 2014; Alumur et al., 2012; Dat et al., 2012; Zarei et al., 2010; Mahapatra et al., 2013). Some studies have focused attention on the application of conflicting objectives in RL network management and design (Chiang et al., 2014; Lee et al., 2013; Pishvaee et al., 2010.; Yu et al., 2015; Pati et al., 2008; Ferri et al., 2015; Zhang et al., 2011). Formulation and application of uncertain input parameters to RL network design has been studied (El-Sayed et al., 2010; Salema et al., 2007; Roghanian and Pazhoheshfar., 2014; Ramezani et al., 2013; Keyvanshokooh et al., 2013). There are no studies that have focused attention on modeling the factors that influence stakeholders to recover and recycle PSWs in RL models for optimization purposes. Most studies have focused attention on factors that influence stakeholders to participate in recovery and recycling programs (Kishino, 1999; Scott, 1999; Owens et al, 2000; Hangu et al, 2000; Domina and Koch, 2002; Isa et al., 2005; Smallbone, 2005; Vicente and Reis, 2008; Omran et al., 2009; Sidique et al., 2009; Troschinetz and Mihelcic, 2009; Sidique et al., 2010b; Dahlen and Lagerkust, 2010; Larsen et al., 2010; Singhirunnusorn et al., 2011; Hotta and Aoki-Suzuki, 2014; Xevgenos et al., 2015; Wang and Yin, 2016, Afroz et al., 2017).

According to the Africa review report on WM (2009), conducted on four countries; Zambia, Kenya, Ghana and Egypt, it was concluded that, there is need to develop WM systems and promote recycling and reusing of waste. It was further recommended that, improving efficiency of recovery and recycling of recyclable materials is dependent on further organizing and formalizing the recycling and WM sectors.

Most developing economies face the challenges of waste collection and this has contributed to lack of sustainable optimal recoveries of valuable resources such as PSWs. According to the World Bank (2012), MSW collection rates are less than 45%. Figure 1.1 depicts the collection rates and composition by region for MSWs for 2012. This shows that more than 50% of MSWs is uncollected for recovery and disposal purposes. Focusing on MSWs composition by region, in Africa 13% of MSWs consists of PSWs and it’s the second largest composition of MSWs. This implies, more than 50% of the second largest generated waste type of MSWs is uncollected.

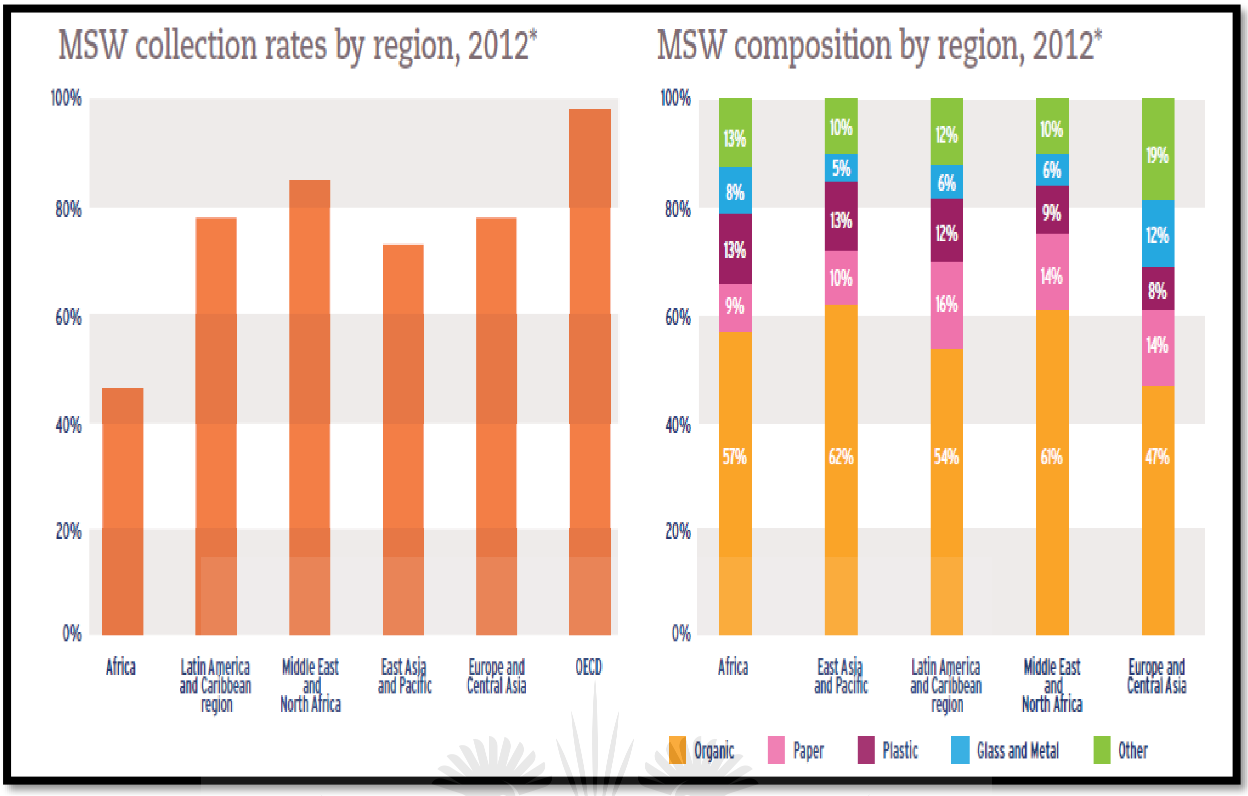


FIG 1.1: MSW COLLECTION RATES AND COMPOSITION BY REGION FOR 2012
(SOURCE: THE WORLD BANK, 2012)

Figure 1.2 below, depicts the MSW disposal by region for 2012 (The World Bank, 2012) and MSW recovery by region for 2007 (GTZ/CWG, 2007). In Africa 47% of MSW generated is openly dumped and only 4% of this waste is recycled. This implies PSWs recovery and recycling is still a crucial problem that requires an urgent sustainable solution. For example, in Lusaka, Zambia, 91% of MSWs is unrecovered with only 3% is recovered by the informal sector and 6% recovered by the formal sector (Figure 1.2). Conclusively, this shows that, the non-existence of adequate waste collection systems in most African countries and Zambia as a whole is only a portion of the barriers to sustainable recovery and recycling of PSWs.

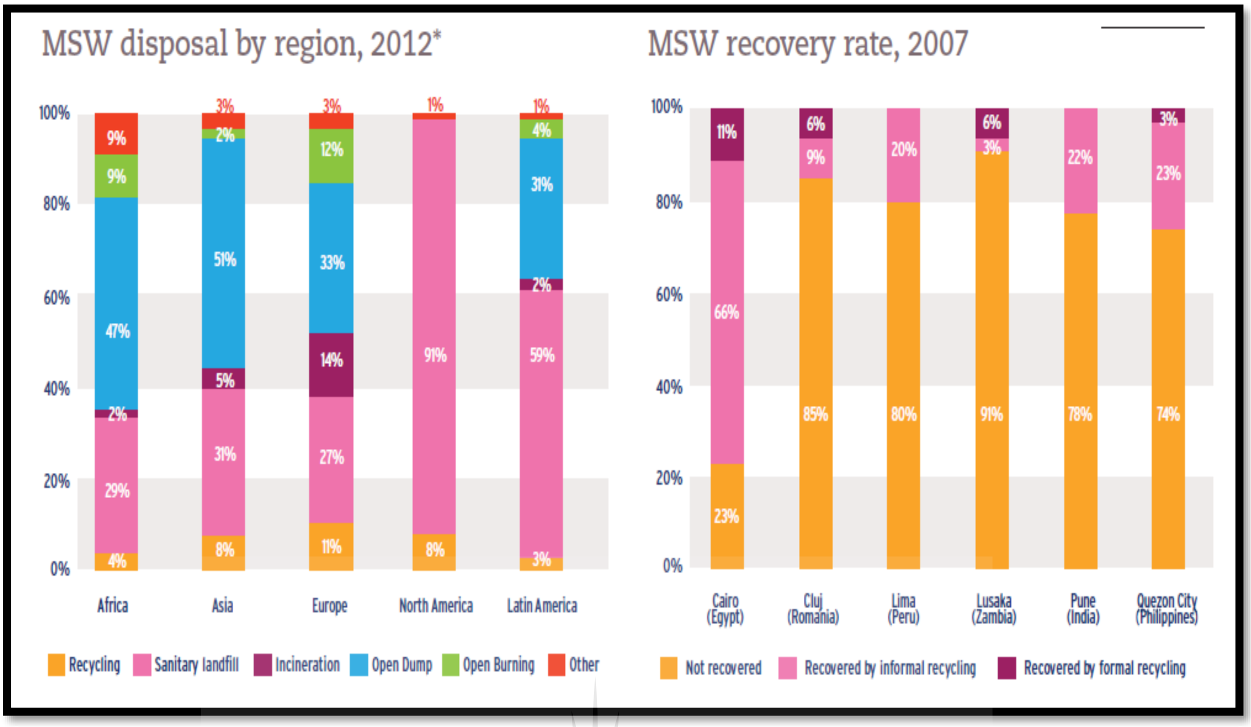


FIG 1.2: MSW DISPOSAL AND RECOVERY BY REGION
(SOURCE: THE WORK BANK, 2012; CTZ/CWG; 2007)

Although there are no significant records on the level of recovery and collection services for PSWs in most developing urban areas in Zambia, it is evident that most of these collection services provided are not effective. Lack of a RL recovery system for PSWs, lack of information on recycling, lack of recycling facilities, lack of complacency by companies on Extended Producer Responsibility (EPR) legislations, Lack of adequate technology for transforming wastes, financial constraints of the municipalities to tackle waste related problems, lack of involvement of the relevant stakeholders in WM issues and lack of understanding the factors that influence stakeholders to participate in WM and recovery programs. The lack of recovery and recycling systems for PSWs has resulted in most of these wastes been disposed of at dump-sites, were recovery is little or unlikely to happen for these valuable resources. Figure 1.3 depicts different types of PSWs disposed of at Buchi dump-site in Kitwe, Zambia. Even though the recovery and recycling of PSWs is conducted by some plastic manufacturing and recycling companies, Formal Waste Collectors (FWCs) and the IWCs, the recovery rates are slightly variable throughout the country. There is need to establish a sustainable recovery and recycling system for PSWs using RL approaches for the towns and cities of Zambia.

FIG 1.3: PILES OF UNRECOVERED PSWS AT BUCHI DUMP-SITE IN KITWE, ZAMBIA [CAPTURED ON 6 JANUARY, 2016]

1.3 Research Aim and Objectives

1.3.1 Research Aim

This research is aimed at examining the process flow of recyclable post-consumer PSWs with the intent of designing a RL model driven by levers and stakeholders that influence optimal sustainable recovery for recycling purposes.

1.3.2 Research Objectives

- To study the current sustainable models used in developed economies for the recovery and recycling of PSWs.
- To examine the existing SWM system in Zambia paying attention to PSWs management.
- To ascertain the major stakeholders in the recovery and recycling of PSWs.
- To develop instruments for extracting data relating to significance and levers
- To develop a RL model for Zambia and test the influence of the explored levers
- To recommend strategies that can optimize the recovery and recycling of PSWs from the stakeholders' perspective.

Model Objectives

- To design and model a RL model based on the levers and stakeholders that influence PSWs recovery and recycling for the Zambian context.
- To formulate levers based mathematic equations for modelling the RL model in order to optimize PSWs recovery and recycling.
- Using the scenario approach, analyse the amount of PSWs that can be recovered and recycled.
- To ascertain the most significant scenario for optimizing PSWs recovery and recycling for the entire RL chain.

1.4 Research Questions and Scope

1.4.1 Research Questions

- What has been studied so far in literature on sustainable models for recovering and recycling PSWs in the world?
- What is the current status of PSWs recovery and recycling in Zambia?
- What are the levers influencing PSWs recovery and recycling in the world?
- Who are the critical stakeholders in the recovery and recycling of PSWs?
- What drives the application of RL?
- What are the barriers preventing sustainable application of RL systems for PSWs recovery and recycling from the stakeholders' perspective?
- How can the critical stakeholders to the recovery and recycling of PSWs be integrated in the RL model?

1.4.2 Research Scope

This research is mainly concerned with the assessment of the process flow of recyclable post-consumer PSWs in the Zambian context for the purposes of designing a RL model.

1.5 Research Justification

This research is expected to contribute to the body of knowledge, theory and practice in various ways. The findings of the study enable policy makers and the stakeholders make sustainable decisions towards the management of PSWs that benefit the communities and the environment as well as the plastic manufacturing and recycling companies in terms of resource utilization. The research raises awareness on PSWs recycling in the communities thus activating initiatives of different stakeholders. This research is relevant to the nation as well as to international agencies with strong financial and technical background as it highlights the levers and strategies necessary in the Zambian context to recover and recycle PSWs. The RL recovery and recycling model designed integrates the critical stakeholders in WM and recovery processes. This integration paves the way for sustainable utilization and management of PSWs. The research highlights the important and critical stakeholders in the recovery of PSWs as well as the levers necessary for integration.

The RL model facilitates the adoption of the system in different areas of the country, Zambia as well as other developing countries as long as the levers influencing the recovery of PSWs are identified at community and household level. Further, the information in the dissertation contributes to the body of knowledge by availing the critical drivers and constraints on PSWs recovery and recycling from the Zambian perspective.

The EM approaches used in this dissertation enable plastic manufacturing and recycling companies' benchmark their plastic recycling technologies with those used in developed nations thus enabling them to understand that different technologies exist. Further, the levers necessary for the recovery of PSWs from the environmental and legislations concerns, market-share, economic, technological, social aspects enable plastic manufacturing and recycling companies understand and sustainably consider the recovery and recycling of PSWs. The RL approach used in the dissertation not only considers the aspect of cost, price, value addition, distance, quantity and quality, but it identifies and highlights the critical waste collection systems preferred by the stakeholders in the recovery and recycling of PSWs thus enabling the development of a sustainable recovery and recycling system for PSWs in the context of Zambia.

1.6 Thesis Outline

The thesis consists of seven chapters and the outline is depicted in Figure 1.4.

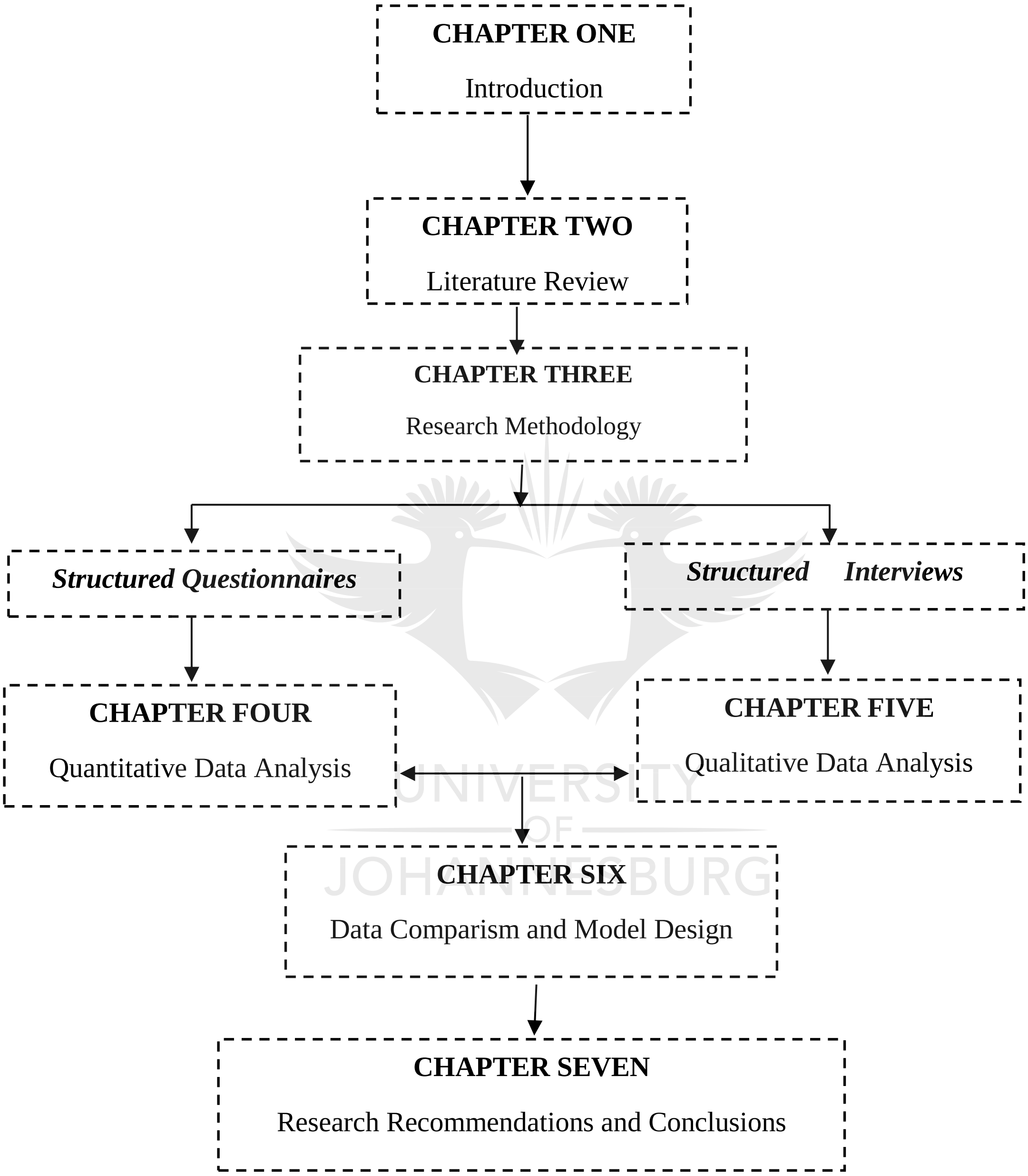


FIG 1.4: THESIS OUTLINE

Chapter Two: Literature Review

2. Introduction

This chapter focuses on reviewing literature that is aimed at answering the research questions. The literature review is analyzed for the purpose of extracting data relevant to the research questions and the proposed model objectives.

2.1 Historical Origins of Solid Waste Management

From the origin of mankind, humans have been mass producing SW since the formation of non-nomadic societies around 10,000 BC (Worrell and Vesilind, 2012). From the middle ages, city streets were covered with foul smelling mud-composed of soil, household waste, human and animal excrement and stagnant water. Efforts were made over the centuries to keep the streets clear of obstruction and disgusting smell (Wilson, 2007). In due course, small communities managed to bury SW just outside their settlements or dispose of it in nearby rivers or water bodies, but as population densities increased, these practices no longer prevented the spread of foul odors or disease (Seadon, 2006). As the communities kept growing, waste accumulated in these communities, people simply lived amongst the filth. According to Girling (2005), in England at around 1000-1800 BC, 'rakers' were periodically employed to remove waste from the streets and anything saleable was removed. The residue was either sold to farmers for use as compost or dumped and this did not last long as the rich refused to pay for waste collection while the poor were more concern with were their next meal would come from. In Mahenjo-Daro in the Indus Valley by 2000 BC (Worrell and Vesilind, 2012); the Greeks had both issued a decree banning waste disposal in the streets and organized the Western World's first acknowledged 'municipal dumps' by 500 BC (Melosi, 1981).

According to Shekdar (2008) SWM techniques aim to simply eliminate waste from the vicinity of habitable areas as a means of maintaining public health. After realizing the hazards of uncontrolled disposal, measures were devised and implemented mainly through sanitary landfilling. Over the years, SWM has moved from the initial concept of eliminating waste from the vicinity of habitat to sustainable resource utilization. A number of concepts aimed at managing SW have been developed. For instance, the Waste Management (WM) hierarchy in Figure 2.1 depicts the different options for managing SW. Waste prevention is the most favorable option in the hierarchy and some studies affirm it as the way forward towards WM (Matete and Trois, 2008; Ngoc and Schnitzer, 2009). In this regard, Bartl (2012) highlights that, putting waste prevention on top of the waste management hierarchy counteracts with the interest of the producers and retailers. While this may be true, reuse and recycling are the next favorable options for managing SW while landfilling is the least favorable option.

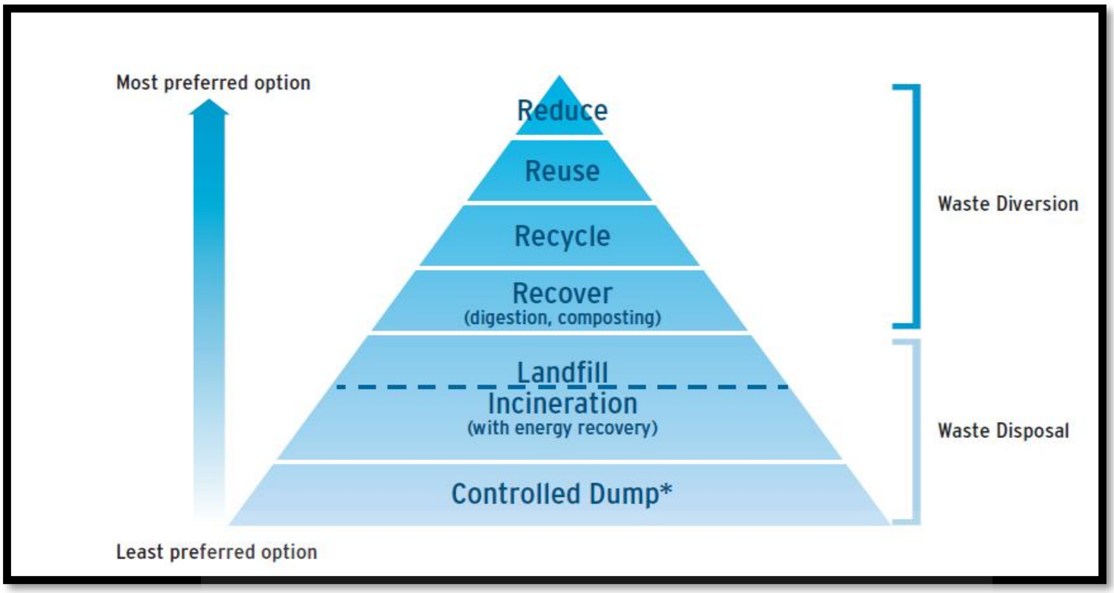


FIG 2.1: WASTE MANAGEMENT HIERARCHY
(SOURCE: HOORNWEG AND BHADA-TATA, 2012)

2.2 Global Significance

SWM has not received considerable priority attention although it is one of the most important functions of a city government. Public health and the external image of a city depend on this utility service (Wilson et al, 2015). A number of system elements in the management of SW encounter a lot of challenges. In developing economies, uncollected SW is an everyday sight to everyone. It is still a serious public health issue in many developing economies and contributes to blocked drains which cause the spread of water-borne diseases and widespread flooding (Wilson et al, 2013c). Nevertheless, waste collection is not the only system element that needs attention in developing economies. Waste prevention, separation, treatment, resource recovery and disposal are all in need of urgent attention. A lack in the management of these system elements contributes to poor management of SW in most developing economies and this result in a number of problems. According to Mor et al (2006), poor management of SW results in serious urban, sanitary and environmental problems such as unpleasant odour and a risk of explosion in landfill areas as well as groundwater contamination because of leachate percolation. To ensure better human health and safety, there is need for effective SWM systems which are both environmentally and economically sustainable (Sexena et al, 2009).

Rapid urbanization, population growth and changes in lifestyle of most developing economies contributes to the continuous increase in the per capita MSW generation (Adag, 2008; Suocheng et al, 2001). The evidence of such changes is the illegally disposed of waste or the uncollected waste on the streets. Such evidence is an indication that authorities charged with WM responsibilities are facing challenges and the waste generators' attitudes towards waste is extremely bad. Even though the per capita waste generation rates for developing economies are lower than that for developed economies, the capacity of responsibilities local authorities face to manage SW from collection to recycling or reuse and disposal is limited (Barton et al, 2007). Kassim and Ali (2006) affirm that, government and local authorities in most metropolitan areas of developing economies are responsible for managing SW systems from the initial point of collection to final processing, but most organizations fail to provide good service, due to several reasons.

A study was conducted by Manaf et al (2009) on the practices and challenges in MSW management. The study highlights the following challenges in SWM in Malaysia; Lack of skilled manpower, irregular collection services, and inadequate equipment used for waste collection, inadequate legal provisions, resource constraints and rapid economic growth and changes in life styles. Further the author points out that, although the primary concern for suitable WM is waste minimization and recovery, production processes are never completely a 'closed loop'. Similar challenges are highlighted in studies conducted by (Reinhart et al, 2016; Arbulú et al., 2016; Sharma et al., 2013; Pattnaik and Reddy, 2010; Khalil and Khan, 2009, Agdag, 2009; Damghani et al., 2008; Henry et al, 2006)

It is important to note that, identification of the main challenges facing many local authorities in waste management doesn't just end there. It is important to develop sustainable solutions such as closing the loop between production processes and resource recovery as highlighted by Manaf et al (2009). Similarly, Wilson et al (2006) highlights on the need to 'close the loop', that is moving away from the traditional 'end-of-pipe' concept of 'WM' to a more holistic concept of 'resource management.'

Globally, the rate of SW generation is continually increasing. According to Karak et al (2012), the annual total SW generation is approximately 17 billion tons and is expected to reach 27 billion by 2050. Hoornweg and Bhada-Tata (2012) indicate that, 13 billion tons of MSWs are generated by the world cities and it is anticipated that, 2.2 billion tons will be generated by 2025. This is primarily due to population growth, increasing urbanization and socio-economic development of the low and medium income economies. Similar factors contributing to the rate of SW generation in developing economies are identified by Minghua et al (2009). This implies that, as the factors contributing to SW generation continue to change and increase a proportional increase to the rate of SW generation occurs.

SW in particular MSWs is a composition of different types of waste categories. PSWs are a composite of MSWs and this waste type continues to increase as a result of its favorable properties. In developing economies, PSWs constitutes 8-11% of MSWs composition and this is anticipated to increase to 13% by 2025 (Hoornweg and Bhada-Tata, 2012). With the various challenges facing the SWM sector of developing economies, management of PSWs is one of them. Andrady (1994) asserts that, most types of plastics are non-biodegradable and substantial quantities of end-of-life plastics continue to accumulate in landfills and as debris in the natural environment resulting in WM issues and environmental damage (Barnes et al, 2009; Ryan et al 2009; Oehlmann et al 2009). Other challenges such as serious environmental littering problems connected to PSWs littering and illegal landfill or incineration continue as thousands of years are needed for plastics to be biodegraded (Papong et al., 2014; Badia et al., 2012; Nampoothiri et al., 2010). For these and other negative impacts associated with PSWs, it is necessary and important to develop sustainable engineering and scientific oriented systems for managing this waste types in developing economies. The systems should be designed adopting solutions oriented at maximizing the three aspects of sustainability (. i.e. economic, environmental and social).

PSWs management is now a pressing concern for industrial societies because of huge plastic products productions attributed to economic growth, lifestyle and technological changes. Plastics are human- made materials manufactured from polymers and have grown in demand over the past years. These plastics are derived from oil, natural gas and some plants. In order to manufacture these plastics, about 4% of the world's petroleum is used to make them while another 4% is used to power its manufacturing process (British Plastics Federation 2008). The production of plastics has grown to average about 8.7% from 1950 to 2012, booming to 1.7 million tons to nearly 300 million tons by 2015 (Plastics Europe, 2015). The growth in plastic production continues as plastics continue to replace other materials. In the packaging industry, most paper packaging has been replaced by plastic packaging (Plastics Europe, 2015). Worldwide, by 2009, plastic packaging accounted for 30% of packaging sales. Figure 2.2 depicts world production of plastic materials according to region (Plastic Europe, 2015). According to Figure 2.2, 7.3% of plastic production is from the Middle East and Africa. Even though these regions represent the least in plastic production, the growth in the use of plastics continues and unfortunately only 4% of MSWs including plastics is recycled in Africa (World Bank, 2012).

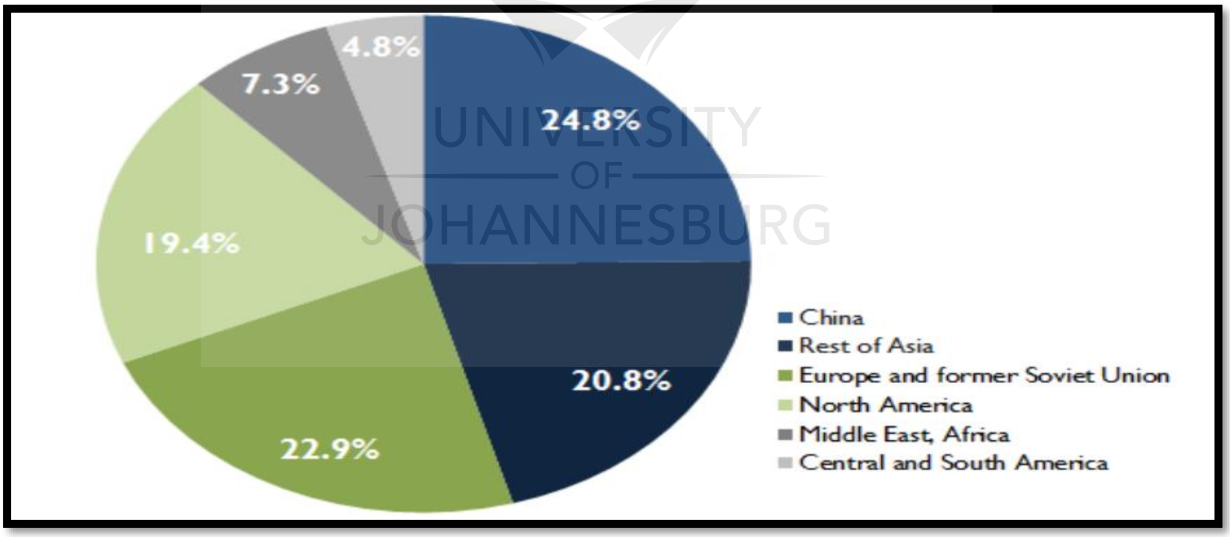


FIG 2.2: WORLD PRODUCTION OF PLASTIC MATERIALS BY REGION 2013
(SOURCE: WORLDWATCH INSTITUTE, 2015)

The recycling rate of 4% of MSWs indicates that, useful resources are underutilized. Additionally, only 22 and 43% of plastic worldwide is disposed of in landfills (UNEP, 2015). According to the United Nations Environment Programme (2015), approximately 57% of plastic in Africa is not collected instead its littered or burned in the open. Recovering plastics for recycling or energy purposes has the potential to minimize negative effects on the environment.

As the economies and populations continue to grow, it is expected that the demand for plastic continues to grow in Africa, Middle East, Latin America and China (WorldWatch Institute, 2015). This implies sustainable ways of managing PSWs for the purposes of reducing environmental effects as well as recapturing the valuable resource in the supply-chain should be implemented effectively. In countries such as Germany, Sweden, Norway and the Netherlands, landfill bans have been enacted for plastics even though these countries have the highest recycling rates compared to countries without landfill bans.

In developing economies, the call for PSWs solutions is greater as the means of managing it have not been seriously tabled out. Even though policies and regulations exist in developing economies, enforcement is the biggest challenge. The existence of the challenges in the WM arena of developing economies does not mean solutions are inevitable. One of the ways of solving the PSWs problem is environmentally and socially weighing the benefits of plastics against the problems they pose. A sustainable approach that considers the environmental, economic and social aspects of managing PSWs should be considered. According to Hopewell et al (2009), recycling is one approach for end-of-life plastic products and recent trends economically and environmentally show an increase in the rate of recovery and recycling of PSWs in developing economies. The increase in the rate of recovery and recycling in developing economies is a sign that such a sustainable approach of plastic recycling is achievable. Nevertheless, challenges such as technological factors and social behavior relating to the collection of recyclable PSWs to substitute for virgin material still exist in both developing and developed economies (Hopewell et al, 2009). To achieve sustainable solutions in PSWs management, EM approaches should be considered during the development and implementation of recovery and recycling strategies.

2.3 Plastic Solid Waste Management in Developed Economies

In this research, developed economies are countries with high development levels based on Human Development Index (HDI), industrialization and economic characteristics. A high level of environmental issues and resource depletion problems are dealt with in developed economies due to high economic development levels.

PSWs, especially from packaging materials and thin-film plastic bags, have become a major problem for MSWs management (Shekdar, 2009). The rise in the production of packaging products from plastic materials contributes to the increase in the amount of PSWs. In developed economies a number of strategies and plans have been developed to tackle this problem. For example, in European member states, challenges of managing packaging waste are emphasized as a result of escalating tipping fees, environment impacts of most packaging materials and the possibility of recovering these wastes as resources (Cruz et al, 2014). As a result of these packaging waste associated problems, a Directive 94/62/EC on packaging and packaging waste (PPW) was published in the European member states. Prior to the publication of the PPW Directive, a number of these states had invested in their recycling systems such as selective collection and sorting equipment and material recovery facilities (MRFs). Other than the technological advancement of the WM systems of the developed economies, a number of these economies have legislations, regulations and waste policies on the recovery and recycling of packaging waste. For example, the Extended Producer Responsibility (EPR) principle in the European member states indicates that, all economic operators trading their packaging on the market are responsible for its recovery and management (OECD, 2001). Further the ERP indicates that, operators should develop their own packaging WM systems which should comply with the general targets set for recycling and recovery laid down by the European Law or hire another entity to manage their packaging waste.

It is imperative to note that, technological advancement in WM systems, the application of legislations/laws influence the recovery and recycling of packaging waste. According to Plastic Europe (2015), 26% of post-consumer plastic produced was recycled while 36% was incinerated for energy recovery in European member states. Further, nine of the European member states- Austria, Belgium, Denmark, Germany, Luxembourg, Netherlands, Norway, Sweden and Switzerland have enacted landfill bans for plastics, even though these countries have the highest recycling rates than countries without landfill bans (WorldWatch Institute, 2015). Xevgenos et al (2015) points out that, by 2020 Europe should be transformed into a recycling society by ensuring waste is managed as a resource. To achieve this goal, The EU's 7th Environmental Agency Plan (EAP) (2014-2020) and the Roadmap to Resource Efficient Europe have been put in place. The purpose of these plans is to eliminate landfilling, limit incineration of non-recyclable materials and reduce waste generation per capita. To achieve these goals, the 7th EAP called for full implementation of waste legislation including Directive 94/32/EC on PPW (European Commission, 2010).

In Australia, a voluntary instrument called Australian Packaging Covenant has been in place since 1999. Its purpose is to promote resource conservation and facilitate for reuse and recycling of packaging waste (Australian Government, 2014). In Japan, management of waste is basically guided by the 3Rs principle of Reduce, Reuse and Recycle. According to Ministry of Environment of Japan (2014), MSWs recycling national targets is set to 24% while reduction of final disposal is set to 50%. In the United States, a vision document called Beyond RCRA: Waste and Materials Management in the Year 2020 (US Environmental Protection Agency, 2002) outlines the necessity of moving from WM to material management while adopting the life cycle approach. It aims to increase sustainable utilization of resources and reduction of waste through source reduction, reuse and recycling (US Environmental Protection Agency, 2002).

It is important to understand that, implementation of legislations and laws directed at packaging waste recycling contributes to sustainable WM in developed economies. Lessons should be learnt from developed economies while developing strategies for the recovery of PSWs in developing economies. It should be noted that, the difference in the context of application, requires that legislations and laws directed towards PSWs recovery and recycling in developing economies are designed to fit the context.

Cruz et al (2015) affirms that, most countries in Europe have transposed the directive into national legislations but the actual operational approaches differ significantly from country to country. In Germany for instance, the legislation on packaging wastes directs packaging manufacturers and distributors to be completely liable for their waste and comply with the system that ensures recycling and recovery operations (Cruz et al, 2015).

Xevgenos et al (2015) conducted a study on success stories for recycling MSWs. The study identifies a number of instruments that influence recycling of MSW in Europe. Waste collection systems such Kerbside, drop-off systems and recycling banks are identified as critical instruments for influencing waste recovery. The EPR is identified as one instrument that contributes to recycling. Nevertheless, the models adopted and implemented across countries differ. Further, regulatory instruments such landfill/incineration and plastic bags bans are considered relevant for promoting sustainable WM. In all the cases reviewed, it is concluded that, there is no 'one size fits all'; each municipality has its special characteristics that should be identified and adjusted for proper implementation.

A study conducted by Zhang and Wen (2014) reveals a number of factors that contribute to the success of PET bottle recycling. The study reveals that, in China, the construction of recycling collection systems for recyclable waste has influenced the success. In Brazil, The United States and Japan, the study reveals that, these countries have specialized organizations responsible for recycling collection of PET bottles. Nevertheless, the study identifies that, Japan has a national-wide law on PET recycling and this contributes to Japan having the highest recycling rates of PSWs among developed economies (Japan for sustainability, 2010). In the United States, different types of waste collection systems such as kerbside waste collection, buy-back recycling centers, Returnable Container Legislation and drop-off centers influence the recycling collection of PET bottles. In Brazil, the IWCs (scavengers) contribute to the successful recovery of PET bottles for recycling purposes.

In order to apply the identified factors that have contributed to successful recovery and recycling of packaging waste (PSWs) it is necessary the understand the current state of PSWs management in developing economies.

2.4 Plastic Solid Waste Management in Developing Economies

In this research, developing economies are countries with under-developed industrial bases, low standards of living and moderate to low Human Development Index (HDI). This is in accordance to the UN description of a developing economy. HDI is adopted from Mahbub ul Haq.

In developing economies, SWM is a major responsibility of the local governments. They are responsible for developing WM systems such as waste storage, collection, treatment, transportation and final disposal. Furthermore, appropriate organizational capacity and cooperation requirements among various stakeholders both in the private and public waste sectors makes the task complex. Most developing economies, are facing challenges of managing PSWs.

As a result of continuous urbanization and economic developments, waste production is steadily growing with stronger trends in developing economies (Courtois, 2012). According to Courtois (2012), the per capita waste generation rate ranges from 0.4 to 1.1 kg per day. The increase in the per capita waste generation is attributed to increased urbanization, economic developments and increasing gross domestic product (GDP), (Linzner and Salhofe, 2014; Batool et al., 2008). The increase in waste generation also contributes to the amount of PSWs generated. Even though the call for WM in developing economies is improving, the local authorities are still facing a number of challenges in managing it. Most of the attention is paid to waste collection rather than disposal. Wastes are collected in order to provide a safe and healthy environment for the people without consideration paid to the after effects of disposing of the waste. According to Hoornweg and Bhada-Tata (2012), approximately 41% of collection coverage is achieved in lower-income countries while 85% in upper-middle income countries. These rates can even be lower depending on waste type and urban location.

PSWs types are considered a valuable resource. With the road to achieving sustainable development which focuses on resource utilization, end-of -life PSWs are recovered for utilization in other processes. In developing economies, most PSWs are collected together with other wastes by the formal and informal waste collectors. The IWCs are the major waste recoveries' and recyclers in developing economies. Most of the recyclables are recovered and recycled by the IWCs through decentralized buying and selling of waste materials (Ezeah et al., 2013; Scheinberg et al., 2011; Gutberlet, 2010; Medina 2007; Coelho, 2011). The recycling systems of the Informal Waste Sector (IWS) are characterized by low technology, small-scale, low numeration and poor record keeping (Wilson et al., 2006). The motivating factor behind the selling of recovered wastes is the revenues and the source of livelihood for a significant number of the urban poor (Wilson et al., 2006; Saski and Araki, 2014). With lack of other positive aspects to motivate the IWS to recover and recycle wastes, this has resulted in low recovery and recycling rates in most developing economies. According to Buenrostro and Bocco (2003) although the IWS is the key player in the recovery of recyclable and reusable wastes, limited amounts of MSWs are recovered and recycled.

A study conducted by Ezeah et al (2013) reveals that, the majority of recyclable waste recovery and recycling is conducted by the IWS. The study reviews the situation of informal recycling in four countries, Egypt, China, Latin America, India and South Africa. The study concludes that, the factors that compel the formation of informal waste recycling such as lack of affordable services, urbanization, low skilled labor force, economic poverty, mass migration and rapid population growth are unforeseen to end and informal waste recycling is set to increase. The study recommends the integration of the IWS into formalized systems.

A study conducted by Scheinberg et al (2010) in Lusaka, Zambia, reveals that, 30% of the waste does not leak in the environment but is actually recovered by the IWCs. The study indicates that Lusaka city is one of the cities with the lowest recovery rates. This study recommends the integration of the IWCs into formalized systems.

A study conducted by Linzner and Salhofer (2014) reveals that, approximately 0.93% of China's urban population is involved in informal waste recycling and collection and a significant share of the recyclables is recovered and processed by the IWS. The study concludes by highlighting the need to integrate the IWCs into formalised systems.

A number of other studies conducted in developing economies acknowledge that the IWS cannot be ignored as a result of the significant benefits it contributes to resource recovery and management in developing economies (Agamuthu, 2010; Besiou et al., 2012; Chaturvedi, 2011; Sang-Arun 2011; Scheinberg, 2012; Scheinberg et al. 2011). To this end, a number of studies have recommended and proposed ways of integrating the IWCs into formalised systems (Asim et al., 2012; Atienza, 2010; Chaturvedi, 2011; Gerdes and Gunsilius, 2010; Ojeda-Benitez et al., 2002; Rathi, 2006; Scheinberg, 2012; Sembiring and Nitivattananon, 2010; Wilson et al., 2006).

The fact that the majority of recyclable PSWs is recovered by the IWS in developing economies (Ezeah et al., 2013; Scheinberg et al., 2011; Gutberlet, 2010; Medina 2007; Coelho, 2011) and that the process of recovery lacks structured systems (Matter et al., 2012), it is necessary to consider developing a structured system for recovering PSWs for the Zambia context in order to improve its recovery and recycling rates (Scheinberg et al (2010).

RL is a concept that has received considerable attention regarding the return of end-of-life products within the supply-chain in developed economies. As such, a number of studies have focused on RL model development as strategies for managing the end-of-life products (Yu and Solvang, 2016; Bing et al, 2012, Dias and Braga, 2016). In order to structure the RL of recyclable PSWs in Zambia, a relationship between RL and WM is necessary. Kinobe et al (2015) notes that, RL and WM activities in the supply-chain focus on reuse, recycling and proper disposal of waste.

2.5 Reverse Logistics Approaches to PSWs Management

RL has become an important source of opportunity for companies to improve visibility and profitability as well as lower costs across the supply chain (Chiou et al., 2012; Frota-Neto et al., 2008). RL contributes to resource utilization, competitiveness and good corporate social responsibility while taking environmental concerns into account (Demirel and Gokkcen, 2008; Chiang et al, 2014). Wong (2010) affirms that companies can create business opportunities through RL by returning post-consumption waste products. A number of developed economies have developed RL in their operations while many developing economies are yet to incorporate it in their operations. RL is still at its infancy stage in most developing economies (Sarkis, 2010).

The first known definition of RL was published in the early nineties by the Council of Logistics Management (CLM). It was defined as: "*...the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal." (Stock, 1992).*

In 1999, Rogers and Tibben-Lembke (1999) defined RL *as the process of planning, implementing and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purposes of recapturing value or proper disposal.*

Later the definition of RL by Rogers and Tibben-Lembke (1999) was adopted by Lysons and Farrington (2006) because it stresses the goal and the processes involved in RL.

The European Working Group on RL (2002) in De Brito and Dekker (2004) expanded the definition of RL as; *"Process of planning, implementing and controlling the backwards flows of raw materials, in-process inventory, packaging and finished goods from a manufacturing, distribution or use point to a point of recovery or proper disposal"*

In the first definition of RL by Stock (1992), the issue is that, the definition of RL is very general as it only emphasizes the role of logistics in all relating activities and that it originates from the WM perspective. The definition by Rogers and Tibben-Lembke (1999) is expanded to include packaging. Tibben-Lembke (2002) further stresses that, many companies are beginning to understand the importance of RL and how to best manage it as its goal is to recapture waste and unwanted or unusable products and as such logistics systems may generate cost savings for companies (Schwartz 2000; Shear 1997).

RL has grown in its areas of application and as such, it is considered applicable in many industries. This is coupled by the fact that it is perceived to focus on returns logistics or reverse distribution. In all the definitions of RL, an element of resource recovery is portrayed. The essence of RL is to ensure smooth flow of materials and therefore this process is sustainable as it deals with much more important issues than simple returns.

In this research, RL is defined as *"a process that integrates the key stakeholders in the recovery of end of life (EoL) or end of use (EoU) recyclable post-consumer plastic packaging products from the point of consumption to the point where value is recaptured.*

Companies are the main users of natural resources and are also responsible for global economic development (Braga Junior and Rizzo, 2010; Dowlatshahi, 2000). With the increase in the amount of waste generated as a result of manufacturing plastic products, there is need to properly manage and dispose of this waste (Ferri et al., 2015). Plastics have become a multipurpose packaging material and its continuous use means, natural resources used in the manufacturing of these products continue to diminish. Several million tons of plastics are produced every year and used for packaging material (Papong et al., 2014; Blanco, 2014). Approximately 50% of plastics are used for single-use disposable applications, such as packaging, agricultural films and disposable consumer items (Hopewell et al 2009). This means once the end of life (EoL) or end of use (EoU), these products are disposed of in the environment. Nevertheless, a relationship exists between RL and WM. This relationship involves activities in the distribution channel such as reuse, recycle and proper disposal of waste (Kinobe et al., 2015). Carter and Ellran (1998) highlights recycling as a means to which companies become environmentally efficient in their definition of RL. Recycling is a cost effective and environmentally friendly venture that extends products lives through application of RL.

The benefits of implementing RL for the purposes of recycling PSWs has resulted in a number of studies. Most studies on RL and PSWs recycling have designed models as a way of optimizing recoveries or profit maximization and /or cost reductions. This implies, understanding the approaches used in model design of other studies on RL and PSWs model development is appropriate for this research.

2.5.1 Plastic Solid Wastes Reverse Logistics Models

To enable plastic manufacturing and recycling companies implement RL systems, it is necessary to assess and determine the drivers that influence their participation from an economic, environmental and social aspect as well as taking the issue of technology, market share and legislations into consideration. A number of studies have been conducted on RL and recycling in developed economies (Demirel et al., 2016; Murakami et al., 2015; Ding et al., 2013; Ohnishi et al., 2012; Blengini et al., 2012; Ling and Poon, 2012; Simpson, 2012; Ravi, 2012; Binnemans et al 2013)

Binnemans et al (2013) conducted a literature review on the overview of recycling rare earth materials. Ding et al (2013) developed and applied two chlorine recycling technologies in Polyurethane industry. Ohnishi et al (2012) applied econometric to analyze the performance of recycling projects in Japanese Eco-Towns. A comparative study on the feasibility of using recycled beverage and CRT glass was conducted (Ling and Poon, 2012). Demirel et al (2016) developed a model that optimizes RL of end of life vehicles in Turkey using mixed integer linear programming (MILP).

The studies above paid attention to the RL and recycling of different products (Binnemans et al, 2013, Ding et al., 2013; Ohnishi et al., 2012). Demirel et al (2016) developed a RL model using mixed integer linear programming. The study by Demirel et al (2016) focuses attention on end of life vehicles. The focus of the research is the RL of PSWs and the studies above focused attention on different end of life products.

A number of studies have focused attention on RL and model development in WM. Bing et al (2012) used the scenario approach and applied MILP to design a RL network for household plastics. The model focused on minimizing transportation costs and environmental impacts. Ferri et al (2015) proposed a RL network designed using mathematical modelling and validated by scenario analysis for MSW in Brazil. The research focused on profit maximization. Zhang et al (2011) proposed an inexact RL model for MSW management. Li and Tee (2012) proposed RL model to integrate the formal and informal e-waste sectors.

Other studies have focused on RL and model development in different industries. Spengler et al (1997) modified and proposed a MILP model for the steel industry. Bigum et al (2013) assessed the network for battery recycling options.

Some studies have developed RL models aimed at either minimizing costs or maximizing profits (Demirel et al, 2014; Alumur et al, 2012; Dat et al., 2012; Zarei et al., 2010; Mahapatra et al., 2013). Other studies have considered a number of conflicting objectives in RL network management and design (Chiang et al., 2014; Lee et al, 2013; Pishvaee et al, 2010.; Yu et al., 2015; Pati et al., 2008).

In order to summarize the reviewed literature on RL and model development, numerous models are designed for different sectors and many of the studies have used multi- product model designs. Models designed aim to maximize profits or minimize costs. Further, most of the studies on RL and model development are designed for developed economies. None of the reviewed studies have paid attention to RL and model development in Africa. Therefore, there is need for studies on RL and model development for the African context as research in this context is still at an infancy stage (Sarkis, 2010).

Further, waste recovery and recycling in developing economies is mainly performed by the IWS and few studies have developed RL models that integrate the IWS. Hence this research aims to fulfill this gap by both designing a RL model for the related country and integrate the major recoveries in developing economies (IWS).

In order to implement RL successfully, Carter and Ellram (1998) affirms that stakeholder commitment is one of the key drivers of RL activities. This implies identifying and understanding the relevant stakeholders for the PSWs reverse logistics systems.

2.6 Relevant Stakeholders for the PSWs Reverse Logistics System

Sustainable SWM systems should be aligned to specific goals of the community by integrating the stakeholders' perspectives and needs such as technical, environmental, political, social, cultural, economic and institutional while combining available appropriate methods of recovery, reduction, prevention and disposal (van de Klundert and Anschutz, 2001; McDougall et al, 2001, Kollikkathara et al, 2009). Van de Klundert (1999) identifies three groups of stakeholders considered relevant in SWM systems. The community sector (representatives of the community); local government and their agencies responsible for public cleanliness and hygiene (public sector) and the private companies (private sector). Further Isa (2005) states that, the key players in the recycling aspect are the generators, collectors, buyers, manufacturers, consumers and middlemen. These stakeholders are required to work together to ensure effective recycling of waste (Tean, 2001). Further, solutions to the challenges of waste recovery and management must be sought from the interaction of a range of stakeholders (Zurbrugg et al, 2012; van de Klundert, 2000). Diaz and Otoma (2013) affirm that cooperation among the stakeholders (residents, informal waste sector and the municipality) results in increased recycling rates as well as cost reduction. van de Klundert (1999) affirms that, involvement of stakeholders is cardinal and results in increased environmental awareness and willingness to pay for WM by the users. The following key stakeholders are discussed in detail for this research.

2.6.1 Households

To achieve successful recycling programs, active and sustained participation of people is required (Ittiravivongs, 2012). Households in a number of countries are being encouraged to start recycling by collecting different materials separately in order to achieve sustainable recovery (Dahlen et al., 2009). The support of households to the effectiveness of programs aimed at recovering recyclables wastes at source is essential (Tunmise and Seng, 2014). In globalizing economies, households are one of the major generators of waste (Rotimi Aliu et al., 2014). Therefore, integrating households in recovery and recycling programs is a key factor to achieving sustainable systems. To ensure effective recoveries from the households, the levers or factors that influence them to participate in recovery programs should be assessed from their perspective.

2.6.2 Plastic Manufacturing and Recycling Industries

The origin of the recycling industry in most developed economies is related to the origins of WM (Melosi, 1981). In this case, it is necessary to adopt the plastic manufacturing and recycling companies in designed recovery and recycling systems. Similarly, as the notion of RL includes activities involved in the recycling chain by bringing wastes back to the production process (Fehr, 1999; Ballou, 2001). Plastic manufacturing and recycling companies are integrated in recovery and recycling programs as they are the prime mover and basic component of RL chain (Fehr, 2014). They buy specific materials from a number of items disposed by institutions and households (Fehr, 2014).

2.6.3 Formal Waste Collectors

Public authorities or the private companies perform formal WM activities (Linzner and Salhofer, 2014). Storey et al (2015) indicates that municipalities play an important role in driving change by way of launching awareness campaigns and source separation programmes. The challenges confronting the municipalities have resulted in the integration of private waste collectors in managing waste. This integration aligns with the notion of sustainable MSWs management that recognizes the provider inclusivity, environmental community groups, licensed micro-enterprises and the IWS (Wilson and Scheinberg, 2010). These integrations also known as Public-Private Partnerships contribute to economies of scale, reduces risks, mobilizes resources and enhances service delivery (Helmsing 2000, Baud, 2001)

2.6.4 Informal Waste Collectors

According to Gunsilius and Gerdes (2010) a number of studies indicate that organized informal recycling activities contribute to WM cost reduction, income provision, opportunities to poor people and positive environmental effects. Wilson et al (2009) indicates that informal waste recycling improves recycling rates and promote source separation. In urban China, the informal sector is actively involved in processing, trading and collection of recyclables thus providing secondary raw materials to meet industry demands (Linzner and Salhofer, 2014). According to the informal recycling hierarchy (i.e. dumpsites pickers, household waste collectors, Itinerant waste buyers, street pickers, middlemen dealers and municipal solid waste crew) the majority of the informal waste workers are involved in collection activities (Wilson et al., 2006). In developing economies, the Informal Waste Sector (IWS) are recognized as key partners in any sustainable initiatives of waste-to-resource (Wilson et al., 2012; Gunilius et al., 2011; Taiwo, 2011). They recover waste from commercial and residential areas, dumpsites, transfer stations, vacant plots or storage containers and landfills (Scheinberg et al., 2010a) as such, they are an integral part of waste management networks and systems (Stores, 2010; Ahmed and Ali, 2004).

These mentioned contributions of the IWS to the recovery of waste shows the importance of integrating them in RL systems. The IWCs are effective stakeholders to sustainable waste management and resource utilization.

