# A bottom-up smart city approach to solid waste management: the case of ICT-enabled waste reclaimers system in two South African cities

A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy

Vincent Siwawa

Johannesburg, 2023

# Declaration

I declare that this thesis is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy to the University of the Witwatersrand, Johannesburg. The thesis has not been submitted before for any degree or examination to any other University.

Signature of Candidate

September 2023

# Abstract

This study delves into the realm of waste management in the context of bottom-up smart cities, focusing on the implementation of an innovative ICT-enabled waste reclaimer system in Cape Town and Johannesburg, South Africa. The central inquiry pertains to the pivotal role played by the bottom-up smart city paradigm in addressing waste management challenges and fostering the inclusion of waste reclaimers within the framework of smart cities. The inadequacies inherent in prevailing top-down smart city approaches and techno-centric solutions extends to the lack of mechanisms within the conventional informal recycling system to furnish reliable, immutable, and transparent waste-related data, thereby compromising security. To address these challenges, a novel approach emerges, fusing the capabilities of the Internet of Things (IoT) and blockchain technology into the informal recycling sector. This ICT-enabled waste reclaimer system introduces a comprehensive framework encompassing training initiatives, the provisioning of protective equipment, smartphones to facilitate communication between households and waste reclaimers, measuring instruments, tricycles, and dedicated spaces for sorting and storing recyclable materials.

Employing a qualitative research methodology, this study incorporates a blend of document analysis, integrative literature review, and semi-structured interviews with key stakeholders. The selection of case studies, namely BanQu, Kudoti, and Regenize, is underpinned by purposive sampling. An array of research instruments including webinars, photography, participant