Identifying the relevant stakeholders in waste management and RL systems is important. Nevertheless, this should be aligned to the needs and perspectives of the stakeholders (van de Klundert and Anschutz, 2001; McDougall et al, 2001, Kollikkathara et al, 2009). The following section discusses vital levers or factors necessary for influencing stakeholders' participation in RL programs.

2.7 Vital Levers for the Reverse Logistics of PSWs

In this research, levers are defined as ideas or actions used to influence people to do what you want them to do. For this research, the levers are the ideas that influence the stakeholders to participate in RL activities of PSWs recovery for recycling purposes.

A sustainable recovery and recycling RL system requires involvement of stakeholders in planning, implementing and monitoring of the changes. Several stakeholders are involved in managing SW and these include; the providers, users and the external agents. Providers are the local authority such as the municipality. These provide the services needed to manage SW from storage, collection, treatment and final disposal. Nowadays, the private waste sector is involved in the management of waste as well as the IWS. The users are the households, public and private institutions, commercial and industrial entities etc. The external agents are the policy makers such as the governments.

To sustainably recover PSWs, an integrated system is necessary to develop and this requires identification of relevant stakeholders. Households, plastic manufacturing and recycling companies, formal and informal waste collectors are identified as the main stakeholders for this research. To integrate these stakeholders in a RL model for the recovery and recycling for PSWs, it is prudent to identify the levers that influence their participation (Barr, 2007; Chung and Leung, 2007; Asim et al., 2012; Atienza, 2010; Chaturvedi, 2011; Xevgenos et al, 2015; Grazhdani, 2016).

2.7.1 Levers influencing households to Participate in RL Programs

Sustainable solutions for recovering and recycling PSWs is of paramount importance and requires identification of levers that influence households to participate in recovery programs. Households are critical stakeholders to the recovery and management of SW and several studies have been conducted.

A number of studies identify demographic factors as influencing levers to households' participation in recovery and recycling programs (Sidique et al., 2010a, 2010b; De Feo and De Gisi, 2010; Barr and Gilg, 2007; Martin et al., 2006). Other studies indicate that, affordable and convenient options for transporting SW to Material Recovery Facilities (MRFs) influence households to participate (Ojeda-Benitez et al., 2002; Medina, 2000; Stern, 1999; Wysopal 1989). Xevgenos et al (2015) concludes that waste collection systems influence households to participate in recovery and recycling programs. Nahman (2010) affirms that voluntary EPR is seen to be successful compared to mandatory programs. Coelho (2011) indicates that a lack of legislations and useful governance interventions is the main problem with recovery and collection systems. Grazhdani (2016) notes that, educating the public on recycling and increasing the number of drop-off recycling facilities and curbside recycling services contributes to high recycling rates.

The following sections discuss in detail the levers that influence households to participate in RL programs. A clear understanding of the levers that influence households to participate in recovery and recycling programs is fundamental for modelling and implementing an efficient and sustainable RL system.

Demographic Factors

Several factors contribute to the challenges facing local authorities in managing SW in developing economies. Lack of understanding the factors that affect the different stages of WM and linkages necessary for enabling the entire handling system to function are one of them (Grazhdani, 2016). Recovering PSWs from households contributes to achieving sustainability and as such, should be overstressed. Increasing global urban population results in urban areas having pressure to house people and hence increasing the amount of waste generations. A number of studies indicate that socio-economic factors such as income level (Owens et al, 2000, Smallbone, 2005); gender (Vicente and Reis, 2008); age (Gamba and Oskamp, 1994; Scott, 1999); education (Judge and Becker, 1993; Owens et al., 2000), and household size (Judge and Becker, 1993) are levers that influence households to participate in recovery and WM programs. Sidique et al (2009) indicates that, using drop-off recycling sites is influenced by age, education, income and household size. Wang and Yin (2016) identifies age as one of the levers that influence resident's willingness to pay for separate waste collection services. Sidique et al. (2010b) suggests that, education has a positive effect on the rate of recycling. The study by Owens et al (2000) reveals a positive correlation between education and recycling participation. Other studies have found the existence of a correlation among socioeconomic factors such as consumption patterns, education, age, gender and income with recycling behavior (Kishino et al., 1999; Hanyu et al., 2000; Domina and Koch, 2002; Troschinetz and Mihelcic, 2009). Further, Antonia (2009) states that demographic factors are the best segmentation tool to determine the characteristics of recyclers and non-recyclers.

The studies above show the levers that influence households to participate in recovery or WM programs. In summary, none of the studies focused on PSWs or used the levers to design recovery and recycling models for PSWs.

Knowledge and Awareness

Knowledge and awareness in managing waste is important as it contributes to stakeholders' understanding of the reasons for participating. Numerous studies have shown that knowledge and awareness is cardinal in influencing participation in recovery and recycling programs.

Isa et al (2005) indicates that, lack of public awareness on recycling contributes to non-participation. Singhirunnusorn et al (2011) concludes that, rising awareness and continuous provision of information on environmental issues and proper SWM are crucial keys for successful community recycling bank projects. According to Xevgenos et al (2015) communication strategies that focus on implementing WMS should focus on awareness rising while providing the opportunity for effective and consistent flow of information among the relevant stakeholders. Afroz et al (2017) indicates that, people who are informed and knowledgeable about recycling have a positive attitude towards recycling.

Tonglet et al (2004) explored the relationship between recycling behavior and waste minimization using cognitive model in order to understand recycling behavior and waste minimization choices made by households and the factors behind such choices. Knowledge to recycle is highlighted as one of the factors that influences recycling behavior in individuals. A positive correlation is found to exist between recycling and public education and information using public campaigns (Nixon and Saphores, 2009).

Further literature on WM and knowledge of people on the environment was recognized long ago as one of the cardinal levers that influence household to recycle (Nixon and Saphores, 2009; Burn and Osakamp 1986). Vicente and Reis (2008) indicates that, national newspapers, magazines, radio and television facilitate in transmitting general messages to the population. Direct media is preferable in transmitting recycling messages successfully (Vincente and Reis, 2008). Abdelnaser et al (2006) states that, public participation in recycling programs is increased with integrated use of media. To increase household participation in recycling programs all available media such as radio and television networks and newspapers must be used to increase public awareness (Omran et al., 2009).

The studies above affirm that knowledge and awareness on recycling is a critical lever for influencing individuals to participate in recovery and recycling programs. This implies that, it is important to understand and assess how this lever influences individuals to recover and recycle PSWs on the Zambian Context.

Economic Incentives

Success in resource recovery lies on societal participation. It should be acknowledged that resource recovery is not ascribed to the efforts of the government alone but requires an all-inclusive culture. To ensure household participation in recovery programs, economic incentives are known to be influencing levers. Welfens et al (2015) indicates that, economic incentives play a critical role in initiating more sustainable behavior patterns. Yau (2010) indicates that economic incentives promoted recycling in Hong Kong. Further, Agamuthu et al (2009) identifies that monetary incentives approaches boost household level recycling activities. The studies above affirm the importance of economic incentives in promoting resource recovery in individuals. Consequently, there is need to conduct and observe how economic incentives influence PSWs recovery and recycling in a Zambian context.

Legislations and Regulations

Numerous waste policies exist in developed economies and evidence of how these policies influence waste recovery at household and community level has been provided. For example, the EU waste policy known to have been transformed through a number of Environmental Action Plans (EAPs) contributes in a number of aspects to SWM (European Commission, 2010). The National Waste Policy in Australia known as 'Less Waste, More Resources' has existed since 2009. This policy gives direction on waste generation, reduction, disposal and management of waste as resources by 2020. Germany is known as one of the countries with the highest recycling rates and legislations influence recovery (Xevgenos et al, 2015). These observations in developed economies of how legislations and regulations influence resource recovery is cardinal for effective application and testing in developing economies.

According to Xevgenos et al (2015) several developed economies such as Japan, Norway, Austria, the Netherlands and the United States have enforced state-wide landfill bans and restrictions on MSW accompanied by a number of variations regarding waste types. For example, in 1997 to 2010 Japan recorded a 70% increase in PET bottles recovery as a result of the EPR system (Zhang and Wen, 2014). Sidique et al (2010) concludes that, regulations are effective means to increasing recycling rates. Enaction, of recycling ordinances by making residential recycling mandatory increases recycling rates.

The above studies provide evidence on how legislations and regulations influence households and communities to participate in recovery and recycling programs. The need to assess legislations and regulations as levers that influence households to participate in RL programs for PSWs is necessary as evidenced from these studies.

Waste Collection Systems

PSWs collection is a complex aspect of waste recovery as it consists of independent and interactive components. According to Dahlen and Lagerkvist (2010), household waste collection systems are divided into property-close collection systems and drop-off points. Property-close collection systems consist of kerbside and door to door collection systems. Kerbside collection systems provide each household with waste receptacles such as containers and instruct households to place their waste containers at the kerbside. In door to door collection systems, households are provided with containers but instructed to keep the waste container at their premises. In drop-off collection systems, residents deliver recyclables to drop-off centers (Zhang and Wen, 2010).

Waste collection systems influence individuals to participate in recovery and recycling programs. According to NAPCOR (1997), drop-off waste collection systems have proven to be more efficient in areas where kerbside is impractical. Further, NAPCOR (1997) indicates that, kerbside collection systems attributed to 55% of PET plastic containers recovery for recycling intentions in the US. A study by TEMA NORD (2014) also indicates that kerbside waste collection systems increase the collection of PSWs for recycling purposes compared to bring systems or drop-off systems.

The influence of each waste collection system can vary depending on the context of application. Made (2003) points out that, throughout the world, household waste collection systems differ and so is their organization. Rodrigues et al, (2016), points out that, the type of waste collection system has an impact on the amount and quality of recyclables collected as well as on user participation. This difference in both system and organization can result in difference findings and therefore the need to assess in different contexts. Other waste collection systems consist of buy-back centers and returnable container legislation (Zhang and Wen, 2014; Xevgenos et al, 2015)

Larsen et al (2010) performed an economic and environmental assessment on waste collection systems. De Feo and Malvano (2012) analyzed the technical aspects of MSW kerbside collection. Some studies have looked at benchmarking waste collection systems (Karagiannidis et al, 2004; Teixeira et al. 2014). In other studies, the efficiency of the amount of waste collected by different types of waste collection systems was compared (Gallardo et al; 2010, 2012).

The above studies assessed waste collection systems but none of the studies modelled the influence of the systems on the recovery and recycling of PSWs. It is necessary to model the influence of the waste collection systems on the recovery and recycling of PSWs on the Zambian context.

Material Recovery Facilities

Material Recovery Facilities (MRFs) influence households and communities to participate in waste recovery programs. In most developing economies, most of the recovery is conducted by the IWS. The IWS lack adequate equipment and machinery to process the recovered waste and in most cases, have no vehicles to move from one place to another collecting waste. According to Kinobe et al (2015) in most developing economies, the RL chain comprises of a number of waste collectors, street children, small scale merchants and waste loaders. Most of these waste collectors are unorganized and depend on waste collected from trucks which deliver the wastes at the landfills or from temporary garbage dump-sites (Matter et al, 2012). To achieve successful sustainable recovery programmes, the influence of MRFs on households has been investigated. Several studies point out MRFs as enhancement factors in the recovery process. Wang and Yin (2016) alludes that convenient facilities provided by the government act as a way of promoting residents' participation in separate waste collection. Rispo et al (2015) highlights that, a variety of infrastructures play a fundamental role in facilitating resident's participation in WM activities as well as ensuring that maximum source-segregated materials are captured. A study by Isa (2005) recommends the need for resource recycling facilities to be provided by the government in order to influence households to participate in recycling programmes. Further, some studies point out that convenience is a strong motivator for residents to recycle waste (Vencatasawmy et al., 2000; Smallbone, 2005). Otherwise, in the absence of convenient disposal facilities, recyclable or reusable waste are illegally disposed of or end up at the landfills (Banga, 2009; Morris, 1994; Tadesse, 2009).

Informal Waste Sector Integration into Formalized Systems

Large amounts of recyclable, reusable and re-manufacturable waste is recovered by the IWS in developing economies. Most of these IWCs earn a livelihood from recovering and recycling wastes. Comparing developed economies to developing economies, recycling still remains an informal activity in developing economies (Agarwal et al., 2005). Several studies have been conducted on the IWS and resource recovery. Some studies have recommended the integration of the IWS into formalized systems as strategies for reducing the overall WM costs of the FWS (Wilson et al., 2009; Velis et al., 2012; Masood, 2013; Matter et al., 2013). Others have developed frameworks for integrating the IWS with the FWS (Wang et al., 1997; Masood, 2013; Paul et al., 2012; Velis et al., 2012; Wilson et al., 2012; Tsai, 2008).

The studies above recognize the importance of the IWS in waste recovery and management programs in developing economies. In order to develop sustainable RL systems, integration of the IWS into the recovery and recycling system is necessary. To achieve such an integration, it is necessary to assess the relevance of the IWS from the households' perspective.

2.7.2 Levers Influencing Plastic Industries to Recover and Recycle PSW

The favorable properties of plastic materials outweigh the properties possessed by other materials. This implies, the plastic industries are using this concept to innovate more products out of plastics. According to the 2015 Global Business Trends, the compound annual growth rate of 3.9% over 2015-2020 is expected to be achieved globally by the polymer industry. With this anticipated growth, more resources will be consumed in the manufacture of more plastics products. In order to reduce the usage of resources, a number of sustainable treatment options for managing and recovering useful plastic materials exist. Treatments such as recycling, remanufacturing and reusing of end-of –life or end-of-use plastic products by the plastic manufacturing and recycling industries.

In developing economies, a number of recovery and WM challenges exist, plastic manufacturing and recycling companies usually refrain from recovering and recycling their end-of-life products. Nevertheless, a number of levers are known to influence plastic industries to recover and recycle their waste and these have been implemented by some plastic industries in developed economies. The context of application is different and therefore, the need to understand the levers that influence plastic manufacturing and recycling industries in developing economies such as Zambia is necessary.

Technological Levers

Technological advancements have not by-passed the plastic industry. A number of innovative changes in product design, recycling and remanufacturing exist. BIO Intelligence (2013) affirms that, the cost of recycling decreased as a result of technological advancements and this has contributed to closing the gap between the value of recycled plastic and virgin plastics. Technological levers enable a number of plastic convertors recycle more plastic wastes. Improvements in sorting, washing and non-bottle packing recycling technologies has become possible in European nations such as Austria, Italy, Germany, Norway and Spain (Hopewell, 2009). With these advancements, a number of technologies are still needed to recycle plastic wastes compared to other waste types and innovations should continue to be an important focus for recyclers (BIO Intelligence, 2013). A number of technological levers such as improvement in sorting techniques and size reduction technologies, improvement in recycling technology and infrastructure, designing of plastic products for recyclability; have great impact on recovery and recycling of PSWs (BIO Intelligence, 2013). Scheirs (1998) states that, continuous development of recovery and recycling technologies and participation by consumers, industries and government are highest order priorities.

Environmental Concerns and legislations Levers

Legislations are known to influence resource recovery in a number of developed economies (Xevgenos et al (2015). A study conducted on markets for recycled plastics affirms that, legislations are one of the levers that influence PSWs recovery and recycling in the European nations (Plastic ZERO, 2013). Zhang and Wen (2014) points out that, application of EPR has influenced PET bottles recovery and recycling in Japan. BIO Intelligence (2013) notes that, EPR systems tend to produce higher collection and recycling rates than voluntary systems.

Environmental protection is one aspect that compels manufacturing industries to recover their wastes. According to Srivastava (2008) environmental concerns are one of RL drivers. Plastic producers from the European perspective have addressed the environmental concerns associated with plastic waste (Plastic ZERO, 2013). This has resulted in the placement of a number of environmental protection policies that compel industries. Furthermore, companies prefer to trade with companies that adhere to environmental protection policies.

Numerous environmental concerns and legislations' levers such as enforcement of producer responsibility regulations, enforcement of national wide law on plastic waste recycling, enforcement of waste segregation at household level, creation of quality standards and certification schemes for plastic recyclers (Plastic Waste Recycling, 2009; BIO Intelligence, 2013; Bing et al, 2012; Matter et al, 2013; Xevgenos et al, 2015) influence plastic manufacturing and recycling industries to recycle PSWs.

Economical Levers

Recovery of waste is mostly performed as a result of the economic impact it presents to companies. The profits incurred from waste recoveries influence many waste collectors. Contreras et al (2009) indicates that in the city of Yokohama, Japan, salvaged recyclable paper and plastics are exported as an economic activity. Economic value attached to waste attracts waste collectors to continue recovering it. For example, in Malaysia, private lorry owners supplement their income by itinerantly purchasing paper and other wastes form households and reselling it to local commercial recycling centers (Agamuthu et al, 2009).

A number of economic levers such as; lowering of energy required during recycling, lowering logistic costs associated with the recovery of PSW, comparable cost of recycling with alternative forms of disposal, comparable price of recycled polymer with virgin polymer (Hopewell et al, 2009; BIO Intelligence, 2013, Plastics ZERO) positively influence more plastic industries to recover and recycle.

Social Levers

According to WRAP (2008d), participating in recycling schemes is an environmental behavior that has a wide participation among the general population and it resulted in 57% participation by the population in the UK survey in 2006. Coelho (2011) indicates that, the collection of PET bottles is completely done by the informal sector yet this resulted in an increase from 19% in 1995 to 56% in 2010.

Social levers such as using incentives to motivate plastic recycling at household levels, efficiency of the municipality, private waste contractors and informal waste collectors in waste collection, incorporation of IWS into the formalized systems, introduction of waste segregation, consumer awareness and education on recycling (Plastic ZERO, 2013; Hopewell et al., 2009; BIO-Intelligence, 2013) result in positive influences on the public to recover and recycle wastes.

Market-Share Levers

Recovery and recycling rates are improved by closer engagement of plastic manufacturers and recyclers with other key players along the supply-chain (BIO Intelligence, 2013). Great need for municipalities, sorters to deal directly with the recyclers is necessary as this promotes recyclability. According to Plasticker (2012a) China already has a considerable domestic market for recycling its own plastic and a total of 15 million tons of PSWs of Chinese origin was recycled in 2011. It is necessary for markets to be available for recycled plastics as this encourages and increases recycling (Plastic ZERO, 2013).

A number of market-share levers are used in influencing plastic convertors to participate in PSWs recoveries in developed economies. Levers such as; development of end markets for polymer recycle streams, closer engagement of recyclers with one another along the supply-chain and existence of market systems relying on recycled-material throughput involvement (Plastic ZERO, 2013; BIO Intelligence, 2013).

2.7.3 Levers for Integrating the Informal Waste Sector into Formalized Systems

In developing economies, waste recovery is an activity mainly performed by the IWS. It consists of different categories of groups and all serving the purpose of resource recovery. It is estimated that 2% of the urban population in low and middle-income countries work in the IWS (Gunsilius et al., 2011). This sector contributes to initiating the development of household recycling practice and creates recycling norms in the society (Zen and Siwar, 2015). According to Hoornweg and Bhada-Tata (2012), most of the waste recovery and recycling is performed by the IWS in developing economies. Although the IWS is the key player in the recovery of recyclable and reusable waste, limited amounts of MSWs are recovered and recycled (Buenrostro and Bocco, 2003). According to the World Bank (2012) only 4% of MSWs is recovered. Even though, the recovery rate is significantly low, the IWS continues to play a major role in sustainable resource recovery and recycling. In as much as the IWS are the major recoveries, little recognition is given to them. According to Wilson et al (2009), in 2006 a recycling rate of 74.3% was achieved by the IWS in Egypt compared to the 10.6% by the FWS as a result of formal recognition by the state government.

It should be noted that, waste removal is not the only activity performed by the IWS but creating a livelihood for their families and working for themselves. Waste is collected at no direct cost to the taxpayers but without recognition, protection or supervision from the city authorities, it makes their work difficult. A number of studies have looked at ways of integrating the IWS into formalized systems.

Agarwal et al (2005) highlights on the need for the IWS to be formally incorporated in the WM systems both at local level systems as well as in the urban frameworks. Devi and Satyanarayana (2001) shows that organising the IWS and promoting micro-enterprises proves to be an effective way of extending affordable services especially in the urban communities. Wilson et al (2006) found that, organising and training informal recyclers into micro-enterprises is a very effective way to upgrade their ability to add value to collected materials and also contribute more to achieving sustainable waste management.

The findings from these studies indicate that integrating the IWS into formalised systems contributes to sustainable waste recovery and management. Other studies have not only suggested integration of the IWS into formlaised systems but have also suggested some strategies. Table 2.1 depicts reviwed strategies for integrating the IWS into formalised systems.

TABLE 2.1: STRATEGIES FOR INTEGRATING THE IWS INTO FORMALIZED SYSTEMS

Reference	Identified Strategies
Fei et al (2016)	✓ Training ✓ Price advantage ✓ Information platforms set-ups ✓ Recycling systems layouts optimization
Storey et al (2015)	✓ Source waste segregation ✓ Effective community engagement ✓ Predictable and steady revenue sources
Kawai et al (2012)	✓ Carefully monitoring of the role of informal sector ✓ Continuous collection of reliable data on recyclable waste
Medina (2002)	✓ Recognition legally ✓ Policies at National ✓ Organization ✓ Conditions Allowance (institutionally, legally) ✓ Initiations of microcredit
Matter et al (2013)	✓ Waste segregation at Household level
Atienza (2010)	✓ approvable policies ✓ Organization ✓ Technical and economic assistance ✓ Safety and health insurance ✓ Enforcement of law ✓ information and education campaigns: IEC ✓ Suitable technology ✓ Local and national stakeholder's gatherings
Sembiring and Nitivattanon (2010)	✓ Partnership establishment between IRS members ✓ Policy makers' perception shift of the IRS ✓ Secondary raw material quality improvement
Chaturvedi (2011)	✓ Channelization and Collection mechanism ✓ Development and capacity research/building ✓ Infrastructure ✓ Dissemination, dialogue and Policies activities
Gutberlet (2008)	✓ IRS Inclusion into waste management ✓ Equity: income gender, social security ✓ Eco-health: environmental and social health ✓ Eco- efficiency: producer responsibility, packaging reduction ✓ Capital basis expansion ✓ Perspective long term: Sustainability ✓ Consideration of Topography
Wilson et al. (2006)	✓ Authorities acceptance of the benefits provided by IRS ✓ Organization ✓ Micro and small/ cooperatives enterprises formation

2.8 Drivers of Reverse Logistics

A study by Lee (2010) reveals that maximization of value from returned products should focus on the back-ward flow of materials by effective RL implementation. To effectively implement RL in the plastic manufacturing industries, its cardinal that the drivers and barriers for successful implementation are studied and considered. Agrawal et al (2016) highlights that most organizations worldwide are exploring the application of RL to enable profitable businesses. Ravi et al (2005) affirms that, in order to implement RL, a critical analysis of the variables affecting it and their mutual interactions is a valuable source of information. Additionally, the absence or presence of these enabling RL factors can become barriers or drivers to its implementation in an industry (Agrawal et al, 2016).

A number of studies have focused on identifying critical success factors for implementing RL, (Brito and Dekker, 2002; Carter and Ellram, 1998; Janes et al., 2010; Damghani et al., 2015). As an engineering management concept, RL is applied to the recovery of PSWs. It is a concept most manufacturing companies use to return their end-of-life valuable products. RL, application is influenced by a number of drivers. According to Srivastava (2008), RL has three main drivers; government legislations, economic value and environmental concerns. Carter and Ellram (1998) indicate that, customers, top management support, stakeholder commitment, regulations, policy entrepreneurs, incentive systems and quality of inputs are the drivers needed in RL activities. Fuller and Allen (1995) note that, application of RL is driven by factors such as corporate social responsibility, economic factors, legislations, logistics itself and technology. From an economic point of view, RL results in job creation and revenues to the people engaged in the recovery activities and socially the technology industry is widened (William et al., 2008). Protecting and preventing wastes from entering the environment is a driver that has motivated most companies to implement it. Most companies describe it as a way of assisting them perform, resulting in the recovery of materials destined for disposal as well as enabling in the reduction of environmental and social impacts (Chaves et al., 2014; Santos et al., 2014). The following RL drivers are considered for this research.

2.8.1 Economic Drivers

Ravi et al (2005) points out economic drivers as one of RL driving force related to all recovery options. In this case, indirect as well as direct economic benefits are received by the company. Chan and Chan (2008) state that, in a company, the most returned products add value to it. For example, a US company ReCellular gained economic advantage through cell phones refurbishing (Guide and Wassenhove, 2003). Akdogan and Coskun (2012) indicate that, economic benefits are related with indirect and direct gains in all recovery actions. Furthermore, studies mention the relevance of economic factors as driving forces to RL implementation (Lau and Wang, 2009; Chiou et al, 2012).

2.8.2 Legislative Drivers

Legislation indicates the jurisdiction that compels companies to recover their products or accept a take back (Peters, 2009). In RL implementation, legislations contribute positively. A study by Zhang and Weng (2014) indicates that, Japan is one of the highest recycler of PET since the establishment of

EPR. Further, a number of countries in developed economies have implemented EPR and it has contributed to high recovery and recycling rates (Xevgenos et al, 2015). More studies indicate legislations as a critical factor in driving the implementation of RL (Rahman and Subramamain, 2012; Knemeyer et al, 2002; Kannan et al, 2014; Mittal and Sangwan, 2013).

2.8.3 Environmental Concerns Drivers

Reverse logistics implementation has growth due to the growing concerns for the environment. Numerous companies have implemented RL operations as a result of environmental reasons (Rogers and Tibben-Lembke, 1999). One of the most important issue facing businesses in environmental concerns (Murphy and Poist 2003). Companies that have implemented environmental concerns strategies only want to partner with companies that have also implemented similar strategies.

2.9 Integrated Sustainable Waste Management and Plastic Waste Recycling

2.9.1 Integrated Sustainable Waste Management

Integrated Sustainable Waste Management (ISWM) concept focuses on issues related to WM by seeking stakeholder involvement while covering resource recovery and waste prevention (Shekdar et al, 2009). ISWM manages SW through comprehensive approaches of preventing and recycling in order to protect human health and the environment (Van de Klundert and Anschütz, 2001). In this regard, a number of studies focus on ISWM as a strategy for managing and recovering wastes.

Mohsen et al (2015) points out that, economic, environmental and social factors should be efficiently integrated and managed in order to achieve sustainability. Shekdar (2009) indicates that, sustainable SWM systems should be developed rather than sustainable societies that are only compatible with financial capacities of their adjoining environment. Van de Klundert (1999) emphasises that SWM is not purely a technical issue but other aspects should be considered while designing a system. Zurbrugg et al (2012) asserts that, integrated sustainable WM should go beyond technical aspects to include several key elements of sustainability in order to be successful. Couth and Trois (2012) points out that, WM strategies for African countries should be holistic and provide a sustainable integrated approach to economic, environmental and social issues.

The studies above indicate the criticality of integrating the key elements of sustainability i.e. economic, social and environmental aspects in managing waste. Emphasis is given to stakeholder involvement and designing of sustainable systems as ways of achieving ISWM.

Couth and Trois (2012) state that, in order to achieve ISWM, Africa should focus on the waste hierarchy. The waste hierarchy focuses on waste prevention, reuse, recycling, composting, incineration and landfilling. To this regard, many studies recognize recycling as the most appropriate method for disposing PSWs though its application depends on a series of local factors (Molgaard, 1995; Denison, 1996; Ayalon et al., 2000; Von Krogh et al., 2001; Grant et al., 2001; Perugini et al., 2004, Hopewell et al, 2009). Recycling is receiving considerable attention as a result of its main environmental benefits which are acknowledged throughout the world and make it one of the most successful, cleanest waste recovery processes (Badia et al., 2012).

2.9.2 Plastic Waste Recycling

The desire for better and improved life styles has resulted in a number of products being manufactured according to customer specifications. One of the fast-growing industries designing tailor made products is the plastic industry. Plastics have replaced many products previous made out of metal, glass, fiber and many other materials. This change is favored by many properties possessed by plastic materials. According to Subramanian (2000), the drivers for such growth in the plastic industry result from plastics having low density, strength, user-friendly, design and fabrication capabilities and low cost. With these favorable properties, plastics have a negative effect on the environment if improperly managed.

Plastic recycling is one action that is used to reduce environmental impacts and prevent resource depletion. It is clearly a WM strategy but can be seen as one current example of implementing the concept of industrial ecology, whereas in a natural ecosystem there are no wastes but only products (Frosch & Gallopoulos 1989; McDonough and Braungart 2002). Plastic recycling plays a significant role in saving fossil resources and substituting for virgin material production (Tonini and Astrup, 2012). To this regard, it is necessary to clarify the types of recyclable plastics, processes of recycling and waste collection systems.

Recyclable Plastics

Recyclable plastics undergo the process of recycling in order to be reprocessed into other products without any difficult. High Density Poly Ethylene (HDPE), Polystryrene (PS), Polyethylene Terephthalate (PET), Polyproylene (PP), Low Density Poly Ethylene (LDPE) and Poly Vinyl Chloride (PVC) among others make up the recyclable plastic category (WastePlastics, 2009). 80% of post-consumer plastics are recyclable and mostly manufactured into bottles, tubes, packs, trays, bags etc. (Plastic Recycling, 2009).

Polyethylene Terephthalate

Worldwide, Polyethylene Terephthalate (PET) has become one of the most favourable packaging materials for water and soft drinks (Welle et al, 2011). This is attributed by its favourable properties such as low weight and density compared to glass bottles. These properties also favour PET plastics compared to other plastics. According to Plastic Recycling (2009), PET plastics have good strength, hardness, stiffness and ductility compared to other plastics and materials. Of the last three decades, PET is considered one of the most cardinal technical plastics (Navarro et al., 2008). Its favourable properties contribute to its extended use resulting in an exponential increase of PET post-consumer waste in MSWs (Dullius et al., 2006; Welle et al, 2011). It is one of the most recovered PSWs as a result of its incredible recycling potential (Ezeah et al., 2013). For this reason, it is necessary to design PET RL systems in order to prevent environmental degradation and sustainable resource utilization challenges.

PET is mainly utilised for mineral waste bottles, food trays, audio/video tapes, roasting bags as well as synthetic fibres and mechanical components (Shen et al., 2009).

Polystyrene

Polystyrene (PS) is one of the recyclable plastics mainly produced by incorporating a blowing agent during polymerisation processes (Plastic Recycling, 2009). It is usually brittle and transparent in its unprocessed form. It is mainly used to manufacture cheap transparent kitchen ware, toys, bottles, food containers and light fittings. It's use in the manufacture of post-consumer products such as food containers and bottles make it prudent for a RL system to be designed for recovering and recycling this plastic type.

Polypropylene

Polypropylene (PP) can bend sharply without breaking and is more rigid compared to PE. It is mainly used in the manufacture of products such as stools and chairs, crates, ropes, woven sacking, netting, surgical instruments, food containers, car battery housing, domestic appliances, wine barrels, suitcases and many more products (Plastic Recycling, 2009). The wide variety in its application indicates that a great amount of post-consumer end-of-life products such as car battery housing, food container, surgical instruments etc are frequently disposed of. According to Hopewell et al (2009) approximately 50% of plastics are manufactured into single-use disposable products such as agricultural films, disposable consumer items and packaging. Some of these packaging and consumer items are manufactured from PP and the need to design recovery systems such as RL models is necessary to enable reprocessing of these end-of-life plastics.

Polyvinyl chloride

Polyvinyl chloride (PVC) is commonly used in the manufacture of water and irrigation pipes, window frames, transparent packaging materials, bottles, building panels, thin sheeting etc. (Plastic Recycling, 2009). The addition of plasticizers produces plasticized polyvinyl chloride (PPVC) used in the production of shoes, raincoats, automobile linings, bottles and many other plastic products. Application in manufacturing packaging and consumer products is evidence enough that end-of-use PVC products are among the PSWs found in MSWs. This implies, the road to sustainable utilization of resources should focus on sustainable SWM options such as recycling. The process of returning waste materials to the processing line as a way of cost reduction and opening up new possibilities is recycling (Veiga, 2013; Chaves et al, 2014; Braga Junior and Rizzo, 2010). Braga Junior et al (2009) affirms that reverse flows are created as a result of recycling and reusing discarded materials. The reversed goods create an important tool for sustainability in organisations (Braga Junior and Rizzo, 2010).

Polyethylene

Polyethylene (PE) consists of two types; Low-density polyethylene (LDPE) and high-density polyethylene (HDPE) (WastePlastics, 2009). Products manufactured using LDPE include sacks, blow-molded bottles, film bags, flexible piping and hosepipes, toys, bowls, telephone cables etc. HDPE products include soft drink bottles, toys, dustbins, cosmetic and detergents containers, industrial bags and many other household products.

The recyclable products manufactured using LDPE and HDPE or any other type of plastics require an understanding of sustainable recycling processes to enable sustainable RL application. A number of recycling processes exist for reprocessing recyclable plastics. According to Ingrao et al (2014), recycling can either be chemical or mechanical. This is attributed to plastic products possessing different chemical and physical properties thus different product applications (BIO Intelligence Services, 2013).

Plastic Recycling Processes

Different types of plastic recycling processes exist for reprocessing end-of-life or end-of-use plastic products. These recycling processes are categorized into mechanical, chemical, feedstock and others (Plastic Recycling, 2009).

Mechanical Recycling

The processing of PSWs through physical means such as melting, shredding, washing, drying and grinding back into plastic products is referred to as mechanical recycling. Mastellone (1999) notes that mechanical recycling is a process for recovering PSWs for re-use in manufacturing plastic products via mechanical means. It is performed on single polymer plastics such as PP, PE, PS, PET and others (Al-Salem et al., 2009). Mechanical recycling is one of the processes that produce most of the products found in our lives such as door and window profiles, blinds and shutters, pipes and grocery bags (Al-Salem et al., 2009). Economically and environmentally, mechanical recycling is the most favorable recycling technique (Al-Salem et al., 2009).

Feedstock Recycling

Feedstock recycling is a recycling process that turns solid polymeric wastes into high value feedstock for use as raw materials in the manufacture of new plastics and petrochemicals (Brems et al., 2012). It comprises of advanced recycling technologies that reprocess PSWs without any deterioration on quality or restriction regarding their application (Brems et al., 2012). Theoretically, it has the potential to boost recovery levels for PSWs (Al-Salem et al., 2009).

Chemical Recycling

Chemical recycling involves converting plastic materials into smaller molecules usually gases or liquids for use as feedstock in the production of new plastics or new petrochemicals (Mastellone, 1999).

Most products of chemical recycling are used as fuels (Al-Salem et al., 2009). Its main advantage is the possibility of treating contaminated and heterogeneous polymers with less pre-treatment.

Pyrolysis

Pyrolysis is an endothermic process carried out in an oxygen-lean environment or in the absence of oxygen (Brems et al, 2012). It's a flexible process and mainly deals with heterogeneous wastes such as automotive shredder residue or comingled wastes (Scheirs, 2009; Paolucci et al., 2010). It's mainly used for electricity generation and steam which are byproducts of a gaseous mixture of carbon dioxide and hydrogen.

Plastic Solid Waste Collection Systems

Waste collection systems contribute significantly to sustainable resource recovery and management. In order to achieve sustainable results, waste collection data should be considered in the waste collection local design and context specific to site conditions (Dahl'en and Lagerkvist, 2010). A number of waste collection systems exist. Dahl'en and Lagerkvist (2010) state that, household waste collection systems are categorized into kerbside collection system and door to door collection systems. Drop-off waste collection require households to deliver recyclables to drop-of centers while for buy-back centers, financial incentives are given on returned recyclables (Zhang and Wen, 2014). A deposit-refund system combines a tax on product consumption with a rebate when the product or its packaging is returned for recycling or appropriate disposal (Wall, 2011).

Waste collection systems vary from one country to the other but the systems of application are similar (Rodrigues et al, 2016). In developing economies, manual labor is used to collect waste while in developed economies, waste collection systems have evolved technically (Dahlen et al, 2007). This implies that, the influence of each type of waste collection system on waste recovery and recycling is important to understand.

Kerbside Collection Systems

Kerbside collection systems for recyclables have significant effects on waste handling in households (Dahlen et al., 2007a; Stern, 1999; Sörbom, 2003). To achieve an increment on the collection efficiency of recyclable materials, assessment of citizen's behavior with regard to the various waste collection systems is important (Gallardo et al, 2012a). Perrin and Barton (2001) conducted a review of two kerbside recycling schemes in which issues associated with transforming household's attitudes and opinions into material recovery is discussed. The review indicates that, providing the correct collection scheme design to households' results in a higher retain proportion of households anticipating using kerbside recycling scheme and captures the traditionally non-committed recycler. It also ensures maximum participation rates and higher diversions of recyclable materials. An economic and environmental assessment of five alternative collections systems with different efficiency for collecting recyclables was conducted in Denmark (Larsen et al, 2010). The results reveal that, kerbside collection can be environmentally more beneficial than drop-off and bring centers. Using kerbside collection systems can result in significant returns of recyclables compared to using drop-off and bring-centers for resident concerned with environmental issues. Dahl'en et al (2008), observed different households' waste collection system design in Sweden and notes that, a higher amount of separate packaging is collected from points close to the property than from drop-off points.

Drop-off Collection systems

Drop-off collection systems require residents to deliver their wastes or recyclables to specified drop of points. Two categories of drop-off collection systems exist; drop-off sites and drop-off centers. In drop-off sites, households bring their wastes (separated into different waste streams) to containers placed at neighbor level while in drop-off centers households bring their waste (separated into different waste streams) to containers recycling centers or green centers (Xevgenos et al (2015). Dah'len and Lagerkvist (2010) show that, residents are required to deliver recyclables while different sizes and shapes of containers are provided. With the system's requirement of residents' dropping off their wastes or recyclables, recycling behavior is influenced in numerous factors by this system. The ease of access to containers in drop-off collection systems is noted as a motivating factor in recycling efforts (Domina and Koch, 2002; Gonzalez-Torre and Adenso-Díaz, 2005; PCAESG, 1999).

Buy-Back Centers

These are establishments were participants deliver recyclable or reusable materials in return for cash payment (Rhyner et al, 1995). The landfill consult (2010) adds that, buy-back facilities purchase secondary materials usually from the public and resell them to brokers or manufacturers. However, these facilities may or may not process the recyclables. Non-processing of recyclables does not limit the influence buy-back centers have on resource recovery. Thompson-Smeddle (2005) indicates that, drop-off facilities reduce the amount of green or useful materials designated for landfilling and also adds value to wastes.

Deposit Refund Systems

The returnable container legislation system is a kind of deposit refund system. It is a combination of a product charge (the deposit) and a subsidy for recycling or proper disposal (the refund). Deposit refund system are widely deployed as an economic instrument which aim at increasing and capturing used packaging (i.e. mainly beverage bottles/cans) for recycling (Astrup and Hedth, 2011). Even though manufacturers or vendors incur additional costs of handling returned products, the costs are often partially offset by interest earned on deposits, unclaimed deposits and sales of collected, used products. It is not surprising to state that waste products discarded improperly have higher social costs than those wastes disposed of properly. For this reason and many other reasons not stated, the deposit refund system is very sufficient in the management of waste. Other than discouraging illegal or improper disposal of waste, the deposit system diverts recyclable items from the waste stream, conserves energy and natural resources and creates new businesses and jobs (Anderson, 2001; Anderson, 2004)

It is important to note that, some of these systems are voluntarily implemented by the industry whereas others are implemented by the state or local authorities. Xevgenos et al (2015) indicates that, most voluntary systems for reusable packaging do not certainly lead to increased recycling of reusable packaging. Anderson (2001) points out that, the quality of the materials delivered to deposit-refund collection has much purity levels than the materials collected through kerbside collection. Holmes et al (2014), shows that, correlating the use of deposit-refund systems and achievement of satisfying high recycling rates, 80% achievement have been recorded in numerous case studies. Further, studies have found that deposit systems result in higher recovery rates of used products and less contamination of recyclables than kerbside recycling programs. Nevertheless, the cost of administration is higher for deposit refunds than kerbside collection systems, (Deposit-refund systems, 2001).

2.10 Factors Determining the Recyclability and Price of PSWs

A number of factors determine the recyclability of PSWs. Plastic wastes are considered recyclable based on factors such as price of virgin materials, local markets existence, accessibility levels, demand and supply for secondary materials, transportation convenience for the materials and the anticipated profit margin potentials (Medina, 2001; Wilson et al., 2006). Determining the recycling potential of the recovered PSWs is necessary for developing sustainable RL systems. In developing economies, the factors that determine the recyclability of plastics prevent optimal recoveries and this prevents implementation of RL systems.

Most PSWs are recovered from unsegregated wastes in developing economies and as such, the IWCs add value to the recovered PSWs before it can be sold. Value is added through classifying, cleaning, washing and drying, aggregating into commercial quantities and compacting (Asim et al, 2012). According to Plastic Zero (2013) sorting is a way of adding value to the recovered polymers. Polymers are sorted according to purity, polymer type and colour. Value addition to the recovered polymers is performed in order to improve the quality as well as the price value of the polymer. In developing economies, the system of RL is not optimised to obtain maximal value creation (Matter et al., 2013). Kinobe et al (2015) recommends source segregation for easing grading and sorting of wastes at the same as a way of adding value and increasing the environmental as well as economic benefits of implementing RL.

In as much as value addition is increased in the recovered PSWs, the price of the recovered products is determined by a number of factors. The standards of the buyer, quality of the recovered PSWs, price of virgin materials, demand and supply of the PSWs in the market, recycling potential of the PSWs are but few of the factors that determine the price of the recovered PSWs (Plastic Zero, 2013; BIO Intelligence, 2013). In developing economies, most IWCs have no control over the amount they get paid per kilogram of recovered materials (Ojeda-Benitez et al., 2002). Extreme price fluctuation exists in the IWS (Gutberlet, 2008).

In designing recovery and recycling systems for PSWs, it is necessary to consider the factors that determine the recyclability of PSWs. This is necessary for bridging the gap between the recoveries and the buyers of the PSWs in order to optimise recoveries as well as increase value creation.

2.11 Barriers to Sustainable Recovery of PSWs

Numerous SWM challenges are encountered by waste service providers in developing economies. Challenges in recovering and recycling PSWs prevent the implementation of RL and as such numerous wastes are found on the environment. A study by Shekdar (2009) reveals a number of challenges facing developing economies in managing and recovering SW. The same challenges are encountered in the management and recovery of PSWs as it is a constitute of SW. Hopewell et al (2009) states that, significant challenges streaming from economic, environmental and technological as well as social behavior exist in the recovery and collection of recyclable wastes for substitution for virgin materials.

2.11.1 PSWs Sorting

Al-Salem et al (2009) notes that, waste sorting for recycling purposes is the most important step in the recycling loop. With lack of source segregation, it poses a challenge. In developed economies a number of automated sorting technologies are used while in developing economies manual sorting is mostly performed by the IWCs. Plastic Zero (2013) conducted a study in a number of countries in developed economies. The study reveals that, PSWs sorting is not sufficiently performed at the source of generation. Further, the RL supply-chain for recovering PSWs are not organized and the IWCs depend on wastes from dumpsites or from trucks delivering wastes to the dumpsites. The PSWs sorting facilities are limited in developing economies as a result of high cost of labor associated with sorting facilities (Plastic Zero, 2013). Further sorting of PSWs from other wastes is performed by the IWCs at low cost (Kinobe et al., 2015).

2.11.2 Inadequate Resources

RL implementation for recovering PSWs for recycling purposes are still at the infancy stage in developing economies. Most industries and the service providers consider RL implementation a cost (Kinobe et al., 2015). Limited resources prevent investment in recycling activities. For the waste service providers (municipality) inadequate resources prevent investment. Most of the municipalities are funded by the government and with limited resources, less attention is given to recovery and recycling programs. Economical risks associated with establishing recycling facilities, lack of recycling infrastructure and technology prevent most waste convertors to consider implementing RL.

2.11.3 Technology Inappropriateness

The majority of machinery used in waste collection and recycling of PSWs is manufactured in developed economies. The machinery and technology are usually not suitable for use in developing economies with different demands. Shekdar et al (2009) highlights that, the handling and treatment equipment manufactured in other countries are usually not of great use since the local conditions and SW characteristics are different. Using such equipment results in underutilization and efficiency reduction. Further, a combination of different types of plastics in product present a huge barrier to the recycling industry.

2.11.4 Increases in the Number of Areas to be Served

Logistic costs of implementing RL is one of the barriers preventing implementation. Plastic Zero (2013) notes logistic costs as a barrier preventing PSWs recovery in Finland and Sweden. This is the same with most converting industries in developing economies. As such, most of the recovery is performed by the IWS. Urbanization and economic advancement contributes to increased waste generation. This has further increased the number of locational areas for waste collection. An increase in the number of locational areas to be served by the municipality means recyclable wastes are not recovered due to many challenges faced by the waste departments (Shekdar et al., 2009).

2.11.5 Societal and Management Apathy

The operational efficiency of SWM depends on the active participation of the municipal agency and citizens. With the social status of SWM being low, there is apathy towards it (Shekdar et al., 2009). Symptoms of this fact include uncollected waste in many areas resulting in low volumes of input materials available for recyclers.

2.11.6 Quality Standards

Quality standards in the recycling industry determine whether the recycled material can compete with virgin materials. The quality of the recycled material plays a part in determining the price of the recycled product. Nevertheless, quality challenges prevent applicability of the recycled material compared to virgin materials (Plastic Zero, 2013). Further limited markets for recycled materials due to great comparison to virgin materials. The need to improve the quality standards of the recycled materials contributes to high production costs.

Chapter Three: Research Methodology

3. Introduction

This chapter presents the research design employed to conduct this research. The philosophical assumptions, research strategies as well as the research methods underpinning this research are presented. Instrument validation and reliability testing as well as data analysis technics are presented. The scope and limitations of the research design are defined while the existing research traditions in RL and WM among research are situated.

The chapter is divided into seven sections. The pragmatic stance in the field of RL and WM is examined. The research strategy follows and it describes the approach used in the research. Sampling techniques and data collection methods are presented. Tests for validity and reliability are discussed in the fourth and fifth sections. The data analysis methods and model development are discussed in the sections that follow.

3.1 The Pragmatic Research Approach

The research philosophy underpinning this research originates from the pragmatism tradition. It argues that the most important determinant of the ontology, epistemology and axiology adopted for a particular research is the research questions. Considering the philosophical assumptions adopted, research can be positivist, interpretive or pragmatic (Creswell, 2009). Research methods such as surveys, case studies and action research can be positivist, interpretive or pragmatic, even though the distribution is contentious (Walsham, 1995). Johnson and Clark (2006) states that, the important issue is how well our philosophical choices reflects and defends the relation to the alternatives adopted but not so much if the research is philosophically informed.

RL and WM research is considered pragmatic if there is evidence of multiple views being chosen to best answer the research questions, values are playing a role in interpreting the results, the researcher adopts both subjective and objective points of views and multiple or mixed methods designs such as quantitative and qualitative are used (Saunders et al, 2009). A number of studies in the field of RL and recycling have used mixed methods approach to develop and design RL models for the recovery of waste.

The epistemological stance on pragmatic approaches is that, depending on the research questions, either or both observable phenomena and subjective meanings can provide acceptable knowledge. The focus is on practical applied research while integrating the different perspectives to interpret data (Saunders et al, 2009). Pragmatic research in the area of RL and WM is aimed at understanding the tactical, operational and strategic aspects of the processes and systems. From the philosophical basis of pragmatic research that is grounded on mixed methods approach, a number of studies in the area of RL can be found. Examples of mixed methods research can be found in Kinobe et al (2015); Ferri et al

(2015); Lee and Ti (2012); Bing et al (2012); Ghiani et al. (2012). Most of these studies have employed questionnaires and mathematical programming to develop RL models. The focus of most of these studies has been to maximize or minimize profits, transportation costs, customer responsiveness and quality. The research at hand uses the pragmatic approach grounded on mixed method research to model the influence levers have on the amount of PSWs that is recovered and recycled.

Using the pragmatic perspective increases the intuitive nature of the research. This implies, the research focuses on the valuable, appropriate and useful results that bring positive consequences to the research. Further the approach avails the opportunity for different methods of data collection and analysis to be employed in the research. The pragmatic approach provides confidence that, the most important issues are addressed in the research.

3.2 Concurrent Mixed-Method Strategy

In the formulation of mathematical equations, mixed methods research strategies are applied to gather and apply the information needed. Examples of such studies are; Kinobe et al (2015); Ferri et al (2015); Lee and Ti (2012); Bing et al (2012); Ghiani et al. (2012). In order to achieve the set research questions and objectives, a concurrent mixed method research strategy is adopted. According to Tashakori and Teddlie (2008) mixed methods research approach are studies of pragmatist paradigm which combine qualitative and quantitative approaches within phases of different research processes. Concurrent mixed-method research approach involves inquiry of philosophical assumptions, use of quantitative and qualitative approaches while merging both approaches in the study (Creswell, 2009). Concurrent mixed method research is used as the study involves the collection of data using both quantitative and qualitative approaches. It is necessary to use concurrent mixed-method research approach as the data collected by qualitative and quantitative approaches is integrated to develop a RL model. Strategies for recovering and recycling PSWs are also suggested. Creswell et al (2003) states that, congruent findings are searched for in data gathered concurrently. It is also necessary to use this approach as the data collected using the two approaches broadens understanding of the research

Further the choice of the research strategy is based on justifications underpinning the following considerations; context of application, waste types, aspect of sustainability, stakeholders, survey studies and methods of modelling.

3.2.1 Context of Application

Most studies on RL and recycling have been conducted in developed economies (Demirel et al., 2016; Murakami et al., 2015; Ding et al., 2013; Bing et al., 2012; Ravi, 2012, Binnemans et al., 2013). Further Saski et al (2010) affirms that, RL application in developing economies is still in the infancy stage. This research is conducted in a developing economy (Africa) in order to contribute to knowledge on RL application and recycling.

3.2.2 Waste Type

RL models have been developed to recover different types of waste. Erkut et al (2008) presents a model for locating MSWs. Zhang et al (2011) proposes an inexact RL model for MSWs management. Fehr et al (2014) closes the balance of tipping to RL by pursuing the objective of shifting opportunities for household waste. Kinobe et al (2015) focuses on the RL of MWSs by analyzing in detail the reprocessing, redistribution, collection and final markets. Pati et al (2008) proposes a mixed integer goal programming model in the paper recycling industry as a way of capturing the interrelationships among the quality, economic and social goals. Alumur et al (2012) investigates a RL system for used products. Dat et al (2012) develops a RL network design for WEEE. Zarei et al (2010) focuses on the RL system for used vehicles.

Few studies have focused on the RL of post-consumer PSWs. Dias and Braga Junior (2016) analyzes RL practices performed by retailers focusing on plastic and cardboard wastes. Coelho et al (2011) examines the PET bottle life cycle in Brazil in order to improve the recycling system by analyzing in an integrated manner the best alternatives. Bing et al (2012) designs a sustainable RL network for household plastic wastes in the Netherlands.

This research takes a different approach by considering the RL of recyclable post-consumer plastic waste from the households back to the distributors/recyclers in a developing economy perspective, Zambia. Even though MSWs constitutes of PSWs and most of the studies have looked at MSWs, this research pays its attention only to recyclable post-consumer PSWs recovered from the households in Zambia. Attention on PSWs recovery and recycling has not been given much attention in the Zambian context.

3.2.3 Aspect of Sustainability

Research on the application of RL for recycling purposes has been conducted from different perspectives. A number of studies have looked at RL and recycling based on the fact that, recycling is one of the aspects of achieving sustainability. Ding et al (2013) considers closed-loop recycling of chlorine and proposes two technologies. Numerous studies have focused on RL and recycling (Simpson, 2012; Murakami et al, 2015; Ravi, 2012; Demirel et al, 2016; Ling and Poon, 2012; Blengini et al. 2012; Ohnishi et al, 2012; Binnemans et al., 2013). The research at hand focuses on RL and recycling of post-consumer plastic wastes from households. The aspect of recycling is considered as studies on this aspect have received less attention in the African context, Zambia.

3.2.4 Stakeholders

Different types of stakeholder are considered in the development and modeling of RL models. Lee and Ti (2012) considers the formal and informal sector to minimize the costs of both stakeholders. Ferri et al (2015) mathematically models and validates the RL model by considering the municipality as the stakeholder while inclusion of the IWS. Kinobe et al (2015) considers the waste pickers, recycling plants and shop scrap merchants. This research has taken a different approach by considering the key stakeholders in the RL supply-chain and WM as suggested by van de Klundert (1999) and Isa (2005).

3.2.5 Survey Studies

A number of studies that have focused on RL application have used surveys as the research instrument. In conducting surveys; questionnaires, interviews and other forms of websites research are used to gather data. A number of authors have used questionnaires to gather data. Kinobe et al (2015) conducted a questionnaire survey in which a sample size of 20 respondents (waste pickers, small scale recycling plants and small-shop merchants) is considered. Murakami et al (2015) conducted interviews with 22 companies. The interviews focused on ways of motivating companies to increase their recycling efforts. Subramoniam et al (2010) conducted a survey with chief engineers and business units from 18 companies. Shaharudin et al (2015) interviewed a total of 6 manufacturing companies in order to explore the obstacles preventing them from improving recovery and returns management. Abdulrahman et al (2015) conducted semi-structured interviews with Chinese auto parts manufacturers.

For this research, three types of surveys and structured interviews are conducted for the purpose of modeling a RL model. The key stakeholders are integrated for the purpose of optimizing PSWs recovery and recycling.

3.2.6 Modeling Approach

Research using mathematical modeling is popular in the development of RL models for managing wastes. These mathematical models are formulated using liner programming in order to recover wastes, reduce transportation costs or maximize profits. Lee and Ti (2012) integrates the informal and formal e-waste sector by using different recovery options as a result of proposing a mixed integer multi-objective linear programming RL model. Bing et al (2014) analyzes the effects of a number of separation, treatment and collection systems for household plastics from PET bottles to plastic wrappings by examining the logistics network and designing decision support tools using mixed integer linear programming. Ghiani et al (2012) proposes an integer programming model for helping decision-makers choose location sites for unsorted waste collection bins as well as their capacities at each collection site in a residential town. Ferri et al (2015) uses generic mathematical modeling to propose a RL network that involves the challenge of managing MSWs in an economic way by considering the new legal requirements. More studies have applied programming to model RL models (Achillas et al, 2010; Schwartz Filho, 2006; Pishvaee et al, 2012; Chaves et al., 2014; Ramezani et al., 2013).

This research uses mass balancing to model the RL model. Mathematical equations and assumptions based on the levers that influence the stakeholders to participate in recovery and recycling programs are modeled using mass balancing. Scenario approach is used to analyze the optimal amount of PSWs that can be recovered and recycled.

3.3 Study Population and Sample Sizes

At the data gathering stage, four categories of respondents are identified. These respondents are adopted in this research according to van de Klundert (1999) and Isa (2005) identification of the relevant stakeholders in WM and recycling systems. The adopted stakeholders are required to work together for sustainable recycling to be achieved (Tean, 2001).

In a study conducted by Kinobe et al (2015), the IWCs and recycling plants are considered as stakeholders. Bing et al (2012) considers the municipality, households and recycling companies. Ferrai et al (2015) considers the municipality and IWS. Li and Ti (2012) considers the formal and informal waste sector. Afroz et al (2017), Vicente and Reis (2008) and Gonzalez-Torre and Adenso-Diaz, (2005) investigate the households. In this research, the following are the adopted stakeholders;

- Households
- Plastic Manufacturing and Recycling Companies or Convertors
- Formal Waste Collectors (FWCs)
- Informal Waste Collectors (IWCs)

Onwuegbuzie and Collin (2007) state that, a mixed method sampling design should be based on the mixed method purpose and design type. Based on concurrent mixed method strategy, multilevel sampling design is used in this research. Multilevel sampling design involves the use of two or more samples drawn from different populations of the research (Onwuegbuzie and Collin, 2007). Kemper et al (2003) affirms that, multilevel sampling in mixed method studies occurs when probability and non-probability sampling techniques are applied on different populations of the research. In this research, data is collected from four categories using probability and non-probability sampling techniques. Four sample sizes are determined for the research. The sample size that represents the population of each data set is determined separately. According to Kumar (2005) a sample is a representation of the subgroup of the population of interest while Kothari and Garg (2014) adds that, a sample is made up of a number of items chosen from the universe to constitute a sample. In this research, the sample sizes are determined considering reliability, representativeness, efficiency and flexibility. Two types of sampling methods are considered:

- ✓ Probability sampling
- ✓ Non-Probability Sampling

3.3.1 Households Sample Size Technique

The sample size for the households is determined by first considering the sampling frame. Using probability sampling methods, the sample size for the households is determined using stratified sampling technique. Since it is not possible to consider the whole population of households in Zambia, the second populated province (Copperbelt) is considered. Consideration is given as no study of this type has been conducted before in the province. Since the population of the households is very large in the province, consideration is paid to selecting the second populated city in the province (Ndola). In this city, a study of this type has never been conducted before. Using the population census of 2010, the number of households in the city is considered. This is performed in order to determine the sample size for the households for this research.

In order to determine the sample size for the population of households in the city of Ndola, reference is made to literature. According to Neuman (2003), the percentage of a sample size is considered from a population by making reference to the population size. The larger the population, the smaller the percentage of population sample. Grinnell and Williams (1990) affirm that a sample size of 30 is sufficient to perform statistical procedures. Nevertheless, using the table suggested by Stoker (2011), the sample size for the city of Ndola is determined. Table 3.1 depicts the sample size determination guidelines.

TABLE 3.1: SAMPLING GUIDELINES
(STOKER, 2011)

Population	Percentage Suggested	Number of Participants
20	100%	20
30	80%	24
50	64%	32
100	45%	45
200	32%	64
500	20%	100
1000	14%	140
10,000	4.5%	450
100,000	2%	1000
200,000	1%	2000

Using Stoker (2011) sampling guidelines, a sample size of 445 households is determined for the city of Ndola. The city comprises of eight different urbans. In order to obtain reliable representation from each urban, stratified sampling technique is used to determine the sample size for each urban. According to Kothari and Garg (2014), if a population under which a sample size is considered does not constitute a homogenous group, stratified sampling technique is applied to determine a representative sample. Saunders et al (2009) highlights that, when a population is divided into a series of relevant stratum, it means a sample is more likely to be a representative as surety is made to make sure each stratum is represented proportionally within the sample.

Using proportional allocation, the sample sizes for the different stratum is determined. The method of proportional allocation ensures that sizes of the samples from the different strata are kept proportional to the sizes of the strata (Kothari and Garg, 2014). Using Equation 3.1 below, the sample sizes of each stratum are determined from a population size of 445 households.

Sample size of each strata; $n_i = n.P_i$ (Equation 3.1)

$n.P_i$ = the number of elements selected from each stratum i

P_i = represents the proportion of population included in stratum i

n = the total sample size

Table 3.2 depicts the household sample size distribution according to stratified sampling using proportional allocation.

TABLE 3.2: STRATIFIED SAMPLING OF THE HOUSEHOLD USING PROPORTIONAL ALLOCATION

Urban	Population	Sample Size	Percentage Selected	Sampling Guidelines Followed
Kansenshi	2,514	37.6 ≈ 38	1.5%	Yes
Nkwazi	4,600	68.9 ≈ 69	1.5%	Yes
Yengwe	3,570	53.5 ≈ 54	1.5%	Yes
Chipulukusu	7,651	114.7 ≈ 115	1.5%	Yes
Kanini	2,683	40.2 ≈ 40	1.5%	Yes
Twapia	6,034	90.4 ≈ 90	1.5%	Yes
Dag Hammerskjoeld	2,335	34.9 ≈ 35	1.5%	Yes
Kaniki	305	4.6 ≈ 5	1.5%	Yes
Total	29,692	445		

3.3.2 Plastic Manufacturing and Recycling Companies Sample Size Technique

The population for the plastic manufacturing and recycling companies consists of plastic manufacturing, recycling and buying companies. Since it is difficult to consider all the companies in the plastic industry in Zambia, the sampled population consists of those companies registered with the

Manufacturing Sector of Zambia and those companies listed on the Lusaka Stock Exchange. The research uses the results from the sampled companies to make generalizations of the entire population.

A total of 38 companies form the population size according to the listing on the Lusaka Stock Exchange and registration with the Zambia Manufacturing Sector. The sample size for the companies is determined by using Stocker (2011) sampling guidelines.

Considering a percentage suggested of 64% when a population size is 50 (Stoker, 2011). The plastic manufacturing and recycling companies sample size is 30. Selection of the companies to participate in the research is determined by sampling without replacement since the population size is finite. According to Kothari and Garg (2014), simple random sampling without replacement gives each element an equal probability of being included in a sample.

3.3.3 Formal Waste Collectors' Sample Size Technique

The population of the FWCs consists of persons in charge of the WM sector from both the municipalities and the private waste collecting companies. The two groups of the FWCs are considered a homogenous group. In order to select the respondents for the sample size, purposive sampling using homogenous sampling is used. Saunders et al (2009) affirms that, homogenous sampling focuses on one particular sub-group in which all the sample members are similar.

According to Guest et al (2006), 12 in-depth interviews suffice for a research that aims to understand commonalities within a fairly homogenous group. Creswell (2007) contends that a sample size of between 25 to 30 interviews should be conducted. Considering the waste collecting companies registered with the Patent and Company Registration Association (PACRA) and the municipalities, a population of 20 is identified. Using the sampling guidelines suggested by Stocker (2011), a sample size of 20 companies is considered based on the suggested percentage of 100%.

3.3.4 Informal Waste Collectors Sample Size Technique

In order to determine the sample size for the IWCs, it is necessary to identify the dumpsites in the study area of Ndola. Two dumpsites are identified; Kaloko and Twapia. Nevertheless, selection of respondents for this data set is not restricted to dumpsites. The population of the IWCs consists of street pickers, dumpsite pickers, household waste collectors, itinerant waste buyers and intermediate dealers.

Simple random sampling is used to select the respondents. According to Grinnell and Williams (1990), a sample size of 30 is sufficient to perform basic statistical procedures. For an unknown population size, it is difficult to determine the sample size. Stoker (2011) sampling guidelines are considered. A total of 60 respondents are considered a sample size to represent a population of 120 IWCs.

3.4 Data Collection Methods

The research approach of concurrent mixed-method involves collection of data by quantitative as well as qualitative methods. In this research, primary and secondary data is collected.

3.4.1 Secondary Data Collection

Secondary data is cardinal for completing the research. Collection of secondary data is performed through the review of research articles, reports, legal documents, published and unpublished works. Referred and non-referred journals are reviewed. The focus of the review is on RL models, PSWs recovery and recycling systems, sustainable PSWs Management and factors influencing stakeholder participation. Information from reports, legal documents as well as published and unpublished works captures data on sustainability in the field of SWM. Literature on key stakeholders in WM and RL is reviewed as well as policies on WM.

3.4.2 Primary Data Collection

Primary data is collected using both quantitative and qualitative collection methods. For quantitative data collection, a questionnaire survey is employed while for qualitative data collection a case study.

A non-experimental descriptive survey is conducted with the households, plastic manufacturing and recycling companies and informal waste collectors. A number of studies have used non-experimental surveys in which questionnaires were used as data collecting instruments. Afroz et al (2017) conducted a questionnaire survey with 350 households to investigate the factors influencing them to participate in plastic waste recycling programs. Kinobe et al (2015) administered a questionnaire survey to 10 waste pickers and 5 recycling companies. Kirma and Mayo (2016) conducted a questionnaire survey with 20 private waste service providers.

The purpose of the questionnaires is to extract data significant for designing the RL model for PSWs. Three different types of closed-ended questionnaires are designed for the households, plastic manufacturing and recycling companies and the IWCs. Stakeholders are influenced to participate in recycling programs by different factors, therefore separate questionnaires are designed. According to Creswell (2009), a survey research can use longitudinal and cross-sectional studies by use of questionnaires or structured interviews for collecting data with the intent to generalize from the sample to the population.

According to Creswell (2007), qualitative research explores and understands the meaning individuals or groups ascribe to a social or human problem. Case study strategy is used to obtain information from the municipalities and the private waste collectors. Under this strategy, open-ended interviews are conducted with the experts in the SWM sector. A number of studies have used interviews to extract data from participants. Wilson (2007) conducted interviews with 10 WM experts in order to extract data on the drivers for managing SW. Shaharudin et al (2015) interviewed 6 manufacturers and

Murakani et al (2015) conducted 22 interviews. Therefore, interviews are conducted with the WM experts in order to extract detailed and comprehensive information since open ended questions are used.

Questionnaires

Advantages of Using Questionnaires

A number of factors are considered for employing questionnaires as data collecting instruments. Questionnaires give participants the opportunity to provide anonymous feedback and data is collected fast. Cohen et al (2007) highlights the advantages of using questionnaires;

- In a short space of time, a number of participants can complete the questionnaire
- The accuracy of the questionnaires can be checked by test administrators
- It is cheap and easy to conduct
- Participants across long distances can be researched
- An optimal response rate can be obtained
- Participants can be assisted with challenging questions by the interviewer

Based on the advantages highlighted by Cohen et al (2007), the questionnaires are considered to be the best data collecting instruments for the households, plastic manufacturing and recycling companies' and the IWCs. Further, the strategy for using questionnaires is based on the appropriateness of distributing the questionnaires across different geographical areas in a relatively short time span and at the same time considering large sample sizes (Leedy and Ormand, 2005). Further, the much-needed information from the households, plastic manufacturing and recycling companies and the IWCs is provided as the respondents reply to the ready-made categories of questions (Kumar, 2011).

Questionnaire Design

Kothari and Garg (2014) point out that, structured questionnaires are questionnaires in which there are concrete, predetermined and definite questions. In order to design the questionnaires sufficient time to decide on the specific wording to be used, approaches and questionnaire structure to meet the research objectives is taken. Closed-ended questionnaires are designed for the households, plastic manufacturing and recycling companies and the IWCs. It took a few months to design the three types of questionnaires. An extensive literature review was conducted prior to the design of the questionnaires. Ghauri and Grønhaug (2005) indicate that, careful review of literature, discussion of ideas and conceptualization of own research is needed prior to the design of the questionnaire. This implies that, the data that is gathered through the questionnaires is directed towards bridging the research gap and answering the research aim, questions and objectives. The three questionnaires are similar in some sections and different in other sections. The purpose is to achieve the set research aim of designing a RL model for PSWs for the Zambian context.

Simple and direct wording for the questionnaires is used. The purpose is to ensure the questions have the same meaning for the respondents as implied by the researcher as well as provide clear understanding. The interest of making sure the respondents complete the questionnaires is taken into consideration during the design. This is done by varying the questionnaires' format and providing a variety of constructs.

The quality and wording of the questionnaires is ensured as it influences the results of the research. The Department of STATKON at the University of Johannesburg and the main supervisors of the research critiqued the questionnaires to ensure quality, proper wording and flow of the questions. The critics are provided to ensure the questionnaires are free from the bias of the interviewer and also ensure respondents have adequate time to provide well thought out answers. Further, the guidelines of answering the questionnaire items are provided at the beginning of each section in all the questionnaires.

Aspects Considered in the Design of the Questionnaires

Maree and Pietersen (2007) point out that, questionnaire design is an important part of the research process as research data is generated from it. The three types of questionnaires are designed to gather the required data for the research as well as facilitate the application of statistic techniques. Data on the design of a sustainable RL model for PSWs in Zambia and strategies for sustainable recovery, recycling and management is aimed for. Five aspects are considered during the design of the questionnaires:

- ***Appearance of the Questionnaire***

  The questionnaires' appearance encourages respondents to take adequate time to complete them (Maree and Pietersen, 2007). The questionnaires are user-friendly, neat and the printing font is not too small.

- ***Order of the Questions***

  The order of the questions in the questionnaires is arranged in a way that does not confuse the respondents. A cover letter is attached to the questionnaires for the purpose of explaining the aim of the study and its relevance. Participants' agreement to participate in the research is also sort. Contact details for the researcher are provided on the cover letter in case a respondent has questions. Easy and simple questions form the first sections of the questionnaires. The focus of the first sections is biographical details of the respondents in order to put them at ease. A sequential order is followed for questions that focus on the same topic and questions with similar responses are arranged together (Mclntyre, 2005).

- ***Type of Questions***

  The questionnaires consist of list, ranking, category and scale-type of questions. These types of questions are divided into open (unstructured) and closed (structured) questions (Bell, 2005). For this research, the questionnaires are designed using closed-ended questions. The closed-ended questions provide the respondents with a set of responses to choose from. For some questions, more than one response is required. In the scale-type of questions, the most widely used scale, Likert-type is applied.

- ***Question Wording***

The variables in the constructs are designed in a way that ensures the same meaning is interpreted by the respondents. Maree and Pietersen (2007) guidelines are ascribed to during questions compiling: proper language; plain, clear and simple questions; one specific statement; double-negative and offensive questions are avoided,

- ***Completion Time of the Questionnaires***

Maree and Pietersen (2007) indicate that, a questionnaire should be completed in under half an hour by learner respondents while 20 minutes should be taken by an adult. The three types of questionnaires have an average completion time of 15 minutes. The household questionnaire is answered on the same day with or without the help of the researcher. Some questionnaires are left for collection on the next day. The IWCs' questionnaires are mainly answered with the help of the researcher. The plastic manufacturing and recycling companies are left with the companies and collected on an arranged day and time.

Household Questionnaires

This questionnaire is divided into four (4) sections. Sections 1 assesses the households on socioeconomic factors of age, gender, education level, income level and household size (Kishino, 1999; Scott, 1999; Owens et al, 2000; Hangu et al, 2000; Domina and Koch, 2002). Section 2 focuses on household knowledge on PSWs recycling (Omran et al., 2009; Vincent and Reis, 2008; Isa et al., 2005). Section 3 focuses on the reasons households participate in PSWs reuse and recycling programs. A number of studies were reviewed in order to design the constructs (Afroz et al., 2017; Omran et al., 2009; Vincent and Reis, 2008; Sidique et al., 2010). Section 4 focuses on households' support to PSWs recycling. A number of constructs such as levers for supporting community PSWs recycling (Vicente and Reis, 2008; Omran et al, 2009; Sidique et al, 2009; Troschinetz and Mihelcic, 2009; Sidique et al, 2010; Hotta and Aoki-Suzuki, 2014; Xevgenos et al, 2015); types of preferred and used waste collection systems (Dahlen and Lagerkust 2010; Larsen et al, 2010; Singhirunnusorn et al, 2011; Xevgenos et al, 2015; Yin, 2016; Gallardo et al., 2012) and the factors for integrating the IWCs into formalized systems (Medina, 2002; Wilson et al 2006; Gutberlet, 2008; Sembiring and Nitivattanon, 2010; Atienza, 2010; Chaturvedi, 2011; Gunsilius, 2011; Matter et al, 2013, Storey et al, 2015; Fei et al, 2016) are assessed. (Annexure A)

Plastic Manufacturing and Recycling Questionnaire

This questionnaire consists of five (5) sections. Section 1 assesses the companies' socioeconomic factors such as, location of the company in the country and the number of employees. Section 2 focuses on plastic manufacturing, recycling and buying practices (Kinobe et al, 2015, Plastic ZERO, 2013; Plastic Waste Recycling, 2009, Bio- Intelligence, 2013). Section 3 focuses on the strategies that influence the companies to recover and recycle PSWs (Srivastava, 2008; Plastic Waste Recycling, 2009; BIO Intelligence, 2013; Bing et al, 2012; Matter et al, 2013; Plastic ZERO, 2013; Xevgenos et al, 2015). Section 4 assesses the companies on the barriers to RL and recycling of PSWs (Carter and Ellram, 1998; Shekdar, 2009; BIO- Intelligence, 2013; Plastic ZERO, 2013; Zhang et al., 2011). Finally, section 5 assesses the companies on the strategies for integrating the IWCs into formalized systems (Medina, 2002; Wilson et al 2006; Gutberlet, 2008; Sembiring and Nitivattanon, 2010; Atienza, 2010; Chaturvedi, 2011; Gunsilius, 2011; Matter et al, 2013, Storey et al, 2015; Fei et al, 2016) and the types of waste collection systems preferred by the companies (Dahlen and Lagerkust 2010; Larsen et al, 2010; Singhirunnusorn et al, 2011; Xevgenos et al, 2015; Yin, 2016; Gallardo et al., 2012). (Annexure B).

Informal Waste Collectors Questionnaire

The IWCs questionnaire had a total of 23 questions which are divided into three (3) sections. Section 1 focuses on the socioeconomic factors of the IWCs of age, gender, income level, education level and types of IWCs (Ezeah et al., 2013; Wilson et al 2006). Section 2 focuses on the collection and trading of PSWs by the IWCs. A number of constructs are designed based on review of literature (Plastic ZERO, 2013; Plastic Waste Recycling, 2009; BIO-Intelligence, 2013; Shen et al., 2009; Ezeah et al., 2013; Scheinberg et al., 2013; Coelho et al., 2011). Section 3 focuses on the strategies for integrating the IWCs (Medina, 2002; Wilson et al 2006; Gutberlet, 2008; Sembiring and Nitivattanon, 2010; Atienza, 2010; Chaturvedi, 2011; Gunsilius, 2011; Matter et al, 2013, Storey et al, 2015; Fei et al, 2016). and the challenges facing the IWCs (Asim, 2012; Wilson et al., 2006; Chaturvedi, 2011; Atienza, 2010, Gutberlet, 2010; Medina, 2007). (Annexure C).

Interviews

Structured open-ended interviews are conducted with WM experts in the municipalities and private waste collectors' companies (formal waste collectors). The purpose of conducting the interviews is to complement the data collected using questionnaires. A total of 20 experts in WM are contacted to participate in the interviews.

Interviews with the formal waste collectors provide the needed information for integrating the IWCs' in the RL model as well as provide the data on sustainable management of PSWs. Since the questions are open-ended but guided, more information on the study is obtained. Further, the interviews are conducted to collect detailed and comprehensive information about the subject matter. Flexibility is one of the merits interviews provide as some questions are restructured when need arises.

A letter of introduction indicating the purpose of the study and its relevance to the Zambian context was sent to the experts before the interviews are conducted (Annexure D). At most the interview with each expert lasts between 1 to 2 hours and it takes two months for all the experts to be interviewed.

The interview questions are similar in some ways to the IWCs' and plastic manufacturing and recycling companies. The main difference is that the questions for the FWCs are open-ended. A total of seventeen questions are asked to the FWCs (see Annexure D). The questions focus on the following aspects;

- Socioeconomic factors (gender, educational qualifications, job titles, type of organization and number of employees in the organization)
- PSWs Recovery and Recycling Practices
- Strategies and levers for positively influencing sustainable PSWs recovery and recycling in Zambia
- Barriers to the Recovery and Recycling of PSWs
- Lever for Integrating the FWCs and IWCs into Formalized systems.

3.5 Research Instrument Validation

Instrument validation is a critical criterion of any research as it indicates the degree an instrument measures what it is intended to measure. Kothari and Garg (2014) define validity as the extent to which differences found with a measuring instrument reflect true differences among those being measured. It checks whether the researchers' instrument of data collection has hit the bull's eye of the objectives of the research (Coleman and Briggs, 2002). The research instruments for this research is validated based on the method of data collection.

3.5.1 Questionnaire Validation

Cohen et al (2007) notes that, the validity of quantitative research design can be improved by, watchful drawing of the sample; application of suitable instruments and applying correct statistical methods. In this study, the questionnaires are validated using content, construct and face validity.

Content validity refers to the extent the research instrument covers the construct's entire content it has intended to measure (Babbie, 2007; Rubin and Babbie, 2005). Content validity is applied by presenting the questionnaires to the experts in the field and these are the supervisors of the study. This is done to validate the entire content of the research is covered.

Construct validity refers to the degree to which a measure confirms to predicted correlations with other theoretical propositions (Kothari and Garg, 2014). It is needed to standardize and enable well measurement of the constructs used in a research by other different groups of related items. In this research, Factor Analysis (FA) is used as a standardization indicator of the instrument by showing which items belong together. It is used to confirm theoretical dimensions are measured or determine underlying factors in a questionnaire of dimensions measured (Pietersen and Maree, 2007b). FA is conducted to determine items in the questionnaires that belong together and are measuring the same dimension.

Further, the questionnaires are construct validated through assessment by the officer at the University of Johannesburg, Statistical Consultation Services (STATKON). Items which are different from the group are either removed or the statements are reconstructed to fit the group. This is conducted before the final supervisors' scrutiny.

The extent to which a research instrument looks valid refers to face validity. Gravetter and Forzano (2003) highlight that, superficial appearance of the face value of the measurement procedure concerns face validity. Face validity is ensured by presenting the questionnaires to the research supervisors for their professional judgement. Further, a pilot study is conducted to ensure that the respondents have no problems understanding the questions and that, instructions are followed. The pilot study assesses how long the respondents take to answer the questionnaire, the clarity of the instructions, which questions are unclear and whether there are questions respondents are uncomfortable to answer.

3.5.2 Questions Validation

Research questions are validated by following the guidelines of Mertens (2010) and Lincoln and Guba (1985) of ensuring four central factors of attending trustworthiness.

Credibility is ensured by using the triangulation method to gather data on the experiences and perceptions of the participants with regard to PSWs management and RL.

Guba and Lincoln (2005) highlights that, to ensure transferability, purposeful sampling could be obtained from and on the context while maximizing the range of specific information. For this research, purposive sampling using homogenous sampling to ensure most of the information on the research scope is obtained from the participants is used.

Conformability is assured by making certain the findings of the research result from the focal point of the research investigation and not from the biasness of the researcher (Babbie and Mouton, 2001).

Dependability is ensured by making certain the findings happen according to the researcher's report and if the study is to be repeated, the same findings would be reported (Durrheim and Wassenaar, 1999).

3.6 Reliability Testing

The test of reliability is one of the important sound tests of measurement (Kothari and Garg, 2014). Welman et al (2005) defines reliability as the extent to which results; are a stable measurement of data, consistent over time; present the total population of the study and if reproduced under similar methodology, the results can be the same. Two aspects of reliability are given attention in this research; stability and equivalence.

Stability in reliability is concerned with securing consistent results with repeated measurements of the same person and with the same instrument. To test for internal consistency of the scale, the Cronbach's alpha is used. The Cronbach's alpha is one of the widely reported popular conventional standards for ascertaining internal consistency reliability (Shelvin et al, 2000; Hinkin, 1995). According to Pallant (2010), the Cronbach's alpha of the scale should be above 0.7. In cases were the Cronbach's alpha is lower than 0.7, it is appropriate to report the mean inter-item correlation. Briggs and Cheek (1986) recommend an optimal range for the mean inter-item correlation of 0.2 to 0.4 while Clark and Watson (1995) recommend a range of 0.15 to 0.4. In order to guide interpretation of the Cronbach's alpha, Nunaly (1978) provides values of guidance in Table 3.3.

Table 3.3: Interpretation of the Cronbach's Alpha Values
(NUNALY, 1978)

Values	**Reliability**
< 0.5	Poor
0.5 to 0.7	Sufficient
> 0.7	Good

In this research, a cut-off point for the internal consistency reliability is 0.5 and for the scales which have a Cronbach's alpha of less than 0.5, the mean inter-item correlation is considered of the range 0.15 to 0.4 (Clark and Watson, 1995).

3.7 Missing Values

The questionnaire is designed in the format of list, ranking, category and scale type of questions. Respondents are provided with various options to tick. Nevertheless, some of the respondents have limited understanding of the questionnaire, therefore missing values are inevitable.

3.8 Data analysis

3.8.1 Quantitative Data Analysis

To satisfy the requirements necessary for answering the research questions and objectives, a number of steps are employed. Firstly, the collected data from the questionnaires is coded in Microsoft Excel and using Statistical Software for Social Sciences (SPSS), the coded data is analyzed. Descriptive statistics focusing on the measures of central tendency and dispersion are analyzed. The measures describe and compare the variables of the research numerically. The mean, median, mode, standard deviation and variance are used for descriptive statistics. Tables, cross-tabulation and diagrams such as bar charts and pie-charts are used in presenting the data findings.

In order to resolve the sets of measured variables into relatively few categories, FA is used. FA is applied on the constructs that assess the stakeholders on the levers that influence them to participate in PSWs recycling programs. The factored levers form the variables for modeling the RL.

Inferential statistics is used to establish relationships within the sample and to make estimates of the population characteristics. According to Kruger and Neuman (2006) inference statistics permits inferences from a sample to a population, uses probability theory to test hypotheses and tests descriptive results on the basis of random or real relationships. In this research, relationships on the levers that influence households and the IWCs to recovery and recycle PSWs are established and tested.

3.8.2 Qualitative Data Analysis

Using themes and codes, the qualitative data is analyzed. Inductive and deductive judgment is used to perform content analysis of the collected data. According to Wilkenson, (2011), content analysis involves the examination of gathered data for repeated occurrences which are methodically identifiable and clustered together by means of a coding scheme. Themes for the gathered data are collected in terms of; PSWs recycling; strategies and drivers that positively influence PSWs recovery and recycling in Zambia, barriers of PSWs recovery and recycling, levers for integrating the IWCs into formalized systems and the way forward to sustainable PSWs management in Zambia.

3.8.3 Concurrent Triangulation

To merge quantitative and qualitative data, concurrent triangulation is used. Creswell (2009) indicates that, both forms of data are collected at the same time and integrated at the interpretation of the overall results. Creswell (2009) further indicates that, selection of the type of research approach is not the end to a research design. The selection of the type of study within the selected research approach is cardinal. Concurrent triangulation model is adopted for this research as it merges qualitative and quantitative data for the purposes of providing a comprehensive analysis of the research problem. Both qualitative and quantitative data are collected from different data sources at the same time and the results are integrated in order to design the RL model for PSWs as well as recommend strategies for recovering PSWs in Zambia. Figure 3.1 depicts the concurrent triangulation model that is adopted in this research.

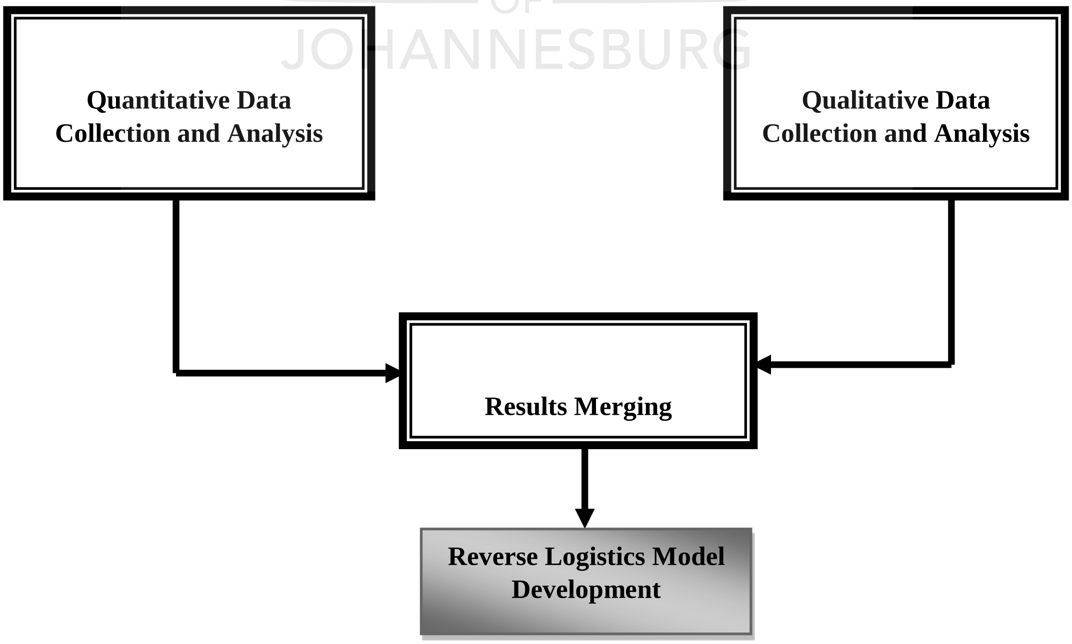


FIG 3.1: CONCURRENT TRIANGULATION DESIGN
(SOURCE: AUTHOR, 2017)

Mergence of qualitative and quantitative data is focused on the levers that influence households, informal and formal waste collectors as well as plastic manufacturing and recycling companies to participate in PSWs recycling programs. The influential levers for each data- set are identified at the assessment stage and compared. These levers are considered for integration in the RL model for PSWs recycling.

Strategies for the recovery and recycling of PSWs are assessed at each data collection point. After assessment, a comparison of statistical and qualitative results is performed in order to merge the results and make recommendations.

3.9 Model Development

The proposed RL model is designed based on the analysis of quantitative and qualitative data according to the research questions and model objectives. The analyzed survey questionnaires and case study interviews assess the stakeholders on the levers that influence their participation in PSWs recovery and recycling programs in Zambia. Also, a number of strategies concerning PSWs recovery and recycling are assessed. Using the identified quantitative and qualitative data analysis techniques, the findings are used in developing the recovery and recycling RL model for PSWs.

A theoretical model based on the findings of the results and literature is used in developing the model. Mass balancing is used in modelling the RL model based on mathematical equations. Under the scenario approach, the RL model is used to analyze the optimal amount of PSWs that can be recovered from the generators and recoveries.

Chapter Four: Quantitative Data Analysis and Discussions

4. Introduction

This chapter presents quantitative results as extracted for the research. Quantitative data is obtained from the questionnaires collected from; households', IWCs and plastic manufacturing and recycling companies' surveys.

Research data presented in this chapter is divided into five sections. Firstly, the response rates from the four data sets are presented. In the second section data from the households is presented. The third section presents the findings on the IWCs. Findings from the plastic manufacturing and recycling companies are presented in the fourth section. The fifth section discusses data on independent sample t-test and Analysis of Variance (ANOVA).

4.1 Response Rates of the Questionnaire Surveys

The response rates presented are for the; household, plastic manufacturing and recycling companies and the IWCs. Equation 4.1 is used in determining the total response rates for the three questionnaires.

$$\text{Total Response Rate} = \frac{\textit{total number of responses}}{\textit{total number in sample} - (\textit{ineligible})} \qquad \text{(Equation 4.1)}$$

Table 4.1 depicts the total response rates. Response rates vary depending on the type of study and method of data collection. Baruch (1999) recommends a response rate of approximately 35% for academic research involving organisations or top management. This implies the response rate of 91.6% from the plastic manufacturing and recycling companies is within range. Others recommend response rates of between 50 to 65% (Willmack et al, 2002). Neuman (2005) recommends a response rate of between 10 to 50% for post questionnaires while for face to face interviews a 90% response rate is recommended. The response rates obtained for this research are within the recommended response rates.

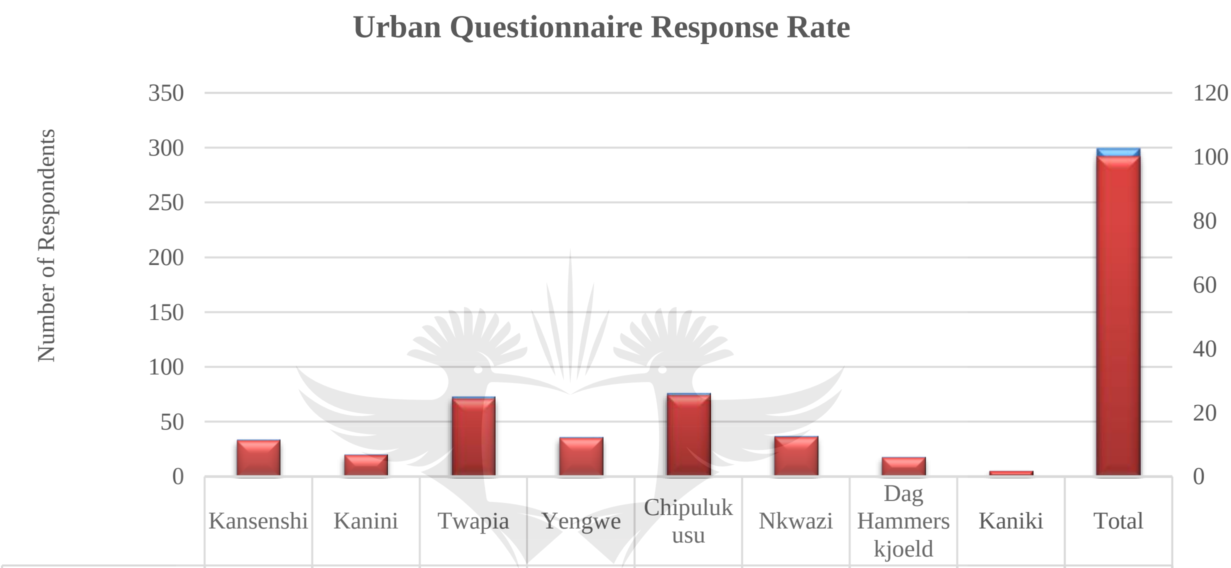
TABLE 4.1: TOTAL RESPONSE RATE FOR THE QUESTIONNAIRES

	Population Size	Total number in sample Size	Total number of responses	Ineligible	Total Response Rate
Households	29,692	445	299	50	75.6%
Plastic manufacturing and recycling companies	38	30	22	6	91.6%
IWCs	120	60	53	4	94.6%

4.2 Household Interpretation of Results

4.2.1 Urban Questionnaire Distribution

With reference to section 3.3.1 on household sample size technique, questionnaires are distributed in a total of eight (8) urbans of the city of Ndola. Figure 4.1 depicts the results of the distribution. Out of the 299 questionnaires collected representing 100%; 11.4% of the respondents are from Kansenshi, 6.7% from Kanini, 24.4% from Twapia and 12% from Yengwe. Chipulukusu is represented by 25.4%, Nkwazi by 12.4%, Dag Hammerskjoeld by 6% and Kanini by 1.7%.



	Kansenshi	Kanini	Twapia	Yengwe	Chipuluk usu	Nkwazi	Dag Hammers kjoeld	Kaniki	Total
Frequency	34	20	73	36	76	37	18	5	299
Valid Percentage	11	7	24	12	25	12	6	2	100

FIG 4.1: SUBURBAN QUESTIONNAIRE RESPONSE RATE

4.2.2 Socioeconomic Information of Households' Respondents

This section describes the socioeconomic information from the household respondents. The data depicted in Table 4.2 depicts the distribution of the respondents' socioeconomic data in terms of age, gender, income level, occupation, education level and household size.

TABLE 4.2: SOCIOECONOMIC INFORMATION OF THE HOUSEHOLDS' RESPONDENTS

Demographics	Frequency and Valid Percentage
Gender	
Male	157 (52.5%)
Female	142 (47.5%)
Age	
Younger than 26 years	173 (57.9%)
26-36 years	76 (25.4%)
37-47 years	32 (10.7%)
48-58 years	13 (4.3%)
59-69 years	4 (1.3%)
Older than 69 years	1 (0.3%0
Education Level	
Primary	30 (10.1%)
Secondary	105 (35.2%)
College	108 (36.2%)
Undergraduate Degree	40 (13.4%)
Postgraduate Degree	14 (4.7%)
Other	1 (0.3%)
Occupation	
Government Employee	23 (7.7%)
Corporate (Private)	74 (24.7%)
Own Business	83 (27.8%)
Housewife	32 (10.7%)
Student	55 (18.4%)
Retired	8 (2.7%)
Other	24 (8.0%)
Income Level	
Below K1,000	52 (17.4%)
K1,000-K5,000	100 (33.6%)
K5,001-K10,000	58 (19.5%)
K10,001-K15,000	26 (8.7%)
K15,001-K20,000	6 (2.0%)
K20,001-K25,000	1 (0.3%)
Above K25,000	2 (0.7%)
No income	53 (17.8%)
Household Size	
Live alone	16 (5.4%)
2 people	17(5.7)
3 people	46 (15.5%)
4 people	76 (25.6%)
5 or 6 people	84 (28.3%)
More than 6 people	58 (19.5%)

In terms of gender, the results show that the male counterpart outweigh the female by 5%. For the age distribution, more than half of the respondents are younger than 26 years old (57.9%). The results on education distribution indicate that most of the respondents have a college education (36.2%). Studies of Owens et al (2000) and Afroz et al (2017) affirm that a positive correlation exists between education and recycling participation. For households' occupation distribution, the majority of the respondents owe their own businesses (27.8%). Income distribution for the households reveals that, the majority of the respondents earn between K1000 to K 5000 a month (33.6%) and this income is on a lower scale of the ranking. Households' distribution reveals that, the majority of the households had 5 or 6 people living in the house (28.3%). In terms of PSWs generation, the households with 5 or 6 people are likely to generate more waste depending on their consumption patterns. Antonia (2009) affirms that socioeconomic factors are the best segmentation tool to determine the characteristics of recyclers and non-recyclers. Differences between different segments of socioeconomic factors and the levers that influence households to participate in recovery and recycling programs are established in section four (4).

4.2.3 Household Knowledge on PSW Recycling

This section discusses the results from the household survey on the level of knowledge respondents have on PSWs recycling, where they learnt about PSWs recycling, the types of recyclable PSWs known by the respondents and the type and amount generated on a monthly basis.

Knowledge on PSW Recycling

Analysis of the results depicted in Table 4.3 reveals that, the majority of the respondents that participated in the survey are knowledgeable about PSWs recycling (72%). Section 4.2.2 reveals that 36.2% of the respondents have college education and this confirms the 72% knowledge about PSWs recycling. Knowledge on PSWs is a positive attribute for assessing respondents that participate in recycling. Nixon and Saphores (2009) indicate that positive correlation exists between recycling and public education and information. Further, the results show that, most of the respondents learnt about PSWs recycling from social media (32.1%). This is supported by Vicente and Reis (2008) who indicate that, national newspapers, magazines, radio and television facilitate in transmitting general messages to the population on recycling. Abdelnaser et al (2006) indicates that public participation in recycling programs is increased by integrated use of media. Further, having 14.3% representation of PSWs recycling in primary schools is unsustainable for achieving future waste recovery and management goals. The future waste recyclers should learn about PSWs at foundation levels of basic education.

TABLE 4.3: HOUSEHOLDS PSWS RECYCLING KNOWLEDGE

	Frequency Number and Valid Percentage
Do you Know about PSW Recycling?	
Yes	211 (72%)
No	82 (28%)
Where did you learn about PSW Recycling?	
Primary School	36 (14.3%)
Secondary School	75 (29.8%)
College or University	31 (12.3%)
Social Media	81 (32.1%)
Political Campaigns	9 (3.6%)
Workplace	11 (4.4%)
Other	9 (3.8%)

Types of Recyclable and Generated PSW

Analysis of the results depicted in Table 4.4 indicates that, the majority of the respondents know that plastic bottles are recycled (39.9%). This is supported by Plastics Recycling (2009) which indicates that most recyclable plastics are manufactured into bottles. The results show that, the majority of the respondents generate plastic bags (52.1%) while 31.2% of the households know that plastic bags are recycled. For the proposed RL model, information and awareness on the types of recyclable plastics needs to be availed to the households in order to create a balance between the amount generated and the amount that is handed in for recycling.

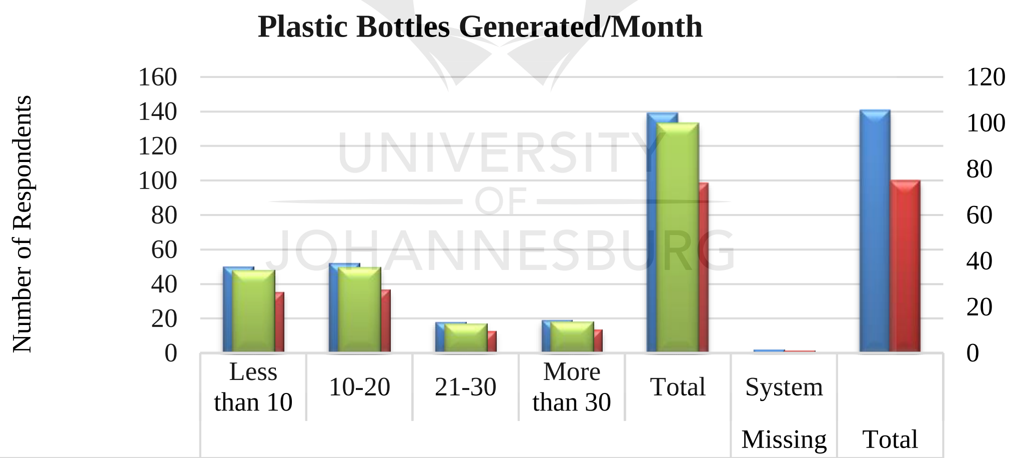
TABLE 4.4: TYPES OF RECYCLABLE AND GENERATED PSWS

	Frequency Number and Valid Percentage
What type of PSW can be Recycled?	
Plastic Bottles	151 (39.9%0
Plastic Bags	118 (31.2%0
Plastic Containers	108 (28.6%)
Others	1 (0.3%)
What type of PSW do you generate?	
Plastic Bottles	141 (29.8%)
Plastic Bags	247 (52.1%)
Plastic Containers	86 (18.1%)

The information on the most generated type of PSWs is important to waste recoveries and recyclers for the proposed RL model. From an economic aspect, knowing the types and amount of PSWs generated by the households provides the data, needed to identify the recycling and sorting machines to purchase; schedule the collection routes, determine the transportation machinery and the workforce needed and quantify the amount that are generated from each household based on the household size determined in section 4.2.2.

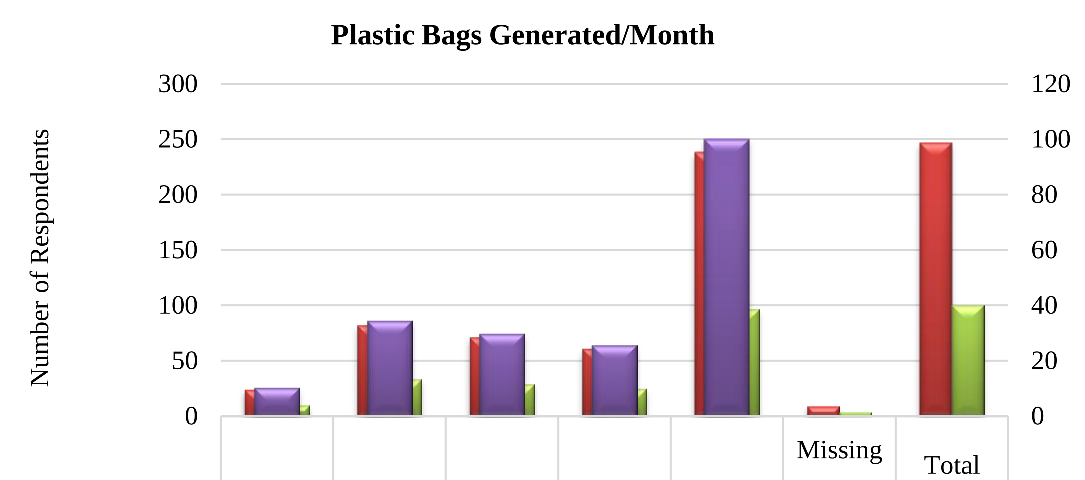
Amount of PSWs Generated by the Respondents/Month

Figures 4.2, 4.3 and 4.4 depict the results on the amount of PSWs generated by the respondents. In terms of plastic bottles, the majority generate between 10 to 20 bottles per month (37.4%). For plastic bags, most respondents generate between 10 to 20 plastic bags per month (34.5%). As for plastic containers, the majority generate less than 10 plastic containers per month (73.5%). This indicates that, plastic containers are not normally generated on a monthly basis. The output on the amount of PSWs generated is important for developing sustainable RL systems which start from the households. The information on the number of people living in the households and the amount of PSWs generated by the respondents on the monthly basis provides a clear picture of quantifiable PSWs that are recovered from the households. Further, the results show that, of the three types of PSWs wastes generated by the respondents, plastic bags are generated more on the quantitative basis. This is supported by the results on the most generated type of PSWs (52.1%).



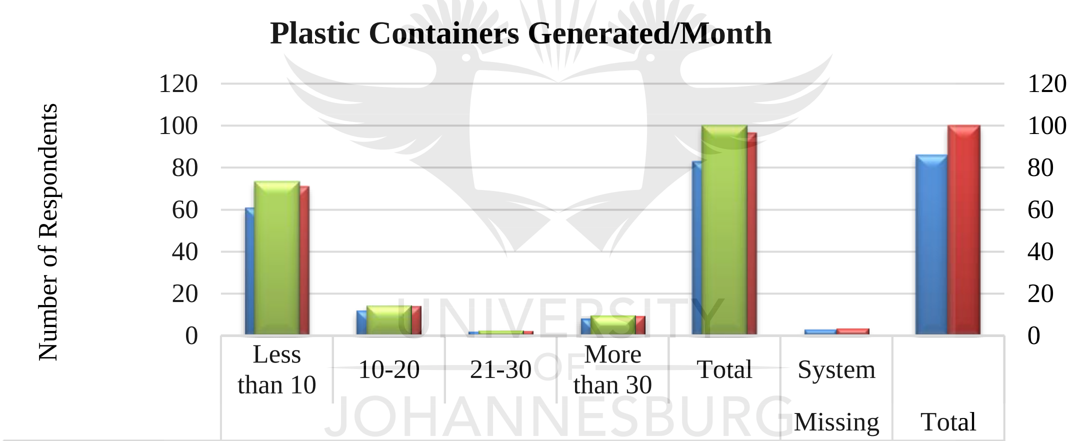
	Less than 10	10-20	21-30	More than 30	Total	System Missing	Total
Frequency	50	52	18	19	139	2	141
Percent	35	37	13	13	99	1	100
Valid Percentage	36	37	13	14	100		

FIG 4.2: AMOUNT OF PLASTIC BOTTLES GENERATED PER MONTH



Frequency	24	82	71	61	238	9	247
Percentage	10	33	29	25	96	4	100
Valid Percentage	10	34	30	26	100		

FIG 4.3: AMOUNT OF PLASTIC BAGS GENERATED PER MONTH



	Less than 10	10-20	21-30	More than 30	Total	System Missing	Total
Frequency	61	12	2	8	83	3	86
Percentage	71	14	2	9	97	3	100
Valid Percentage	73	14	2	10	100		

FIG 4.4: AMOUNT OF PLASTIC CONTAINERS GENERATED PER MONTH

4.2.4 Reasons for Households' Participation in PSWs Reuse and Recycling

This section discusses results on the assessment of whether households recycle and/or reuse PSWs and the purposes they reuse the PSWs for. Results on whether the households segregate their waste; the waste collection providers and the frequency of waste collection per week are also discussed. Further the results on why the respondents recycle PSWs and why they do not recycle are discussed.

PSW Recycling, Reusing and Purposes for Reusing

The results in Table 4.5 indicate that, the majority of the respondents do not recycle PSWs (80.2%). The low rate in PSWs recycling is supported by the fact that most recyclables in developed economies are recovered by the IWCs through decentralised selling and buying of waste materials (Ezeah et al., 2013; Scheinberg et al., 2011; Gutberlet, 2010; Medina 2007; Coelho, 2011). The research shows that only 1% of the IWCs recover PSWs from the households. This is a low representation by the IWCs considering that, most studies indicate that, the IWCs are major waste recoveries in developing economies. It is an indication that, the IWCs are not integrated in the household waste recovery programs.

TABLE 4.5: PSWS RECYCLING, REUSING AND PURPOSES FOR REUSING

Question	Frequency Number and Valid Percentage
Do you Recycle PSWs?	
Yes	59 (19.8%)
No	239 (80.2%)
Do you Reuse PSWs?	
Yes	223 (74.8%)
No	75 (25.2%)
For what purpose do you reuse the PSWs?	
Storing food stuffs	117 (34.3%)
Storing fluids e.g. water, juice etc.	127 (37.2%)
Storing trash	95 (27.9%)
Other	2 (0.6%)

Although the majority of the respondents indicate knowing about PSWs recycling in Section 4.2.3 the majority do not participate in recycling programs. PSWs reusing shows that, the majority of the respondents' reuse (74.8%) PSWs for storing fluids etc (37.2%). PSWs reusing is highly favoured on the WM hierarchy as a sustainable aspect of managing wastes. Reusing PSWs gives the products a second life thus contributing to SWM and resource utilization. This implies, the aspect of virgin material preservation is not addressed by reusing PSWs and this, can only be achieved through recycling.

The information on PSWs recycling statistics provides the much-needed information for developing a RL model for recovery and recycling PSWs. 19.8% participation in household recycling programs shows the need to develop a sustainable RL model. Further the low representation indicates the need to identify the levers that influence the households to participate.

Segregation of Plastic Solid Wastes

Respondents that recycle PSWs are assessed on waste segregation and of the 59 respondents that answered "Yes" to PSWs recycling. Figure 4.5 depicts that, 54% of the respondents segregate waste while 42% do not segregate waste.

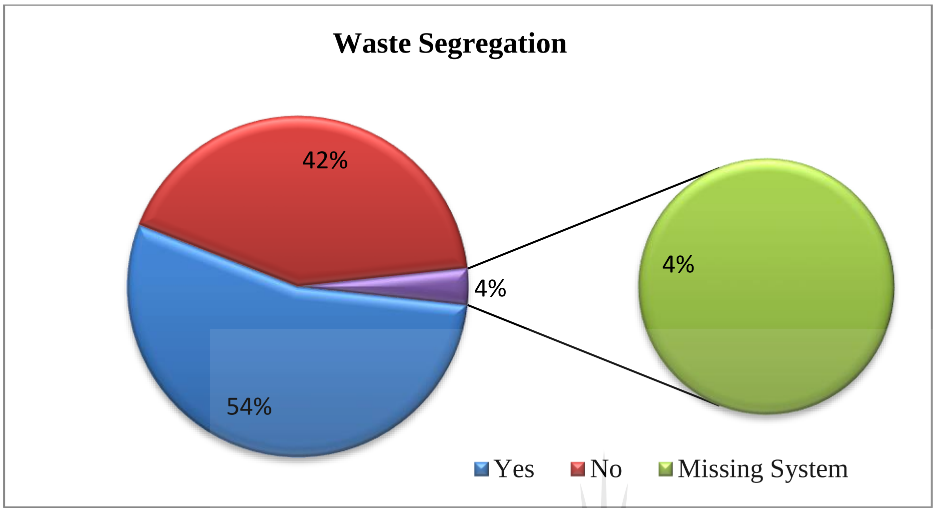


FIG 4.5: WASTE SEGREGATION

Waste segregation by the majority of the respondents shows a positive direction towards sustainable resource recovery. Rispo et al (2015) supports source- segregation as a fundamental role of achieving maximum materials recovery. 42% of none-segregation of PSWs is a high contribution to unsustainable resource recovery. In order to achieve high PSWs segregation rates, for the proposed RL model, waste segregation should start at the source of generation and the households should be trained and educated.

Waste Collection Providers

Figure 4.6 depicts results on waste collection providers. Most of the households have their waste collected by the private waste collectors (42%). For those that indicated "other" (37%), the majority resort to non-sustainable options of managing PSWs such as burying and burning.

The low representation of the IWCs and the municipality indicates that these stakeholders are not fully engaged in the recovery of PSWs from households. The plastic manufacturing and recycling companies' low representation also indicates that, these stakeholders have not designed RL systems at their companies. High percentages of waste burying and burning confirm the findings on MSWs disposal methods. 47% of waste in Africa is open dumped while 9% is burnt (World Bank, 2012). The United Nations Environmental Programme (2015) affirms that 57% of plastics in Africa is not collected but littered or burned in the open.

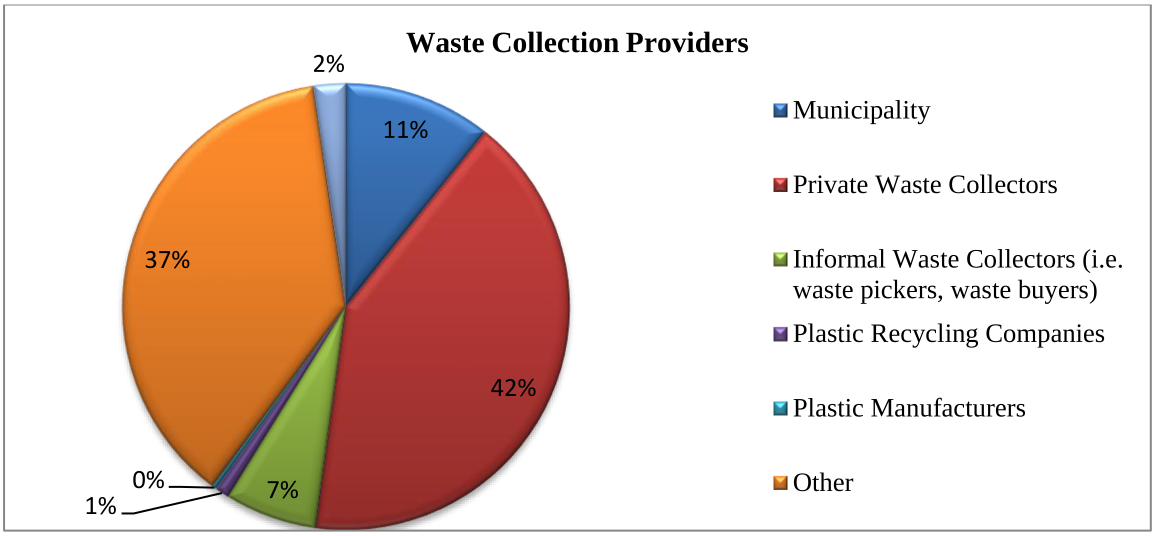


FIG 4.6: WASTE COLLECTION PROVIDERS

Low representation of the municipality, IWCs and the plastic manufacturing and recycling companies shows the need to develop a RL model that integrates these stakeholders. BIO-intelligence (2013) indicates that, in order to achieve sustainable recovery rates for PSWs, there is need for closer engagement among the plastic manufacturers and recyclers and other players along the supply-chain

Frequency of Waste Collection

Figure 4.7 depicts results on the frequency of waste collection by the waste collection providers. Majority of the respondents have their PSWs collected once a week (81%). As a result of the absence of convenient disposal facilities, recyclable or reusable waste is illegally disposed of or ends up at the landfills (Banga, 2009; Morris, 1994; Tadesse, 2009). The low frequency can be attributed to why most respondents resort to unsustainable options of managing PSWs. The low frequency in waste collection is not an efficient means to achieving sustainable waste recovery and management. Hoornweg and Bhada-Tata (2012) state that, approximately 41% of collection coverage is achieved in lower-income countries. The results show the need to develop a RL system for recapturing valuable PSWs back in the supply-chain. Further, sustainable recovery rates for PSWs can be achieved if information on the amount of recyclable PSWs generated per month per household (Section 4.2.2) is available as it facilitates in determining the number of waste collection frequencies for each urban (household).

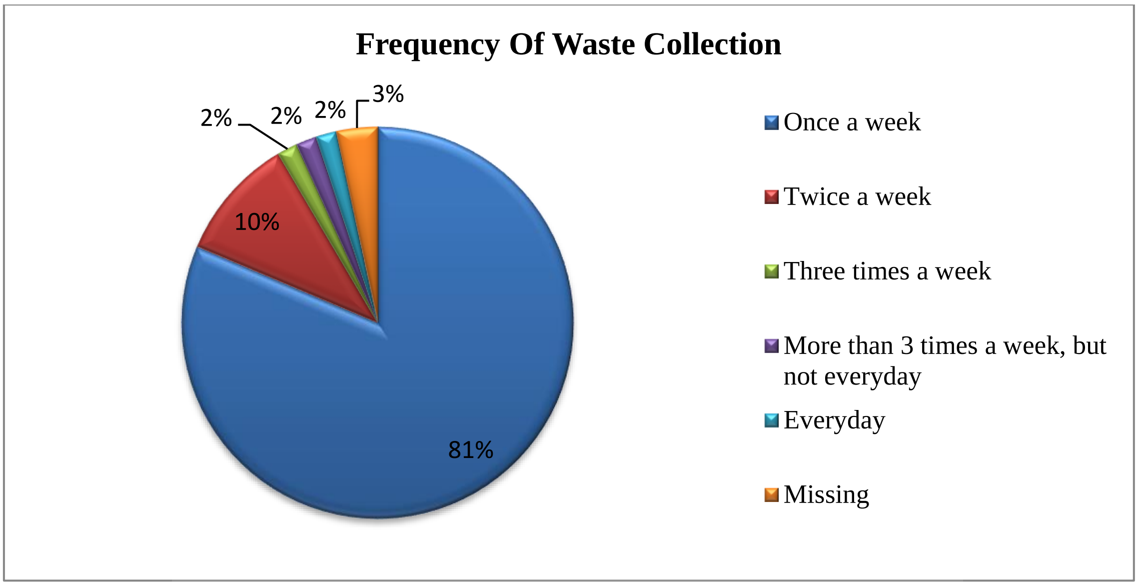


FIG 4.7: WASTE COLLECTION FREQUENCIES

Reasons for Recycling PSWs

The descriptive statistics depicted in Table 4.6 indicate that, the most important reason for recycling is, 'I have a strong interest in the health and well-being of the community in which I live' (4.68, 0.539); followed by 'I am concerned about creating a better place to live in,' (4.49, 0.751) and 'Recycling creates a better environment for future generations' (4.49, 0. 817) being the third ranked reason for participating in recycling. 'Recycling reduces the amount of waste that goes to the landfill' (4.36, 0.846) is ranked fourth. The first four reasons for the respondent's participation in recycling programs have the results above the average mean value. From a WM perspective, maintaining a healthy environment has being one of the key drivers for developing ISWM systems (Wilson et al, 2006, Shekdar, 2009) and the first four reasons point directly to healthy and environmental concerns. Nevertheless, SWM is now more focused on sustainable resource utilization and this is where the aspects of RL come in and focus both on the environmental concerns as well as the economic benefits of resource recovery.

TABLE 4.6: REASONS FOR RECYCLING PSWS

	Reasons for Recycling PSW	Mean	Standard Deviation (SD)
1	Recycling reduces the amount of waste that goes to the landfill	4.36	0.846
2	Recycling preserves the natural resources	4.03	1.050
3	Recycling creates a better environment for future generations	4.49	0.817
4	I am concerned about creating a better place to live in	4.49	0.751
5	I have a strong interest in the health and well-being of the community in which I live	4.68	0.539
6	Recycling bins are provided	2.54	1.478
7	Recycling incentives or rewards are provided	2.37	1.461
8	Bin space can be preserved	3.49	1.194
9	Friends are doing it	2.61	1.365
10	Recycling creates employment for others	4.14	1.042

Reasons for not Recycling PSWs

Table 4.7 depicts results on the assessment of the reasons households do not participate in recycling programs. About 23.1% rank, 'there are no facilities for recycling plastic waste,' 21.6% rank 'there is lack of information about recycling plastic waste,' and 12.7% rank, 'recycling plastic waste is not mandatory.' 'Existing waste collection systems are not adequate' (10.2%) is fourth in ranking and 'there are no rewards or incentives for recycling PSWs' is fifth. 'Formal or informal waste collectors do not collect the plastic wastes' is ranked sixth. The first six reasons are important for successful implementation of RL systems. These reasons are supported in literature as important factors to households' participation in recycling programs (Rodrigues et al, 2016; Welfens et al (2015; Xevgenos et al, 2015; Singhirunnusorn et al., 2011; Yau, 2010). The indicated reasons for households not participating in recycling programs depict the current state of PSWs recycling in Zambia. These reasons are important factors to consider when developing recovery and recycling systems that integrate households. Plastic manufacturing and recycling companies, private waste collectors and the municipality should take these factors in consideration when designing RL systems for waste recovery.

TABLE 4.7: REASONS FOR NOT RECYCLING PSW

	Reasons for Not Recycling PSW	Frequency	Valid Percentage	Ranking
1	Recycling plastic waste is not mandatory	91	12.7%	3
2	Recycling plastic waste is inconveniencing	9	1.3%	12
3	I have no time for recycling plastic waste	25	3.5%	7
4	There are no facilities for recycling plastic waste	166	23.1%	1
5	There are no rewards or incentives for recycling plastic waste	65	9.1%	5
6	There are better ways to handle plastic waste	9	1.3%	12
7	There is lack of information about recycling plastic waste	155	21.6%	2
8	I have storage and handling problems	18	2.5%	10
9	It is not my responsibility to recycle plastic waste	19	2.6%	9
10	Whether I recycle plastic waste not, it will not make a difference	7	1.0%	13
11	Recycling plastic waste is difficult	23	3.2%	8
12	The existing waste collection system are not adequate	73	10.2%	4
13	I don't generate enough plastic waste	11	1.5%	11
14	Formal or informal waste collectors do not collect the plastic waste	47	6.5%	6

4.2.5 Households' Support to PSW Recycling

This section discusses results on the assessment of the levers that service providers such as the municipality, private waste collectors and plastic manufacturing and recycling companies should assess when developing RL systems supported by the households. Results on the type of waste collection systems used by the households that recycle PSWs and the type of waste collection system, households that do not recycle PSWs would prefer to use in order to support the recovery and recycling of PSWs are discussed. Further results from the assessment of the households on the 'strategies for integrating the IWCs into formalised systems' are also discussed.

Levers for Supporting Community PSWs Recycling

The descriptive statistics depicted in Table 4.8 indicate that, 'introduce information dissemination on plastic waste recycling through media and campaign,' (4.58, 0.817), 'introduce a national-wide regulation on PSWs waste recycling to encourage everyone's participation,' (4.49, 0.841), 'introduce household PSWs recycling training programs' (4.45, 0.945), 'increase the number of environmental campaigns on plastics recycling' (4.44, 0.823), 'provide the public with PSWs recycling infrastructures' (4.42, 0.891), 'introduce incentives to encourage participation in PSWs recycling,' (4.23,0.995), 'encourage households to allow waste buyers to buy PSWs from their homes,' (4.20, 1.114), 'introduce financial incentives to households meeting set PSWs recycling targets,' (4.19,1.032), 'provide well serviced municipal plastic collection points, (4.14,1.119), 'provide households with a separate bin for

PSWs that are collected weekly,' (4.12,1.068), 'encourage household PSWs separation,' (4.10, 1.111) and 'encourage efficient door to door PSWs collection by legalized scavengers,' (4.09, 1.065) have mean values above 4 on a Likert scale of 1 to 5.

Most studies show that information dissemination through media and campaigns, training of households on recycling, provision of incentives and recycling infrastructures and enforcement of regulations and legislations on plastic waste recycling work in promoting household participation (Xevgenos et al, 2015; Welfens et al., 2015; Sidique et al., 2010b; Abdelnaser et al., 2006). In Table 4.8 the levers with the mean value above 4 have a positive influence on households to participate in PSWs recovery and recycling programs. In order to develop the RL model driven by the levers that influence the households to participate in recovery and recycling programs for PSWs, the identified levers are modelled in the RL model. However, the number of levers with the mean above 4 is more than 10. FA is conducted to reduce the number of levers to a more manageable number.

TABLE 4.8: LEVERS FOR SUPPORTING PSWS RECYCLING

		Mean	**Standard Deviation (SD)**
1	Introduce household plastic recycling training programs	4.45	0.945
2	Introduce information dissemination on plastic waste recycling through media and campaign	4.58	0.817
3	Increase the number of environmental campaigns on plastics recycling	4.44	0.823
4	Introduce incentives to encourage participation in plastic waste recycling	4.23	0.995
5	Provide the public with plastic waste recycling infrastructures.	4.42	0.891
6	Encourage household plastic waste separation	4.10	1.111
7	Encourage households to allow waste buyers to buy plastic waste from their homes	4.20	1.114
8	Provide households with a separate bin for plastic waste that are collected weekly	4.12	1.068
9	Charge an additional charge for collection of recyclable plastic waste that is not separated	3.04	1.369
10	Encourage door to door plastic waste collection	3.97	1.202
11	Encourage efficient door to door plastic waste collection by legalized scavengers	4.09	1.065
12	Provide well serviced municipal plastic collection points	4.14	1.119
13	Introduce a national-wide regulation on plastic waste recycling to encourage everyone's participation	4.49	0.841
14	Introduce financial incentives to households meeting set plastic waste recycling targets	4.19	1.032

Preferred Waste Collection Systems by Households

Waste collection systems are an important subset of ISWM. The results in Table 4.9 depicts that, Kerbside collection system (89.7%) is the most preferred followed by buy-back recycling centres (83.7%). EPR system is third (70.3%) while drop-off system is ranked fourth (63.2%). It is necessary to assess the different waste collection systems as the amount of PSWs that is recovered is affected by the type of waste collection (Rodrigues et al, 2016; Dahlen et al., 2010, Sidique et al., 2010). Most studies show that kerbside waste collection system is preferred compared to other systems (Dahlen et al., 2008; Larsen et al, 2010; Gallardo et al, 2012a). This may be attributed to the fact that, in kerbside collection system, households are allocated with waste receptacles and are responsible for placing them for emptying at the curb on collection days. In order to achieve sustainable recoveries, some studies show that, the combination of waste collection system is cardinal (Sidique et al., 2010a; Sidique et al., 2010b). In the urban areas of Ndola, the households have shown their preference of waste collection systems. Determining the type of waste collection systems is important for the proposed RL because waste collection can influence households' participation in recovery and recycling programs.

EPR system is ranked third by the households; however, in developed economies such as Japan, Germany and The Netherlands, EPR has positively influenced PSWs recovery and recycling (Xevgenos et al., 2015). In order to achieve sustainable recoveries of PSWs, a combination of kerbside, buy-back centres and EPR waste collections systems is necessary for the proposed RL model.

TABLE 4.9: WASTE COLLECTION SYSTEMS PREFERRED BY HOUSEHOLDS

	Yes		**No**	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Deposit System (Returnable Container Legislation	139	59.7%	94	40.3%
Kerbside Collection System	210	89.7%	24	10.3%
Drop-off System	148	63.2%	86	36.8%
Buy Back Recycling Centres	195	83.7%	38	16.3%
EPR System	163	70.3%	69	29.7%

Types of Waste Collection Systems in Use by PSWs Recyclers

Figure 4.8 depicts the results on the assessment of the types of waste collection systems used by the respondents that indicated "yes" to recycling PSWs. Majority of the respondents use kerbside waste collection system (68%), followed by drop-off systems (14%) and buy-back centres (8%). Considering the number of households already participating in recovery and recycling programs of PSWs, these results point out the most influential waste collection system to consider for implementation in areas where PSWs is not recovered. Nevertheless, consideration should be given to the preferred waste collection systems (Table 4.9). The results depicted in Section 4.2.4 show that 80.2% of the respondents do not participate in PSWs recovery and recycling programs while 19.8% participate. Of the 80.2% that do not participate, the majority prefer kerbside, buy-back centres and EPR systems. In order to achieve sustainable recoveries, a combination of the waste collection systems should be implemented giving preference to kerbside, buy-back centres, EPR systems and lastly drop-of centres. Nevertheless, this should not be done in isolation of the frequency of waste collection. Perrin and Barton (2001) indicates that, providing the correct collection scheme design to households contributes to higher retain proportions and also captures the traditionally non-committed recycler thus ensuring maximum recovery of recyclables.

Figure 4.8 depicts that, only 2% represents EPR system. This shows that, EPR system has not been effectively enforced in Zambia. Proper enforcement of EPR has resulted in successful recovery and recycling stories for PSWs in developing economies (Xevengos et al., 2015). For the proposed RL, EPR system is considered in order to ensure sustainable recoveries and recycling of PSWs.

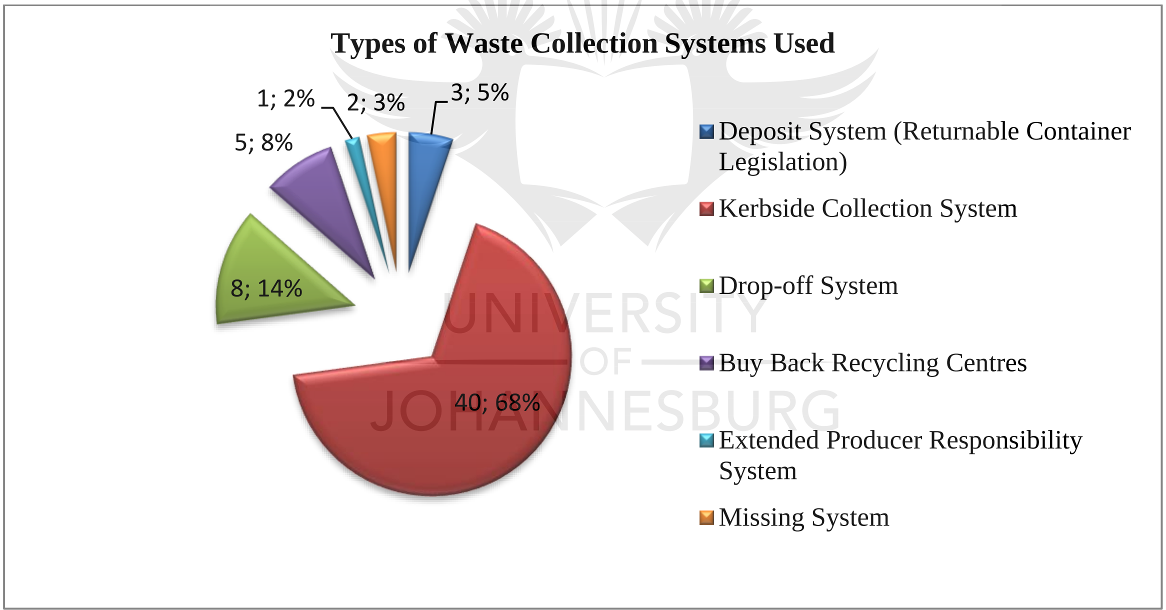


FIG 4.8: TYPES OF WASTE COLLECTION SYSTEMS USED BY PSW RECYCLERS

Integration of Informal Waste Sector into Formalised Systems

The descriptive statistics in Table 4.10 depicts that the majority of the factors have a mean value above 4. Based on the rating of the Likert-scale, the majority of the respondents rate the factors in a positive direction towards integrating the IWS into formalised systems. 'Development of structured PSWs recovery and recycling systems' is rated the most important factor for integrating the IWS into formalised systems. This factor is very important since most processes of recovery in developing economies lack structured systems (Matter et al., 2012). Development of structured plastic waste recovery and recycling systems by the waste service providers and the manufacturers/recyclers works in integrating the IWS into formalized systems. The point of entry for the IWS is clearly designed as well as their roles to the recovery and recycling process. 'Improving the technical and management practices of waste pickers by educating them on waste collection and sorting' is ranked second. This factor is very important since most of the IWCs lack education and training (Wilson et al; 2006). Proper training of the IWCs on waste sorting and cleaning can result in sustainable recoveries since the IWCs are the major recoveries in developing economies. The factors in Table 4.10 should be considered carefully when implementing RL systems for PSWs as these are the views of the households on the way forward to integrating the IWS into the formalised systems.

Further analysis of the factors, 'giving waste pickers formalised uniforms and identification cards for easy identification in society' (3.98, 1.244) has a mean value below the average. The respondents have not considered this factor important, however, 'legalizing plastic waste collection by waste pickers' (4.17, 0.964) should be in concurrent with identification cards and uniforms. This implies, this, factor should be considered important in the RL model.

TABLE 4.10: FACTORS FOR INTEGRATING THE IWCS INTO FORMALISED SYSTEMS

		Mean	Standard. Deviation (SD)
1	Municipality, private waste collectors or plastic manufacturers/recyclers subsidizing selective plastic waste collection performed by informal waste cooperatives.	4.27	0.895
2	Door-to-door plastic waste collection (residences and points of consumption) performed by individual scavengers	4.04	1.100
3	Manufacturers/recyclers awarding contracts for plastic waste collection to waste pickers	4.28	0.941
4	Legalizing plastic waste collection by waste pickers	4.17	0.964
5	Improving the technical and management practices of waste pickers by educating them on waste collection and sorting	4.52	0.752
6	Creating markets for waste pickers to sell their collected plastic wastes	4.24	1.023
7	Providing waste pickers with loans or grants to enable them to purchase storage or transportation facilities	4.10	1.053
8	Giving waste pickers formalized uniforms and identification cards for easy identification in society	3.98	1.244
9	Development of structured plastic waste recovery and recycling systems.	4.58	0.779

4.3 Factor Analysis and Reliability Tests on Households

4.3.1 Levers for Supporting Community PSWs Recycling

Households are influenced to participate in recovery and recycling programs by a number of factors. The levers for supporting community PSWs recycling is assessed on the households. Section 4.2.5

depicts the descriptive statistics on the levers for supporting community PSWs recycling as rated by the households. Majority of the levers have a mean value above the average.

For the purposes of developing a RL model driven by the levers that influence households to participate in recovery and recycling programs for PSWs, it is necessary to establish levers that can be modelled. Principal axis FA with varimax rotation is performed on the variables in Table 4.8 (Section 4.2.5) in order to group the variables into levers. FA performed with the 14 items on levers for supporting community PSWs recycling allows four new dimensions to be formed; the results are summarised in Table 4.11 and based on the highest loadings in each dimension, the naming is as follows:

- Lever 1- Knowledge and awareness on PSWs recycling
- Lever 2- PSWs segregation for recycling initiatives
- Lever 3- Legislations and regulations on PSWs recycling
- Lever 4- effective PSWs collection and recycling systems

The four levers together amount for 56.2% of the initial variance (KMO = 0.830; Bartlett *p*-value = 0.000; Cronbach's alpha ranging from 0.50 to 0.75. KMO of 0.830 shows that enough items are predicted for each factor (lever). The Bartlett test indicates that, the variables are highly correlated to provide a reasonable basis for FA. Based on the cut-off point established for this research (Section 3.6) the Cronbach's alpha is set at 0.5 to 0.7 (Nunaly, 1978, Devillis, 2003). Table 4.11 depicts that, after rotation, Lever 1 accounts for 30.5% of the variance, Lever 2 accounts for 9.8% of the variance, Lever 3 accounts for 8.7% of the variance and Lever 4 accounts for 7.2% of the variance. The factor loadings of the rotated levers with loadings less than 0.4 are omitted to improve clarity.

TABLE 4.11: RESULTS ON FACTOR ANALYSIS ON LEVERS FOR SUPPORTING COMMUNITY PSWS RECYCLING

Factors	Loadings [a]	% Variance explained	Cronbach's alpha
***Lever 1**: Knowledge and Awareness on PSWs recycling*		30.5%	0.75
Increase the number of environmental campaigns on plastics recycling	0.700		
Introduce information dissemination on plastic waste recycling through media and campaigns	0.680		
Introduce household plastic recycling training programs	0.595		
Provide the public with plastic waste recycling infrastructures.	0.417		
***Lever 2**: PSW Segregation for Recycling Initiatives*		9.8%	0.60
Encourage household plastic waste separation	0.727		
Provide households with a separate bin for plastic waste that are collected weekly	0.547		
***Lever 3**: Legislations and Regulations on PSW Recycling*		8.7%	0.55
Introduce a national-wide regulation on plastic waste recycling to encourage everyone's participation	0.702		
Introduce financial incentives to households meeting set plastic waste recycling targets	0.525		
***Lever 4**: - Effective PSWs Collection and Recycling Systems*		7.2%	0.50
Encourage door to door plastic waste collection	0.552		
Encourage efficient door to door plastic waste collection by legalised scavengers	0.456		

Lever 1; which indexes knowledge and awareness on PSWs recycling has strong loadings on the first four items. All the items on Lever 1, have positive loadings indicating a positive direction towards measuring the same scale on the construct. Lever 2 indexed towards PSWs segregation for recycling initiatives has positive loadings showing the items are measuring the same scale. Lever 3 and Lever 4 have positive loadings and these shows the items are measuring the same scale. Further analysis of the loadings on each lever shows that, the items have high loadings on each of the levers and hence fit to measure the same construct.

The four levers are considered as the levers that influence households to participate in PSWs recovery and recycling programs. These levers are considered on the basis of the items loadings, KMO of 0.830 and Bartlett p-value (p = 0.00) and reliable internal consistency. The levers are modelled in the RL model to determine the amount of PSWs recovered for recycling purposes by the households.

Studies at household level on the factors or levers that influence household participation in plastic recycling support the established levers. Afro et al (2017) affirms that, knowledge and awareness on plastic recycling results in a positive attitude in people towards recycling and this is in support of

Lever 1. PSWs segregation for recycling initiatives (Lever 2) is supported in literature by studies such as (Hotta and Aoki-Suzuki, 2014; Matter et al., 2013; Karim Ghani et al., 2013). Legislations and regulations influence household participation in recycling programs in Japan and other developed economies (Xevgenos et al., 2015, Zhang and Wen, 2014, Sidigue et al (2010). These studies support Lever 3. Effective plastic collection and recycling systems (Lever 4) is supported in literature by studies such as (TEMA NORD, 2014; Rodrigues et al., 2016).

4.3.2 Factors for Integrating the IWCs into Formalised systems

Principal axis FA with varimax rotation is performed with the 12 items on levers for integrating the IWCs into formalised systems allow two new dimensions to be formed; the results are summarised in Table 4.12 and based on the highest loadings in each dimension, the naming of the new dimensions is as follows:

- Lever 5- Effective support structures for the IWCs
- Lever 6- Legalisation of PSWs collections performed by the IWCs.

The two levers together amount for 51.4% of the initial variance (KMO = 0.811; Bartlett *p*-value 0.000; Cronbach's alpha ranging from 0.67 to 0.73). The two established levers have acceptable internal consistency since the Cronbach's alpha is within range. KMO of 0.811 shows that enough items are predicted for each factor lever. The Bartlett test indicates that, the variables are highly correlated to provide a reasonable basis for FA.

Lever 5 accounts for 37.2% of the variance while lever 6 accounts for 14.1% of the variance. The loadings on lever 5 are all positive indicating a positive direction towards measuring the same scale of the construct. Lever 6, loadings are all positive indicating the same scale is measured for the construct.

Levers 5 and 6 are important factors for consideration in the proposed RL model as assessed from the households' perspective. Effective support structures for the IWCs (Lever 5) and Legalisation of PSWs collection performed by the IWCs (Lever 6) are established levers from the households' perspective.

TABLE 4.12: RESULTS ON FACTOR ANALYSIS ON LEVERS FOR INTEGRATING THE IWCS INTO FORMALISED SYSTEMS

Factors	Loadings [a]	% Variance explained	Cronbach's alpha
***Lever 5**: Effective Support Structures for the IWCs*		37.2%	0.725
Giving waste pickers formalized uniforms and identification cards for easy identification in society	0.578		
Improving the technical and management practices of waste pickers by educating them on waste collection and sorting	0.575		
Manufacturers/recyclers awarding contracts for plastic waste collection to waste pickers	0.494		
Development of structured plastic waste recovery and recycling systems.	0.465		
Providing waste pickers with loans or grants to enable them to purchase storage or transportation facilities	0.462		
Legalizing plastic waste collection by waste pickers	0.453		
Creating markets for waste pickers to sell their collected plastic wastes	0.409		
***Lever 6**: Legalization of PSWs Collections Performed by the IWCs*		14.1%	0.666
Door-to-door plastic waste collection (residences and points of consumption) performed by individual scavengers	0.702		
Municipality, private waste collectors or plastic manufacturers/recyclers subsidizing selective plastic waste collection performed by informal waste cooperatives.	0.669		

4.4 Informal Waste Collectors' Interpretation of Results

4.4.1 Informal Waste Collectors' Socioeconomic Factors

This section describes the socioeconomic information from the IWCs respondents. The data is analysed in order to show the distribution of the respondents in terms of age, gender, income level and education level. Table 4.13 depicts the results on the socioeconomic factors.

TABLE 4.13: SOCIOECONOMIC INFORMATION OF THE IWCS

Demographics	Respondents Frequency and Valid Percentage
Gender	
Male	44 (83%)
Female	9 (17%)
Age	
Younger than 26 years	18 (34%)
26-36 years	26 (49.1%)
37-47 years	7 (13.2%)
48-58 years	1 (1.9%)
59-69 years	1 (1.9%)
Education Level	
Primary	28 (52.8%)
Secondary	25 (47.2%)
Income	
Less than K 100	2 (3.8%)
K100-K500	11 (20.8%)
K501-K1000	13 (24.5%)
K1001-K1500	14 (26.4%)
K1501-K2000	11 (20.8%)
More than 2000	2 (3.8%)

The IWCs age distribution shows that 85% of the male counterpart are involved in waste recovery compared to the female counterpart, 17%. For age distribution, the majority of the IWCs are between the age of 26 to 36 years (49.1%). The education level distribution shows that, the majority of the collectors have primary education (52.8%). In terms of income level distribution, majority generate between K1001 to K1500 per month (26.4%).

4.4.2 Types of Informal Waste Collectors'

With reference to Section 3.3.4, this research assesses five (5) types of IWCs. Figure 4.9 depicts the distribution of the types of IWCs and the majority are dumpsite pickers with only 17% representing the household waste collectors. The low representation of the household waste pickers is an indication that, few IWCs are engaged in household PSWs recovery. This information is supported by the information obtained in Section 4.2.4 (Table 4.6); only 7% of the IWCs recover PSWs from households. The low representation by the highest recoveries shows that, the IWCs have not been formally integrated in the household PSWs recovery and recycling programs. High percentage representation by dump-site pickers (43%) implies the majority of PSWs is found at the dump-sites. This means the PSWs collected by the waste service providers are not recovered for recycling but merely disposed of. Street waste collectors' percentage representation (28%) implies high disposition of the PSWs on the streets by the consumers. This implies, if more than 17% of IWCs engage in household PSWs recovery, the amount of PSWs disposed of at the dump-sites and on the streets, is likely to be reduced. Nevertheless, this depends on how well the levers that influence households to participate in recovery and recycling programs are implemented by the plastic manufacturing and recycling companies as well as the waste service providers.

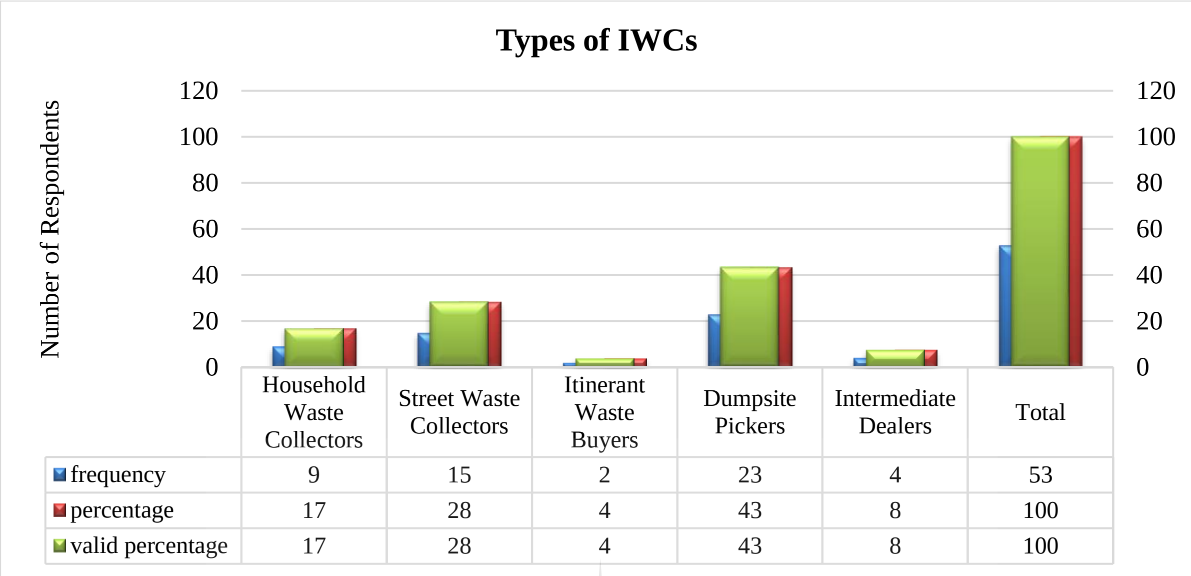


FIG 4.9: TYPES OF INFORMAL WASTE COLLECTORS

4.4.3 Collection and Trading of PSW by the IWCs

This section describes results on the assessment of the IWCs on; the type of PSWs they collect; the amount collected per day; where they collect the PSWs from; the distance travelled per day collecting PSWs, the hours spent per day collecting PSWs; the form of transport used in collecting PSWs and whether they pay for the PSWs.

Types of Plastic Solid Wastes Recovered

Table 4.14 depicts the results on the assessment of the IWCs on the type of PSWs they recover. The majority of the IWCs recover plastics bottles (44.7%). Plastic Recycling (2009) and Shen et al (2009) state that, the majority of the recyclable post-consumer plastics are manufactured into bottles and this confirms the high recovery rates of bottles by the IWCs. Further, this may be attributed to the demand for the bottles for reuse and recycling purposes. To ensure a sustainable RL model, assessment of PSWs with an economic value is important (Contreras et al., 2009). The IWCs usually recovery wastes with an economic value and 44.7% representation by plastic bottles implies an economic value attachment.

TABLE 4.14: TYPES OF PLASTIC SOLID WASTES RECOVERED

	Frequency	Percentage	Percentage of Cases
Plastic Bottles	42	44.7%	80.8%
Plastic Containers	32	34.0%	61.5%
Plastic Bags	20	21.3%	38.5%

Amounts of Plastic Solid Wastes Collected per Day

The IWCs are assessed on the amount of PSWs they recover per day and the results in Table 4.15 depict that, for plastic bottles, the majority recover less than 100 bottles per day (48.8%). Plastic bags recoveries per day are between 100 to 150 bags (39.1%). As for plastic containers, the majority recover less than 100 containers per day (83.3%). 24.4% of IWCs indicate that, they recover more than 200 plastic bottles per day. The results on the type and amount collected by the IWCs conclusively show that, most of the IWCs recover plastic bottles.

TABLE 4.15: AMOUNTS OF PLASTIC SOLID WASTES COLLECTED PER DAY

		Less than 100	100-150	151-200	More than 200	Total
Plastic Bottles	Count	20	11	0	10	41
	Row N %	48.8%	26.8%	0.0%	24.4%	100.0%
Plastic Bags	Count	9	9	1	4	23
	Row N %	39.1%	39.1%	4.3%	17.4%	100.0%
Plastic Containers	Count	25	2	1	2	30
	Row N %	83.3%	6.7%	3.3%	6.7%	100.0%
Other	Count	0	0	0	0	0
	Row N %	0.0%	0.0%	0.0%	0.0%	0.0%

The low recovery rates of PSWs by the IWCs are an indication that, sustainable recovery systems to optimize the recovery of PSWs are needed. Buenrostro and Bocco (2003) notes that, the IWCs are the key players in the recovery of recyclable and reusable wastes, however the amounts recovered and recycled are limited. The limitation in the amount of recyclable and reusable wastes is attributed to unstructured RL systems in developing economies (Ezeah et al., 2013; Scheinberg et al., 2011; Gutberlet, 2010; Medina 2007; Coelho, 2011)

Analysis of the amount of PSWs recovered on the daily basis by the IWCs, for example plastic bottles, less than 100 bottles are recovered per day; in a month, 2970 bottles can be recovered and of this amount, only 17% is recovered from the households (505 plastic bottles) per month while the households generate 1040 plastic bottles per month. In order to optimize the recovery from the households, integration of the IWCs in the proposed RL model is necessary as the amount of PSWs recovered by them is significant.

Form of Transport, Distance Travelled and Hours Spent in the Recoveries

Results on the assessment of the IWCs on the forms of transport, the distance travelled per day recovering PSWs and the hours spent per day are depicted in Table 4.16. The majority of the IWCs walk (92.5%) and travel less than 5Km (50.9%) per day recovering PSWs. Six to sixteen hours is spent per day recovering PSWs (34%) by the majority of the IWCs. Lack of advanced recovery and transportation systems in the IWS contributes to low recovery rates.

TABLE 4.16: FORM OF TRANSPORT, DISTANCE TRAVELLED AND HOURS SPENT IN THE RECOVERIES

Form of Transport Used	
Walking	49 (92.5%)
Bicycle	4 (7.5%)
Kilometres Travelled per Day Recovering PSW	
Less than 5Km	27 (50.9%)
5Km – 10Km	13 (24.5%)
11Km – 15Km	8 (15.1%)
16Km-20Km	4 (7.5%)
More than 20Km	1 (1.9%)
Hours Travelled per Day Recovering PSW	
Less than 2 hours	2 (3.8%)
2 hours -6 hours	15 (28.3%)
6hours – 10hours	18 (34%)
10hours – 16hours	18 (33.9%)

This information is necessary for the proposed RL model as it highlights the areas that need improvement as the IWCs are integrated in the formalised systems by the plastic manufacturing and recycling companies. Provision of sustainable means of transporting the recovered PSWs and establishment of strategic points for waste recovery can result in reduced recovery hours and distance. Chaturvedi (2011) suggests collection mechanism and channelization as the strategies of integrating the IWCs into formalised systems. This implies, information on the number of hours spent recovering PSWs per day and distance travelled per day provides the information necessary for the plastic manufacturing and recycling companies to channel and establish suitable recovery points in the proposed RL model. Further, reduced distance and recovery hours contribute to sustainable recoveries as well as acting as economic drivers to the plastic manufacturing and recycling companies. Chan and Chan (2008) found that, to a company, most returned products add value to it. Atienza (2010) recommends technical and financial assistance. The IWCs can only be assisted when information on the type of transportation and collection systems is known. Further improved transportation and collection systems increases the collection distance covered while reducing the number of hours spent.

Plastic Solid Wastes Collection Pick-up Points

It is important to assess the IWCs on the waste collection pick-up points and Table 4.17 depicts that, the majority of them collect their waste type from the dump-sites (27.6%) These results correspond to the results in Section 4.4.2 on the types of IWCs. The majority of the IWCs are dump-site pickers. The fact that, PSWs recoveries are conducted and permitted in some schools, households, churches and shops is an important attribute on the need to engage these stakeholders in the recovery of PSWs. Nevertheless, this can be achieved by designing a RL system that integrates these stakeholders. Households are key in the recovery of PSWs as every consumer represented at a school, church or shop origins from a household and also households have the second highest percentage presentation (19.4%). This implies the necessity to design recovery systems that stream from households. 19.4% representation by the households as pick-up points for the PSWs by the IWCs shows that, PSWs is happening in households though the percentage is low. The low representation by the households is attributed to the none-existence of structured RL systems that have integrated households and the IWCs.

TABLE 4.17: PLASTIC SOLID WASTES COLLECTION PICK-UP POINTS

	Frequency	Percentage
Households	19	19.4%
Schools	14	14.3%
Markets	16	16.3%
Shops	18	18.4%
Dump-sites	27	27.6%
Other	4	4.1%

Plastic Solid Waste Charging Pick-up Points

Recovery of PSWs involves paying for it or not. The results on this assessment show that, the majority do not pay for the recovery of PSWs from their pick-up points (85%). Free recoveries of PSWs by the IWCs shows that, the households, schools, markets or shops are influenced by other levers other than monetary gains to participate and give away PSWs. This is a positive direction towards the achievement of sustainable resource utilisation and recovery. Figure 4.10 depicts the results.

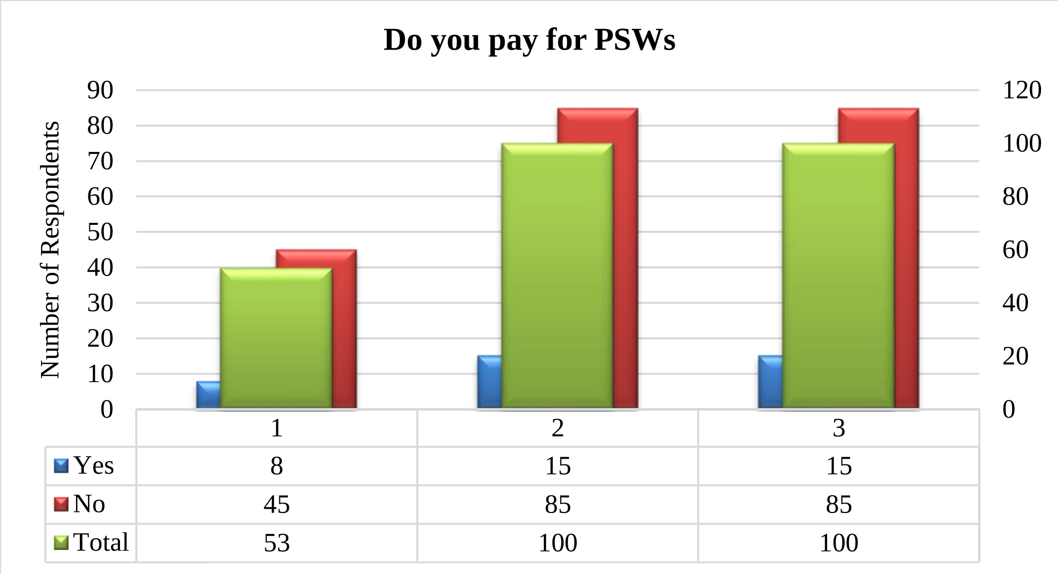


FIG 4.10: DO YOU PAY FOR PSW?

The 15% of the IWCs that indicated "yes" to paying for the PSWs, the results in Table 4.18 depicts that, the majority of the IWCs are charged by the households (50%). This shows that, some of the stakeholders in the supply-chain are driven to participate in the recovery of PSWs by monetary incentives. Nevertheless, the percentage representation of the households that charge the IWCs is very low and cannot prevent sustainable recoveries. Also, monetary levers have been identified to influence stakeholders such as households to participate in recovery programs (Yau, 2010; Welfens et al, 2015). The economic lever is a positive influence to the recovery of PSWs as it contributes to the recovery of clean segregated wastes since unsegregated and dirt wastes are never paid for.

TABLE 4.18: WASTE COLLECTION POINTS THAT CHARGE THE INFORMAL WASTE COLLECTORS

	Frequency	**Percentage**	**Percentage of Cases**
Households	4	50.0%	50.0%
Dump-sites	3	37.5%	37.5%
Other	1	12.5%	12.5%

The IWCs are assessed on the price of payment for the different types of PSWs recovered. The results indicate that, 12% pay K0.3 per bottle; 12% pay K1 per 10 bottles; 13% pay K1 per bottle; 37% pay K10 per 50Kg bag of bottles and 13% pay K5 per 50Kg of bottles. The price distribution for the plastic containers shows that, 100% of the respondents are charged K2 per plastic container recovered. Further analysis of the price distribution for plastic bags shows that 100% of the IWCs are charged K10 per 1 ton of plastic bags.

The results show a lack of consistence in the pricing system for the plastic bottles. Fei et al (2016) recommends price advantage as a strategy for integrating the IWCs into formalised systems. The proposed RL model provides the price advantage to the IWCs because of a structured system consisting of key stakeholders in the recovery and recycling of PSWs. Engagement of the key stakeholders in the recovery of PSWs contributes to the development of systematic pricing system for trading the recovered PSWs since formalised procedures are established for determining the price of the PSWs.

Further, most of the IWCs are motivated to recover PSWs because of the economic value attached to the product as well as making a livelihood out of it (Wilson et al, 2006, Saski et al., 2014). This implies establishing standard pricing and recovery systems can motivate and increase the amount of recovery from the IWCs.

4.4.4 Value Addition to the PSWs

This section describes results on the assessment of the IWCs on; the points of sell for the recovered PSWs, forms of sorting conducted on the recovered PSWs and types of value addition to the recovered PSWs.

Points of Sell for Plastic Solid Wastes

Value addition to the recovered PSWs for the purposes of recycling involves a number of processes and therefore, the IWCs are assessed on this aspect. The point of sell for their recovered PSWs is assessed as one aspect of value addition. Table 4.19 depicts that, the majority of the IWCs sell their PSWs to immediate dealers (51.3%). These are primary and secondary dealers such as recycling SMEs, junk shops, brokers, wholesalers etc. Immediate dealers mainly buy PSWs for resell to recyclers and manufactures. Value is added to the recovered PSWs by the immediate dealers by way of cleaning and sorting.

TABLE 4.19: POINTS OF SELL FOR PSWS

	Frequency	Percentage	Percentage of Cases
Intermediate Dealers	40	51.3%	75.5%
Plastic Manufacturing Companies	6	7.7%	11.3%
Plastic Recycling Companies	29	37.2%	54.7%
Other	3	3.8%	5.7%
Total	78	100.0%	147.2%

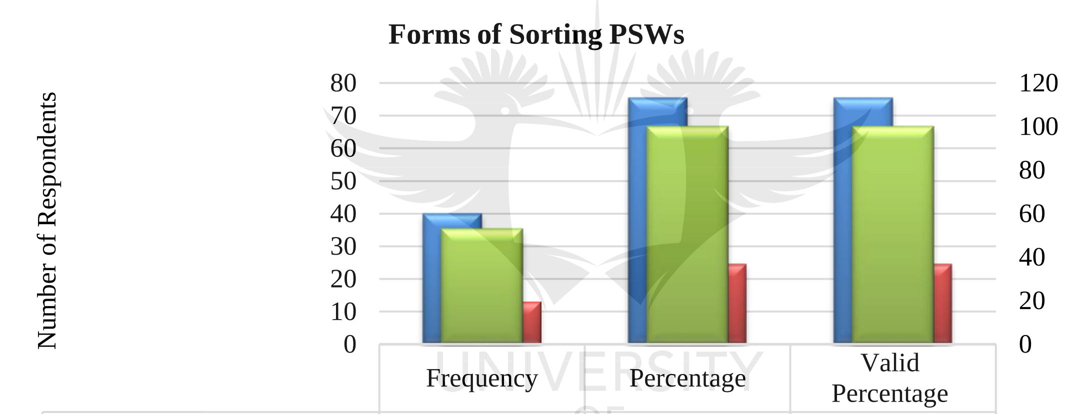
A low representation by the plastic manufacturing companies shows that, few of the companies are directly engaged in the recovery of PSWs despite being the main distributors. This also shows that, implementation of RL for PSWs is still at an infancy stage in the plastic manufacturing companies.

37.2% representation by the plastic recycling companies shows that, a considerable amount of PSWs is recovered from the IWCs. A combination of 51.3%, 37.2% and 7.7% into a structured RL system results in 96.2% available points of sell for PSWs for the IWCs.

Assessment of the points of sell for PSWs from the IWCs perspective is necessary for structuring the RL model taking into consideration the stakeholders to be integrated. The assessment provides the information needed for modelling the RL model into an optimal system.

Forms of Sorting Plastic Solid Wastes

Value can be added to the recovered wastes in terms of the form in which it is sorted after recovery. Figure 4.11 depicts that, the majority of the IWCs sort the recovered PSWs according to its polymer type (75%). Plastic Zero (2012) indicates that, value is added to the recovered polymers by sorting it according to polymer type, purity and colour. Assessment on the forms of sorting to the recovered PSWs is necessary as it provides the standards for trading the recovered PSWs in the proposed RL model.



	Frequency	Percentage	Valid Percentage
Polymer Type (PP, PE, PET etc.)	40	75	75
Purity	13	25	25
Total	53	100	100

FIG 4.11: FORMS IN WHICH PSWS SORTED

Forms of Value Addition to Plastic Solid Wastes

Table 4.20 depicts the forms in which value is added to the recovered PSWs. The results show that, the majority of the IWCs add value to the recovered wastes by cleaning it (36.4%). Asim et al (2012) indicates that value is added to the recovered PSWs by classifying, cleaning, washing and drying, aggregating into commercial quantities and compacting. Cleaning the recovered PSWs rises the price at which PSWs is sold. BIO-Intelligence (2013) indicates that, the price of recovered PSWs rises depending on the quality. Therefore, it is necessary for IWC to add value to the recovered PSWs as a way of quality improvement. Nevertheless, to ensure sustainability in the proposed RL model, this aspect of value addition should begin at the pick-up points such as households. If value addition such as waste segregation and cleaning of PSWs starts from households, high recovery rates can be achieved by the IWCs. In a number of countries, households are encouraged to engage in sustainable recycling by collecting recyclable wastes separately (Dahlen et al, 2009). Source separation contributes to value addition and can help the IWCs achieve high recycling rates and promote source separation (Wilson et al., 2006).

TABLE 4.20: FORMS OF VALUE ADDITION TO THE RECOVERED PSWS

	Frequency	Percentage
By cleaning it	28	36.4%
By classifying it into categories	22	28.6%
Washing and drying it	14	18.2%
Grouping into commercial quantity	4	5.2%
Other	9	11.7%

Assessment of the results shows that, strategic forms of value addition to the recovered PSWs such as grouping into commercial quantities are merely practised. This may be attributed to the none-existence of structured commercial systems for trading the recovered PSWs.

4.4.5 Factors Determining the Price of Recovered PSWs

Table 4.21 depicts the results on the assessment of the IWCs on factors that determine the prices of recovered PSWs. The majority indicate that, demand and supply for PSWs in the market determine the price (42.1%). Understanding the factors that determine the price of the recovered PSWs is a key strategy for developing a sustainable RL model. This aspect is key for recycling and manufacturing companies as economic drivers are important factors that influence implementation of RL systems. Also, as observed in Section 4.4.3 on the inconsistence of the pricing system of PSWs by the stakeholders. Such inconsistence prevents optimal recoveries but standardisation of the pricing system can motivate more recoveries. Further, involvement of the IWCs in formalised recovery and recycling systems can contribute to formation of standard prices for PSWs rather than demand and supply being the major determinant. A combination of the standards of the buyer (24.2%), quality of the PSWs (14.7%) and demand and supply of the PSWs on the market (42.1%) can result in a standardised pricing system that can benefit the involved stakeholders. Ojeda-Benitez et al (2002) points out that, the IWCs have no control over the pricing systems as they are paid per kilogram of the recovered materials. Gutberlet (2008) indicates that, extreme price fluctuation exists in the IWS and therefore, establishing a structured RL system can alleviate this challenge.

TABLE 4.21: FACTORS DETERMINING THE PRICE OF RECOVERED PSWS

	Frequency	Percentage
Standards of the Buyer	23	24.2%
The price of the virgin materials	6	6.3%
Quality of the plastic solid wastes	14	14.7%
The facility for reprocessing and technology	1	1.1%
Demand and Supply of the plastic solid wastes in the market	40	42.1%
Recycling potential of the plastic solid waste	9	9.5%
Other	2	2.1%

4.4.6 Waste Collection Systems preferred by the IWCs'

Waste collection systems are an important aspect of WM and for the IWCs, this aspect is equally important. Different types of waste collection systems exist and each can influence the IWCs differently. Table 4.22 depicts the results of the assessment. The majority of the IWCs prefer the drop-off waste collection system (51.8%). Drop-off collection systems can work to the advantage of the IWCs as the generators are expected to drop-off the PSWs at a specific collection point. From the generators' perspective, the case may be different as the motives to drop-off the waste differs. The preference of the drop-off waste collection system aligns with the fact that, the majority of the IWCs are dump-site pickers mainly involved in recovering PSWs dropped off at the dump-sites. This implies, the RL systems that integrates different stakeholders, should be established on the basis of different waste collection systems. In Section 4.2.5, 89.7% of the households prefer using Kerbside waste collection systems and only 63.2% prefer drop-off collections systems. To achieve sustainable recoveries, a combination of waste collection is necessary as 25% of the IWCs prefer kerbside waste collection systems. Rodrigues et al, (2016), points out that, the type of waste collection system can have an impact on the amount and quality of recyclables for collection as well as on user participation. This implies, a combination of waste collection systems is necessary to influence different user preferences.

TABLE 4.22: PREFERRED WASTE COLLECTION SYSTEMS BY THE INFORMAL WASTE COLLECTORS

	Frequency	**Percentage**	**Percentage of Cases**
Kerbside Collection System	14	25.0%	26.4%
Drop-off System	29	51.8%	54.7%
Buy Back Centers	12	21.4%	22.6%
Extended Producer Responsibility System	1	1.8%	1.9%

4.4.7 Levers for Integrating the IWCs' into Formalised Systems

The descriptive statistics in Table 4.23 indicate that, among the twelve items comprising the scale of levers for integrating the IWCs into formalised systems; 'creating markets for waste pickers to sell their collected plastic wastes' (4.91) and 'building plastic waste recycling targets to encourage waste pickers to collect more waste' (4.91) are found to have the highest rating on a Likert scale of 1 to 5. These two factors are important to the IWCs in the sense that without established markets for their recovered PSWs, the whole purpose of recovering would be irrelevant. Also, creation of recycling targets for the recyclers is a critical option of integrating the IWCs as most of the recovery is conducted by them and most recyclers depend on them. This implies, for recycling targets to be achieved, the IWCs should be integrated into a systematic RL system that specifics the amount of PSWs to be recovered to meet recycling targets for their buyers. 'Provision of loans to waste pickers to enable them purchase storage or transportation facilities' (4.85) is ranked second as a factor for integrating them into formalised systems. Wilson et al (2006) points out that, the IWS is characterised by low technology. Most IWCs lack storage and transportation facilities. Section 4.4.3 on the forms of transport used by the IWCs indicates that 92.5% of the IWCs have no transportation facilities. In order, to achieve sustainable recoveries of PSWs, transportation systems such as bicycles are cardinal and necessary. Proper storage facilities are also important for preserving the recovered wastes.

Most of the IWCs lack proper training on the recovery and collection of wastes and as such, their health is always at risk. This is attributed to the fact that, most of the recoveries involve unsegregated wastes and most IWCs lack protective clothing. To achieve sustainable recoveries, the health of the IWCs should be a priority and in this assessment, 'provision of training to waste pickers on their health and the environment' (4.68) is ranked third. Gutberlet (2008) recommends environmental and social health of the IWCs as strategies for integrating them into formalised systems. 'Increasing waste collection and recycling facilities' (4.60) is ranked fourth. This lever is important for enabling the IWCs conduct their work. In Section 4.4.6 the IWCs identify the type of waste collection system they prefer. This implies increasing the number of drop-of centres for the IWCs to enable them recover the PSWs sustainably. Increasing the recycling facilities is necessary for boosting more recoveries. The purpose of recovering PSWs for recycling purposes is in vain without a significant number of recycling facilities. In Section 4.4.4, only 37.2% of the recovered PSWs is sold to the plastic recycling companies. To integrate the IWCs into formalised systems, Chaturvedi (2011) recommends infrastructure development while Fei et al (2016) recommends recycling systems layout optimization. 'Provision of education to the waste pickers on waste sorting and collection' (4.57) is ranked in the fifth position. Majority of the IWCs have no formalised training on sorting and collection of recovered wastes. To enable sustainable integration and increased benefits from the IWCs, Fei et al (2016) recommends training as a strategy for integrating the IWCs into formalised systems.

TABLE 4.23: FACTORS FOR INTEGRATING THE IWCS INTO FORMALISED SYSTEMS

		Mean	**Standard Deviation**
1	Plastic Waste segregation performed at household levels	3.51	1.564
2	Door-to-door collection performed by individual scavenger	3.60	1.291
3	Awarding of contracts to waste pickers for plastic wastes recovery by recyclers or manufacturers	4.17	1.205
4	Legalizing plastic waste collection by waste pickers	4.30	0.799
5	Provision of education to waste pickers on waste sorting and collection	4.57	0.605
6	Creating markets for waste pickers to sell their collected plastic wastes	4.91	0.295
7	Provision of loans to waste pickers to enable them purchase storage or transportation facilities	4.85	0.411
8	Provision of training to waste pickers on their health and the environment	4.68	0.471
9	Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	4.49	0.750
10	Increasing waste collection and recycling facilities	4.60	0.660
11	Building plastic waste recycling targets to encourage waste pickers to collect more waste	4.91	0.295
12	Increasing awareness on the importance of waste pickers in the supply-chain to the public	4.49	0.669

The first six items on the levers for integrating the IWCs into formalised systems have mean value above 4.5. The other six items have the mean value below 4.5, however, these levers are important for integrating the IWCs into formalised systems. From the IWCs perspective, the level of importance on the levers for integrating them into formalised systems varies considerably from 3.51 to 4.91. The mean average value is 4.5 and ‘creating markets for waste pickers to sell their collected plastic wastes’ (4.91, 0.295) and ‘building plastic waste recycling targets to encourage waste pickers to collect more waste’ (4.91, 0.295) are found to be important. These two levers need to be given the highest consideration when formalising the IWCs into formalised systems.

To ensure sustainable recoveries from the IWCs, the levers in Table 4.23 are critical factors that influence optimal recoveries from the IWCs perspective. For the proposed RL, these are the levers that are modelled. Nevertheless, the number of levers is too many to be modelled and FA is conducted on the twelve items to reduce the number.

4.4.8 Challenges facing the Informal Waste Collectors'

Table 4.24 depicts the descriptive statistics on the assessment of the importance of the challenges the IWCs face in the recovery of PSWs. 'Lack of government support to informal waste collection and recycling' (4.83, 0.612) has the highest rating. Wilson et al (2009) notes that recognition of the IWCs by the government is important and contributes to increased recovery rates. 'Lack of markets to sell our recovered plastics' (4.43, 0.910) is rated second and this factor concedes with highest rated factor for integrating the IWCs into formalised systems (Section 4.4.7). This shows that establishing markets for IWCs is cardinal to the recovery and recycling process. This is achievable through structured RL systems that integrate the recyclers and manufacturers of plastics and consumers. BIO- Intelligence (2013) highlights on the need to engage relevant stakeholders in the recovery and recycling of PSWs along the supply-chains in order to create markets. 'Lack of support from the community and municipality' (4.40, 0.689) is rated third. This challenge is evident on the assessment of the pick-up points for PSWs by the IWCs (Section 4.4.3). Only 19.4% of the households are pick-up points for the IWCs. This shows that, there is less support from the households. Municipality support to the IWCs is cardinal as informal waste recoveries and collections contribute to reduced WM costs (Gunsilius and Gerdes (2010).

Ten items comprising of the challenges facing the IWCs have mean values above 4 and this shows that, the majority of the items are rated with a level of importance. Only one item has a mean value less than 4. 'Lack of government support to informal waste collection and recycling' should be given the highest level of importance when alleviating the challenges facing the IWCs while "lack of tools for sorting waste,' should be given least importance.

TABLE 4.24: CHALLENGES FACING THE INFORMAL WASTE COLLECTOR'

		Mean	Standard Deviation
1	Lack of tools for sorting waste	3.92	1.398
2	Lack of waste segregation from the community	4.04	1.236
3	Lack of support from the community and municipality	4.40	0.689
4	Lack of training on waste sorting and collection	4.32	0.894
5	Lack of waste transportation equipment	4.21	1.035
6	Lack of markets to sell our recovered plastics	4.43	0.910
7	Lack of government support to informal waste collection and recycling	4.83	0.612
8	Lack of regulations and legislations on plastic waste recycling	4.25	0.939
9	Lack of formalized legalization of waste pickers in the waste management systems	4.28	0.928
10	Lack of recovery systems for plastic waste collection	4.40	0.817
11	Lack of awareness on the importance of informal sector in the waste recovery process	4.34	0.831

4.5 Factor Analysis and Reliability Tests on the IWCs

4.5.1 Levers for Integrating the IWS into Formalised Systems (IWCs Perspective)

Principal axis FA with varimax rotation is performed with the 12 items on levers for integrating the IWCs into formalised systems (IWCs perspective) and allows two new dimensions to be formed; the results are summarised in Table 4.25 and based on the highest loadings in each dimension, the naming of the new dimensions is as follows:

- Lever 5- Effective support structures for the IWCs
- Lever 6- Legalisation of PSWs collections performed by the IWCs

The two levers together amount for 74.8% of the initial variance (KMO = 0.877; Bartlett *p*-value = 0.000; Cronbach's alpha ranging from 0.8 to 0.91. In order to meet Kaiser criterion, variables with the measure of sampling adequacy less than 0.6 are omitted. The two established levers have acceptable internal consistency since the Cronbach's alpha is within range. KMO of 0.877 shows that enough items are predicted for each factor (lever). The Bartlett test indicates that, the variables are highly correlated to provide a reasonable basis for FA.

Lever 5 accounts for 61.9% of the variance while lever 6 accounts for 12.9% of the variance. The loadings on lever 5 are all positive indicating a positive direction towards measuring the same scale of the construct. Lever 6, loadings are all positive indicating the same scale is measured for the construct.

TABLE 4.25: RESULTS ON FACTOR ANALYSIS ON LEVERS FOR INTEGRATING THE IWCS INTO FORMALISED SYSTEMS

Factors	Loadings [a]	% Variance explained	Cronbach's alpha
Factor 1 *(Lever 5): Effective Support Structures for the IWCs*		61.9%	0.914
Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	0.817		
Increasing waste collection and recycling facilities	0.803		
Provision of training to waste pickers on their health and the environment	0.802		
Provision of education to waste pickers on waste sorting and collection	0.768		
Increasing awareness on the importance of waste pickers in the supply-chain to the public	0.736		
Legalizing plastic waste collection by waste pickers	0.581		
Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	0.817		
Factor2 *(Lever 6): Legalization of PSW Collections Performed by the IWCs*		12.9%	0.864
Plastic Waste segregation performed at household levels	0.869		
Door-to-door collection performed by individual scavenger	0.823		
Awarding of contracts to waste pickers for waste collection to waste pickers by recyclers or manufacturers	0.635		

Levers 5 and 6 are important levers for consideration in the proposed RL model as assessed from the IWCs' perspective. A number of studies recommend 'effective support structures for the IWCs

(Lever 5). Gunisilius (2012), suggests political support and Medina (2002) suggests policies at national level for IWCs' support. 'Legalisation of PSWs collection performed by the IWCs (Lever 6) is supported in literature by a number of studies. Medina (2002) and Gunsilius (2012) suggests legal recognition. Atienza (2010) suggests enforcement of law on IWCs recognition

4.5.2 Challenges facing the IWCs'

Principal axis FA with varimax rotation is performed with the 11 items on the challenges facing the IWCs in the recovery and recycling of PSWs and allows two new dimensions to be formed; the results are summarised in Table 4.26 and based on the highest loadings in each dimension, the naming of the new dimensions is as follows:

Factor 1- Lack of sustainable recovery and systems for PSWs

Factor 2- Lack of support from the government on PSWs recovery.

The two factors together amount for 77.3% of the initial variance (KMO = 0.872; Bartlett *p*-value = 0.000; Cronbach's alpha ranging from 0.70 to 0.94). The two established levers have acceptable internal consistency since the Cronbach's alpha is within range. KMO of 0.872 shows that enough items are predicted for each factor. The Bartlett test indicates that, the variables are highly correlated to provide a reasonable basis for FA. Factor 1 account for 66.7% of the variance while Factor 2 accounts for 10.6% of the variance.

TABLE 4.26: RESULTS ON FACTOR ANALYSIS ON CHALLENGES FACING THE IWCS

Factors	Loadings [a]	% Variance explained	Cronbach's alpha
Factor 1*): Lack of Sustainable Recovery Systems for PSWs*		66.7%	0.944
Lack of regulations and legislations on plastic waste recycling	0.942		
Lack of formalized legalization of waste pickers in the waste management systems	0.904		
Lack of recovery systems for plastic waste collection	0.821		
Lack of waste transportation equipment	0.751		
Lack of awareness on the importance of informal sector in the waste recovery process	0.728		
Lack of waste segregation from the community	0.638		
Lack of training on waste sorting and collection	0.487		
Factor2*): Lack of Support from the Government on PSWs Recovery*		10.6%	0.743
Lack of tools for sorting waste	0.751		
Lack of markets to sell our recovered plastics	0.696		
Lack of support from the community and municipality	0.622		

The first factor indexing 'lack of sustainable recovery and recycling systems for PSWs' has strong loadings on all the items. Nevertheless, 'lack of training on waste sorting and collection' has the lowest loading of less than 0.5. This item is included because its loading is above 0.4 and it fits in the named factor (construct). The second factor indexing 'lack of government support on PSWs recovery' has positive strong loadings on all the items. This shows that, the items are measuring the same scale of the construct.

4.6 Plastic Manufacturing and Recycling Companies Interpretation of Results

This section discusses the results on the assessment of plastic manufacturing and recycling companies. A total of 22 questionnaires are analysed in this section.

4.6.1 Companies Socioeconomic Factors

This section describes the socioeconomic information about the plastic manufacturing and recycling companies. The data is analysed in order to show the distribution of the companies in terms of type of industry, size of organization and the province in which the company is located.

Table 4.27 depicts the distribution of the companies in terms of industry type. 80% of the companies are plastic manufacturing companies. Only 12% of the companies are plastic recycling companies. 12% representation by the plastic recycling companies shows few companies recycle PSWs in the surveyed provinces.

TABLE 4.27: TYPE OF INDUSTRY

	Frequency	Percentage	Percentage of Cases
Manufacturing Company	20	80.0%	90.9%
Plastic Recycling Company	3	12.0%	13.6%
Plastic Buying Company	2	8.0%	9.1%
Total	25	100.0%	113.6%

The results in Figure 4.12 depict that, the majority of the companies have less than 100 employees (73%). These results depict that 73% of the surveyed companies are small to medium companies.

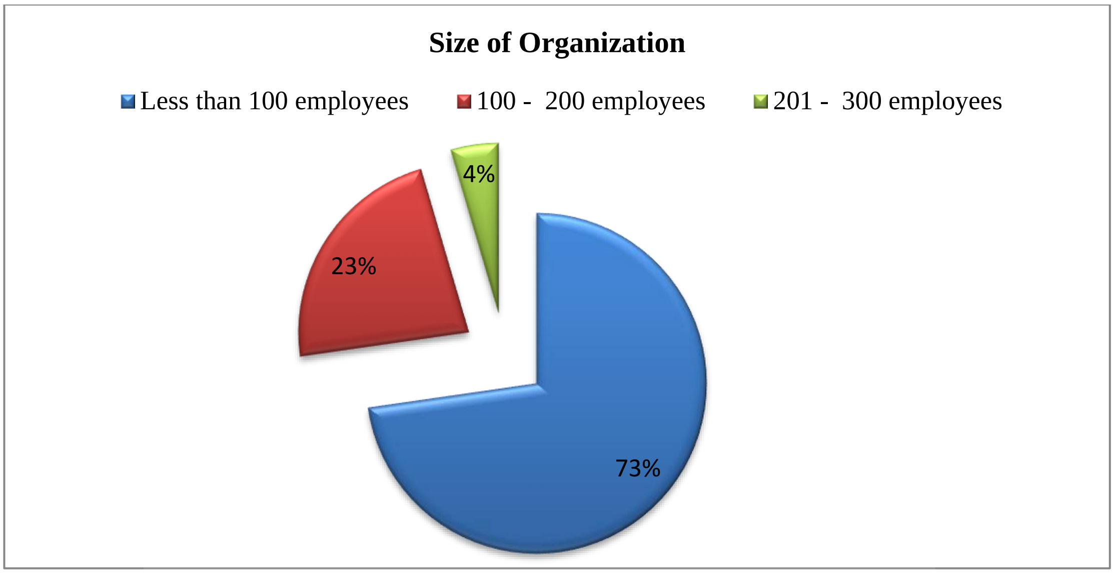


FIG 4.12: SIZE OF ORGANIZATION

The results depicted in Figure 4.13 indicate that; 81.8% of the companies are located in Lusaka province while 18.2% are located in the Copperbelt province.

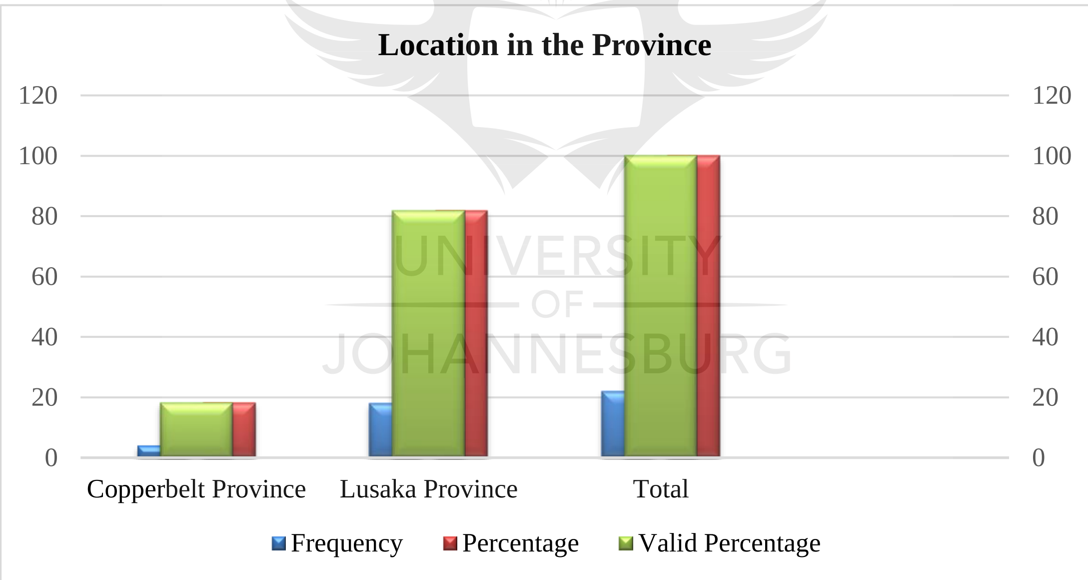


FIG 4.13: LOCATION OF COMPANIES

4.6.2 Plastic Manufacturing, Recycling and Buying Practises

This section discusses results on plastic manufacturing, recycling and buying practises conducted by the companies. In order to assess these practises, the following information is elicited; amount of plastic manufactured, amount of PSWs bought and recycled; the type of recycling technologies used in recycling plastic wastes and the types of PSWs recycled. The types of products manufactured from recycled PSWs and the factors that determine recyclability of PSWs, are assessed. The companies are also assessed on; suppliers of PSWs and the forms in which it is supplied and the price determinants for PSWs. Further the companies are assessed on the reasons for practising RL of PSWs.

Plastic Manufacturing, Recycling and Buying Practises

The results in Table 4.28 depict that, the majority of the companies manufacture plastic products 95.5%. This implies that, 95.5% of the plastic manufacturing companies are responsible for the PSWs generated in Zambia. Development of a RL model for the recovery of PSWs is logical since the majority of the companies manufacture plastic products.

With only 45.5% of the companies recycling PSWs, this provides evidence to the current state of PSWs on the environment and in the dump-sites. Most of the PSWs is recovered from the dumpsites as depicted in Section 4.4.2. Further, Section 4.2.4 shows that, only 1% of the plastic recycling companies and 2% of the plastic manufacturers recover PSWs from the households.

4.5% of the plastic companies buy PSWs from other stakeholders. The low representation of the buying practises indicates the none-existence of structured RL system for recovering and recycling PSWs in Zambia. The results in Table 4.28 provide relevant information on the need to develop a RL model for recovering and recycling PSWs in Zambia.

TABLE 4.28: PLASTIC MANUFACTURING, RECYCLING AND BUYING PRACTICES

	Frequency and Valid Percentage
Does your Company Manufacture Plastic Products?	
Yes	21 (95.5%)
No	1 (4.5%)
Does your Company Recycle PSW?	
Yes	10 (45.5%)
No	12 (54.5%)
Does your Company Buy PSW?	
Yes	1 (4.5%)
No	9 (40.9%)
Missing System	12 (54.5%)

Types and Amounts of Plastic Products Manufactured

The type and amount of PSWs produced by plastic manufacturing companies is depicted in Table 4.29. The results are presented in terms of the type of plastics and highest-ranking tonnage manufactured per month. The majority of the companies manufacture Polyethylene (PE, LLDPE, HDPE) products between 0 to 500 tons per month (68.8%). Polystyrene (PS) is the second in ranking with 0 to 500 tons production per month (66.7%) while Polyethylene Terephthalate (PET) is manufactured between 0 to 500 tons per month (58.3%).

The types of plastic products manufactured by the manufacturers are all recyclable products. Considering the number of plastic products manufactured on a monthly basis, the figures are significant for implementing a RL system for recovering these plastic wastes to sustain plastic recycling companies. For instance, 500 tons of PET plastic products are manufactured per month by 7 companies. This means, in a year, 42,000 tons of PET plastic products are manufactured and distributed in Zambia. Further consideration of 500 tons of each type of other manufactured recyclable plastic products on a monthly basis, the amount of 15000 tons is manufactured per month and it is significant and sustainable for a RL system.

TABLE 4.29: TYPES AND AMOUNTS OF PLASTIC PRODUCTS MANUFACTURED PER MONTH

		0-500 tonnes	501-1000 tonnes	1001-1500 tonnes	1501-2000 tonnes	More than 2000 tonnes
Polyethylene Terephthalate (PET)	Count	7	1	0	1	3
	Row N %	58.3%	8.3%	0.0%	8.3%	25.0%
Polystyrene (PS)	Count	4	1	0	0	1
	Row N %	66.7%	16.7%	0.0%	0.0%	16.7%
Polypropylene (PP)	Count	5	0	0	1	4
	Row N %	50.0%	0.0%	0.0%	10.0%	40.0%
Polyethylene (PE, LLDPE, HDPE)	Count	11	0	1	0	4
	Row N %	68.8%	0.0%	6.3%	0.0%	25.0%
Polyvinyl chloride (PVC)	Count	1	0	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%	0.0%
Polyethylene (PE)	Count	1	1	0	0	0
	Row N %	50.0%	50.0%	0.0%	0.0%	0.0%
Polyolefin	Count	1	0	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%	0.0%

Type and amount of Plastic Solid Wastes Recycled

Table 4.30 depicts the type and amount of PSWs recycled. The results show that, only three types of plastics are recycled. 1501 to 2000 tons of PET is recycled per month. For PP, 1001 to 1500 tons is recycled and 0 to 500 tons of PE (LLDPE, HDPE) is recycled per month. The other types of plastics are not recycled.

PET plastic products have the highest recycling rate per month because it is one of the most favourable packaging material (Welle et al. 2011). Majority of the water and soft drink bottles are manufactured from PET plastics. The results in Section 4.4.3 on the types of PSWs recovered by the IWCs confirm that, 44.7% of the PSWs recovered are plastic bottles.

Information on the current state of PSWs recycling practices and the types and amount of PSWs recycled is necessary for the proposed RL model. An understanding of the types and amount of PSWs recycled by the recycling companies on the monthly basis is necessary to the IWCs and the FWCs as well as the households. This information provides a platform for forecasting recoveries by the integrated stakeholders. From a RL perspective, the most returned products add value to the RL system of a company (Chan and Chan, 2008).

TABLE 4.30: TYPES AND AMOUNTS OF PSWS RECYCLED PER MONTH

		0-500 tonnes	501-1000 tonnes	1001-1500 tonnes	1501-2000 tonnes	More than 2000 tonnes
Polyethylene Terephthalate (PET)	Count	0	0	0	3	0
	Row N %	0.0%	0.0%	0.0%	100.0%	0.0%
Polypropylene (PP)	Count	1	1	2	0	0
	Row N %	25.0%	25.0%	50.0%	0.0%	0.0%
Polyethylene (PE, LLDPE, HDPE)	Count	4	0	1	1	0
	Row N %	66.7%	0.0%	16.7%	16.7%	0.0%

Sellers of Plastic Solid Wastes

Table 4.31 depicts the sellers of PSWs to buying companies. The results show that, the majority of the PSWs is bought from plastic manufacturing companies. This implies that, 80% of the companies that manufacture plastic products do not practise recycling but instead sell the PSWs to plastic buying companies and only 4.5% of the companies buy PSWs. The results show the none -existence of a structured RL system. The results further show inconsistence and this may be attributed to lack of understanding of the term PSWs by the plastic manufacturing companies.

TABLE 4.31: SELLERS OF PSWS TO BUYING COMPANIES

	Frequency	Percentage	Percentage of Cases
1. Plastic Manufacturing Companies	20	80.0%	90.9%
2. Plastic Recycling Companies	3	12.0%	13.6%
3. Plastic Buying Companies	2	8.0%	9.1%

Types of Plastic Recycling Technologies Used

Table 4.32 depicts the results on the assessment of recycling technologies used by the surveyed plastic recycling companies. The results are presented in terms of the type of plastic and the type of recycling technology. For the three types of recycled plastics, mechanical recycling technology has the highest ranking. It is the only type of technology used for recycling plastics by the recycling companies. Al-Salem et al (2009) states that, mechanical recycling is used in most of the products found in our lives. It is used to recycle PP, PE, PS, PET and other materials. This justifies the high representation by most plastic manufacturing and recycling companies in Zambia. Nevertheless, consideration should be made by plastic convertors in investing in other sustainable recycling technologies such as feedstock recycling and others.

TABLE 4.32: PLASTIC RECYCLING TECHNOLOGIES USED BY RECYCLING COMPANIES

		Mechanical Recycling	Feedstock Recycling	Chemical Recycling	Pyrolysis
Polyethylene Terephthalate (PET)	Count	4	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%
Polypropylene (PP)	Count	6	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%
Polyethylene (PE, LLDPE, HDPE)	Count	7	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%

Further the research assesses the companies on the types of products manufactured from recycled plastics. Table 4.33 depicts the results of the assessment. The results are presented in terms of the plastic type with its by-product. For PET, 100% is recycled into plastics bottles and for PE (LLDPE, HDPE) 57.1% is recycled into plastic bottles while 42.9% is recycled into plastic containers.

PET and PE are usually recycled in plastic bottles (Plastic Recycling, 2009). Welle et al (2011) states that, worldwide, PET has become one of the favourable packaging material used for water and beverage packages. This justifies the 100% of recycling PET products into plastic bottles. PE consists of low density PE and high-density PE and this justifies the 57.1% recycled into plastic bottles and 42.9% recycled into plastic containers. Plastic Recycling (2009) indicates that, PE in manufactured into film bags, bottles, containers, toys and many other plastic products.

TABLE 4.33: BY-PRODUCTS OF RECYCLED PLASTICS

		Plastic Bottles	Plastic Containers	Plastic Bags	Other
Polyethylene Terephthalate (PET)	Count	4	0	0	0
	Row N %	100.0%	0.0%	0.0%	0.0%
Polypropylene (PP)	Count	0	0	0	0
	Row N %	0.0%	0.0%	0.0%	0.0%
Polyethylene (PE, LLDPE, HDPE)	Count	4	3	0	0
	Row N %	57.1%	42.9%	0.0%	0.0%

Determinants of Recyclability and Price of PSWs

Table 4.34 depicts the results on the factors that determine the price of PSWs. The majority of the companies indicate that 'demand for recycled plastics' determines the price (41.2%) while 35.3% indicate 'quality of the recovered plastics'. The results in Section 4.4.5 on the assessment of the factors that determine the price of PSWs, 42.1% of the IWCs indicate 'demand and supply of the PSWs on the market.' This is a significant aspect for determining the price of the recovered PSWs for the proposed RL model. This correspondence is an indication that, the plastic recyclers and the IWCs are aware of the factors that determine the price of the recovered PSWs. BIO-Intelligence (2013) indicates that the price of the recovered PSWs is determined by a number of factors such as 'demand and supply of the PSWs in the market,' 'quality of the recycled product' and 'the standards of the buyer.'

TABLE 4.34: DETERMINANTS OF THE PRICE FOR PSWS

	Frequency	**Percentage**	**Percentage of Cases**
1. Demand for recycled plastics	7	41.2%	87.5%
2. Quality of the recycled product	6	35.3%	75.0%
3. The facility for reprocessing and technology	1	5.9%	12.5%
4. Virgin plastic prices	3	17.6%	37.5%

The factors that determine the price of the recovered PSWs are important recommendation strategies for the proposed RL model. 35.3% representation by quality of the recycled product is another important factor that can increase recoveries. From the waste recoveries perspective, the quality of the recovered PSWs is subject to increase for the purposes of gaining the price advantage. Further, the factors that determine the price of the recovered PSWs act as benchmarks for price determination.

Increasing the demand and supply of PSWs on the market and improving the quality of the recovered PSWs can result in a comparable price advantage with virgin plastic materials. 17.6% of the plastic waste recyclers indicate it as a significant price determine for PSWs.

Factors Determining Recyclability of Plastic Solid Wastes

The factors that determine the recyclability of PSWs are depicted in Table 4.35. Among the six items considered as factors for determining the recyclability of the recovered PSWs. 'The potential profit from the recycled plastic waste' (4.70) is the highest rated factor while 'level of accessibility of the plastic waste' (2.70) is the least rated. The majority of the factors, ''the price of virgin materials,' 'existence of local markets for recycled plastic,' and 'Supply and demand of the recycled plastic, 'have the mean value above 4. Based on the rating of the Likert-scale, the majority of the factors are 'agreed' on by the respondents. A number of factors determine the recyclability of PSWs. Medina (2001) and Wilson et al (2006) indicate that, local market existence, accessibility levels, anticipated potential profit margin and price of the virgin materials.

Potential profit from the recycled plastic waste is rated highest compared to other factors because implementation of RL for recycling purposes is driven by the economic value of the recovered product. Most companies are driven to implement RL systems because of driving factors such as economic, environmental and legislative drivers (Srivastava, 2008).

TABLE 4.35: DESCRIPTIVE STATISTICS FOR PSWS DETERMINANTS OF RECYCLABILITY

	Mean	Standard Deviation
1. The price of virgin materials	4.50	0.527
2. Existence of local markets for recycled plastic	4.10	0.316
3. Supply and demand of the recycled plastic	4.00	0.471
4. Level of accessibility of plastic waste	2.70	1.418
5. Convenience of transporting the materials	3.00	1.333
6. Potential profit from the recycled plastic waste	4.70	0.483

The economic driver for most recycling companies is the anticipated potential profit from the recycled PSWs. Most companies are influenced to implement RL of PSWs because of the potential profit. In order for companies to consider recycling PSWs, a comparison on the price of virgin plastic material is considered. This determines whether the companies make considerable profit from selling the recycled plastic at a price lower than the virgin plastic material. Most recycled plastic materials have a price lower than virgin plastic materials but consideration of profit is always projected. Existence of markets for recycled plastic materials is a cardinal factor to consider. Without markets for recycled products most companies collapse. This implies, this factor is important as it also projects the potential profit and the price for the recycled PSWs. In this case, the factors with the mean value above 4 should be given attention for the proposed RL model.

Reasons for Recycling PSWs

The descriptive statistics on the reasons companies recycle PSWs is depicted in Table 4.36. Among the eleven items considered as reasons for recycling PSWs, 'having a plastic waste recovery and recycling system,' (4.20) has the highest mean value while 'government regulations and policies' (2.40) has the least mean value on the Likert-scale rating of 1 to 5.

'Having a plastic waste recovery and recycling system,' 'EPR' and 'household participation in plastic waste recovery and recycling,' are the only items with mean value above 4. In developing economies, these factors have driven the sustainable RL of packaging waste. Xevgenos et al (2015) indicates that, EPR, public participation in waste recovery programs and structured RL systems drive the recovery and recycling of packaging wastes.

In developing economies, 'scavenger participation in plastic waste recovery for recycling' is a key factor because the IWS are the major recoveries. In this assessment, this factor has a mean value of 2.6 which is below the average mean value. Lack of involvement of the IWS in structured RL of PSWs attributes to low recovery rates in Zambia. Scheinberg et al (2010) concludes that Lusaka city in Zambia is one of the cities with the lowest recovery and recycling rates based on the low representation by IWS. 'Government regulations and policies,' (2.4) has a mean value below 4. This factor has not driven the plastic recycling companies to practice recycling in Zambia yet in developed economies, government regulations and policies on WM are one of the major reasons companies implement RL systems.

For the proposed RL system, the factors that drive the implementation of RL of packaging wastes in developed economies are given consideration and at the same time taking into consideration, the local factors.

TABLE 4.36: DESCRIPTIVE STATISTICS FOR REASONS FOR RECYCLING PSWS

	Mean	**Standard. Deviation**
1. Having a quality management system (ISO)	3.90	1.287
2. Having a plastic waste recovery and recycling system	4.20	0.422
3. Household participation in plastic waste recovery for recycling	4.10	0.316
4. Collaboration with other companies for plastic waste returns	3.40	1.506
5. Access to effective and state of the art technology	2.90	1.449
6. Extended Producer Responsibility	4.20	1.033
7. Social Corporate Responsibility	3.70	1.252
8. Cheap source of raw materials from local informal sector (. i.e. scavengers etc.)	2.60	1.075
9. Government Regulations and Policies	2.40	1.430
10. Scavenger (Informal Sector) participation in plastic waste recovery for recycling	2.60	1.174
11. Municipality and private sector participation in plastic waste recovery for recycling	3.20	0.919

4.6.3 Strategies and Levers for Sustainable Recovery and Recycling of PSWs

This section presents results on the assessment of the companies on strategies and levers that influence sustainable recovery and recycling of PSWs in Zambia. A total of 22 companies responded to the questions in this section. Companies are also assessed on the type of waste collection systems that can influence sustainable recovery of PSWs.

Strategies to Influence Sustainable PSWs Recovery and Recycling

The descriptive statistics in Table 4.37 indicate that, 'having plastic waste segregation at household levels,' (4.45), and 'development of a recovery and recycling system for industries in the plastics industry,' (4.41) are 'agreed' on. Highest in rating is 'having plastic waste segregation at household levels.' PSWs segregation at household level is important for ensuring sustainable recoveries. Matter et al (2013) affirms that source segregation is an important aspect of ensuring sustainable waste recovery. The plastic wastes segregated at source are recovered with less dirt and this reduces the cleaning time. Also sorting of plastic wastes from other kinds of wastes is reduced. Developing RL systems for recovering and recycling PSWs is a vital strategy as it integrates the recoveries and recyclers in the supply-chain hence ensuring optimal recoveries. BIO Intelligence (2013) recommends development of recovery and recycling supply-chain as a way forward to sustainable PSWs recycling.

TABLE 4.37: DESCRIPTIVE STATISTICS ON THE STRATEGIES FOR SUSTAINABLE RECOVERY AND RECYCLING OF PSWS

	Mean	**Standard Deviation**
1. Letting the informal sector (scavengers/waste pickers) sell to your organization	3.32	1.086
2. Letting the other formal plastic manufacturing companies sell to your organization	3.23	0.922
3. Having designated areas where plastic wastes are collected for recycling purposes (Material Recovery Facilities, MRF)	3.55	0.858
4. Letting your organization import plastic waste from other countries	1.86	1.082
5. Letting our organization conduct door to door plastic waste collection from households, institutions etc.	2.23	1.152
6. Letting our organization work in collaboration with the municipality to collect plastic waste for recycling purposes	3.00	1.195
7. Letting your organization provide incentives to plastic waste returners to your organization	3.14	1.207
8. Development of a recovery and recycling system for industries in the plastics industry	4.41	0.666
9. Having plastic waste segregation at household levels	4.45	0.671

'Having designated areas where plastic wastes are collected for recycling purposes,' (3.55), 'letting the IWS (scavengers/waste pickers) sell to your organization,' (3.32), 'letting the other formal plastic manufacturing companies sell to your organization,' (3.23), 'letting your organization provide incentives to plastic waste returners to your organization,'(3.14), ' letting our organization work in collaboration with the municipality to collect plastic waste for recycling purposes,'(3.0), 'Letting our organization conduct door to door plastic waste collection from households, institutions etc.,'(2.23), and ' letting your organization import plastic waste from other countries,'(1.86), on the scale inclined from neutral (3) to strongly disagree (1).

For the proposed RL model, 'having plastic waste segregation at household levels,' (4.45) is the most considerable factor while 'letting your organization import plastic waste from other countries,' (1.86), is the least for consideration.

Waste Collection Systems for Sustainable PSW Recovery

The descriptive statistics in Table 4.38 indicate that, 'kerbside collection systems,' (4.50), 'EPR' (4.05) and 'buy-back recycling centres,' (4.00) are rated with 'agree' (4) on a Likert-scale of 1 to 5. These results correspond to the results in Section 4.2.5 (Table 4.9) on the types of waste collection systems preferred by the households. 89.7% prefer kerbside waste collection, 83.7% prefer buy-back centres and 70.3% prefer EPR systems. Kerbside collection system is the most sustainable collection systems from the household and plastic manufacturing and recycling companies' perspective. For the IWCs, the preferred waste collection systems as assessed in Section 4.4.6 are, drop-off centres (51.8%) and kerbside (25%). Sidique et al (2010) indicates that, a combination of waste collection systems such as kerbside and drop-of centres contribute to high recycling rates.

For the proposed RL, a combination of waste collection systems is the strategic attribute of ensuring sustainable and optimal recoveries. This means, kerbside waste collection system should be implemented at household levels while drop-of centres and buy-back centres are established by the plastic manufacturing and recycling companies and EPR is effectively enforced so that the companies abide by it.

Further, based on the rating of the waste collection systems in Table 4.38, kerbside waste collection is highly recommended for the proposed RL model followed by 'buy-back centres.' 'Returnable container legislation' and 'selective collection performed by scavengers' are least in consideration.

TABLE 4.38: DESCRIPTIVE STATISTICS OF WASTE COLLECTION SYSTEMS FOR SUSTAINABLE RECOVERY OF PSWS

	Mean	Standard Deviation
1. Deposit System (Returnable Container Legislation)	3.77	1.152
2. Kerbside (Curbside) Collection systems	4.50	0.673
3. Drop-Off Collection systems	3.32	1.041
4. Buy-back Recycling centers	4.00	0.816
5. Extended Producer Responsibility Systems	4.05	0.722
6. Selective Collection performed by Scavengers	3.77	0.813

Levers for Sustainable Recovery and Recycling of PSWs

Levers that influence companies to recovery and recycle PSWs are assessed. Technological, economic, environmental and legislative concerns, market share and social levers. Based on literature review, these levers were identified as the influential levers for plastic manufacturing and recycling companies to recovery and recycle PSWs. For the proposed RL model, it is necessary to identify the most influential lever from each category of influencing levers. The most influential lever from each category is modelled in the RL model.

Technological levers

The descriptive statistics in Table 4.39 show the results on technological levers' assessment. The most important technological lever to influence sustainable recovery and recycling of PSWs from the company's perspective is 'ensuring material applicability in manufacturing processes,' (4.36, 0,581) followed by 'designing of products for recyclability,' (4.36, 0.658). The first two levers are the only levers with a mean value above 4. On a Likert-scale of 1 to 5, the first two levers are 'agreed on' (4). The mean value is used to rate the most influential lever for consideration in the proposed RL because it reveals the current situation of the technological lever that can influence PSWs recovery and recycling from the company's perspective.

For the proposed RL model, 'ensuring material applicability in manufacturing processes,' (4.36, 0,581) is considered highly for modelling compared to 'designing of products for recyclability,' (4.36, 0.658) because the standard deviation for 'ensuring material applicability in manufacturing processes' deviates closer to the mean as compared to the other lever. Least for consideration in the proposed RL model is 'improvement in size reduction technologies,' (3.32, 1.171).

BIO Intelligence (2013) states that, ensuring material applicability in manufacturing processes and designing of products for recyclability impacts the recovery and recycling of PSWs.

TABLE 4.39: DESCRIPTIVE STATISTICS FOR TECHNOLOGICAL LEVERS

	Mean	Standard Deviation
1. Improvement in recycling technology and infrastructure e.g. extrusion, blow molding etc.	3.59	1.469
2. Improvement in size reduction technologies	3.32	1.171
3. Improvement in the sorting technologies	3.77	1.378
4. Designing of products for recyclability	4.36	0.658
5. Ensuring material applicability in manufacturing processes	4.36	0.581

Market-Share Levers

In Table 4.40, the descriptive statistics on market levers indicate that, 'development of end markets for polymer recyclate stream,' (4.36, 0.658), 'existence of market systems relying on recycled-material throughput involvement; (4.36, 0.727) and 'Closer engagement of recyclers with one another along the supply-chain,' (4.14, 0.710), are the only levers with mean value above 4. Based on a Likert-scale of 1 to 5, these levers are 'agreed on'.

In economies where PSWs recovery and recycling has been successfully implemented, markets for polymer recycle streams exist. Plastickier (2012a) affirms that China already has markets for trading its recycled polymer. China is one of the biggest importer of PSWs because of already existing market systems that rely on recycled materials.

For the proposed RL model, the most influential market-share lever for modelling is 'development of end markets for polymer recycle stream,' (4.36, 0.658), while 'transnational co-operation on waste plastic recycling,' (3.68, 1.129) is the least for consideration.

TABLE 4.40: DESCRIPTIVE STATISTICS OF MARKET-SHARE LEVERS

	Mean	Standard Deviation
1. Development of end markets for polymer recycle stream	4.36	0.658
2. Closer engagement of recyclers with one another along the supply-chain	4.14	0.710
3. Recyclers to deal directly with municipalities, sorters, scavengers and households	3.91	1.231
4. Existence of market systems relying on recycled-material throughput involvement	4.36	0.727
5. Transnational cooperation on waste plastic recycling	3.68	1.129

Social Levers

In Table 4.41, the descriptive statistics depict that, the highest rated economic lever to influence sustainable recovery and recycling of PSWs is 'increasing consumer awareness on plastic recycling,' (4.50, 0.512), 'education of the households/community on the relevance of IWCs in the supply-chain,' (4.41, 0.503), 'efficiency of the municipality, private waste contractors or IWCs in waste collection,' (4.36, 0.581) and 'use of incentive schemes to motivate plastic recycling at household levels,' (4.32, 0.780) have mean values above 4. These levers are 'agreed to' on a Likert-scale from 1 to 5.

Increasing consumer awareness on plastic recycling is known to influence consumer participation in recovery and recycling programs (Singhirunnusorn et al., 2011). Awareness on PSWs recycling is not practiced in Zambia. The IWCs are the major recoveries of waste in developing economies. Educating the households on the relevance of the IWCs in the supply-chain enhances the process of integrating the IWCs into formalized systems. Efficiency of the waste service providers in waste collection means recoverable PSWs are delivered on time to the recyclers. In most developing economies, waste collection is less than 50% (World Bank, 2012). Improvement in the efficiency of waste service providers improves recoveries.

For the proposed RL model, 'increasing consumer awareness on plastic recycling,' (4.50, 0.512),' is considered the most influential social lever for modelling at the plastic manufacturing and recycling companies level. Section 4.3.1 on the assessment of the levers for modelling at the household level, knowledge and awareness on PSWs recycling (L_1) is one of the influential lever. This shows that, at household level and company level, consumer awareness on PSWs recycling is important.

TABLE 4.41: DESCRIPTIVE STATISTICS OF SOCIAL LEVERS

	Mean	Standard Deviation
1. Use of incentive schemes to motivate plastic recycling at household levels	4.32	0.780
2. Efficiency of the municipality, private waste contractors or informal waste collectors in waste collection	4.36	0.581
3. Introduction of plastic waste segregation at household level for recycling purposes	3.59	0.908
4. Increasing consumer awareness on plastic recycling	4.50	0.512
5. Education of the households/community on the relevance of informal waste collectors in the supply-chain	4.41	0.503

Environmental and Legislative Concerns Levers

Table 4.42 depicts the descriptive statistics on the assessment of the companies on environmental and legislative concerns levers. 'Enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes,' (4.55, 0.963) 'enforcement of environmental awareness programmes on the importance of plastic waste recycling,' (4.45, 0.510), 'enforcement of national-wide law on plastic waste recycling,' (4.27, 1.032) and 'legalization of selective collection performed by waste pickers from households, retailers, dumpsites etc.,' (4.05, 0.653) have mean values above 4. On the Likert scale of 1 to 5, these levers are inclined to 'agree' (4). The highest rated is 'enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes,' (4.55, 0.963).

Enforcement of Producer Responsibility Regulations on PSWs recycling is cardinal for achieving sustainable recovery and recycling. In countries such as Japan, the Netherlands and Germany, these regulations have influenced sustainable recovery and recycling (Xevgenos et al., 2015; Zhang and Wen, 2014). In 2010, Japan achieved the highest recycling rate as a result of EPR enforcement (Zhang and Wen, 2014).

For the proposed RL model, the most influential environmental concerns and legislations lever for modelling is 'enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes,' (4.55, 0.963). Adoption of this lever is based on the current rating on the Likert scale by the companies.

TABLE 4.42: DESCRIPTIVE STATISTICS FOR ENVIRONMENTAL CONCERNS AND LEGISLATIONS LEVERS

	Mean	**Standard Deviation**
1. Enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes	4.55	0.963
2. Enforcement of national-wide law on plastic waste recycling	4.27	1.032
3. Legalization of selective collection performed by waste pickers from households, retailers, dumpsites etc.	4.05	0.653
4. Enforcement of environmental awareness programs on the importance of plastic waste recycling	4.45	0.510
5. Enforcement of waste segregation at household level	3.59	1.098
6. Creation of quality standards and certification schemes for plastic recyclers	3.77	1.110

Economical Levers

The descriptive statistics in Table 4.43 depicts that, 'the cost of recycling compared with alternative forms of acceptable disposal alternatives,' (4.32, 0.894), 'the price of the recycled polymer compared to virgin polymer,' (4.23, 0.685), and ''high demand for the materials in manufacturing,' (4.14, 0.899) have mean values above 4 on the Likert scale and are inclined to 'agree' scale. The highest rated economical lever for influencing PSWs recovery and recycling is 'the cost of recycling compared with alternative forms of acceptable disposal alternatives,' (4.32, 0.894) while the least rated is 'lower energy requirements during input production,' (3.50, 1.535).

The cost of recycling compared to alternative forms of acceptable disposable alternatives has driven most developed economies to consider recycling PSWs. In economies such as Japan, landfilling waste is costly compared to the cost of recycling (Xevgenos et al., 2015). Comparing the cost of PSWs recycling with landfilling in the Zambian context can influence plastic manufacturing and recycling companies to consider implementing RL. Most companies in Zambia dispose of the plastic wastes as the cost of landfilling is cheaper than the cost of recycling.

For the proposed RL model, the most influential economical lever for modelling is 'the cost of recycling compared with alternative forms of acceptable disposal alternatives,' (4.32, 0.894).

TABLE 4.43: DESCRIPTIVE STATISTICS FOR ECONOMIC LEVERS

	Mean	Standard Deviation
1. Lower energy requirements during input production	3.50	1.535
2. High demand for the materials in manufacturing	4.14	0.889
3. The cost of recycling compared with alternative forms of acceptable disposal alternatives.	4.32	0.894
4. The price of the recycled polymer compared to virgin polymer	4.23	0.685

4.6.4 Barriers to Sustainable Recovery and Recycling of PSWs

The descriptive statistics in Table 4.44 show that, ‘lack of citizen/household participatory in plastic waste recycling schemes,’(4.45, 0.510), ‘Lack of recycling technology and infrastructure,’(4.41, 0.734), ‘lack of enforcement of EPR,’ (4.32, 0.716), ‘lack of regulations and legislation to enforce plastic waste recovery and recycling,’ (4.27, 1.032), and ‘different materials combined in plastic products complicate recycling,’(4.09, 0.750) have mean values above 4 and are inclined to ‘agree’ on the Likert scale of 1 to 5. These barriers are given consideration in the proposed RL model. ‘Lack of citizen/household participatory in plastic waste recycling schemes,’ (4.45, 0.510) is given the highest consideration since it is the highest rated barrier.

In developed economies, most households are encouraged to start recycling by collecting recyclable materials separately in order to achieve sustainable recovery (Dahlen et al., 2009). Successful recycling programs are achieved with active participation of people (Ittiravivongs, 2012). MRFs are an important aspect of achieving sustainable RL. Rispo et al (2015) outlines that, a variety of infrastructure contributes to facilitating residents’ participation in recovery programs. In developing economies, most of the recovery consists of unorganized IWCs depending on waste collected from trucks or temporary garbage dumps (Matter et al., 2012). Improvement in recycling technology and infrastructure is acknowledged by BIO-Intelligence (2013) as a technological lever for influencing plastic convertors to recovery and recycle PSWs. For the proposed RL model, household participation in PSWs recovery and recycling is considered a sustainable strategy for resolving the current RL challenge facing the plastic manufacturing and recycling companies.

‘Logistic costs associated with the recovery of PSWs,’ (3.91, 0.811), ‘high production costs,’ (3.86, 1.037), ‘weaker market demand for recycled resins.’ (3.86, 1.082), ‘high cost of labor associated with sorting facilities,’ (3.64, 0.953), ‘limited applicability of recycled plastics compared to virgin plastics,’ (3.59,0.959), ‘low volumes of input materials available for recyclers,’ (2.77, 1.541) and ‘economical risks associated with the establishment of plastic recycling facilities,’ (2.64, 1.177) have the mean value ratings inclined from 'neutral' to strongly disagree.' These are given the least consideration in the proposed RL model.

TABLE 4.44: DESCRIPTIVE STATISTICS FOR BARRIERS TO SUSTAINABLE RECOVERY AND RECYCLING OF PSWS

	Mean	Standard Deviation
1. Low volumes of input materials available for recyclers	2.77	1.541
2. Economical risks associated with the establishment of plastic recycling facilities	2.64	1.177
3. Logistic costs associated with the recovery of plastic solid wastes	3.91	0.811
4. Different materials combined in plastic products complicate recycling.	4.09	0.750
5. Lack of recycling technology and infrastructure	4.41	0.734
6. Lack of citizen/household participatory in plastic waste recycling schemes	4.45	0.510
7. High cost of labor associated with sorting facilities	3.64	0.953
8. High production costs	3.86	1.037
9. High quality standards required in recycled plastic materials	3.45	1.057
10. Limited applicability of recycled plastics compared to virgin plastics	3.59	0.959
11. Weaker market demand for recycled resins	3.86	1.082
12. Lack of regulations and legislation to enforce plastic waste recovery and recycling	4.27	1.032
13. Lack of enforcement extended producer responsibility (EPR)	4.32	0.716

4.6.5 Factors for Integrating the IWCs into Formalised Systems (Companies Perspective)

Integration of the IWCs into formalised systems is an important strategy for consideration in waste recovery and recycling programs. The plastic manufacturing and recycling companies are assessed on the factors for integrating the IWCs into formalised systems. Descriptive statistics results depicted in Table 4.45 indicate that, 'increasing awareness on the importance of waste pickers in the supply-chain to the public,' (4.68, 0.477), 'creating markets for waste pickers to sell their collected plastic wastes,' (4.59, 0.590), 'increasing waste collection and recycling facilities,' (4.50, 0.598), 'building plastic waste recycling targets to encourage waste pickers to collect more waste,' (4.36, 0.492), 'provision of education to waste pickers on waste sorting and collection,' (4.32, 0.646), 'provision of loans to waste pickers to enable them purchase storage or transportation facilities,' (4.32, 0.716), 'awarding of contracts to waste pickers for waste collection by recyclers or manufacturers,' (4.23, 0.528), 'provision of training to waste pickers on their health and the environment,' (4.09, 1.019) and 'legalizing plastic waste collection by waste pickers,' (4.05, 0.999) have mean values above 4 on the Likert scale of 1 to 5. These factors were rated with 'agree' on the scale and for integrating the IWCs into formalized systems, these factors are given consideration. Nevertheless, 'increasing awareness on the importance of waste pickers in the supply-chain to the public,' (4.68, 0.477), is given the highest priority.

Increasing awareness on the relevance of the IWCs in the supply-chain to the public is important because it increases acceptability (Gunsilius, 2012; Storey et al., 2015). Market creation for PSWs recovered by the IWCs increases recovery rates as the IWCs are driven by the economic benefit of trading the recovered wastes. Existing markets motivates them to recover more. Increasing waste collection and recycling facilities provides platforms for the IWCs to trade the recovered wastes (Fei et al., 2016; Chaturvedi, 2011).

'Plastic waste segregation performed at household levels,' (3.59, 1.054), 'provision of waste pickers with formalized uniforms and identification cards for easy identification in society,' (3.50, 1.144) and 'door-to-door collection performed by individual scavenger,' (3.05, 1.253) on the scale are within 'neutral.' These factors are considered moderate factors for integrating the IWCs into formalised systems by the companies.

Considering the results in Section 4.5.1 on the levers for integrating the IWCs into formalised systems (IWCs perspective), 'effective support structures for the IWCs' and 'legalization of PSWs collection performed by the IWCs,' are supported by the plastic manufacturing and recycling companies.

TABLE 4.45: DESCRIPTIVE STATISTICS ON STRATEGIES FOR INTEGRATING THE IWCS INTO FORMALISED SYSTEMS

	Mean	Standard Deviation
1. Plastic Waste segregation performed at household levels	3.59	1.054
2. Door-to-door collection performed by individual scavenger	3.05	1.253
3. Awarding of contracts to waste pickers for waste collection to waste pickers by recyclers or manufacturers	4.23	0.528
4. Legalizing plastic waste collection by waste pickers	4.05	0.999
5. Provision of education to waste pickers on waste sorting and collection	4.32	0.646
6. Creating markets for waste pickers to sell their collected plastic wastes	4.59	0.590
7. Provision of loans to waste pickers to enable them purchase storage or transportation facilities	4.32	0.716
8. Provision of training to waste pickers on their health and the environment	4.09	1.019
9. Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	3.50	1.144
10. Increasing waste collection and recycling facilities	4.50	0.598
11. Building plastic waste recycling targets to encourage waste pickers to collect more waste	4.36	0.492
12. Increasing awareness on the importance of waste pickers in the supply-chain to the public	4.68	0.477

4.7 Independent Sample T-Tests Analysis

4.7.1 Socioeconomic Factors and Households' Levers' Relationship Analysis

This section discusses the results on the analysis of the relationship between socioeconomic factors of age, gender, education level and income level on levers that influence households to participate in recovery and recycling programs. The assessment is conducted to determine significant differences between socioeconomic factors and the levers. This assessment is cardinal for the recovery and recycling of PSWs as it highlights the key socioeconomic factors to focus on during the modeling of the proposed RL model. The following are the levers which are assessed;

- Knowledge and awareness on PSWs Recycling (L_1)
- PSW Segregation for Recycling Initiatives (L_2)
- Legislations and Regulations on PSWs Recycling (L_3)
- Effective PSWs Collection and Recycling Systems (L_4)

Socioeconomic factors on knowledge and awareness on PSWs Recycling (Lever 1)

Table 4.46 depicts a summary of the independent sample t-tests results on the comparison of the mean scores on the continuous variables for two different groups of socioeconomic factors (age, gender, education level and income level) on Lever 1 (knowledge and awareness on PSWs recycling).

The results on gender indicate a significant difference in the scores for male (M = 4.34, SD = 0.651) and female (M = 4.52, SD = 0. 604); *t* (297) = -2.389, *p* = 0.018 (two-tailed). The difference in the rating of the lever by the male and female counterpart is revealed by the *p*-value. It is less than 0.05 hence a significant difference. The magnitude of the difference in the means (mean difference = 0.174, 95% CI: -0.317 to -0.031) is very small (eta squared = 0.018). This shows that, only 1.8% of the variance in knowledge and awareness on PSWs recycling is explained by gender. These results indicate that more female rated knowledge and awareness on PSWs recycling as a key lever for influencing PSWs recycling compared to the male counterpart.

For the proposed RL model, the significant difference in the rating of knowledge and awareness on PSWs by the male and female counterpart is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference for the proposed RL model.

For age, the results indicate that, there was no significant difference in the scores for household respondents younger than 26 years (M = 4.45, SD = 0.598) and household respondents older than 26 years (M = 4.39, SD = 0.782); *t* (297) = 0.782, *p* = 0.445 (two-tailed). The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = 0.058, 95% CI: -0.088 to 0.204) is very large (eta squared = 2.056). This indicates that 20.6% of the variance in knowledge and awareness is explained by age.

The results on the independent samples t-test scores to compare household respondents with secondary and tertiary education levels indicate that, there is no significant difference between secondary education (M = 4.47, SD = 0.597) and tertiary education (M = 4.38, SD = 0.666); *t* (295) = 1.174, *p* = 0.241 (two-tailed). This is revealed by the *p*-value which is greater than 0.05. The magnitude of the differences in the means (mean difference = 0.087, 95% CI: -0.059 to 0.233) is very large (eta squared = 4.649). This indicates that, 46.5% of the variance in knowledge and awareness is explained by education level.

Finally, the independent samples t-test scores indicate that, there is no significant difference between households earning below K 5000 (M = 4.36, SD = 0.694) and those earning above K 5000 (M = 4.51, SD = 0.586) on the scores of knowledge and awareness on PSWs recycling; *t* (243) = -1.704, *p* = 0.090

(two-tailed). The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the differences in the means (mean difference = -0.147, 95% CI: -0.317 to 0.003) is very small (eta squared = 0.012). This indicates that, 1.2% of the variance in knowledge and awareness on PSWs recycling is explained by income level.

TABLE 4.46: SOCIOECONOMIC FACTORS ON AWARENESS AND KNOWLEDGE ON PSWS RECYCLING

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	4.34	0.651	-2.389	0.018	0.174	0.018
	Female	4.52	0. 604				
Age	Younger than 26 years	4.45	0.598	0.782	0.445	0.058	2.056
	Older than 26 years	4.39	0.782				
Education Level	Secondary	4.47	0.597	1.174	0.241	0.087	4.649
	Tertiary	4.38	0.666				
Income Level	Below K5000	4.36	0.694	-1.704	0.090	-0.147	0.012
	Above K5000	4.51	0.586				

Socioeconomic factors on PSWs segregation for recycling initiatives (Lever 2)

The results on the comparison of the mean scores for age, gender, education level and income level on PSWs segregation for recycling initiatives are discussed in this section. Table 4.47 depicts the summary of the results.

The independent samples t-test to compare PSWs segregation for recycling initiatives scores for male (M = 3.86, SD = 0.838) and female (M = 3.87, SD = 0.744), indicate that, there is no significant difference; *t* (297) = 0.033, *p* = 0.974. The *p*-value is greater than 0.05 hence the significant difference. The magnitude of the difference in the means (mean difference = 0.033, 95% CI: -0.177 to 0.813) is very small (eta squared = 0.004). It indicates that 0.4% of the variance in PSWs segregation for recycling initiatives is explained by gender.

For age, the independent samples t-test scores indicate that, there is no significant difference between households' respondents younger than 26 years (M = 3.88, M = 0.773) and older than 26 years (M = 3.84, SD = 0.813); *t* (297) = 0.467, *p* = 0.641 (two-tailed). The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = 0.043, 95% CI:

-0.139 to 0.225) is very small (eta Squared = 0.001). It indicates that, 0.1% of variance in PSWs segregation for recycling initiatives is explained by age.

TABLE 4.47: SOCIOECONOMIC FACTORS ON PSWS SEGREGATION FOR RECYCLING INITIATIVES

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	3.86	0.838	0.033	0.974	0.033	0.004
	Female	3.87	0.744				
Age	Younger than 26 years	3.88	0.773	0.467	0.641	0.043	0.001
	Older than 26 years	3.84	0.813				
Education Level	Secondary	3.87	0.784	0.248	0.804	0.023	0.005
	Tertiary	3.85	0.796				
Income Level	Below K5000	3.76	0.866	-2.584	0.010	-0.266	0.029
	Above K5000	4.02	0.725				

The results of the independent sample t-test to compare PSWs segregation for recycling initiatives scores for household respondents with secondary (M = 3.87, SD = 0.784) and tertiary (M = 3.85, SD = 0.796) education indicates that, there is no significant difference, t (295) = 1.174, p = 0.241. The p-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = 0.087, 95% CI: -0.059 to 0.233) is very small (eta squared = 0.005). It indicates that, 0.5% of the variance in PSWs segregation for recycling initiatives is explained by education level.

The independent sample t-test results to compare PSWs segregation for recycling initiatives scores for household respondents with an income level below K 5000 (M = 3.76, SD = 0.866) and an income level above K 5000 (M = 4.02, SD = 0.725) indicates that, there is a significant difference; t (243) = -2.584, p = 0.010. The p-value is less than 0.05 hence a significant difference. The magnitude of the difference in the means (mean difference = -0.266, 95% CI: -0.477 to 0.054) is very small (eta squared = 0.029). It indicates that, 2.9% of the variance in PSWs segregation for recycling initiatives is explained by income level. The results indicate that, households' respondents with an income level above K5000 rates PSWs segregation for recycling initiatives highly compared to household's respondents with an income level below K5000.

For the proposed RL model, the significant difference in the rating of PSWs segregation for recycling initiatives by the households' respondents with income level above K5000 is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference for the proposed RL model.

Socioeconomic factors on legislations and regulations on PSWs Recycling (Lever 3)

This section discusses the results on the socioeconomic factors of age, gender, education level and income level on legislations and regulations on PSWs recycling. Table 4.48 depicts the summary of the independent sample t-test analysis.

For gender, the independent sample t-test score to compare legislations and regulations on PSWs recycling for male (4.23, SD = 0.727) and female (M = 4.32, SD = 0.726) indicates that, there is no significant difference; t (297) = -1.122, p = 0.263. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = -0.094, 95% CI: -0.260 to 0.071) is very small (eta squared = 0.004). It indicates that, only 0.4% of the variance in legislations and regulations on PSWs recycling is explained by gender.

The independent sample t-test on the comparison of legislations and regulations on PSWs recycling scores for household respondents younger than 26 years (M = 4.25, SD = 0.747) and older than 26 years (M = 4.31, SD = 0.700) indicates that, there is no significant difference; *t* (297) = -0.707, *p* = 0.480. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = -0.060, 95% CI: -0.228 to 0.107) is very small (eta squared 0.002). It indicates that, only 0.2% of the variance in legislations and regulations on PSWs recycling is explained by age.

The independent t-test results to compare legislations and regulations on PSWs recycling scores for household respondents with secondary (M = 4.35, SD = 0.717) and tertiary (M = 4.21, SD = 0.735) education reveals that, there is no significant difference; *t* (295) = 1.603, *p* = 0.110. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean difference = 0.136, 95% CI: -0.021 to 0.302) is very small (eta squared = 0.009). This indicates that, only 0.9% of the variance in legislations and regulations on PSWs recycling is explained by education level.

The independent t-tests to compare legislations and regulations on PSWs recycling scores for household respondents with income level below K 5000 (M = 4.21, SD = 0.747) and income levels above (M = 4.40, SD = 0.680) indicates that, there is a significant difference; *t* (243) = -2.008, *p* = 0.046. The *p*-value is less than 0.05 hence the significant difference. The magnitude of the difference in the means (mean difference = -0.191, 95% CI: -0.378 to -0.004) is very small (eta squared = 0.016). This indicates that, only 1.6% of the variance in legislations and regulations on PSWs recycling is explained by income level. These results indicate that, households' respondents with income levels above K 5000 rate legislations and regulations on PSWs recycling highly compared to respondents with an income below K 5000.

For the proposed RL model, the significant difference in the rating of legislations and regulations on PSWs recycling by household respondents earning below K 5000 and those earning above K 5000 is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference in the proposed RL.

TABLE 4.48: SOCIOECONOMIC FACTORS ON LEGISLATIONS AND REGULATIONS ON PSWS RECYCLING

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	4.23	0.727	-1.122	0.263	-0.094	0.004
	Female	4.32	0.726				
Age	Younger than 26 years	4.25	0.747	-0.707	0.480	-0.060	0.002
	Older than 26 years	4.31	0.700				
Education Level	Secondary	4.35	0.777	-1.603	0.110	0.136	0.009
	Tertiary	4.21	0.735				
Income Level	Below K5000	4.21	0.747	-2.008	0.046	-0.191	0.016
	Above K5000	4.40	0.680				

Socioeconomic factors on effective PSWs collection and recycling systems (Lever 4)

This section discusses the results on the socioeconomic factors of age, gender, education level and income level on effective PSWs collection and recycling systems. Table 4.49 depicts the summary of the independent sample t-test analysis.

The independent sample t-test scores on the comparison of effective PSWs collection and recycling systems on male (M = 3.94, SD = 0.974) and female (M = 4.13, SD = 0.856) reveal that, there is no significant difference, t (297) = -1.82, p = 0.070. The p-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = -0.194, 95% CI: -0.404 to -0.016) is very small (eta squared = 0.011). This indicates that, only 1.1% of the variance in effective PSWs collection and recycling systems is explained by gender.

The independent sample t-test results on the comparison of effective PSWs collection and recycling systems scores on household respondents younger than 26 years (M = 4.09, SD = 0.916) and older than 26 years (M = 3.94, SD = 0.930) reveal that, there is no significant difference, *t* (297) = 1.344, *p* = 0.180. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = 0.145, 95% CI: -0.067 to -0.358) is very small (eta squared = 0.006). This indicates that, only 0.6% of the variance in effective PSWs collection and recycling systems is explained by age.

TABLE 4.49: SOCIOECONOMIC FACTORS ON EFFECTIVE PSWS COLLECTION AND RECYCLING SYSTEMS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	3.94	0.974	-1.82	0.070	-0.194	0.011
	Female	4.13	0.856				
Age	Younger than 26 years	4.09	0.916	1.334	0.180	0.145	0.006
	Older than 26 years	3.94	0.930				
Education Level	Secondary	4.23	0.903	3.509	0.001	0.372	0.040
	Tertiary	3.86	0.913				
Income Level	Below K5000	4.03	0.957	-0.091	0.928	-0.011	0.000
	Above K5000	4.04	0.933				

The results of the independent sample t-test on the comparison of effective PSWs collection and recycling systems scores on household respondents with secondary (M = 4.23, SD = 0.903) and tertiary (M= 3.86, SD = 0.913) reveal that, there is a significant difference; *t* (295) = 3.509, *p* = 0.001. The *p*-value is less than 0.05 hence the significant difference. The magnitude of the difference in the means (mean = 0.372, 95% CI: 0.163 to 0.580) is very small (eta squared = 0.040). This indicates that, only 4% of the variance in effective PSWs collection and recycling systems is explained by education level. The results show that, households' respondents with secondary education rate effective collection and recycling systems highly compared to households with tertiary education. The significant difference in the education levels on effective PSWs collection and recycling systems may be attributed to the fact that, most respondents with secondary level education live in high density areas where waste collection services are not given full attention.

For the proposed RL model, the significant difference in the rating of effective PSWs collection and recycling systems by household respondents with secondary and tertiary education is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference in the proposed RL.

The independent sample t-test to compare effective collection and recycling systems scores on household respondents with income level below K 5000 (M = 4.03, SD = 0.957) and income level above K 5000 (M = 4.04, SD = 0.933) indicates that, there is no significant difference; *t* (243) = -0.091, *p* = 0.928. The *p*-value is greater than 0.05 hence the significant difference. The magnitude of the difference in the means (mean = -0.011, 95% CI: -0.257 to 0.235) is very small (eta squared = 0.00003).

4.7.2 Socioeconomic Factors and IWCs Integration levers (Households' Perspective)

This section discusses the results on the analysis of the relationship between socioeconomic factors of age, gender, education level and income level on levers that should be considered when integrating the IWCs into formalized systems. The assessment is conducted to establish if there are significant differences in the rating of the levers from the household demographic factors perspective. The levers considered are;

- Effective Support Structures for the IWCs (Lever 5)
- Legalization of PSW Collections Performed by the IWCs (Lever 6)

Socioeconomic factors and effective support structures for the IWCs

This section discusses the results on the socioeconomic factors of age, gender, education level and income level on effective support structures for the IWCs. Table 4.50 depicts a summary of the independent sample t-test analysis. The independent sample t-test scores to compare effective support structures for the IWCs scores on male (M = 4.21, SD = 0.606) and female (M = 4.32, SD = 0.592) indicates that, there is no significant difference; t (295) = -1.573, *p* = 0.117. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = -0.109, 95% CI: -0.246 to 0.027) is very small (eta squared = 0.008). It indicates that, only 0.8% of the variance in effective support structures for the IWCs is explained by gender.

The independent sample t-test scores to compare effective support structures for the IWCs scores on household respondents younger than 26 years (M = 4.25, SD = 0.627) and older than 26 years (M = 4.29, SD = 0.564) reveal that, there is no significant difference; *t* (297) = -0.552, *p* = 0.581. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = -0.039, 95% CI: -0.178 to 0.100) is very small (eta square = 0.001). It indicates that, only 0.1% of the variance in effective support structures for the IWCs is explained by age.

The independent sample t-test to compare effective support structures for the IWCs scores on household respondents with secondary (M = 4.29, SD = 0.623) and tertiary (M = 4.25, SD = 0.586) education indicates that, there is no significant difference; *t* (295) = 0.539, *p* = 0.590. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = 0.038, 95% Ci: -0.100 to 0.176) is very small (eta squared = 0.001). Its indicates that, only 0.1% of the variance in effective support structures for the IWCs is explained by education level.

The independent sample t-test scores to compare effective support structures for the IWCs scores on household respondents with income level below K 5000 (M = 4.26, SD = 0.600) and above K 5000 (M = 4.30, SD = 0.615) indicates that, there is no significant difference; *t* (243) =- 0.577, *p* = 0.564. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = 0.04, 95% Ci: -0.203 to 0.111) is very small (eta squared = 0.001). It indicates that, only 0.1% of the variance in effective support structures for the IWCs is explained by the income level.

TABLE 4.50: SOCIOECONOMIC FACTORS ON EFFECTIVE SUPPORT STRUCTURES FOR THE IWCS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	4.21	0.606	-1.573	0.117	-0.109	*0.008*
	Female	4.32	0.592				
Age	Younger than 26 years	4.25	0.627	-0.552	0.581	-0.039	0.001
	Older than 26 years	4.29	0.564				
Education Level	Secondary	4.29	0.623	0.539	0.590	0.038	0.001
	Tertiary	4.25	0.586				
Income Level	Below K5000	4.26	0.600	0.577	0.564	0.04	0.001
	Above K5000	4.30	0.615				

Socioeconomic factors and legalization of PSWs collections performed by the IWCs

The results on the socioeconomic factors of age, gender, education level and income level on legislation of PSWs collections performed by the IWCs are discussed in this section. Table 4.51 depicts the summary of the independent sample t-test analysis.

The independent sample t-test scores to compare legalization of PSWs collections performed by the IWCs on male (M = 4.08, SD = 0.884) and female (M = 4.24, SD = 0.846) indicates that, there is no significant difference; *t* (297) = -1.527, *p* = 0.128. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = -0.153, 95% CI: -0.350 to 0.044) is very small (eta squared = 0.008). It indicates that, only 0.8% of the variance in legalization of PSWs collections performed by the IWCs is explained by gender.

The independent sample t-test scores to compare legalization of PSWs collections performed by the IWCs on household respondents younger than 26 years (M = 4.23, SD = 0.833) and older than 26 years

(M = 4.06, SD = 0.909) indicates that, there is no significant difference; *t* (297) = 1.637, *p* = 0.103. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference in the means (mean = 0.166, 95% CI: -0.034 to 0.365) is very small (eta squared = 0.009). It indicates that, only 0.9% of the variance in legalization of PSWs collection performed by the IWCs is explained by age.

TABLE 4.51: SOCIOECONOMIC FACTORS ON LEGALIZATION OF PSW COLLECTIONS PERFORMED BY THE IWCS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Gender	Male	4.08	0.884	-1.527	0.128	-0.153	*0.008*
	Female	4.24	0.846				
Age	Younger than 26 years	4.23	0.833	1.637	0.103	0.166	0.009
	Older than 26 years	4.06	0.909				
Education Level	Secondary	4.36	0.870	3.674	0.000	0.365	0.044
	Tertiary	4.24	0.846				
Income Level	Below K5000	4.15	0.822	-0.279	0.780	-0.031	0.001
	Above K5000	4.18	0.908				

The scores of the independent sample t-test to compare legalization of PSWs collections performed by the IWCs on household respondents with secondary (M = 4.36, SD = 0.870) and tertiary (M = 4.24, SD = 0.846) education indicates that, there is a significant difference; *t* (295) = 3.674, *p* = 0.000. The *p*-value is less than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = 0.365, 95% CI: 0.169 to 0.560) is very small (eta squared = 0.044). It shows that, only 4.4% of the variance in legalization of PSWs collection performed by the IWCs is explained by education level. Further, the significant difference indicates that, the secondary educated household respondent's rate legislation of PSW collection performed by the IWCs highly compared to respondents with tertiary education.

The independent sample t-test to compare legalization of PSWs collections performed by the IWCs scores on household respondents with income level below K 5000 (M = 4.15, SD = 0.822) and above K 5000 (M = 4.18, SD = 0.908) indicates that, there is no significant difference; *t* (243) = -0.279, *p* = 0.780. The *p*-value is greater than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = -0.031, 95% CI: -0.253 to 0.190) is very small (eta squared = 0.001). It indicates that, only 0.1% of the variance in legalization of PSWs collections performed by the IWCs is explained by income level.

4.7.3 Independent Sample T-Tests Analysis on Socioeconomic Factors and IWCS' Levers'

The results on the independent sample t-test analysis of socioeconomic factors of age, education level and income level on the levers for integrating the IWCs into formalized systems assessed from the IWCs perspective is presented in this section. The basis of the assessment is to determine significant differences between socioeconomic factors and the levers. Further, the socioeconomic factors with a significant difference on the levers are important modelling input for the proposed RL model. The following are the levers which are assessed;

- Effective Support Structures for the Informal Waste Collectors (Lever 5)
- Legalization of PSW Collections Performed by the Informal Waste Collectors (Lever 6)

Socioeconomic factors and effective support structures for the IWCs

The results on the socioeconomic factors of age, education level and income level on effective support structures for the IWCs are discussed in this section. Table 4.52 depicts the summary of the independent sample t-test analysis.

The independent sample t-test scores to compare effective support structures for the IWCs on the IWCs younger than 26 years (M = 4.41, SD = 0.581) and older than 26 years (M = 4.58, SD = 0.544) indicates that, there is no significant difference; *t* (51) = -1.075. *p* = 0.2888. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference between the means (mean = -0.174, 95% CI: -0.498 to 0.151) is small (eta squared = 0.022). It indicates that, only 2.2% of the variance in effective support structures for the IWCs is explained by age

The independent sample t-test results to compare effective support structures for the IWCs scores on the IWCs with primary (M = 4.46, SD = 0.599) and secondary (M = 4.59, SD = 0.512) education indicates that, there is no significant difference; *t* (51) = -0.795, *p* = 0.430. The *p*-value is greater than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = -0.122, 95% CI: -0.432 to 0.187) is very small (eta squared = 0.012). This indicates that, 1.2% of the variance in effective support structures for the IWCs is explained by education level.

The independent t-test results to compare effective support structures for the IWCs scores on the IWCs with income level below K 1000 (M = 4.31, SD = 0.599) and above K 1000 (M = 4.73, SD = 0.432) indicates that, there is a significant difference; t (45) = -2.923, *p* = 0.005. The *p*-value is less than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = -0.421, 95% CI: -0.711 to -0.131) is large (eta squared = 0.159). It indicates that, 15.9% of the variance in effective support structures for the IWCs is explained by income level. The results indicate that, the

IWCs with an income above K1000 rate effective support structures for the IWCs highly compared to the IWCs with an income below K1000.

For the proposed RL model, the significant difference in the rating of effective support structures for the IWCs by the IWCs with income level below K1000 and above K1000 is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference for the proposed RL model.

TABLE 4.52: SOCIOECONOMIC FACTORS ON EFFECTIVE SUPPORT STRUCTURES FOR THE IWCS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Age	Younger than 26 years	4.41	0.581	-1.075	0.2888.	-0.174	0.022
	Older than 26 years	4.58	0.544				
Education Level	Primary	4.46	0.599	-0.795	0.430	-0.122	0.012
	Secondary	4.59	0.512				
Income Level	Below K1000	4.31	0.599	-2.923	0.005	-0.421	0.159
	Above K1000	4.73	0.432				

Socioeconomic factors and legalization of PSW collection performed by the IWCs

The scores on the socioeconomic factors of age, education level and income level on legalization of PSW collection performed by the IWCs are discussed in this section. Table 4.53 depicts the summary of the independent sample t-test analysis.

The independent sample t-test scores to compare legalization of PSWs collection performed by the IWCs on the IWCs younger than 26 years (M = 3.54, SD = 1.401) and older than 26 years (M = 3.88, SD = 1.100) indicates that, there is no significant difference; t (51) = -0.968, p = 0.338. The p-value is greater than 0.05 hence no significant difference. The magnitude of the difference between the means (mean = -0.339, 95% CI: -1.043 to 0.365) is very small (eta squared = 0.018). It indicates that, only 1.8% of the variance in legalization of PSWs collection performed by the IWCs is explained by age.

The independent sample t-test scores to compare legalization of PSWs collection performed by the IWCs on the IWCs with primary (M = 4.17, SD = 0.877) and secondary (M = 3.31, SD = 1.374) indicates that, there is a significant difference; t (40) = 2.680, p = 0.011. The p-value is less than 0.05

hence the significant difference. The magnitude of the difference between the means (mean = 0.860, 95% CI: 0.211 to 1,509) is large (eta squared = 0.152). It indicates that, 15.2% of the variance in legalization of PSWs performed by the IWCs is explained by education level. The scores show that, IWCs with primary education rated legislation of PSWs collection performed by the IWCs highly compared to the IWCs with secondary education.

For the proposed RL model, the significant difference in the rating of legalization of PSWs performed by the IWCs by the IWCS with primary and secondary education levels is important as a modeling scenario. It is necessary to show the difference in the amount of PSWs recovered and recycled as a result of this significant difference for the proposed RL model.

The independent sample t-test scores to compare legalization of PSWs performed by the IWCs with income level below K 1000 (M = 3.63, SD = 1.097) and above K1000 (M = 3.89, SD = 1.314) indicates that, there is a significant difference; t (51) = -0.783, p = 0.438. The magnitude of the difference between the means (mean = -0.261, 95% CI: -0.929 to 0.408) is very small (eta squared = 0.012). This indicates that, only 1.2% of the variance in legalization of PSWs performed by the IWCs is explained by income.

TABLE 4.53: SOCIOECONOMIC FACTORS ON LEGALIZATION OF PSW COLLECTION PERFORMED BY THE IWCS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Age	Younger than 26 years	3.54	1.401	-0.968	0.338	-0.339	0.018
	Older than 26 years	3.88	1.100				
Education Level	Primary	4.17	0.877	2.680	0.011	0.860	0.123
	Secondary	3.31	1.374				
Income Level	Below K1000	3.63	1.097	-0.783	0.438	-0.261	0.001
	Above K1000	3.89	1.314				

4.7.4 Socioeconomic Factors and Challenges Facing the IWCs in PSW Recovery

The scores on the analysis of the socioeconomic factors of age, education level and income level on the challenges facing the IWCs in PSWs recovery assessed from the IWCs perspective is presented in this section. The basis of the assessment is to determine significant differences between demographic factors and the challenges. The assessment is extremely important for the recovery and recycling programs of PSWs because it highlights challenges as perceived from the socioeconomic factors of the IWCs. The following are the levers which are assessed;

- Lack of Sustainable Recovery Systems for PSWs
- Lack of Support from the Government on PSW Recovery

Socioeconomic factors and lack of sustainable recovery systems for PSWs

The results on the socioeconomic factors of age, education level and income level on lack of sustainable recovery systems for PSWs scores is discussed in this section. Table 4.54 depicts the summary of the independent sample t-test analysis.

TABLE 4.54: SOCIOECONOMIC FACTORS ON LACK OF SUSTAINABLE RECOVERY SYSTEMS FOR PSWS

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Age	Younger than 26 years	4.12	0.909	-0.925	0.359	-0.224	0.017 (small)
	Older than 26 years	4.34	0.794				
Education Level	Primary	4.28	0.831	0.079	0.937	-0.224	0.0001 (small)
	Secondary	4.26	0.852				
Income Level	Below K1000	3.84	0.854	- 0.4169	0.0000	-0.837	0.283 (large)
	Above K1000	4.68	0.575				

The independent sample t-test results to compare lack of sustainable recovery systems for PSWs scores on the IWCs younger than 26 years (M = 4.12, SD = 0.909) and older than 26 years (M = 4.34, SD =0.794) indicates that, there is no significant difference; *t* (51) = -0.925, *p* = 0.359. The *p*-value is greater than the 0.05 hence no significant difference. The magnitude of the difference between the means (mean = -0.224, 95% CI: -0.710 to 0.262) is very small (eta squared = 0.017). It indicates that, 1.7% of the variance in lack of sustainable recovery systems for PSWs is explained by age.

The independent sample t-test to compare lack of sustainable recovery systems for PSWs scores on the IWCs with primary (M = 4.28, SD = 0.831) and secondary (M = 4.26, SD = 0.852) education indicates that, there is no significant difference; *t* (51) = 0.079, *p* = 0.937. The *p*-value is greater than 0.05 hence no significant difference. The magnitude of the difference between the means (mean = 0.018, 95% CI: -0.446 to 0.483) is very small (eta squared = 0.0001). It indicates that, 0% of the variance in lack of sustainable recovery systems for PSWs is explained by education level.

The independent sample t-test to compare lack of sustainable recovery systems for PSWs scores on the IWCs with income level below K 1000 (M = 3.84, SD = 0.854) and above K1000 (M = 4.68, SD = 0.575) indicates that, there is a significant difference; t (44) = -4.169, p = 0.000. The p-value is less than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = -0.837, 95% CI: -1.241 to -0.432) is very large (eta squared = 0.283). It indicates that, 28.3% of the variance in lack of sustainable recovery systems for PSWs is explained by income level. The scores indicate that, the IWCs with income level above K1000 rate lack of sustainable recovery systems for PWSs highly compared to the IWCs with income levels below K1000.

Socioeconomic Factors and Lack of Support from the Government on PSW Recovery

The results on the socioeconomic factors of age, education level and income level on lack of support from the government on PSWs recovery scores is discussed in this section. Table 4.55 depicts the summary of the independent t-test analysis.

The independent sample t-test scores to compare lack of support from the government on PSWs recovery on the IWCs younger than 26 years (M = 4.13, SD = 0.751) and older than 26 years (M = 4.31, SD = 0.896) indicates that, there is no significant difference; t (51) = -0.748, p = 0.458. The p-value is greater than 0.05 hence no significant difference. The magnitude of the difference between the means (mean = -0.185, 95% CI: -0.680 to 0.311) is very small (eta squared = 0.011). This indicates that, 1.1% of the variance in lack of support from the government on PSWs recovery is explained by age.

The independent sample t-test scores to compare lack of support from the government on PSWs recovery scores on the IWCs with primary (M = 4.37, SD = 0.722) and secondary (M = 4.12, SD = 0.966) indicates that, there is no significant difference; t (51) = 1.070, p = 0.290. The p-value is greater than 0.05 hence no significant difference. The magnitude of the difference between the means (mean = 0.249, 95% CI: -0.218 to 0.716) is small (eta squared = 0.022). It indicates that, 2.2% of the variance in lack of support from the government on PSWs recovery is explained by education level.

The independent sample t-test scores to compare lack of support from the government on PSWs recovery scores on the IWCs with income level below K 1000 (M = 4.00, SD = 0.772) and above K1000 (M = 4.49, SD = 0.859) indicates that, there is a significant difference; t (51) = -2.198, p = 0.032. The p-value is less than 0.05 hence the significant difference. The magnitude of the difference between the means (mean = -0.494, 95% CI: -0.945 to 0.043) is moderate (eta squared = 0.093). It indicates that, 9.3% of the variance in lack of support from the government on PSWs recovery is explained by income level. The scores indicate that, IWCs with an income level above K1000 rate lack of support from the government on PSWs recovery highly compared to the IWCs with income level below K1000.

TABLE 4.55: SOCIOECONOMIC FACTORS ON LACK OF SUPPORT FROM THE GOVERNMENT ON PSWS RECOVERY

		Mean	SD	*t*	*P-value*	Mean Difference	Effect Size
Age	Younger than 26 years	4.13	0.751	-0.748	0.458	-0.185	0.011 (small)
	Older than 26 years	4.31	0.896				
Education Level	Primary	4.37	0.722	1.070	0.290	0.249	0.022 (small)
	Secondary	4.12	0.966				
Income Level	Below K1000	4.00	0.772	-2.198	0.030	-0.494	
	Above K1000	4.49	0.859				0.093 (small)

4.8 Analysis of Variance Tests

4.8.1 Households' Locational Areas and the Influencing Levers

One-way between-groups ANOVA is conducted to identify the significant differences in the mean scores on the dependent variables (levers) across the three groups (low, medium and high-density areas). The purpose of the analysis is to identify the levers that have the most significant difference across the locational areas. The levers considered in this analysis are;

- Knowledge and Awareness on PSW Recycling (Lever 1)
- PSW Segregation for Recycling Initiatives (Lever 2)
- Legislations and Regulations on PSWs Recycling (Lever 3)
- Effective PSWs Collection and Recycling Systems (Lever 4)

The households assessed in this research are categorized into low, medium and high-density areas based on location of the urban areas. A total of 90 household respondents from the low-density area, 96 for the medium-density areas and 113 for the high-density areas. The number of households in each locational area is based on the analyzed questionnaires. Figure 4.14 shows a representation of the locational areas based on the urban areas.

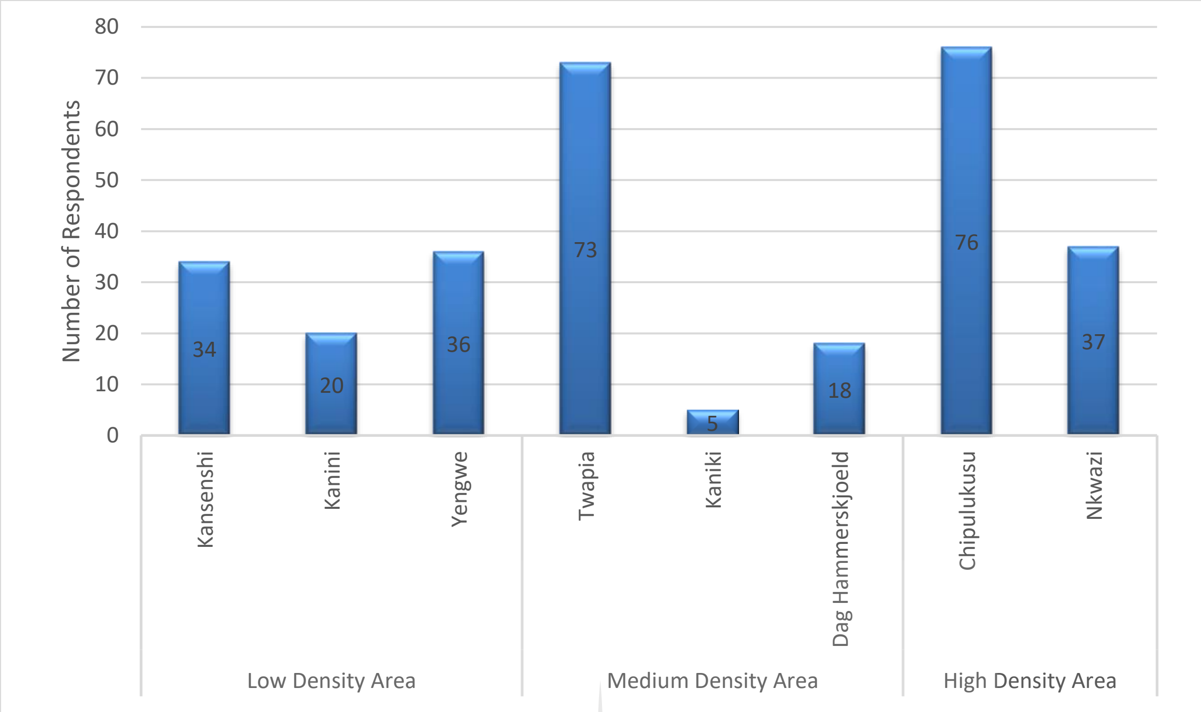


FIG 4.14: LOCATIONAL AREAS REPRESENTATION

Households' Locational Areas and Lever 1

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on knowledge and awareness on PSWs recycling (Lever 1). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is no statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 2.436, p = 0.089. Despite reaching statistical significance, the actual difference in mean scores between the groups is small. The effect size, calculated using eta squared, is 0.016. This indicates that, 1.6% of the variance in knowledge and awareness on PSWs recycling (Lever 1) is explained in the household locational areas. The rating of Lever 1 by the three locational areas is not different. The mean values are inclined within agree on a Likert scale of 1 to 5. Table 4.56 summaries the results of the analysis.

TABLE 4.56: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 1

Variable	Mean	df	F	Sig
Lever 1				
Low Density Area	4.36	2	2.436	0.089
Medium Density Area	4.36	296		
High Density Area	4.53			

Households’ Locational Areas and Lever 2

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on PSWs segregation for recycling initiatives (Lever 2). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is no statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 0.708, p = 0.493. Despite reaching statistical significance, the actual difference in mean scores between the groups is small. The effect size, calculated using eta squared, is 0.000005. This indicates that, 0.0% of the variance in PSWs segregation for recycling initiatives (Lever 2) is explained by the locational areas. The mean values for the locational areas are inclined within neutral on a Likert scale of 1 to 5. Thus, there is no significant difference and the p-value is more than 0.05. Table 4.57 summaries the results.

TABLE 4.57: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 2

Variable	Mean	df	F	Sig
Lever 2				
Low Density Area	3.93	2	0.708	0.493
Medium Density Area	3.79	296		
High Density Area	3.88			

Households Locational Areas and Lever 3

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on legislations and regulations for PSWs recycling (Lever 3). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is no statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 1.075, p = 0. 343. Despite reaching statistical significance, the actual difference in mean scores between the groups is small. The effect size, calculated using eta squared, is 0.007. This indicates that, 0.7% of the variance in legislations and regulations on PSWs recycling (Lever 3) is explained by the locational areas. Table 4.58 depicts the summary of the results

TABLE 4.58: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 3

Variable	Mean	df	F	Sig
Lever 3				
Low Density Area	4.23	2	1.075	0.343
Medium Density Area	4.22	296		
High Density Area	4.35			

Households Locational Areas and Lever 4

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on effective PSWs collection and recycling systems (Lever 4). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is a statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 13.885, $p = 0.000$. Despite reaching statistical significance, the actual difference in mean scores between the groups is moderate. The effect size, calculated using eta squared, is 0.09. Post-hoc test comparisons using the Dunnett's T3 test (equal variances not assumed), indicates that the mean scores for Group 3 (M = 4.36, SD = 0.808) differ significantly from Group 1 (M= 3.73, SD = 0.825) and Group 2 (M = 3.91, SD = 1.018). However, Group 1 and Group 2 do not differ significantly from each other. Table 4.59 presents the summary of the results.

TABLE 4.59: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 4

Variable	**Mean**	**df**	**F**	**Sig**
Lever 4				
Low Density Area	3.73	2	13.885	0.343
Medium Density Area	3.91	296		
High Density Area	4.36			

The mean scores in the three groups indicate that, Group 3 (High Density Areas) rate effective PSWs collection and recycling systems highly compared to Group 1 (Low Density Areas) and Group 2 (Medium Density Areas). This is attributed to the fact that; most high-density areas do not have adequate waste collection systems. This supported by Hoornweg and Bhada-Tata (2012), approximately 41% of collection coverage is achieved in lower-income countries while 85% in upper income countries. This is a huge concern for achieving sustainable PSWs recovery and recycling. Further, the results on the assessment of waste collection services, 37% of the households dispose their wastes unsustainably by burying or burning it. The high rating of effective PSWs collection and recycling systems by the high-density areas is attributed to lack of proper waste collection services

4.8.2 Households' Locational Areas and Levers to Integrate the IWCs into Formalized Systems

One-way between-groups ANOVA is conducted to identify the significant differences in the mean scores on the dependent variables (IWCs integration levers) across the three groups (low, medium and high-density areas). Post-hoc tests are used to identify where the differences lie. The purpose of the analysis is to identify the levers for integrating the IWCs into formalized systems that has the most significant difference across the locational areas. The levers considered in this analysis are;

- Effective Support Structures for the Informal Waste Collectors (lever 5)
- Legalization of PSW Collections Performed by the Informal Waste Collectors (Lever 6)

Households' Locational Areas and Lever 5

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on effective support structures for the IWCs (Lever 5). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is no statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 1.576, p = 0.209. Despite reaching statistical significance, the actual difference in mean scores between the groups is small. The effect size, calculated using eta squared, is 0.010. This shows that, 1% of the variance in effective support structures for the IWCs is explained by locational areas. Table 4.60 presents the summary of the results.

TABLE 4.60: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 5

Variable	**Mean**	**df**	**F**	**Sig**
Lever 5				
Low Density Area	4.27	2	1.576	0.209
Medium Density Area	4.19	296		
High Density Area	4.33			

Households' Locational Areas and Lever 6

A one-way between-groups ANOVA is conducted to explore the influence of locational areas for households on legalization of PSWs collections performed by the IWCs (Lever 6). Subjects are divided into three groups according to their population density (Group 1: Low Density Area; Group 2: Medium Density Area; Group 3: High Density Area). There is a statistically significant difference at the $p < 0.05$ level in LOT scores for the three locational area groups: F (2, 296) = 19.134, p = 0.000. Despite reaching statistical significance, the actual difference in mean scores between the groups is large. The effect size, calculated using eta squared, is 0.114. The Post- hoc comparisons using Dunnett's T3 test (equal variances not assumed), indicates that the mean scores for Group1 (M = 3.77, SD = 0.845); Group 2 (M= 4.14, SD = 0.848) and Group 3 (M = 4.48, SD = 0.773) differ significantly from each other. The mean scores indicate that, the three groups' rating of legalization of PSWs collections performed by the IWCs differ. Group 3 (High Density Areas) rates legalization of PSWs collection performed by the IWCs highly followed by Group 2 (Medium Density Areas) and Group 1 (Low Density Areas) is last. The high rating of legalization of PSWs collection performed by the IWCs by Group 3 is attributed to the fact that, most IWCs emerge from high density areas were the activities of informal recovery and collection of PSWs are accepted. This supports the need for the high-density areas to rate legalization of PSWs performed by the IWCS. Table 4.61 presents the summary of the results.

TABLE 4.61: ONE-WAY ANOVA BETWEEN HOUSEHOLD LOCATION AREAS AND LEVER 5

Variable	Mean	df	F	Sig
Lever 5				
Low Density Area	4.27	2	1.576	0.209
Medium Density Area	4.19	296		
High Density Area	4.33			

Based on the consideration of a perfect symmetrical normal distribution curve which has 68.3% of the area under the curve within one standard deviation of the mean, the inferential statistical analysis of the levers that have shown a significant difference at the *p*-value 0.05 are inputted in the proposed model.

The basis for inputting the mean and the standard deviation of the levers that have shown significant differences is considered under the scenario approaches discussed in chapter 6.

The lever data to be inputted into the model allows for a standard deviation of minus 1 (s= -1) and plus 1 (s= +1) from the mean. The mean value for the levers is considered as the value that represents the current proportion of recycling as represented by the households. The standard deviation describes how far the households are from reaching the current proportion. Consideration of the S= -1 and S= +1 standard deviation provides information on the amount of PSWs recovered and recycled above and below the mean proportion.

Chapter Five: Qualitative Data Analysis

5. Introduction

This chapter presents qualitative information from the interviews that are conducted with the; municipality and the private waste collectors. Thematic analysis is used in analyzing the data and the findings are presented in the sections that follow.

5.1 Interview Preparation

The interviews are based on the research objectives and pinpointed to the aspects of RL and PSWs recovery and recycling. The objective of the interviews is to confirm or reject the findings from quantitatively analyzed data. Interview permission letters are sent to the companies prior to the interviews. The purpose and relevance of the interviews is explained in the letters (see Annexure D). Further, confidentiality assurance is noted in the letters.

5.1.1 Questions Setting

Prior to the start of the interviews, the interviewee educational background and area of expertise is noted. This is conducted for the purpose of understanding the expertise of the interviewee with regard to the research purpose. The interview is then conducted as outlined in the structured questions. (See Annexure E).

5.1.2 Interview Documenting

One on one interviews are conducted and the interviewer notes the interviewee responses. In order to emphasize the essence of the interviewee’s responses, notes are taken. This is also conducted to ensure clarity when analyzing the interview findings.

5.1.3 Participants Selection

The selection of the participants is based on the type and size of the organization. The interviewees are selected from the departments that manage SW. Selection of the participants from the municipality and the private waste collecting companies presents vast knowledge and information. Table 5.1 depicts the list of participants with their job titles and organization.

TABLE 5.1: LIST OF PARTICIPANTS

No.	Organization	Participant Job Title
1	Private Waste Collectors	Waste Manager
2	Privates Waste Collectors	Waste Manager
3	Private Waste Collectors	Waste Manager
4	Private Waste Collectors	Waste Manager
5	Private Waste Collectors	Waste Manager
6	Private Waste Collectors	Waste Manager
7	Private Waste Collectors	Regional Waste Manager
8	Municipality	Health Inspector
9	Municipality	Waste Manager
10	Municipality	Waste Manager

Different views from the participants on the questions of discussion during the interviews are received. The contributions provide information and understanding on; types of PSWs recovered; the purpose of recovering PSWs, amount of PSWs recovered per day, recovery points; buyers of the recovered PSWs, strategies for supporting sustainable recovery and recycling of PSWs, barriers in the recovery and recycling of PSWs and the levers for integrating the IWCs into formalised system. Information and suggestions on the way forward to implementing RL for PSWs in the plastic manufacturing and recycling industries is provided.

5.2 Interview Responses

A total of 20 permission letters are purposively distributed to selected municipalities and private waste collecting companies. 10 interviews are granted and this results in a response rate of 50%. Response rates of between 50 to 65% are recommended for interviews (Willmack, 2002). This confirms that, the response rate for the interviews is within the recommended range. The following sections discuss the results from the interviews based on the themes that are formed.

5.2.1 Socioeconomic Information of the Participants

A total of eight (8) male and two (2) female waste managers participated in the interviews. The highest qualification of the interviewees is a graduate degree. Interviewing the waste managers enables the interviewer gather authentic and detailed information on the subject matter.

5.2.2 PSWs Recovery Practices

This section describes the results from the interviews on PSWs recovery. The private waste collecting companies' points out that, they recover PSWs for recycling purposes. The types of PSWs recovered consist of plastic bottles, containers and bags. This information matches with the results in Section 4.4.3 on the assessment of the types of plastic wastes the IWCs recover. The results in Section 4.4.3 depict that, plastic bottles, bags and containers are recovered. On a daily basis, the majority indicate that, less than 200 plastic bottles, containers and bags are recovered from markets, shops, households and dump-sites. The private waste collectors indicate that, some recoveries are paid for while others indicate recoveries are free. The recovered PSWs are sold to plastic manufacturing and recycling companies for recycling purposes.

In terms of waste collection systems used to recover the PSWs, buy-back collection systems and kerbside waste collection systems are indicated. Kerbside waste collection system is also preferred by the households, IWCs and plastic manufacturing and recycling companies. The IWCs highly rate drop-off centers to kerbside waste collection systems. Sidique et al (2010) states that, a combination of kerbside waste collection and drop-off centers increase waste recovery and recycling rates. This indicates that, the different types of waste collection systems should be integrated in the proposed RL model.

The municipality that participated in the interviews indicates that, recovery of PSWs is not conducted in their organizations. The majority of the PSWs collected by the municipality is disposed of at the dump-sites. The municipality indicates that, kerbside waste collection systems and drop-off sites are used as the waste collection systems. PSWs are collected for disposal from households, shops, markets, city-centers, commercial and industrial institutions and from illegal disposals.

5.2.3 Strategies for Sustainable PSWs recovery and recycling

This section describes the results on the strategies for sustainable PSWs recovery and recycling as outlined by the interviewees. The private waste collectors indicate that, source separation at households' level, legalization of PSWs recycling, development of recovery and recycling systems for plastic industries and having designated areas for PSWs recovery purposes can increase sustainable recoveries. Others indicate that IWCs legalization increases the amount of recoveries. The municipality indicates that, IWCs integration in the recovery of PSWs as well as legalization of PSWs by the government. Source separation at household levels and development of recovery and recycling systems for the industries in the plastic is highlighted. In Section 4.6.3 on the assessment of the strategies for sustainable recovery and recycling of PSWs from the plastic manufacturing and recycling company's perspective, PSWs source segregation at household level is highly rated followed by development of recovery and recycling systems for industries in the plastic industry. The results from the FWCs and the plastic manufacturing and recycling companies indicate 'plastic waste segregation at household level. This is supported by Matter et al (2013).

For the proposed RL model for PSWs, source segregation is recommended by the involved stakeholders. At household level, one of the influencing levers' is PSWs segregation for recycling initiatives. This further indicates that, all the involved stakeholders agree on source segregation of PSWs at household level.

Other sustainable aspects for increasing PSWs recovery and recycling outside the guided interviews are highlighted by the interviewees. Tax exemption on imported recycling machinery and public awareness on PSWs recycling are highlighted. Other interviewees indicate, source segregation of PSWs from all points of generation, increase in the number of recycling companies, education of learners in learning institutions on the importance of PSWs recycling, government support on the enforcement of PSWs recycling and provision of grants to companies that desire to venture in PSWs recycling.

5.2.4 Barriers to the Recovery and Recycling of PSWs

Numerous barriers preventing sustainable recovery and recycling of PSWs exist. In order to overcome these barriers, assessment from the service providers' perspective is cardinal. The private waste collectors and municipality indicate critical barriers that need attention in the Zambian context. The interviewees from both the private waste collecting companies and the municipality indicate that; lack of regulations and legislations to enforce PSWs recovery and recycling, lack of enforcement of EPR, lack of citizen/household participatory in PSWs recycling schemes and logistic costs associated with the recovery and recycling of PSWs are the major barriers.

In literature, a number of studies support the highlighted barriers to the recovery and recycling of PSWs and other types of wastes. Shedkar et al (2009) indicates that, societal apathy in terms of lack of society participation in waste recovery and management programs. Lack of enforcement of legislations and regulations on waste recovery and recycling exists in developing economy (Henry et al., 2006; Manaf et al., 2009) and this is indicated by the municipalities and the private waste collectors.

Further, in Section 4.6.4 on the assessment of the barriers to PSWs recovery and recycling from the plastic manufacturing and recycling companies, lack of enforcement of EPR, lack of enforcement of legislations and regulations on PSWs recovery and recycling are highly rated. Further, in Section 4.4.8, the IWCs indicate lack of support from the government on plastic waste collection and recycling. Lack of support from the government on PSWs recovery and recycling reflects lack of enforced EPR and legislations on PSWs recovery and recycling. Further, Section 4.2.4, 'lack of mandatory PSWs recycling' is ranked third by the households as one of the reasons preventing them to recycle.

Lack of EPR and legislations on PSWs recovery and recycling is considered as the major barrier to the recovery and recycling of PSWs by the stakeholders.

5.2.5 Levers for Integrating the IWCs into Formalized Systems

The IWCs are known to be the major recoveries of waste in developing economies. This is acknowledged in a number of studies as well as the communities. The private waste collectors and the municipality are assessed on the levers that can sustainably integrate the IWCs into formalized systems as a way forward to optimized PSWs recoveries. The majority of the interviewees indicate; increasing awareness on the importance of IWCs in the supply-chain to the public, increasing waste recycling facilities, legalizing of PSWs recoveries by the IWCs and building plastic recycling targets as a way of encouraging the IWCs to recover more. Households' participation is not exempted. The interviewees indicate that, PSWs segregation performed by the household level will work in integrating the IWCs into the formalized systems. Source segregation at household level is highly considered by the involved stakeholders (Section 5.2.3).

The levers for integrating the IWCs into formalized systems is assessed on households, IWCs and the plastic manufacturing and recycling companies as well as the FWCs. The purpose of assessing the levers is based on the fact that, the IWCs are key recoveries of PSWs in developing economies. Nevertheless, the levers for integrating the IWCs work in integrating the FWCs in the proposed RL. The basis of the assumption is that, both the IWCs and FWCs are service providers and therefore in the recovery and recycling of PSWs, their objective is to increase recoveries and recycling.

From the household perspective and the IWCs perspective, two key levers are factored out using FA. The established levers at the household and IWCs level (Lever 5 and Lever 6) have similar items (Section 4.5.1 and 4.3.1). From the plastic manufacturing and recycling companies; increasing awareness on the importance of the waste pickers in the supply-chain to the public; creating markets for the waste pickers and increasing waste collection and recycling facilities are highly rated. The factors highlighted by the plastic manufacturing and recycling companies and the FWCs fit in the two factored levers (Lever 5 and Lever 5) as the key levers for integrating the IWCs into formalized systems.

From the FWCs perspective, the levers that can influence them to participate sustainably and efficiently in PSWs recovery and recycling is establishment of effective support structures for PSWs recycling and legalization of PSWs performed by the FWCs. The support structures are in the form of households' participation in the recovery programs by source segregation of PSWs, development of recovery and recycling systems for plastic industries and having designated areas for PSWs recovery purposes.

Chapter Six: Data Comparism and Reverse Logistics Model Design

6. Introduction

This chapter describes the comparism of data from the questionnaire survey and the interviews as well as the RL model design. Significant inputs gathered for this research including; data from the statistical analysis of the households; plastic manufacturing and recycling companies and the service providers is used in designing the RL model. Firstly, comparative analysis of data from the questionnaire survey and interviews is discussed. Secondly, the existing SW and PSWs management and flow systems in Zambia including the Solid Waste Authority -, waste generation and storage, collection and transfer, processing and diversion, disposal is discussed. Thirdly, the chapter describes the development of the RL model considering the stakeholders and the levers. The relevance of the stakeholders and levers in the model is explained. Mathematical assumptions of the recovery process are also discussed in the third section. Fourly, the chapter describes the scenario approaches used in analysing the RL model. The analysis involves adjustment of the statistical figures in order to determine; the optimal PSWs recoverable and recyclable.

6.1 Comparing Quantitative and Qualitative Data

The correlation between the questionnaire survey and the structured interviews is discussed in this section. Similar constructs on the questionnaire survey and structured interviews are assessed for the purpose of designing the RL model and recommending strategies for sustainbale recovery and recycling of PSWs.

6.1.1 Similarities between the quantitative data and the qualitative data

Similarities between quantitative data and qualitative data are explained based on the research objectives.

- **To examine the existing SWM system in Zambia paying special attention to PSWs management.**

  Based on the assessment of the questionnaires from the surveyed stakeholders (households, IWCs and the plastic manufacturing and recycling companies) a number of factors indicate that RL of PSWs in Zambia is still at its infancy. Section 4.2.4, 4.4.3, 4.4.8, 4.6.2 and 4.6.4 provide a clear picture of the status of PSWs management and recycling in the Zambian context. The FWCs also indicate that, RL of PSWs as a waste management concept is still in its infancy in Zambia. Section 5.2.2. and 5.2.4 provide the FWCs perspective on the status of PSWs management and recycling in Zambia.

Comparative analysis of the questionnaire survey and the interviews on the status of PSWs management in Zambia indicates that RL of PSWs is still at its infancy. This information validates the need to design a RL model for PSWs recovery and recycling.

- **To develop instruments for extracting data relating to significance and levers**

  Based on the developed instruments for extracting data, a number of constructs relevant to the design of the RL are developed.

  One key construct involves integrating the IWCs into formalised systems. The questionnaire survey recommends integration of the IWCs on the basis of two levers that support the integration and these are; effective support structures to the IWCs (Lever 5) and legalisation of PSWs collection performed by the IWCs (Lever 6). The interviews indicate the need to integrate the IWCs based on; increasing awareness on the importance of IWCs in the supply-chain to the public, increasing waste recycling facilities, legalizing of PSWs recoveries by the IWCs, building plastic recycling targets, households' participation in recovery and recycling programs and source segregation of PSWs from all points of generation. The factors pointed out in the interviews are the items that form the two levers for integrating the IWCs into formalised systems. This implies, the questionnaire and the interviews identify similar levers for adopting the IWCs in the proposed RL model

- **To recommend strategies that can optimize the recovery and recycling of PSWs from the stakeholders' perspective.**

  A number of strategies for optimising PSWs recovery and recycling are assessed in the questionnaire survey and the interviews. From the questionnaire survey a number of strategies focusing on technological, economic, social, environmental and legislative concerns including market share are suggested. From the interviews, strategies such as, source separation at households' level, legalization of PSWs recycling, development of recovery and recycling systems for plastic industries and having designated areas for PSWs recovery are suggested. Based on the notion of sustainable recovery and recycling of PSWs, strategies recommended in the interviews are the major strategies in the questionnaire survey.

6.2 Plastic Solid Wastes Flow in Zambia

In Zambia, management of SW is governed by the Local Government Act Section 84. The regulations under this act are citied as the local government (SWM) regulations, 2011. These regulations are used to manage SW generated, brought in from one area or through another area or with other waste managed together as SW (GRZ, 2011). The regulations bind all waste generators, transporters, recyclers and collectors of SW. The regulations stipulate the establishment of a Waste Management Unit (WMU) in every council to focus on and coordinate activities relating to SWM within the area. The WMU operates in a cost neutral manner by generating enough money for payment on all required expenditures as well as providing an affordable and efficient waste collection and disposal system for the city.

A statutory body known as the Environmental Council of Zambia (ECZ) exists to control, organise and ensure environmental protection through regulations enforcement, promotion of awareness, controlling and prevention of pollution for sustainable development of good health as well as the welfare of people and animals of Zambia.

In Zambia, management of PSWs is conducted together with the other types of waste. These constitute MSWs, residential, commercial, industrial and market wastes. The amount of PSWs generated is not recorded by the WMUs. According to the study that was conducted by Hoornweg and Bhada-Tata (2012), in Zambia 5% of the MSWs generated is PSWs. Further the study indicates that, 842 tonnes of MSWs are generated per day in Zambia and of this amount, only 20% is collected for disposal. This does not indicate the amount of PSWs recovered. 3% of MSWs is recovered by the IWCs while 6% is recovered by the FWCs (GTZ/CWG, 2007). Figure 6.1 depicts the current flow of PSWs generated from the households

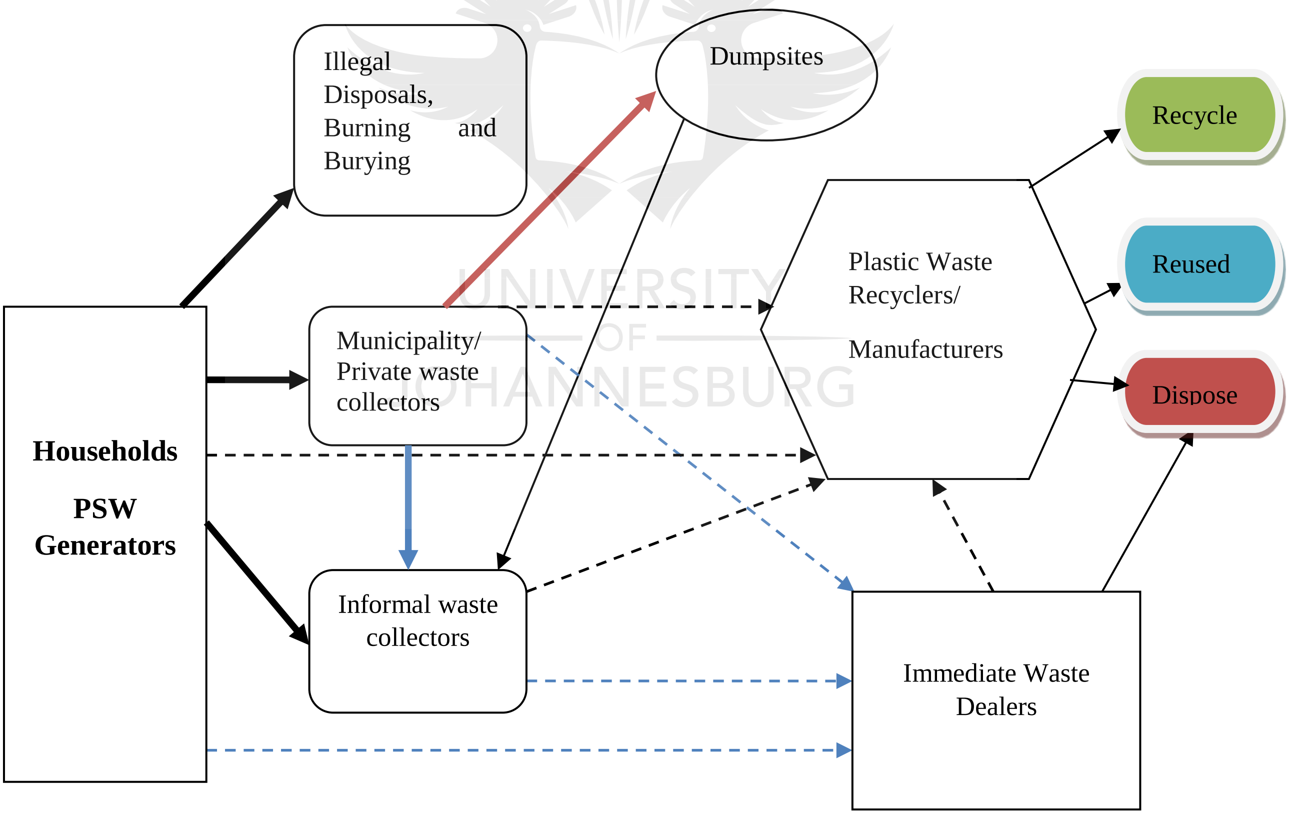


FIG 6.1: CURRENT PLASTIC SOLID WASTES FLOW

Different types of post-consumer PSWs are generated and stored by the households. These wastes are collected by either the FWCs (. i.e. municipality or private waste companies) or the IWCs. Figure 6.1 depicts that, the PSWs collected are either recovered for reuse or recycling purposes by the IWCs and FWCs. Nevertheless, the current flow of PSWs recovery and recycling system is unsystematic and lacks proper strategic management flows.

6.3 Description of the Proposed RL Model for PSWs

This section describes the RL model for recovering and recycling PSWs in Zambia for SSWM and resource utilization. The model is developed with the concept of integrating the relevant stakeholders in WM. Households are identified as the key generators of post-consumer PSWs and therefore the model is developed with the approach of households being the main suppliers of the end-of-life or end-of-use post-consumer PSWs. The formal and informal waste collectors are the service providers while the plastic manufacturing and recycling companies are the key distributors, buyers and convertors of the PSWs.

The proposed PSWs RL model is divided into three stages. The first stage consists of plastic products distribution by the plastic products manufacturers and distributors. The assumption is that; the manufactured plastic products are purchased by the consumers; which are the households. The second stage consists of PSWs generation by the households and storage for recovery purposes. In the third stage, PSWs are either recovered by the service providers for the purposes of recycling or it is disposed of directly by the households as waste. The FWCs are the municipality and the private waste collecting companies. The IWCs consist of; the street pickers, household collectors, itinerant waste buyers, dumpsite pickers and intermediate dealers. The PSWs collected are sorted according to the purchase requirements of the PSWs buyers and convertors. The PSWs disposed of at the dumpsites by the service providers (i.e. FWCs) and households is recovered by the IWCs for sell to waste convertors. The assumption is that, the service providers sell the PSWs to the original distributors of the plastic products. This implies, the PSWs are bought by any plastic converting and recycling company. Figure 6.2 depicts the proposed RL flow of PSWs.

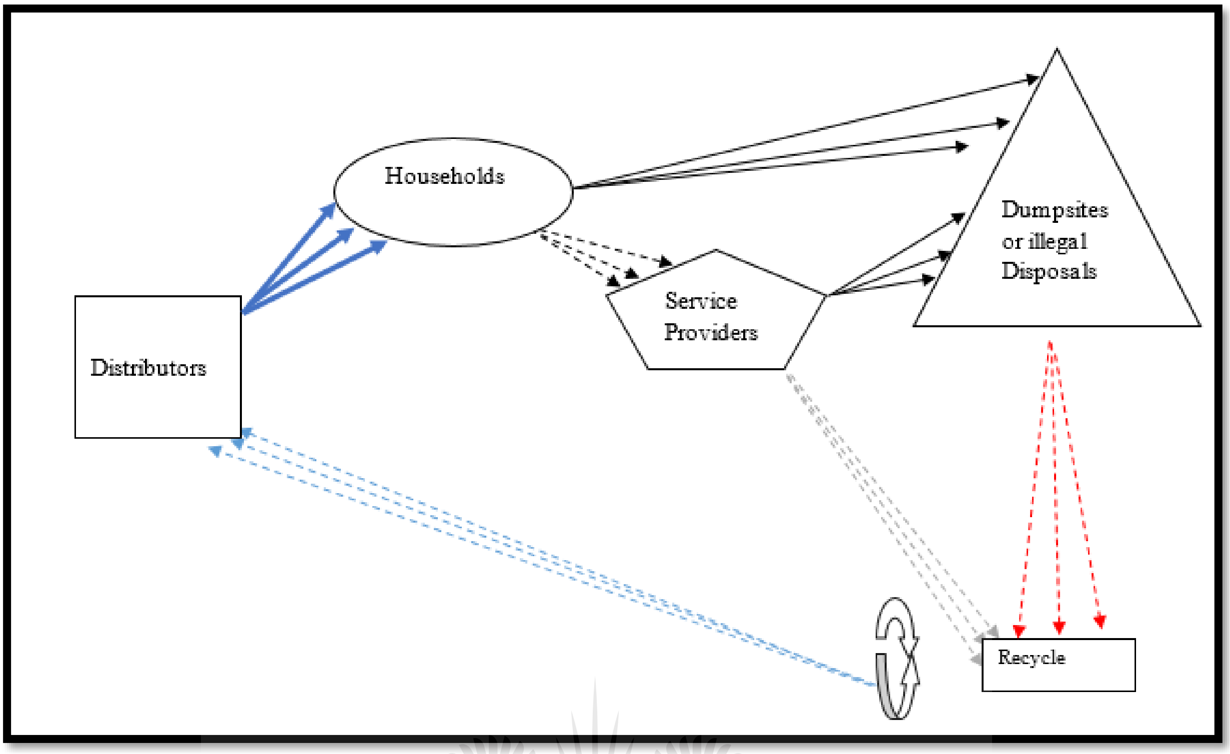


FIG 6.2: PROPOSED REVERSE LOGISTICS FLOW FOR PSWS

The following indexes are used to describe parameters and variables of the model

- Distributors: These are distributors, manufacturers or recyclers of post-consumer plastic products.
- Households: These are households that purchase the post-consumer plastic products. Plastic packaged products or plastic products
- Service Providers: These are formal and informal waste collectors involved in the collection and sorting of PSWs for recovery and recycling purposes.
- The blue line indicates the amount of plastic packaged products or products distributed and sold to households
- The black line indicates the amount of PSWs disposed of as waste at the dumpsites or landfills.
- The black dotted line indicates the amount of PSWs collected from households for recovery and recycling purposes
- The green dotted arrow indicates the amount of PSWs collected and sorted for selling to the plastic distributors/manufacturers/recyclers by the service providers.
- The red dotted line indicates the amount of PSWs recovered by the IWCs from the dump-sites or from illegal disposal for sell to plastic recyclers and convertors.
- The blue dotted line indicates the amount PSWs bought by the distributors for recycling purposes.

In order to optimise the amount of PSWs recovered from the households for recycling purposes, the proposed RL model integrates levers that influence the recovery. The integrated levers influence PSWs recovery at each stage of recovery in the model. The stages of recovery in Figure 6.2 include; households, service providers, dump-sites, illegal disposals and distributors/manufacturers/recyclers. Levers influencing the stakeholders at each stage of recovery in the proposed RL are established on the basis of statistical analysis of the data on the levers that influence stakeholders to participate in recovery and recycling programs for PSWs. The levers that influence recovery at the three stages are discussed in the following sections.

6.3.1 Households' influencing Levers

With reference to chapter 2, a number of levers influence households to participate in waste recovery and recycling programs. These levers in waste recovery and management stream from socioeconomic factors such as gender, age, income level, education level, occupation and household size. Other than socioeconomic factors, households are influenced to recover waste based on the knowledge and awareness they have on recycling or they can recover based on the types and availability of waste collection systems offered by the service providers. Waste policies and legislations are also levers that influence households to participate in waste recovery programs. Economic incentives in form of monetary or non-monetary influences households to recover and hand in plastic wastes for recycling or reusing purposes.

In order to establish the levers that influence households to participate in recovery and recycling programs for PSWs, an extensive review of literature is conducted. Question 1 in Section D of the questionnaire is developed based on literature review and it is used to assess the levers that influence households to participate in recovery and recycling programs at community level (Annexure A). A total of fourteen (14) items in the construct are assessed. Using the measure of central tendency and measures of dispersion, the items are analysed. The mean and standard deviation values are considered for analysis. Only two items have mean and standard deviation values below 4 on a Likert scale of 1 to 5 (Section 4.2.5). The rating of the items on a scale of 1 to 5 of the Likert-scale is inclined from 4 to 5 for 12 items. Nevertheless, the number of items are too many and therefore, FA is used to reduce the number of items to a manageable number.

FA is performed and a total of four levers are established (Section 4.3.1). In order to consider the set of items as a suitable selection in the levers, Kaiser-Meyer-Olkin is considered. Values from 0 to 1 are considered. In Section 4.3.1, the KMO value is 0.811 and the Bartlett p-value is 0.000. These values are considered adequate for FA. The measure of contribution the items make to the established levers is considered by checking the items' loadings. Loadings of 0.4 and above are considered for each item. Items with loadings below 0.4 are not considered. Further, the internal consistency of the levers is checked using the Cronbach's alpha. The established levers have the Cronbach's alpha regarding from 0.5 to 0.75 and these are considered suitable. Interpretation of the Cronbach's alpha values is guided by

Nunaly (1978). With reference to Section 4.3.1, the following levers influence households to participate in PSWs recovery and recycling programs;

- L_1 = Knowledge and Awareness on PSWs Recycling
- L_2 = PSWs Segregation for Recycling Initiatives
- L_3 = Introduction of legislations and Regulations on PSWs Recycling
- L_4 = Effective PSWs Collection and Recycling Systems

Proper implementation of the levers influences the total waste collected from the households. Otherwise improper implementation reduces the amount of PSWs recovered. Figure 6.3 depicts the influencing levers at household level.

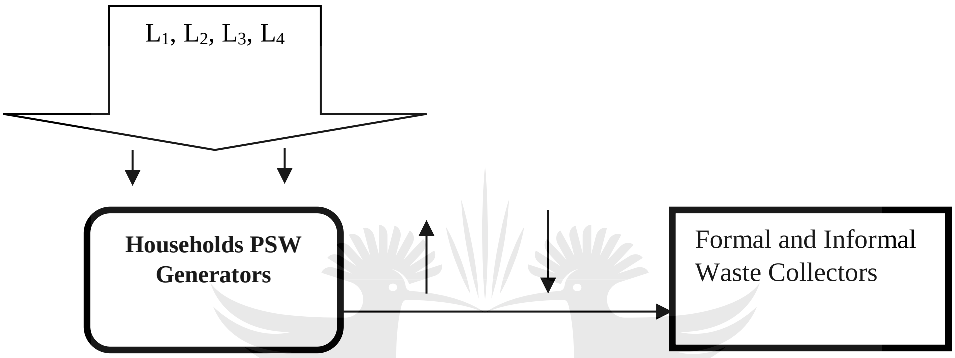


FIG 6.3: LEVERS AT HOUSEHOLD LEVEL

6.3.2 Formal and Informal Waste Collectors Influencing Levers

The formal and informal waste collectors in this research are the service providers. As mentioned in the literature review, integration of the IWCs into formalised systems is important for maximising the amount of PSWs recovered and recycled in a developing economy. In this research, the formal and informal service providers are grouped into one category.

A total of 11 items are established after extensive review of literature. Question 1 in Section C of the IWCs questionnaire (Annexure C) is used to establish the levers. A total of 12 items are assessed and using a scale of 1 to 5 of the Likert-scale, 10 items are inclined from 4 to 5 (Section 4.4.7). Nevertheless, the items are too many for consideration as levers in the proposed RL model. FA is performed on the items and two levers are established (Section 4.5.1). Adoption of the levers in the proposed RL model is guided by the items loading on the established levers (items' loadings above 0.4), the sampling adequacy (KMO = 0.877), Bartlett *p*-value (p=0.00) and the Cronbach's alpha ranging from 0.8 to 0.91. With reference to Section 4.5.1, the established levers are considered for adoption in the proposed RL model. For the FWCs the levers that influence participation in waste recovery and recycling programs are not different from the IWCs. Based on content analysis, the FWCs are influenced by the same levers as the IWCs (Section 5.2.5). The following are the levers at the service providers' level.

- L_5 = Effective Support Structures for the Service Providers
- L_6 = Legalization of PSWs Collection Performed by the Service Providers

Figure 6.4 depicts the levers at the service providers' level. Effective implementation of the two identified levers increases the amount of PSWs recovered and recycled. Otherwise improper implementation results in reduced recoveries.

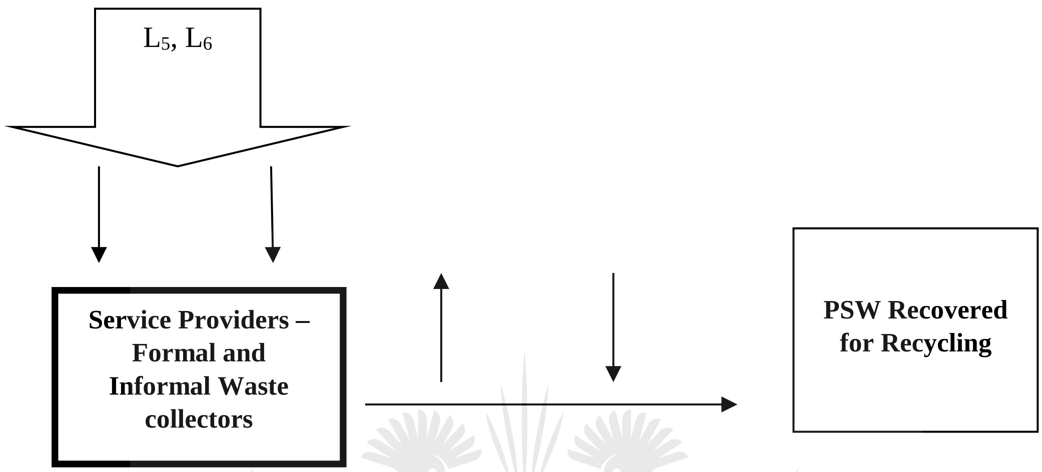


FIG 6.4: LEVERS AT SERVICE PROVIDERS LEVEL

6.3.3 Plastic Manufacturing and Recycling Companies Influencing Levers'

In this research, plastic manufacturing and recycling companies are considered the distributors of plastic products. The companies are influenced by a number of levers to recover and recycle PSWs as mentioned in the literature review (Section 2.7.2). In chapter four, Section 4.6.3 five levers are considered for adoption in the proposed RL at the plastic manufacturing and recycling companies level. The levers focus on technological, economic, social, market-share, environmental concerns and legislations aspects. The levers are identified from each category of sustainability aspects based on the mean value and standard deviation ratings. The item with the highest mean value rating is identified as the influential lever for integration from each category of sustainability aspects. The following levers are considered for integration in the proposed RL model. (Note, the numbering of the levers is according to the flow of the RL model).

- L_7 = Ensuring material applicability in manufacturing processes (Technological Lever)
- L_8 = Development of end markets for polymer recycle stream (Market Share Lever)
- L_9 = Education of the households/community on the relevance of the informal waste collectors in the supply-chain (Social Lever)
- L_{10} = Enforcement of producer responsibility regulations to encourage collection of plastic wastes (Environmental Concerns and Legislations Lever)

- L_{11} = The cost of recycling compared with alternative forms of acceptable disposal alternatives (Economic Lever)

Figure 6.5 depicts the levers at the plastic manufacturing and recycling companies' level. Effective implementation of the depicted levers increases the amount of PSWs recovered and recycled by the companies. Otherwise, lack of effective implementation reduces the amount of PSWs recovered and recycled.

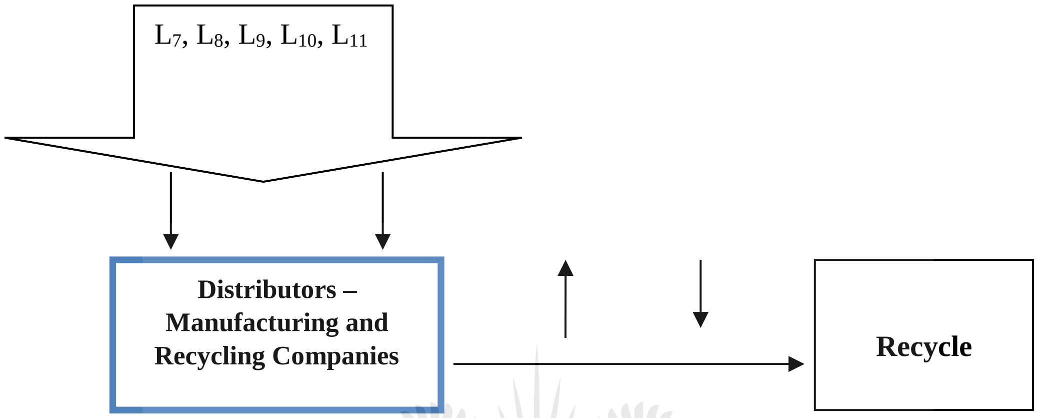


FIG 6.5: LEVERS AT DISTRIBUTORS LEVEL

6.4 Reverse Logistics Model Design and Modelling

This section presents the integration of the selected stakeholders and levers into a systematic recovery and recycling RL model. Figure 6.6 illustrates the proposed RL model. PSWs are manufactured and distributed by the plastic manufacturers. With reference to chapter four, Section 4.8.1, the households' designation in the model is based on population sizes of the households' location areas-; low density, medium density and high-density. Plastic consumption patterns in the three areas differ based on a number of factors such as income levels, population size, education level etc. In this model the basis of plastic consumption is based on population size. The households buy the post-consumer plastic packaged products. PSWs are generated by the households after the end-of-life of the products. The generated PSWs are recovered by two types of service providers-; formal and informal. The service providers recover the PSWs for sell to plastic convertors (distributors). The whole RL system is influenced by levers. The levers that influence recovery at each stage of the recovery process are indicated in the previous sections.

The RL model is designed to ensure optimal recovery. This implies illegally disposed of PSWs and landfilled PSWs are recovered and the model depicts. The RL model is modelled in Microsoft Excel using mass balancing. Mathematical assumptions are applied for the purpose of balancing the model.

In literature, a number of studies have looked at RL and recycling of materials (Demiral et al., 2016; Murakami et al., 2015; Binnesmas et al., 2013; Ravi, 2012; Blengini et al., 2012). These studies did not model the RL of the recycled materials using factors that influence recovery. Most of these studies focused on the conceptual frameworks, network modelling and review studies. Further, the focus of the studies was not to optimise the recovery of PSWs for recycling purposes.

Other studies have focused on network design using mathematical programming and simulation (Ferri et al., 2015; Demirel et al., 2014; Bigum et al., 2013; Bing et al., 2012; Dat et al., 2012; Zhang et al., 2011). The focus of these studies was to minimize costs or maximize profits. Mass balancing of the levers that influence stakeholders to participate in recovery and recycling programs for PSWs has not been studied. The next section presents the mathematical assumptions used to mass balance the model.

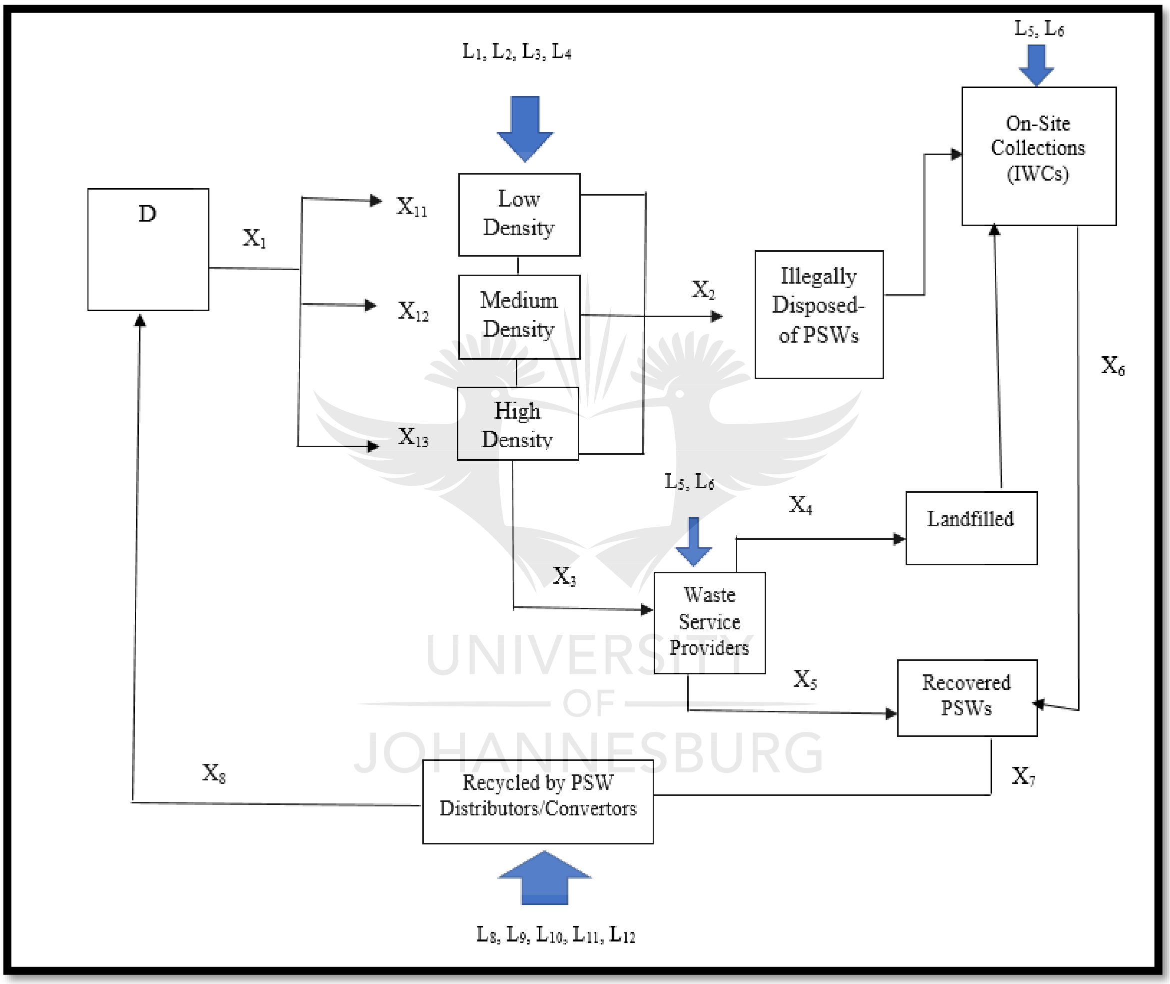


FIG 6.6: PROPOSED RL MODEL FOR PSWS

6.4.1 Mathematical Assumptions for the Proposed RL Model

The mathematical assumptions proposed for the RL model are designed for optimizing the amount of PSWs recovered from the stakeholders for recycling purposes. The RL model involves all the links defined in Figure 6.2, which considers PSWs generation points (households, the illegal disposals and dump-sites); the collection points (service providers) and the final destination of the recovered PSWs for recycling (distributors). The RL model makes the insertion of the levers that influence the stakeholders to recover and participate in recycling programs (Figure 6.6). The following are the key mathematical assumptions used;

- $X_3 = \sum_{L_1}^{L_4} LX_9 + \sum_{L_1}^{L_4} LX_{10} + \sum_{L_1}^{L_4} LX_{11}$ (Equation 6.1)
- $X_2 = X_1 – X_3$ (Equation 6.2)
- $X_4 = X_3 – X_5$ (Equation 6.3)
- $X_5 = X_3 (L_5 + L_6)$ (Equation 6.4)
- $X_6 = X_2(L_5 + L_6) + X_4(L_5 + L_6)$ (Equation 6.5)
- $X_7 = X_5 + X_6$ (Equation 6.6)
- $X_8 = X_7 (L_7 + L_8 L_9 + L_{10} + L_{11})$ (Equation 6.7)
- $(L = 1, 2, \ldots\ldots\ldots\ldots 11)$
- $(0 \leq L \leq 1)$
- The levers are considered as proportions.
- X_1 is equal to the amount of plastic products manufactured and distributed by the plastic distributors and it is equated to 35000 tons per month.
- X_2 is the amount of PSWs illegally disposed of.
- X_3 is the amount of PSWs generated and handled in for recycling purposes by the households because of the influence of the levers.
- X_4 is the amount of PWSs disposed at the dump-sites mainly by the FWCs.
- X_5 is the amount of PSWs recovered for recycling purposes by the formal and informal waste collectors as a result of the influence of the levers.
- X_6 is the amount of PSWs recovered for recycling purposes by the IWCs (i.e. PSWs recovered from illegal disposals and from the landfills) as a result of the influence of the levers.
- X_7 is the total amount of PSWs recovered by the formal and informal waste collectors from the households, illegal disposals and the dump-sites for sell to the plastic distributors.
- X_8 is the actual amount of PSWs bought and recycled by the plastic distributors as a result of the influence of the levers.
- X_9 is the sample size of the low-density area used in the research (90)
- X_{10} is the sample size of the medium-density area used in the research (96)
- X_{11} is the sample size of the high-density area used in the research (119)
- Total sample size is $(X_9 + X_{10} + X_{11})$

❖ The influence of the levers at each locational area (low, medium and high-density areas) may differ. This implies the amount of plastic products consumed is based on the proportion of the sample sizes in the locational area to the total sample size for the locational areas on the total input value (35000 tons).

The amount of plastic packaged products manufactured and considered as the input value in the model is the amount manufactured by the plastic manufacturing companies on a monthly basis as stated in the questionnaire (35000 tons). Section 4.6.2 provides the basis used for considering the number of plastic products manufactured at 35000 tons per month.

Taking the RL model into consideration, the scenario approaches are applied to analyse the amount of PSWs that can be recovered and recycled by the plastic distributors. Four types of scenario approaches are used for analysis. Three types of scenario approaches take into consideration the results of the statistical analysis in chapter four and the other scenario focuses on the results from literature review. The following section discusses the scenario approaches in detail.

6.4.2 Application of Scenario Approach to the Proposed RL

Four types of scenario approach are used to analyse the amount of recoverable and recyclable PSWs by the plastic distributors. The following are the scenario approaches considered;

- Application of the mean mid-point values: This represents the current state of PSWs recovery and recycling by the stakeholders in the locational areas.
- Application of the standard deviation values: This accommodates deviations within the first scenario approach (mean mid-point)
- Application of the most significant relationship values: This represents the extracted significant relationship between the levers and the socioeconomic factors.
- Application of the leading and lagging approach: This represents adoption of the levers from a nation with the highest recycling rate for PSWs and vice versa.

These scenarios are applied in the mathematical assumptions in order to balance the RL model. The scenario that recovers the highest amount of PSWs is considered the best scenario for optimizing PSWs in Zambia. In literature, Bing et al (2012) applied six strategic scenario approaches to minimize the transportation cost. Ferri et al (2015) mathematically modelled the RL network and validated it using six scenario approaches in order to minimize transportation costs.

Mean Value Scenario

The mean-mid-point scenario is based on the mean values for the questions that assesses the levers that influence stakeholders to participate in PSWs recovery and recycling programs in chapter four. The mean scenario approach represents the current state of PSWs recovery and recycling. The mean values are used as descriptors of the current state of PSWs as assessed in chapter four.

Table 6.1, 6.2 and 6.3 depict the mean and the mean midpoint values. The mean values for the levers that influence households are adopted from Section 4.8.2. The mean values for the plastic manufacturing and recycling companies are adopted from Section 4.6.3 and the mean values for the service providers are adopted from Section 4.5.1. These values are applied in the mathematical assumptions and mass balancing is applied to the RL model to analyse the amount of PSWs recovered and recycled by the plastic distributors.

TABLE 6.1: MEAN VALUES FOR HOUSEHOLDS

Levers	Locational Area	Mean Value
L_1: Awareness and knowledge on PSW Recycling	Low Density Area	4.36
	Medium Density Area	4.36
	High Density Area	4.53
L_2: PSW Segregation for Recycling Initiatives	Low Density Area	3.93
	Medium Density Area	3.79
	High Density Area	3.88
L_3: Introduction of legislations and Regulations on PSW Recycling	Low Density Area	4.23
	Medium Density Area	4.22
	High Density Area	4.35
L_4: Effective PSW Collection and Recycling Systems	Low Density Area	3.73
	Medium Density Area	3.91
	High Density Area	4.36

TABLE 6.2: MEAN VALUES FOR WASTE SERVICE PROVIDERS

Levers		Mean Value
L_5: Effective Support Structures for the Informal Waste Collectors	Waste Service Providers	4.52
$L_{6:}$ Legalization of PSW Collection Performed by the IWCs		3.76

TABLE 6.3: MEAN VALUES FOR PLASTIC DISTRIBUTORS

	Lever	Mean
Plastic Manufacturing and Recycling Companies	L_7 = Ensuring Material Applicability in Manufacturing Processes (Technological Lever)	4.36
	L_8 = Existence of markets systems relying on recycled-material throughput involvement (Market Share)	4.36
	L_9 = education of the households/community on the relevance of the informal waste collectors in the supply-chain (Social Lever)	4.50
	L_{10} = Enforcement of producer responsibility regulations to encourage collection of plastic wastes (Environmental Concerns and Legislations Lever)	4.55
	L_{11} = The cost of recycling compared with alternative forms of acceptable disposal alternatives (Economic Lever)	4.32

Standard Deviation Scenario

In the standard deviation scenario, the standard deviations for the levers that influence households to participate in PSWs recovery and recycling programs are adopted from Section 4.8.2. For the plastic manufacturing and recycling companies, the standard deviation for the levers are adopted from Section 4.6.3 and for the waste service providers, the standard deviations are adopted from Section 4.5.1. Tables 6.4, 6.5 and 6.6 depicts the standard deviations scenario.

The basis of the standard deviation scenario is to project the amount of PSWs that can be recovered and recycled based on how the stakeholders deviate from the current scenario depicted in the mean mid-point scenario. In simple terms, standard deviation is the average distance from the mean and therefore, the standard deviation is used to describe how far the stakeholders are far from reaching the current mean mid-point scenario. In other terms, the standard deviation scenario projects the amount of PSWs that is recovered and recycled based on the influence the levers have on the stakeholders, as the standard deviation of the lever moves towards and away from the mean value; one standard deviation away from the mean or one standard towards the mean value. In this scenario, the plus and minus one (1) standard deviation approach is used.

TABLE 6.4: HOUSEHOLDS STANDARD DEVIATIONS

Levers		Mean Value	SD	SD + 1	SD - 1
L_1: Awareness and knowledge on PSW Recycling	Low Density Area	4.36	0.516	4.88	3.84
	Medium Density Area	4.36	0.673	5.03	3.69
	High Density Area	4.53	0.676	5.21	3.85
L_2: PSW Segregation for Recycling Initiatives	Low Density Area	3.93	0.737	4.67	3.19
	Medium Density Area	3.79	0.783	4.57	3.01
	High Density Area	3.88	0.835	4.72	3.05
L_3: Introduction of legislations and Regulations on PSW Recycling	Low Density Area	4.23	0.647	4.88	3.58
	Medium Density Area	4.22	0.742	4.96	3.47
	High Density Area	4.35	0.771	5.12	3.58
L_4: Effective PSW Collection and Recycling Systems	Low Density Area	3.73	0.825	4.56	2.91
	Medium Density Area	3.91	1.018	4.93	2.89
	High Density Area	4.36	0.808	5.16	3.55

TABLE 6.5: WASTE SERVICE PROVIDERS STANDARD DEVIATION

Levers		Mean Value	SD	SD +1	1 - SD
L_5: Effective Support Structures for the Informal Waste Collectors	Informal Waste Collectors	4.52	0.545	5.07	3.88
L_6: Legalization of PSW Collection Performed by the IWCs		3.76	0.545	4.31	3.22

TABLE 6.6: PLASTIC DISTRIBUTORS STANDARD DEVIATIONS

	Lever	Mean Value	SD	SD =+1	SD = -1
Plastic Manufacturing and Recycling Companies	L_7 = Ensuring Material Applicability in Manufacturing Processes (Technological Lever)	4.36	0.581	4.94	3.78
	L_8 = Existence of markets systems relying on recycled-material throughput involvement (Market Share)	4.36	0.658	5.02	3.70
	L_9 = Education of the households/community on the relevance of the informal waste collectors in the supply-chain (Social Lever)	4.50	0.512	5.01	3.99
	L_{10} = Enforcement of producer responsibility regulations to encourage collection of plastic wastes (Environmental Concerns and Legislations Lever)	4.55	0.963	5.51	3.59
	L_{11} = The cost of recycling compared with alternative forms of acceptable disposal alternatives (Economic Lever)	4.32	0.894	5.21	3.43

Significant Levers Scenario

The significant levers scenario is based on the results obtained from the independent sample t-test conducted on the socioeconomic factors and the levers that influence households' and the IWCs to participate in recovery and recycling programs. For the plastic manufacturing and recycling companies, the mean scores from the descriptive statistics are considered for modelling in the RL model.

In order to model the RL model based on the significant levers scenario, the socioeconomic factors that show significant differences on the levers are considered for modelling across the different locational areas. The mean score for the socioeconomic factors with the significant difference are modelled in the RL for the households' and the waste service providers. The mean scores are adopted from Section 4.7.1 and 4.7.3. For the plastic manufacturing and recycling companies, the mean values are adopted from Section 4.6.3.

The purpose for considering the mean values for the socioeconomic factors that have shown significant difference on the levers is based on the notion that, the mean values project the current state of influence the socioeconomic factors have on the levers. Modelling the mean values for the socioeconomic factors and the levers avails the amount of PSWs recoverable and recyclable by the plastic distributors. Table 6.7 depicts the mean scores considered based on the significant levers scenario.

TABLE 6.7: SIGNIFICANT SCENARIO MEAN SCORES

Locational Areas Significant Levers (Low, Medium and High-Density Areas)	
Levers	Mean Values (Significant Basis)
L_1: Awareness and knowledge on PSW Recycling	4.52
L_2: PSW Segregation for Recycling Initiatives	4.02
L_3: legislations and Regulations on PSWs Recycling	4.40
L_4: Effective PSWs Collection and Recycling Systems	4.23
Formal and Informal Waste Collectors	
Levers	Mean Values (Significant Basis)
L_5: Effective Support Structures for the Informal Waste Collectors	4.73
L_6: Legalization of PSW Collection Performed by the IWCs	4.17
Pl**astic Manufacturing and Recycling Companies**	
L_7: Ensuring Material Applicability in Manufacturing Processes (Technological Lever)	4.36
L_8: Existence of markets systems relying on recycled-material throughput involvement (Market Share)	4.36
L_9: Education of the households/community on the relevance of the informal waste collectors in the supply-chain (Social Lever)	4.50
L_{10}: Enforcement of producer responsibility regulations to encourage collection of plastic wastes (Environmental Concerns and Legislations Lever)	4.55
L_{11}: The cost of recycling compared with alternative forms of acceptable disposal alternatives (Economic Lever)	4.32

Leading and Lagging Scenario

Japan is the highest PSWs recycler in the world. According to Plastic Waste Management Institute, in 2010, a recycling rate of 77% was achieved. This is an improvement from 73% achieved in 2006. According to the Guardian (2015), Table 6.8 depicts the leading levers that have contributed to Japan achieving high recovery and recycling rates;

TABLE 6.8: JAPANS' LEADING LEVERS FOR PSWS RECOVERY AND RECYCLING

No.	Leading Levers
1	Enforcement of recycling laws to address disposal and treatment of PSWs
2	Enforcement of plastic waste segregation at the consumer (households) and business levels (Municipality)
3	Increased awareness on the benefits of plastic segregation and recycling
4	Enforcement of free waste collection for segregated PSWs at household level.
5	Collection of segregated PSWs at different days from regular Kitchen waste
6	Plastic Manufacturers excessive support to local PSWs processing agents
7	Excessive application of recycled plastic materials at Industrial

Based on the results from the assessment of the stakeholders on PSWs recovery and recycling, PSWs is still at its infancy and in a lagging state compared to other developed economies. The results in Section 4.2.3 indicates that 80.2% of the households do not participate in PSWs recycling programs. In Section 4.4.3. the results indicate that less than 100 plastic bottles and container are recovered per day by the IWCs while the FWCs recover less than 200 plastic bottles on a daily basis (Section 5.2.2). Further only 45.5% of the plastic manufacturing and recycling companies recycle PSWs (Section 4.6.2). The current state of PSWs recovery and recycling in Zambia is in a lagging status as depicted by the results. This implies, application of the leading scenario that focuses on the factors that have contributed to the success story of PSWs recycling in Japan can improve the PSWs recycling status in Zambia.

Mathematically, the amount of recoverable and recyclable PSWs by the plastic distributors is determined by considering Japans' recycling rates and percentage on the number of plastic products manufactured in Zambia.

6.4.3 Analysis of the Scenario Approaches

Mean Value Scenario

Application of the mean values in the mathematical assumptions and mass balancing the RL model optimizes the amount of PSWs recovered and recycled by the plastic manufacturing and recycling companies by 738 tons per month in the three locational areas.

The mean scenario indicates that, of the 35000 tons of plastic products distributed by the plastic distributors and assumed to be the actual amount of PSWs generated by the households, only 738 tons is recovered and recycled by the plastic convertors as a result of the influence of the levers. The mean scenario identifies unsustainability in the recovery and recycling system. It shows that, the current level of influence the levers have on the stakeholders is significantly low.

Standard Deviation Scenario

Application of standard deviation plus 1 values in the mathematical assumptions and mass balancing the RL model, 994 tons of PSWs are recovered and recycled by the plastic distributors per month. The scenario indicates that, as the influence of the levers on the stakeholders' deviates by 1 towards the current state (mean value scenario), the amount of PSWs recovered and recycled increases. This indicates that, as the influence of the levers on the households increase positively, the amount of PSWs recovered and recycled increases.

Application of standard deviation minus 1 values in the mathematical assumptions and mass balancing the RL model, 517 tons of PSWs are recovered and recycled by the plastic distributors per month. The scenario analyses that, as the influence of the levers shifts away from the mean scenario by 1, the amount of PSWs recovered and recycled decreases. A decrease in the level of influence of the levers on the stakeholders from the current state of PSWs recovery and recycling, the amount of PSWs recycled by the plastic distributors decreases.

Significant Levers Scenario

Application of the mean values of the socioeconomic factors (gender, age, education level, income level) that show significant difference on the independent sample t-test scores analysis, the amount of PSWs recovered for recycling purposes by the plastic distributors is 796 tons per month. This scenario shows that, socioeconomic factors on the stakeholders can influence the amount of PSWs recovered for recycling purposes. Analysis of the scenario approaches, the amount of PSWs recovered and recycled indicates that, the current state and standard deviation minus 1 scenarios optimizes less PSWs compared to the significant levers scenario. This scenario shows that, socioeconomic differences on the levers that influence the households and waste service providers influences the recovery and recycling of PSWs in a positive aspect.

Leading and Lagging Scenario

Application and effective enforcement of Japan's leading levers to the current state of PSWs recovery and recycling in Zambia can lead to 77% improvement in recycling rates. In order to determine the amount that can be recovered and recycled, the current amount of PSWs manufactured by the surveyed companies is considered. Appropriately 35000 tons of plastic products are manufactured on a monthly basis by the surveyed companies.

Taking the current state of PSWs recovery and recycling (mean value scenario), only 2.1% of 35000 tons manufactured is recycled by the plastic distributors. This implies that, to achieve 77% recycling rates, 26,950 tons of PSWs should be recovered and recycled. Recycling of 26,959 tons per month can be achieved by effective enforcement of Japans' leading levers in Table 6.14.

6.4.4 Optimal Scenario Approach

Based on the scenario approaches used in analysing the amount of PSWs recovered and recycled by the RL model, different amounts of PSWs are determined. The scenario approaches that have considered the statistical data indicate that, the mean scenario approach optimizes 738 tons while the standard deviation minus 1 scenario optimizes 517 tons. A positive deviation towards the mean value scenario, the amount of PSWs recovered and recycled by the plastic distributors increases by 256 tons. Application of the significant levers scenario optimizes 58 tons more of PSWs compared to the mean value scenario.

Considering the scenarios that have applied statistical values in analysing the amount of PSWS, the standard deviation plus 1 optimizes the highest amount of PSWs, 994 tons per month. This scenario indicates that, positive increases in the influence the levers have on the stakeholders, the amount of PSWs recovered and recycled increases proportionally.

Application of the Japans' leading levers results in the highest amount of recoverable and recyclable PSWs. This scenario only makes assumptions based on effective enforcement of the leading levers. In this case, the optimal scenario approach is the standard deviation plus 1.

Chapter Seven: Conclusions and Recommendations

7. Introduction

This chapter concludes the outcome of the research conducted through review of literature, questionnaire surveys and interviews in response to the research aim and objectives. The aim of the research is to examine the flow process of end-of-life post-consumer plastic packaged products with the intent of designing the levers' driven RL model for recovering PSWs purposed for recycling.

The chapter is presented as follows. Section 1 presents the conclusion according to; the research objectives, independent sample t-tests, ANOVA and the RL model. Section 2 presents the research contributions while section 3 presents the recommendations. Section 4 outlines the themes for future research and section 5 presents the research limitations.

7.1. Conclusion

This section concludes the research by providing the various detail findings of the research.

7.1.1 Conclusion in relation to the Research Objectives

- **To study the current sustainable models used in developed economies for the recovery and recycling of PSWs**

A number of factors contribute to the success in the management of PSWs in developed economies as reviewed from literature. Technological advancements in recycling technologies and waste collection systems enable successful implementation of recovery and recycling of PSWs. Effective enforcement of waste policies and legislations on packaging wastes contributes to high recovery and recycling rates. Economic instruments such as EPR directs all economic operators trading packaging on the markets to develop packaging WM systems that comply with the recycling targets set by the government.

Technical instruments such as waste collection systems, source separation and waste treatment options such as recycling drive the recovery of PSWs in developed economies. Other factors include household participation in recovery and recycling programs and mandatory source separation of wastes. Communicative instruments aimed at awareness and knowledge dissemination to the public. Deposit refund systems and regulatory instruments such as landfill bans are some of the factors that contribute to success stories in the recovery and recycling of packaging wastes in developed economies.

Based on these factors, a number of RL models have been developed to focus on the recovery and recycling of PSWs. In literature, majority of the models have focused on cost minimization and profit maximization as well as reduction of transportation costs. Most of the models developed on

RL have focused on the developed economies context. The aspect of sustainability on PSWs recovery has focused on recycling.

In developing economies, literature points out that, the application of the RL logistics is still at an infancy stage, majority of the recovery and recycling in developing economies is performed through informal structures. Majority of the factors that have contributed to success stories in developed economies have not been effectively enforced in developing economies.

The findings from literature provide insight on the critical and relevant factors for application in developing economies RL logistics systems. These findings also provide important inputs for designing the RL model for PSWs in the Zambian context.

- **To ascertain the major stakeholders in the recovery and recycling of PSWs**

The relationship that exists between RL and recycling contributes to significant amount of waste recoveries. From literature review, implementation of RL requires a number of stakeholders from distributors, generators, service providers, convertors and the government. Distributors are identified as the suppliers or manufacturer/recyclers of the products. The generators are the households, public and private institutions etc. while the service providers are the formal and informal collectors. The identified stakeholders in the research depicts an all-inclusive approach which is relevant in WM and recovery programs for sustainability purposes. The identified stakeholders are critical to policy makers and waste convertors because they provide information necessary for making sustainbale policies and strategies regarding WM and recovery. These policies and strategies reflect an all-inclusive approach.

- **To examine the existing SWM system in Zambia paying special attention to PSWs management**

Literature reveals that PSWs management in Zambia is still facing significant challenges. The manufacturers of plastic packaged products are not reliable for managing PSWs generated from their products. EPR is not effectively enforced on the companies to guarantee recoveries. Legislation and regulations on the management of PSWs from all points of generation does not exist. Only 3% of the MSW is recovered by the IWCs while 6% by the FWCs. Data on the amount of PSWs recovered and recycled by the involved stakeholders does not exist. There is no structured integrated RL system for sustainable recovery and recycling of PSWs from points of generation to points of recycling.

From the households' questionnaire survey, a number of respondents are knowledgeable about PSWs recycling but only 19.8% participate in existing recovery and recycling programs. Despite less participation, a considerable amount of recyclable post-consumer packaging PSWs is generated on a monthly basis. A number of reasons attributing to lack of participation in recovery and recycling programs are the factors that have enabled successful implementation of recovery and recycling programs in developed economies.

From the plastic manufacturing and recycling companies' questionnaire survey, 95.5% manufacture different types of recyclable plastic packaged products while only 45.5% recycle. A considerable number of plastics products are manufactured monthly in the forms of PET, PP, PE, PS but the system of recovery and recycling is considerably low. The types of technology employed in the recycling of PSWs have not advanced as compared to developed economies. 10% of the plastic recycling companies employ mechanical recycling and purchase the PSWs from dump-sites, households and waste pickers. The status of PSWs management and recovery in the Zambian context can be improved to an advanced level with more participation of the plastic manufacturing and recycling companies. Having waste recovery and recycling systems for PSWs, household participation and EPR has driven PSWs recycling in the companies that recycle.

From the FWCs structured interviews, the majority of the private waste collecting companies manage PSWs sustainably by recovering for recycling purposes. However, the municipality does not conduct any form of recovery of PSWs for recycling purposes. Majority of the recovery of PSWs by the FWCs is from the dump-sites indicating a lack of a structured link between the FWCs and the households.

From the IWCs questionnaire survey, the majority of the IWCs are dump-site pickers recovering PSWs for recycling and reuse purposes. Only 17% of the IWCs are households waste collectors. Household recovery by the IWCs has shown a weak link between the two groups. Different types of plastic wastes in the form of bottles, containers and bags are recovered on a daily basis. Less than 100 plastic bottles, between 100 to 150 plastic bags and less than 100 plastic containers are recovered per day. The majority of the recoveries are conducted at the dump-sites while the immediate dealers are the major purchasers.

The questionnaire survey and structured interviews provide critical information that validates the information obtained from literature review. The information provided on the current state of PSWs management in the Zambian context is cardinal and relevant to the policy makers and waste convertors when implementing sustainable RL systems for PSWs.

- **To develop instruments for extracting data relating to significance and levers.**

Based on extensive review of literature on the levers that influence the identified stakeholders to participate in recovery and recycling programs, a number of levers are identified. The findings from literature are used to design structured questionnaires and interview questions that focus on extracting information on the levers that influence stakeholder to participate in recovery and recycling programs from the Zambian perspective. The information extracted from the stakeholders is necessary for designing the proposed RL model for the Zambian context. The information analysed from the designed research instruments reveals important information for the government, policy makers, the WM sector and plastic manufacturing and recycling companies. The developed instruments provide information important for managing PSWs that focus on the levers that influence the identified stakeholders to participate in RL programs. The developed instrument are valuable tools for extracting information for different context of application that focus on PSWs recovery or other types of wastes.

- **To recommend strategies that can optimize the recovery and recycling of PSWs from the stakeholders' perspective.**

Implementation of RL systems is driven by a number of levers. Effective stakeholders' involvement, environmental concerns, economic drivers, legislative drivers and corporate social responsibility. The survey and interviews ascertain a number of specific levers that can work in the Zambian context. From the households' perspective, knowledge and awareness on PSWs recycling, PSWs segregation for recycling initiatives, legislations and regulations on PSWs recovery and effective PSWs collection and recycling systems work in influencing household's participation. From the plastic manufacturing and recycling companies; ensuring material applicability in manufacturing processes, development of end markets for polymer recycle stream, education of the households/community on the relevance of the IWCs in the supply-chain, enforcement of producer responsibility regulations to encourage collection of plastic wastes and the cost of recycling compared with alternative forms of acceptable disposal alternatives work in influencing companies to implement RL programs for PSWs. From the waste service providers, effective support structures for PSWS recovery and recycling and legalization of PSWs collection performed by the waste service providers work in influencing the RL of PSWs in the Zambian context.

The strategies recommended are important to the WM sector and the plastic manufacturing and recycling companies because the key factors for implementing RL from the stakeholders' perspective are highlighted in an all-inclusive approach. The strategies provided are applicable to other contexts influenced by similar levers and facing similar PSWs management challenges.

7.1.2 Conclusion in relation to the Independent Sample t-test Scores

- **To establish the relationship between the independent variables and dependent variables**

Literature shows that relationships exist between socioeconomic factors and the levers that influence stakeholders to participate in waste recovery and recycling programs. The research establishes relationships based on the key levers that are factored out using FA.

The independent sample t-test scores of socioeconomic factors (age, gender, education level and income level) on the levers that influence households to participate in recovery and recycling programs show significant differences on gender and knowledge and awareness on PSWs recycling. The female counterpart rate knowledge and awareness on PSWs recycling highly compared to the male counterpart. A significant difference is observed between income level and PSWs segregation for recycling purposes. Households respondents with an income level above K5000 rate PSWs segregation for recycling purposes highly compared to households with income level below K5000.A significant difference is observed on income level and legislations and regulations on PSWs recycling. Households with income level above K 5000 rate legislations and regulations highly compared to the households with income level below K 5000. A significant difference is observed on education level and effective PSWs collection and recycling systems. Households with secondary education rate effective PSWs collection and recycling systems highly compared to households with tertiary education. A significant difference is observed on education level and legalization of PSWs collection performed by the IWCs. A high rating of legalization of PSWs collections performed by the IWCs is observed in households with secondary education. There no significant difference on socioeconomic factors and effective support structures for the IWCs.

The independent sample t-test scores of socioeconomic factors (age, education level and income level) on the levers for integrating the IWCs into formalized systems from the IWCs perspective reveal some significant differences. A significant difference on effective support structures for the IWCs and income level is observed. IWCs making an earning of above K1000 identify the need for more support towards the recovery of PSWs. A significant difference on income level and legalization of PSWs collection performed by the IWCs is observed. The need to legalize PSWs collections performed by the IWCs is highly rated by the IWCs with income level above K1000.

A number of challenges are faced by the IWCs in the recovery of PSWs. A significant difference is observed on lack of sustainable recovery systems for PSWs and income level. A significant difference on income level and lack of support from the government on PSWs recovery is observed. The IWCs with an income level above K1000 rate the two main challenges highly compared to the IWCs with an income level below K1000.

The relationships established are relevant in WM and RL implementation programs as they show significant socioeconomic factors that require considerable attention in RL implementation programs for recycling wastes. The differences in the socioeconomic factors provide an important scenario approach for the proposed RL model. The results also show that socioeconomic factors have a significant influence on the levers that influence stakeholders to participate in recovery and recycling programs. To the policy makers and WM and plastic manufacturing companies, these are important consideration aspects in projected recovery and recycling programs.

7.1.3 Conclusion in relation to the ANOVA Tests

- **To establish the relationship between the independent variables and dependent variables**

One-way between-groups ANOVA is conducted to identify the significant differences in the mean scores on the dependent variables (levers) across the three groups (low, medium and high-density areas). Six types of levers are considered; knowledge and awareness on PSWs recycling (Lever 1), PSWs segregation for recycling initiatives (Lever 2), legislations and regulations on PSWs recycling (Lever 3), effective PSWs collection and recycling systems (Lever 4), effective support structures to the IWCs (Lever 5) and legalization of PSWs collection performed by the IWCs.

There is no statistically significant difference in knowledge and awareness on PSWs recycling, PSWs segregation for recycling initiatives, legislations and regulations on PSWs recycling, effective support structures for the IWCS and the three locational areas. A statistically significant difference in effective collections and recycling systems and the three locational area groups is found to exist. The results show that the households in the high-density areas rate effective collection and recycling systems highly compared to the low and medium density areas.

A statistically significant difference is found in legalization of PSWs collections performed by the IWCs and the three locational areas. The low-density areas rate legalization of PSWs performed by the IWCs highly compared to the medium density and high-density areas. Further, the medium density areas rating of legalization of PSWs performed by the IWCs is on a higher side than the high-density areas.

The results provide critical information regarding the influence of the levers in different locational areas to policy makers and WM and plastic manufacturing sectors. The results show that levers applied to different contexts can produce different results. The results also provide important information regarding conducting preliminary studies before implementing recovery and recycling programs.

7.1.4 Conclusion in relation to the RL Model

- **To develop a RL model for Zambia and test the influence of the explored levers**

A levers' driven RL model that integrates key stakeholders in WM and RL has been designed for the Zambian context. Levers based mathematical equations are applied to the model for the purpose of optimizing the amount of PSWs that can be recovered and recycled. Mass balancing is used in modelling the RL model through a scenario approach. Four scenario approaches are used in analysing the amount of PSWs that is recoverable and recyclable.

For the purposes of optimising the amount of PSWs that is recoverable and recyclable by the plastic manufacturing and recycling companies, the standard deviation plus 1 scenario is found to recover and recycle the highest amount of PSWs per month.

The proposed levers' driven RL model is a valuable tool to the waste recyclers and the stakeholders in WM and the plastic industry as it provides the information that aids in decision making processes with regard to PSWs recovery and recycling in an all-inclusive approach. Although the model is proposed for the recovery and recycling of PSWs in the plastic industry, it can be extended to other sectors or regions influenced by similar or different levers. The model provides guidance practices to other countries with similar realities of PSWs management that involve the IWCs.

7.2 Research Contributions

The contributions of this research are based on theory and practise. The following section discuss the contributions.

7.2.1 Contributions to Theory

This research contributes to existing theory on RL, WM, the plastic manufacturing and recycling industry and sustainability. The contribution on the levers, barriers and strategies for implementing RL and plastic recycling in a developing economy constitutes a fresh perspective to existing theory.

The levers, barriers and strategies on RL and plastic recovery from the different stakeholders' perspective provides a board understanding and picture on the way forward to achieving sustainable resource utilization and WM in Africa.

The designed and proposed levers' driven RL model for recovering and recycling PSWs constitutes a fresh perspective on the existing PSWs RL models.

7.2.2 Contribution to Practise

The contribution of the research to RL and WM practises is attributed by the levers driven RL model proposed for implementation in plastic manufacturing and recycling companies and other players involved in the recovery and recycling of PSWs. The model providers significant levers that should be considered during the development and implementation of RL systems. The proposed RL model is applicable to other types of recyclable wastes as well as different contexts influenced by similar levers. Further the levers and stakeholders modelled in the proposed RL model are subject to change depending on the levers influencing stakeholders in an area of application. The model is useful as it determines and optimizes the amount of recyclable PSWs and this provides a prominent position in resource utilization and WM.

The significant difference of the socioeconomic factors (age, gender, income level and education level) on the levers that influence households and the IWCs to participate in PSWs recovery and recycling programs has practical contribution to the policy makers and waste convertors. The difference in the socioeconomic factors on the rating of the levers shows that, attention shown be given to demographic factors in the context of application when designing and implementing RL for recovering and recycling PSWs and other wastes.

7.3 Research Recommendations

PSWs recovery and recycling is a process that involves an all-inclusive concept for sustainable recoveries to be achieved. Therefore, the research aimed at examining the process flow of post-consumer plastic packaged products with the intent of designing a RL models that integrates the levers that influence the stakeholders to participate in recovery and recycling programs. Literature review, surveys and interviews are conducted in order to fulfil the research objectives. A number of aspects are identified in literature review, surveys and interviews that require consideration. This research recommends the following specific strategies;

- ***Awareness on PSWs recovery and recycling***

  Awareness on PSWs recycling and its environmental benefits should be provided to the households. This can be intensified at learning institutions particularly primary schools. In work places and political campaigns. Social media such as the local television stations and radio should inform the public on PSWs recycling and its environmental benefits.

  This recommendation is supported in literature as a way of influencing stakeholders' participation in recovery and recycling programs (Singhirunnusorn et al., 2011; Xevgenos., et al 2015; Afroz et al., 2017)
- ***Awareness on the significance of the IWCs in PSWs recovery and recycling***

  The community as well as other stakeholders should be informed on the relevance of the IWCs in recovery programs. The IWCs are the major waste recoveries in developing economies, therefore the community should be informed on the benefits of integrating these stakeholders in recovery programs.

  This recommendation is supported in literature as a way forward to sustainable PSWs recovery and recycling in developing economies (Medina, 2002; Gutberlet, 2008; Atienza, 2010; Gunsilius, 2012)
- ***Legislations and Regulations on PSWs recycling***

  Legislations on plastic recycling plays a significant role in increasing recovery and recycling rates in developed economies. This implies, the policy makers should introduce a nation-wide legislation on PSWs recycling at all points of recovery in Zambia.

  Literature states that, legislations and regulations contribute to sustainable resource recovery (Sidigue et al., (2010; European Commission, 2010).
- ***Enforcement of EPR***

EPR system drives the implementation of RL in some developed economies. This implies, companies manufacturing and distributing plastic packaged products should be responsible for proper disposal of the end-of-life plastic products in Zambia.

This recommendation has contributed to sustainable recoveries in developed economies (Xevengos et al., 2015; Cruz et al., 2014)

- ***Relevance of Socioeconomic Factors in Recovery Programs***

  Significant difference exists on how socioeconomic factors of age, gender, income level and education level influence recovery and recycling programs. Consideration should be given on socioeconomic factors when designing and implementing RL.

  This recommendation is partially new because the research has modelled the influence of socioeconomic factors on the levers that influence stakeholder participation in recovery and recycling programs. Other studies have shown the correlational impact of socioeconomic factors on resource recovery without modelling (Sidique et al., 2009; Kishino et al., 1999; Hanyu et al., 2000; Domina and Koch, 2002; Troschinetz and Mihelcic, 2009).

- ***Source Segregation***

  Source separation of PSWs should be encouraged from households as well as other points of waste generation. This can be achieved by provision of waste receptacles for storing plastic wastes. It can be intensified by enforcing a legislation on source segregation of PSWs with the provision of receptacles.

  A number of studies in literature support this recommendation (Matter et al., 2013; Hotta and Aoki-Suzuki, 2014; Karim Ghani et al., 2013). It improves recovery rates and resource utilization.

- ***Effective Waste Collection Services***

  The survey on the households reveals that, a number of households in high density areas are not provided with proper waste collection services while those provided with waste collection systems, waste is collected once per week. The research recommends that effective waste collection and recovery services to be provided. Integration of the IWCs in the recovery of PSWs is a way of increasing the recoveries as well as provision of effective recovery rates. An integrated recovery system can work in providing an effective collection service for PSWs as well as other recyclable wastes.

  Literature supports that, effective waste collection systems results in sustainbale recoveries for recyclable or reusable wastes (Zhang and Wen, 2014; Rodrigues et al, (2016).

- ***Increase the Number of Recycling Facilities***

The survey reveals that few companies are involved in recovering and recycling PSWs. For the households as well as other stakeholders to be motivated to participate in recovery programs, an increase in drop-off centres, buy-back centres and recycling facilities is recommended.

Literature states that, a variety of infrastructure plays a fundamental role in facilitating resident participation in WM activities as well as ensuring maximum source-segregated materials (Rispo et al, 2015).

- ***Establishment of Quality Standards***

Quality standards should be developed for the recovered PSWs across the entire supply-chain to improve recoveries and the price system. The IWCs should be informed of the stipulated standards. BIO-Intelligence (2013) and Plastic ZERO (2013) indicate that, as a way forward to improving recovery rates, established quality standards work in determining the price for the recovered PSWs and improving recovery rates. This supports the recommendation.

- ***Inclusion of the IWCs in Formalised Recovery Systems***

The IWCs should be included in the formalised recovery and recycling systems for sustainable recoveries to be achieved. Plastic manufacturing and recycling companies should establish systems that have specific IWCs recovering PSWs for them.

For developing economies, this recommendation is supported by a number of studies (Masood, 2013; Paul et al., 2012; Velis et al., 2012; Wilson et al., 2012; Davis et al., 2006; Tsai, 2008) as a way forward to sustainbale recoveries of recyclable and reusable wastes.

- ***Establishment of Structured Pricing System***

A structured pricing system should be established. The surveys and interviews reveal that, there isn't a standard system for selling the recovered PSWs. Establishment of a standard pricing system will work in determining the quality of the recovered products as well as motivate the recoveries.

In the RL supply-chain for recyclable wastes in developing economies, extreme price fluctuation exists in the IWS (Gutberlet, 2008). This supports the recommendation for establishing structured pricing systems.

- ***Comparison of Recycling Costs to other Disposal Alternatives***

A number of alternatives for managing PSWs exist. To determine the sustainability of each option, cost is one aspect that should be measured. This implies, other forms for disposing PSWs such as landfilling or incineration should be comparable to recycling.

In order to increase recycling rates, BIO-Intelligence (2013) supports the comparison of recycling costs to other disposal alternatives. This approach influences sustainbale recoveries in developed economies (Xevengos et al., 2015).

- ***Provision of Incentives***

  Incentives work in motivating people to participate in waste recovery and recycling programs. This implies, recovering and recycling companies should design strategic motivating incentives.

  According to Welfens et al (2015) economic incentives play a critical role in initiating more sustainable behaviour patterns and this supports the recommendation of incentives provision by the plastic manufacturing and recycling companies.

- ***Investment in Sustainability***

  Most developing economies including Zambia have not paid attention to sustainable options of managing wastes. The local authorities charged with the responsibilities of managing wastes are not well funded by government to consider investing in sustainable options such recycling. The research recommends that government and policy makers should pay more attention to sustainable WM options and invest in these options.

  This recommendation is supported in literature. According to the Africa review report on WM (2009), conducted in four countries; Zambia, Kenya, Ghana and Egypt, it was concluded that, there is need to develop WM systems and promote recycling and reusing of waste.

- **Adoption of the Proposed RL model**

  The survey on the companies that recover and recycle PSWs shows that, the majority are motivated to implement RL as a result of having a recovery and recycling system in place. The research recommends that plastic manufacturing and recycling companies as well as other stakeholders involved in the recovery and recycling of PSWs should adopt the proposed RL model.

  This recommendation is considered a new contribution since the RL model is designed by the researcher without consideration given to literature.

7.4 Themes for Future Research

The following studies are suggested for future research

- Modelling the levers driven RL model using a suitable simulation software
- Adoption of the levers driven RL model by the integrated stakeholders
- Identification of the roles of each stakeholder in the proposed levers' driven RL model.
- Assessing the impact of integrating the IWCs in the proposed RL model
- ERP and its impact on PSWs recovery and recycling in Zambia
- Quantification of the amount of PSWs recovered based on the adopted RL model in other areas of the country.

7.5 Research Limitations

It is important to note that, the research consists of four groups of data collection points. The households, plastic manufacturing and recycling companies, the FWCs and the IWCs. The research is conducted in the second populated province of Zambia. For the households and the IWCs survey, the second populated city of the Copperbelt is considered. For the FWCs' interviews, the companies registered with the PACRA in Ndola and Kitwe are considered. For the plastic manufacturing and recycling companies, companies registered with the manufacturing sector of Zambia and listed on the Lusaka Stock Exchange are considered.

The empirical data generated in the research process for the households' survey is limited to the 2010 census population of Zambia in Ndola city. The results have not captured all the geographical regions of the respective country as a result of lack of capacity. The city of Ndola is the third largest city of Zambia and a study of this type has never been conducted before. Nevertheless, it is able to give a considerable representation of the situation regarding the research topic.

The results of the IWCs consist of, household waste collectors, street waste collectors, itinerant waste buyers, dump-site waste pickers and the intermediate waste dealers. For the plastic manufacturing and recycling companies, the results consist of plastic manufacturing, recycling and buying companies. For the FWCs (private collecting companies and the municipality) the results consist of waste management experts. The households' results consist of respondents that had lived in the household for a period of three months consistently.

The perceptions of the stakeholders considered in the research dominate the findings of the research. Consideration of more proportionate data collection response points may give more reliable results and a balanced aspect on the topic.

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Annexure A: Plastic Solid Waste Recovery for Recycling by Households in Zambia Questionnaire

University of Johannesburg
Engineering Management Department
P.O Box 170114
Doornfontein 2028
Johannesburg Date

Dear Sir/Madam,

I am a PhD Student at the University of Johannesburg in the Department of Engineering Management. I am undertaking a survey to assess status of plastic solid waste recycling by households, whether households are practicing plastic waste recycling or if households would participate in plastic recycling if it was introduced. The survey will further seek to identify the factors that influence or prevent households to participate in plastic solid waste recycling. Finally, the survey will also determine the amount of plastic solid waste types and amount appropriately generated and recovered for recycling purposes by households.

It should not take you more than 10 minutes of your time. Your response is of the utmost importance to me.

Please do not enter your name or contact details on the questionnaire. It remains anonymous.

Should you have any queries or comments regarding this survey, you are welcome to contact me at +260-975 225294 or email me at bupe.mwanza@gmail.com.

Yours Sincerely,

Bupe G Mwanza (nee Mutono)

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING [X] THE RELEVANT BLOCK OR WRITING DOWN YOUR ANSWER IN THE SPACE PROVIDED.

EXAMPLE of how to complete this questionnaire

Your gender?
If you are female

Male	1
Female	~~2~~ X

SECTION A – Background Information

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. We assure you that your response will remain anonymous. Your cooperation is appreciated.

1. Gender

Male	1
Female	2

2. What is your age?

Younger than 26 years	1
26-36 years	2
37-47 years	3
48-58 years	4
59-69 years	5
Older than 69 years	6

3. Your highest educational qualification?

Primary	1
Secondary	2
College	3
Undergraduate Degree	4
Postgraduate Degree	5
Other (specify)	6

4. Your Occupation?

Government Employee	1
Corporate (Private)	2
Own Business	3
Housewife	4
Student	5
Retired	6
Other (specify)	7

5 What is your income level?

Below K1,000	1
K1,000-K5,000	2
K5,001-K10,000	3
K10,001-K15,000	4
K15,001-K20,000	5
K20,001-K25,000	6
Above K25,000	7
No income	8

6. Size of your household, i.e. the number of people, including yourself, who has lived in your house/dwelling for the last three months.

Live alone	1
2	2
3	3
4	4
5 or 6	5
More than 6	6

SECTION B

This section of the questionnaire explores your knowledge on plastic solid waste recycling.

1. Do you know about plastic waste recycling?

Yes	1
No	2

2. If the answer to Q1, is **yes,** where did you learn about plastic recycling?

Primary School	1
Secondary School	2
College or University	3
Social Media	4
Political Campaigns	5
Workplace	6
Other (specify)	7

3. If the answer to Q1 is **yes**, what plastic items do you know can be recycled?

Plastic Bottles	1
Plastic Bags	2
Plastic Containers	3
Other (specify)	4

4. What type of plastic waste do you normally generate?

Plastic Bottles	1
Plastic Bags	2
Plastic Containers	3
Other (specify)	4

5. On average, how much of the selected plastic waste type in Q4 do you generate per month?

	Less than 10	10-20	21-30	More than 30
Plastic Bottles	1	2	3	4
Plastic Bags	1	2	3	4
Plastic Containers	1	2	3	4
Other (specify)	1	2	3	4

SECTION C

This section of the questionnaire explores your reasons for or not participating in plastic waste recycling.

NOTE:

By recycling; we mean handling in plastic waste for recycling purposes.
By Reuse; we mean using the plastic product for the purpose other than what it was intended for after it has served its intended purpose.
Landfilling refers to the disposal of solid waste at engineered facilities in a series of compacted layers of land and the frequent daily covering of the waste with soil.

Incineration is a waste treatment technology that involves the burning of organic materials and /or substance to reduce the waste volumes.

1. Do you recycle plastic waste?

Yes	1
No	2

2. Do you reuse the plastic waste?

Yes	1
No	2

3. If you answered **yes** to question 2 in this section, for what purposes do you reuse the plastic solid waste?

Storing food stuffs	1
Storing fluids e.g. water, juice etc.	2
Storing trash	3
Other (specify)	4

4. If you answered **yes**, to question 1 in this section, do you segregate or separate your plastic waste from other wastes?

Yes	1
No	2

5. Who collects your plastic wastes?

Municipality	1
Private Waste Collectors	2
Informal Waste Collectors (i.e. waste pickers, waste buyers)	3
Plastic Recycling Companies	4
Plastic Manufacturers	5
Other (Specify)	6

6. If you answered **yes**, to question 1 in this section, on average, what is the frequency of plastic waste collection?

Once a week	1
Twice a week	2
Three times a week	3
More than 3 times a week, but not everyday	4
Everyday	5

If you answered **yes** to **question 1** in this section C, please answer question 7. If you answered **no** to **question 1** please skip question 7 and continue from question 8.

To what extent do you agree with the following recycling statements? Please indicate your answer using the following 5-point scale where:

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

7. I do recycle plastic waste because;

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Recycling reduces the amount of waste that goes to the landfill	1	2	3	4	5
Recycling preserves the natural resources	1	2	3	4	5
Recycling creates a better environment for future generations	1	2	3	4	5
I am concerned about creating a better place to live in	1	2	3	4	5
I have a strong interest in the health and well-being of the community in which I live	1	2	3	4	5
Recycling bins are provided	1	2	3	4	5
Recycling incentives or rewards are provided	1	2	3	4	5
Bin space can be preserved	1	2	3	4	5
Friends are doing it	1	2	3	4	5
Recycling creates employment for others	1	2	3	4	5

8. I do not recycle plastic waste because;

Recycling plastic waste is not mandatory	1
Recycling plastic waste is inconveniencing	2
I have no time for recycling plastic waste	3
There are no facilities for recycling plastic waste	4
There are no rewards or incentives for recycling plastic waste	5
There are better ways to handle plastic waste	6
There is lack of information about recycling plastic waste	7
I have storage and handling problems	8
It is not my responsibility to recycle plastic waste	9
Whether I recycle plastic waste not, it will not make a difference	10
Recycling plastic waste is difficult	11
The existing waste collection system are not adequate	12
I don’t generate enough plastic waste	13
Formal or informal waste collectors do not collect the plastic waste	14

SECTION D

This section of the questionnaire explores the factors to support community participation in household plastic waste recycling.

To what extent do you agree with the following recycling statements? Please indicate your answer using the following 5-point scale where:

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

1. To support community participation in household plastic waste recycling, the following should be done;

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Introduce household plastic recycling training programs	1	2	3	4	5
Introduce information dissemination on plastic waste recycling through media and campaign	1	2	3	4	5
Increase the number of environmental campaigns on plastics recycling	1	2	3	4	5
Introduce incentives to encourage participation in plastic waste recycling	1	2	3	4	5
Provide the public with plastic waste recycling infrastructures.	1	2	3	4	5
Encourage household plastic waste separation	1	2	3	4	5
Encourage households to allow waste buyers to buy plastic waste from their homes	1	2	3	4	5
Provide households with a separate bin for plastic waste that are collected weekly	1	2	3	4	5
Charge an additional charge for collection of recyclable plastic waste that is not separated.	1	2	3	4	5
Encourage door to door plastic waste collection services at no charge	1	2	3	4	5
Encourage efficient door to door plastic waste collection by legalised scavengers	1	2	3	4	5
Provide well serviced municipal plastic collection points	1	2	3	4	5
Introduce a national-wide regulation on plastic waste recycling to encourage everyone's participation	1	2	3	4	5
Introduce financial incentives to households meeting set plastic waste recycling targets	1	2	3	4	5

NOTE

Deposit System (Returnable Container Legislation): is any law that requires collection of a monetary deposit on soft-drink, juice, milk, water, alcoholic-beverage, and/or other reusable packaging at the point of sale.

Kerbside Collection System: is a service provided to households, typically in urban and suburban areas, of removing household waste by the municipality or private waste collectors.

Drop-off Collection System: is a system where residents are required to deliver recyclables to a location where containers/bins are provided for depositing the materials.

Buy-Back Recycling Centers: are establishments where participants can deliver materials/recyclables in return for a cash payment

Extended Producer Responsibility System: is a system that imposes a certain quota for the recycling of wastes from products or packaging materials on the manufacturer of the products or the manufacturer of products that

If you answered **no** to question Q1 in section **C** (**do not recycle plastic waste**), please answer question 2. If you answered **yes** to question 1, please skip question 2 and continue from question 3 in this section.

2. Would you participate in plastic waste recycling if the following waste collection systems were introduced?

	Yes	No
Deposit System (Returnable Container Legislation)	1	2
Kerbside Collection System	1	2
Drop-off System	1	2
Buy Back Recycling Centres	1	2
Extended Producer Responsibility System	1	2

3. What type of plastic waste collection system do you use?

Deposit System (Returnable Container Legislation)	1
Kerbside Collection System	2
Drop-off System	3
Buy Back Recycling Centres	4
Extended Producer Responsibility System	5

4. How important is each of the following to you in terms of incorporating the informal waste collectors into a formalized system? Please indicate your answer using the following 5-point scale where

1. Totally unimportant
2. Unimportant
3. Important
4. Neutral
5. Very important

	Totally unimportant	Unimportant	Neutral	Important	Very important
Municipality, private waste collectors or plastic manufacturers/recyclers subsidizing selective plastic waste collection performed by informal waste cooperatives.	1	2	3	4	5
Door-to-door plastic waste collection (residences and points of consumption) performed by individual scavengers	1	2	3	4	5
Manufacturers/recyclers awarding contracts for plastic waste collection to waste pickers	1	2	3	4	5
Legalizing plastic waste collection by waste pickers	1	2	3	4	5
Improving the technical and management practices of waste pickers by educating them on waste collection and sorting	1	2	3	4	5
Creating markets for waste pickers to sell their collected plastic wastes	1	2	3	4	5
Providing waste pickers with loans or grants to enable them to purchase storage or transportation facilities	1	2	3	4	5
Giving waste pickers formalized uniforms and identification cards for easy identification in society	1	2	3	4	5
Development of structured plastic waste recovery and recycling systems.	1	2	3	3	5

Thank you for your co-operation in completing this questionnaire.

Annexure B: Plastic Solid Wastes Recovery and Recycling in Zambia: A Survey of the Informal Waste Collectors Questionnaire

University of Johannesburg
Engineering Management Department
P.O Box 170114
Doornfontein 2028
Johannesburg

Date

Dear Sir/Madam,

I am a PhD Student at the University of Johannesburg in the Department of Engineering Management. I am undertaking a survey on plastic waste recovery and recycling for sustainable resource utilization and waste management in Zambia. One of the key objectives of my research is to examine the key stakeholders to the recovery of plastic waste for recycling. The informal sector is identified as a key stakeholder in the recovery process. Therefore, this survey investigates the informal sector on plastic waste recovery for recycling purposes. It determines the types of informal sector existing in Zambia and their contribution to sustainbale plastic solid waste recovery and recycling. Further, plastic waste collection, value addition and logistical information is examined from the informal waste sectors' perspective. The factors for integrating them into formalized systems are also examined.

It should not take you more than 10 minutes of your time. Your response is of the utmost importance to me.

Please do not enter your name or contact details on the questionnaire. It remains anonymous.

Should you have any queries or comments regarding this survey, you are welcome to contact me at +260-975225294 or email me at bupe.mwanza@gmail.com.

Yours Sincerely,

Bupe G Mwanza (nee Mutono)

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING [X] THE RELEVANT BLOCK OR WRITING DOWN YOUR ANSWER IN THE SPACE PROVIDED.

EXAMPLE of how to complete this questionnaire

Your gender?
If you are female

Male	1
Female	2 X

SECTION A – Background Information

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. We assure you that your response will remain anonymous. Your cooperation is appreciated.

1. Gender

Male	1
Female	2

2. What is your age?

Younger than 26 years	1
26-36 years	2
37-47 years	3
48-58 years	4
59-69 years	5
Older than 69 years	6

3. Your highest educational qualification?

Primary	1
Secondary	2
College	3
Undergraduate Degree	4
Postgraduate Degree	5
Other (specify)	6

5 What is your income level per month?

Less than K 100	1
K100-K500	2
K501-K1000	3
K1001-K1500	4
K1501-K2000	5
More than 2000	6

Note
Household waste collector: *This involves individuals or groups going from door-to-door collecting waste (from households, institutions, functions etc.)*
Street Waste Pickers: *Street pickers gather secondary raw materials from mixed waste in markets, streets, garbage bins, drains and transfer stations all over the urban areas.*
Itinerant Waste Buyers: *Itinerant waste buyers (IWB) go from door-to-door of households, institutions and commercial centers collecting, trading or purchasing recyclable materials/items that people consider of no value.*
Dumpsite Pickers: *This involves waste pickers who pick out useful materials prior to it being covered at the landfill/dumpsite whenever a truck full of solid waste arrives at the open dump/landfill.*

Middlemen (Intermediate Dealers): *Primary and secondary dealers, recycling SMEs, junk shops, intermediate processors, brokers and wholesalers constitute middlemen.*

6. What type of informal waste collector are you?

Household Waste Collector	1
Street Waste Collector	2
Itinerant Waste Buyer	3
Dumpsite Picker	4
Intermediate Dealers	5
Other (Specify)	6

SECTION B

This section of the questionnaire explores information regarding plastic waste collection, value addition and trading.

1. What type of plastic wastes do you collect?

Plastic Bottles	1
Plastic Containers	2
Plastic Bags	3
Other (Specify)	4

2. How much do you collect per specific plastic waste per day?

	Less than 100	100-150	151-200	More than 200
Plastic Bottles	1	2	3	4
Plastic Bags	1	2	3	4
Plastic Containers	1	2	3	4
Other (specify)	1	2	3	4

3. What type of transport do you use when you collect the plastic waste?

Walking	1
Hand Cart	2
Bicycle	3
Small Vehicle	4
Donkey Cart	5
Other (Specify)	6

4. How many Kilometers do you travel per day collecting wastes?

Less than 5Km	1
5Km – 10Km	2
11Km – 15Km	3
16Km-20Km	4
More than 20Km	5

5. How many hours per day do you move around collecting wastes?

Less than 2 hours	1
2 hours -6 hours	2
6hours – 10hours	3
10hours – 16hours	4
More than 16hours	5

6. Where do you normally collect plastic wastes from? **Mark all applicable**

Households	1
Schools	2
Markets	3
Shops	4
Dump-sites	5
Other (Specify)	6

7. Do you pay for the plastic wastes collected?

Yes	1
No	2

8. If you answered **yes**, to question 7 above, who charges you for plastic waste collected?

Households	1
Schools	2
Markets	3
Shops	4
Dump-sites	5
Other (Specify)	6

9. If you answered **yes**, to question 7 above, how much do you pay for?

Plastic Bottles	
Plastic Containers	
Plastic Bags	
Other (Specify)	

10. Where do you sell your plastic wastes? **Mark all applicable**

Intermediate Dealers	1
Plastic Manufacturing companies	2
Plastic Recycling Companies	3
Other (Specify)	4

11. How much do you sell each specific type of plastic waste for?

Plastic Bottles	
Plastic Containers	
Plastic Bags	
Other (Specify)	

12. In what form do you sell your recovered plastic wastes?

Pellets	1
Regrind	2
Flakes	3
Other (Specify)	4

13. How do you sort the plastic wastes collected? According to:

Polymer Type (PP, PE, PET etc.)	1
Purity	2
Color	3
Other (Specify)	4

14. What determines the price at which you sell the plastic solid waste collected? **Mark all applicable**

Standards of the Buyer	1
The price of the virgin materials	2
Quality of the plastic solid wastes	3
The facility for reprocessing and technology	4
Demand and Supply of the plastic solid wastes in the market	5
Recycling potential of the plastic solid waste	6
Other (Specify)	7

15. How do you add value to the recovered plastic solid wastes? **Mark all applicable**

By cleaning it	1
By classifying it into categories	2
Washing and drying it	3
Compacting it	4
Grouping into commercial quantity	5
Other (Specify)	6

NOTE

Deposit System (Returnable Container Legislation):*is any law that requires collection of a monetary deposit on soft-drink, juice, milk, water, alcoholic-beverage, and/or other reusable packaging at the point of sale.*

Kerbside Collection System: *is a service provided to households, typically in urban and suburban areas, of removing household waste by the municipality or private waste collectors.*

Drop-off Collection System: *is a system where residents are required to deliver recyclables to a location where containers/bins are provided for depositing the materials.*

Buy-Back Recycling Centers*: are establishments where participants can deliver materials/recyclables in return for a cash payment*

Extended Producer Responsibility System*: is a system that imposes a certain quota for the recycling of wastes from products or packaging materials on the manufacturer of the products or the manufacturer of products that use the packaging materials*

16. What type of plastic waste collection system do you prefer?

Deposit System (Returnable Container Legislation)	1
Kerbside Collection System	2
Drop-off System	3
Buy Back Recycling Centres	4
Extended Producer Responsibility System	5

SECTION C

This section of the questionnaires investigates the strategies of incorporating the informal sector into the formal sector of plastic waste recovery and recycling and the challenges they face.

1. How important is each of the following to you in terms of your incorporation in the formal waste collection system? Please indicate your answer using the following 5-point scale where

1. Totally unimportant
2. Unimportant
3. Neutral
4. Important
5. Very important

	Totally Important	Unimportant	Neutral	Important	Very Important
Plastic Waste segregation performed at household levels	1	2	3	4	5
Door-to-door collection performed by individual scavenger	1	2	3	4	5
Awarding of contracts to waste pickers for waste collection to waste pickers by recyclers or manufacturers	1	2	3	4	5
Legalizing plastic waste collection by waste pickers	1	2	3	4	5
Provision of education to waste pickers on waste sorting and collection	1	2	3	4	5
Creating markets for waste pickers to sell their collected plastic wastes	1	2	3	4	5
Provision of loans to waste pickers to enable them purchase storage or transportation facilities	1		3	4	5
Provision of training to waste pickers on their health and the environment	1	2	3	4	5
Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	1	2	3	4	5
Increasing waste collection and recycling facilities	1	2		4	5
Building plastic waste recycling targets to encourage waste pickers to collect more waste	1	2	3	4	5
Increasing awareness on the importance of waste pickers in the supply-chain to the public	1	2	3	4	5

2. How important is each of the following challenges to you? Please indicate your answer using the following 5-point scale where

1. Totally unimportant
2. Unimportant
3. Neutral
4. Important
5. Very important

	Totally Unimportant	Unimportant	Neutral	Important	Very Important
Lack of tools for sorting waste	1	2	3	4	5
Lack of waste segregation from the community	1	2	3	4	5
Lack of support from the community and municipality	1	2	3	4	5
Lack of training on waste sorting and collection	1	2	3	4	5
Lack of waste transportation equipment	1	2	3	4	5
Lack of markets to sell our recovered plastics	1	2	3	4	5
Lack of government support in informal waste collection and recycling	1	2	3	4	5
Lack of regulations and legislations on plastic waste recycling	1	2	3	4	5
Lack of formalized legalization of waste pickers in the waste management systems	1	2	3	4	5
Lack of recovery systems for plastic waste collection	1	2	3	4	5
Lack of awareness on the importance of informal sector in the waste recovery process	1	2	3	4	5

Thank you for your co-operation in completing this questionnaire

Annexure C: Plastic Solid Wastes Recovery and Recycling in Zambia: A Survey of Plastic Manufacturing and Recycling Companies Questionnaire

University of Johannesburg
Engineering Management Department
P.O Box 170114
Doornfontein 2028
Johannesburg

Date

Dear Sir/Madam,

I am a PhD Student at the University of Johannesburg in the Department of Engineering Management. I am undertaking a survey in the plastic manufacturing and recycling industries to determine the type and amount of plastics recycled, the strategies, technologies and systems used in the recovery of plastic wastes for recycling. Further the survey will determine the drivers that would influence sustainable recovery and recycling of plastic solid wastes in Zambia for sustainable resource utilization and waste management. Your response is of utmost importance as it will enable me design a reverse logistics system for plastic solid wastes in Zambia.

It should not take you more than 10 minutes of your time. Your response is of the utmost importance to me.

Please do not enter your name or contact details on the questionnaire. It remains anonymous.

Should you have any queries or comments regarding this survey, you are welcome to contact me at +260-975225294 or email me at bupe.mwanza@gmail.com.

Yours Sincerely,

Bupe G Mwanza (nee Mutono)

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CROSSING [X] THE RELEVANT BLOCK OR WRITING DOWN YOUR ANSWER IN THE SPACE PROVIDED.

EXAMPLE of how to complete this questionnaire

Your gender?
If you are female

Male	1
Female	2 [X]

SECTION A – Background Information about the Respondent

This section of the questionnaire refers to background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. We assure you that your response will remain anonymous. Your cooperation is appreciated.

1. Gender

Male	1
Female	2

2. Your highest educational qualification?

Primary	1
Secondary	2
College	3
Undergraduate Degree	4
Postgraduate Degree	5
Other (specify)	6

SECTION B- Background Information about your Organization

This section of the questionnaire refers to background information about your organization. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of companies. We assure you that your response will remain anonymous. Your cooperation is appreciated

1. What type of industry does your organization fit in?

Plastic Manufacturing Company	1
Plastic Recycling Company	2
Plastic Buying Company	3
Other (Specify)	4

2. Approximately how many employees are there in your organisation?

Less than 100 employees	1
100 - 200 employees	2
201 - 300 employees	3
301 - 400 employees	4
401 - 500 employees	5
More than 500 employees	6

3. In which province in Zambia is your company?

Copperbelt Province	1
Lusaka Province	2
Central Province	3
Other (specify)	

SECTION C

This section of the questionnaire explores information regarding plastic products manufacturing, plastic waste recycling and buying at your organizations

1. Does your company manufacture plastic products?

Yes	1
No	2

2. If you answered yes to question 1, how many tons of plastic products does your company produce monthly?

	0-500 tonnes	501-1000 tonnes	1001-1500 tonnes	1501-2000 tonnes	More than 2000 tonnes
Polyethylene Terephthalate (PET)	1	2	3	4	5
Polystyrene (PS)	1	2	3	4	5
Polypropylene (PP)	1	2	3	4	5
Polyethylene (PE, LLDPE, HDPE)	1	2	3	4	5
Polyvinyl chloride (PVC)	1	2	3	4	5
Polyethylene (PE)	1	2	3	4	5
Polyolefin	1	2	3	4	5
Other (specify)	1	2	3	4	5

Questions 3-15 are for companies that recycle or buy plastic wastes.

3. Does your company recycle plastic wastes?

Yes	1
No	2

4. Does your company buy plastic wastes?

Yes	1
No	2

5. How many tons of plastic wastes does your company recycle monthly?

	0-500 tonnes	501-1000 tonnes	1001-1500 tonnes	1501-2000 tonnes	More than 2000 tonnes
Polyethylene Terephthalate (PET)	1	2	3	4	5
Polystyrene (PS)	1	2	3	4	5
Polypropylene (PP)	1	2	3	4	5
Polyethylene (PE, LLDPE, HDPE)	1	2	3	4	5
Polyvinyl chloride (PVC)	1	2	3	4	5
Polyethylene (PE)	1	2	3	4	5
Polyolefin	1	2	3	4	5
Other (specify)	1	2	3	4	5

6. How many tons of plastic wastes does your company buy monthly?

	0-500 tonnes	501-1000 tonnes	1001-1500 tonnes	1501-2000 tonnes	More than 2000 tonnes
Polyethylene Terephthalate (PET)	1	2	3	4	5
Polystyrene (PS)	1	2	3	4	5
Polypropylene (PP)	1	2	3	4	5
Polyethylene (PE, LLDPE, HDPE)	1	2	3	4	5
Polyvinyl chloride (PVC)	1	2	3	4	5
Polyethylene (PE)	1	2	3	4	5
Polyolefin	1	2	3	4	5
Other (specify)	1	2	3	4	5

7. If you answered **yes** to question 4, where do you buy the plastic wastes from?

Plastic manufacturing companies outside Zambia	1
Street Waste Collectors	2
Itinerant Waste Buyers	3
Dumpsite Pickers	4
Intermediate Dealers	5
Households	6
Other (Specify)	7

8. In what form do you buy plastic wastes?

Pellets	1
Regrind	2
Flakes	3
Other (Specify)	4

9. What determines the price of the plastic wastes? **Mark all applicable**

Demand for recycled plastics	1
Regulations and policies	2
International recovered plastic prices	3
Quality of the recycled product	4
The facility for reprocessing and technology	5
Virgin plastic prices	6
Other (Specify)	7

10. How much do you buy each specific type of plastic waste per Kg? (In full)

Plastic Bottles		
Plastic Containers		
Plastic Bags		
Other (Specify)		

11. What recycling technology does your company employ for recycling of each type of plastic wastes?

	Mechanical Recycling	Feedstock Recycling	Chemical Recycling	Pyrolysis
Polyethylene Terephthalate (PET)	1	2	3	4
Polystyrene (PS)	1	2	3	4
Polypropylene (PP)	1	2	3	4
Polyethylene (PE, LLDPE, HDPE)	1	2	3	4
Polyvinyl chloride (PVC)	1	2	3	4
Polyethylene (PE)	1	2	3	4
Polyolefin	1	2	3	4
Other (specify)	1	2	3	4

12. What type of products does your organization manufacture from the recycled plastic wastes?

	Plastic Bottles	Plastic Containers	Plastic Bags	Other (Specify)
Polyethylene Terephthalate (PET)	1	2	3	4
Polystyrene (PS)	1	2	3	4
Polypropylene (PP)	1	2	3	4
Polyethylene (PE, LLDPE, HDPE)	1	2	3	4
Polyvinyl chloride (PVC)	1	2	3	4
Polyethylene (PE)	1	2	3	
Other (specify)	1	2	3	4

13. What determines the price of the plastic wastes? **Mark all applicable**

Demand for recycled plastics	1
Regulations and policies	2
International recovered plastic prices	3
Quality of the recycled product	4
The facility for reprocessing and technology	5
Virgin plastic prices	6
Other (Specify)	7

14. To what extent do you agree with the following?

The following factors determine whether plastic waste will be recycled;	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The price of virgin materials	1	2	3	4	5
Existence of local markets for recycled plastic	1	2	3	4	5
Supply and demand of the recycled plastic	1	2	3	4	5
Level of accessibility of plastic waste	1	2	3	4	5
Convenience of transporting the materials	1	2	3	4	5
Potential profit from the recycled plastic waste	1	2	3	4	5

15. To what extent do you agree with the following?

We recycle plastic waste at our organisation because of;	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Having a quality management system (ISO)	1	2	3	4	5
Having a plastic waste recovery and recycling system	1	2	3	4	5
Household participation in plastic waste recovery for recycling	1	2	3	4	5
Collaboration with other companies for plastic waste returns	1	2	3	4	5
Access to effective and state of the art technology	1	2	3	4	5
Extended Producer Responsibility	1	2	3	4	5
Social Corporate Responsibility	1	2	3	4	5
Cheap source of raw materials from local informal sector (. i.e. scavengers etc.)	1	2	3	4	5
Government Regulations and Policies	1	2	3	4	5
Scavenger (Informal Sector) participation in plastic waste recovery for recycling	1	2	3	4	5
Municipality and private sector participation in plastic waste recovery for recycling	1	2	3	4	5

SECTION D

This section of the questionnaire explores the strategies and drivers that would positively influence sustainable plastic waste recovery and recycling in Zambia.
To what extent do you agree with each of the following statements? Please indicate your answer using the following 5-point scale where:

1. = Strongly disagree
2. = Disagree
3. = Neutral
4. = Agree
5. = Strongly Agree

1. The following strategies would positively influence the recovery and supply of plastic waste for recycling to your organization;

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Letting the informal sector (scavengers/waste pickers) sell to your organization	1	2	3	4	5
Letting the other formal plastic manufacturing companies sell to your organization	1	2	3	4	5
Having designated areas where plastic wastes are collected for recycling purposes (Material Recovery Facilities, MRF)	1	2	3	4	5
Letting your organization import plastic waste from other countries	1	2	3	4	5
Letting our organization conduct door to door plastic waste collection from households, institutions etc.	1	2	3	4	5
Letting our organization work in collaboration with the municipality to collect plastic waste for recycling purposes	1	2	3	4	5
Letting your organization provide incentives to plastic waste returners to your organization	1	2	3	4	5
Development of a recovery and recycling system for industries in the plastics industry	1	2	3	4	5
Having plastic waste segregation at household levels	1	2	3	4	5
Having the government legalise plastic waste recycling	1	2	3	4	5

NOTE

Deposit System (Returnable Container Legislation):is any law that requires collection of a monetary deposit on soft-drink, juice, milk, water, alcoholic-beverage, and/or other reusable packaging at the point of sale.

Kerbside Collection System: is a service provided to households, typically in urban and suburban areas, of removing household waste by the municipality or private waste collectors.

Drop-off Collection System: is a system where residents are required to deliver recyclables to a location where containers/bins are provided for depositing the materials.

Buy-Back Recycling Centers: are establishments where participants can deliver materials/recyclables in return for a cash payment

Extended Producer Responsibility System: is a system that imposes a certain quota for the recycling of wastes from products or packaging materials on the manufacturer of the products or the manufacturer of products that use the packaging materials.

Selective Collection: is a system where separation of materials by a single citizen or organized in communities is intended for recycling

2. The following solid waste collection systems would positively influence plastic waste recycling at your organization;

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Deposit System (Returnable Container Legislation)	1	2	3	4	5
Kerbside (Curbside) Collection systems	1	2	3	4	5
Drop-Off Collection systems	1	2	3	4	5
Buy-back Recycling Centres	1	2	3	4	5
Extended Producer Responsibility Systems	1	2	3	4	5
Selective Collection performed by Scavengers	1	2	3	4	5

3. The following **technological drivers** would sustainably influence the recovery and recycling of plastic wastes;

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Improvement in recycling technology and infrastructure e.g. extrusion, blow moulding. Etc.	1	2	3	4	5
Improvement in size reduction technologies	1	2	3	4	5
Improvement in the sorting technologies	1	2	3	4	5
Designing of products for recyclability	1	2	3	4	5
Ensuring material applicability in manufacturing processes	1	2	3	4	5

4. The following **market drivers** would sustainably influence the recovery and recycling of plastic wastes.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Development of end markets for polymer recycle stream	1	2	3	4	5
Closer engagement of recyclers with one another along the supply-chain	1	2	3	4	5
Recyclers to deal directly with municipalities, sorters, scavengers and households	1	2	3	4	5
Existence of market systems relying on recycled-material throughput involvement	1	2	3	4	5
Transnational cooperation on waste plastic recycling	1	2	3	4	5

5. The following **social drivers** would sustainably influence the recovery and recycling of plastic wastes.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Use of incentive schemes to motivate plastic recycling at household levels	1	2	3	4	5
Efficiency of the municipality, private waste contractors or informal waste collectors in waste collection	1	2	3	4	5
Introduction of plastic waste segregation at household level for recycling purposes	1	2	3	4	5
Increasing consumer awareness on plastic recycling	1	2	3	4	5
Education of the households/community on the relevance of informal waste collectors in the supply-chain	1	2	3	4	5

6. The following **environmental concerns and legislation drivers** would sustainably influence the recovery and recycling of plastic wastes

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Enforcement of Producer Responsibility Regulations to encourage collection of plastic wastes	1	2	3	4	5
Enforcement of national-wide law on plastic waste recycling	1	2	3	4	5
Legalization of selective collection performed by waste pickers from households, retailers, dumpsites etc.	1	2	3	4	5
Enforcement of environmental awareness programmes on the importance of plastic waste recycling	1	2	3	4	5
Enforcement of waste segregation at household level	1	2	3	4	5
Creation of quality standards and certification schemes for plastic recyclers	1	2	3	4	5

7. The following **economic drivers** would sustainably influence the recovery and recycling of plastic wastes

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Lower energy requirements during input production	1	2	3	4	5
High demand for the materials in manufacturing	1	2	3	4	5
The cost of recycling compared with alternative forms of acceptable disposal alternatives.	1	2	3	4	5
The price of the recycled polymer compared to virgin polymer	1	2	3	4	5

SECTION E

This section of the questionnaire explores the barriers to plastic waste recovery and recycling. To what extent do you agree with the following statements?

1. The following are the barriers to sustainable recovery and recycling of plastic wastes.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Low volumes of input materials available for recyclers	1	2	3	4	5
Economical risks associated with the establishment of plastic recycling facilities	1	2	3	4	5
Logistic costs associated with the recovery of plastic solid wastes	1	2	3	4	5
Different materials combined in plastic products complicate recycling.	1	2	3	4	5
Lack of recycling technology and infrastructure	1	2	3	4	5
Lack of citizen/household participatory in plastic waste recycling schemes	1	2	3	4	5
High cost of labour associated with sorting facilities	1	2	3	4	5
High production costs	1	2	3	4	5
High quality standards required in recycled plastic materials	1	2	3	4	5
Limited applicability of recycled plastics compared to virgin plastics	1	2	3	4	5
Weaker market demand for recycled resins	1	2	3	4	5
Lack of regulations and legislation to enforce plastic waste recovery and recycling	1	2	3	4	5
Lack of enforcement extended producer responsibility (EPR)	1	2	3	4	5

SECTION F

This section of the questionnaires investigates the strategies of incorporating the informal sector into the formal sector of plastic waste recovery and recycling.

1. How important is each of the following to you in terms of incorporating the informal waste collectors into a formalized system? Please indicate your answer using the following 5-point scale where;

6. Totally unimportant
7. Unimportant
8. Neutral
9. Important
10. Very important

	Totally Important	Unimportant	Neutral	Important	Very Important
Plastic Waste segregation performed at household levels	1	2	3	4	5
Door-to-door collection performed by individual scavenger	1	2	3	4	5
Awarding of contracts to waste pickers for waste collection to waste pickers by recyclers or manufacturers	1	2	3	4	5
Legalizing plastic waste collection by waste pickers	1	2	3	4	5
Provision of education to waste pickers on waste sorting and collection	1	2	3	4	5
Creating markets for waste pickers to sell their collected plastic wastes	1	2	3	4	5
Provision of loans to waste pickers to enable them purchase storage or transportation facilities	1		3	4	5
Provision of training to waste pickers on their health and the environment	1	2	3	4	5
Provision of waste pickers with formalized uniforms and identification cards for easy identification in society	1	2	3	4	5
Increasing waste collection and recycling facilities	1	2		4	5
Building plastic waste recycling targets to encourage waste pickers to collect more waste	1	2	3	4	5
Increasing awareness on the importance of waste pickers in the supply-chain to the public	1	2	3	4	5

Thank you for your co-operation in completing this questionnaire.

Annexure D: Letter Requesting Interview with the Experts in the Waste Management Sector

Bupe G Mwanza
bupe.mwanza@gmail.com
06 January, 2016

Affiliation with:

Department of Quality and Operations Management
Faculty of Engineering and the Built Environment
University of Johannesburg Bunting Road Campus
P. O. Box 524
Auckland Park 2006
Johannesburg
South Africa

Dear Sir

RE: Request for Input through Questionnaire Answering for my PhD Research in the Plastic Manufacturing Industry

I am a PhD student with the University of Johannesburg, undertaking research in the plastic manufacturing industry, with a focus on sustainable solid waste management through plastic solid waste recycling and the improvement thereof.

This letter serves as a formal request for your company to answer my questions on the research that I am conducting in the plastic manufacturing industry.

As part of the initial work that I have to undertake, I will be interviewing the 'Experts' in the waste management sector. My focus is on; determining the status on plastic recycling and the associated challenges and opportunities. The research will try to identify the technologies and the type of plastics being recycled. Finally, it will also determine whether plastic solid waste recycling can contribute to sustainable solid waste management.

I trust that you are able to avail your valuable time in answering and supporting my research. The study will be made available publicly and published as part of contributing to the solutions in the development of the Plastic Manufacturing Industry.

Thanking you in advance for your time.

Yours Sincerely,

Bupe G Mwanza

+26-0975225294

Annexure E: Guided Structured Interview Questions for the Formal Waste Collectors

Background Information about the Respondent

1. Gender ……………………………………………………………………………………….

2. What is your highest educational qualification? ……………………………………………

3. What is your position at this company? ……………………………………………………….

4.In which category does your organization fit? ………………………………………………

- Municipality
- Private Waste Company

Plastic Solid Waste Recovery and Recycling Practices

5. Does your company recover plastic solid waste products? …………………………………

6. For what purpose does your company recover plastic solid waste products ……………….

- Reuse
- Recycling
- Energy Recovery

7. What type of plastic solid wastes does your company recover? …………………………….

- Plastic bottles
- Plastic containers
- Plastic bags

8. How much does your company collect per specific plastic solid waste per day? …………

- Less than 100
- Between 100 and 200
- Less than 200
- More than 200

9. Where do you recover the plastic solid wastes from?

- Dump-sites
- Shops
- Schools
- households

10. Do you pay for the plastic solid wastes recovered?...

11. who charges you for the plastic solid wastes? …………………………………………..

- Households
- Schools

- Markets
- Shops

12. Where does your company sell the recovered plastic solid wastes? ……………………..
    - Plastic recycling companies
    - Plastic manufacturing companies
    - Immediate dealers
13. What type of plastic waste collection system do you use to recover wastes?
    - Kerbside waste collection
    - Deposit system
    - Drop-off system
    - Buy-back centers

Strategies and Levers for Sustainable Plastic Solid Waste Recovery and Recycling

14. What are the strategies to sustainbale plastic solid waste recovery and recycling?
    - Letting the informal sector (scavengers/waste pickers) sell to your organization
    - Letting the other formal plastic manufacturing companies sell to your organization
    - Having designated areas where plastic wastes are collected for recycling purposes (Material Recovery Facilities, MRF)
    - Letting your organization import plastic waste from other countries
    - Letting our organization conduct door to door plastic waste collection from households, institutions etc.
    - Letting our organization work in collaboration with the municipality to collect plastic waste for recycling purposes
    - Letting your organization provide incentives to plastic waste returners to your organization
    - Development of a recovery and recycling system for industries in the plastics industry
    - Having plastic waste segregation at household levels
    - Having the government legalize plastic waste recycling

Barriers to Sustainable Recovery and Recycling of Plastic Solid Wastes

15. What are the barriers to plastic solid waste recovery?
    - Lack of tools for sorting waste
    - Lack of waste segregation from the community
    - Lack of support from the community and municipality
    - Lack of training on waste sorting and collection
    - Lack of waste transportation equipment
    - Lack of markets to sell our recovered plastics
    - Lack of government support in informal waste collection and recycling

- Lack of regulations and legislations on plastic waste recycling
- Lack of formalized legalization of waste pickers in the waste management systems
- Lack of recovery systems for plastic waste collection
- Lack of awareness on the importance of informal sector in the waste recovery process

Levers for Integrating the IWCs into Formalized Systems

16. What factors should be implemented for integrating the IWCs into formalized systems?

- Plastic waste segregation performed at household levels work in integrating the IWCs?
- Door-to-door collection performed by individual scavenger
- Awarding of contracts to waste pickers for waste collection to waste pickers by recyclers or manufacturers
- Legalizing plastic waste collection by waste pickers
- Provision of education to waste pickers on waste sorting and collection
- Creating markets for waste pickers to sell their collected plastic wastes
- Provision of loans to waste pickers to enable them purchase storage or transportation facilities
- Provision of training to waste pickers on their health and the environment
- Provision of waste pickers with formalized uniforms and identification cards for easy identification in society
- Increasing waste collection and recycling facilities
- Building plastic waste recycling targets to encourage waste pickers to collect more waste
- Increasing awareness on the importance of waste pickers in the supply-chain to the public

Way forward to sustainable plastic solid waste management.

17. What factors should be implemented to support the recovery and recycling of PSWs for sustainbale waste management? ………………………………………………………………………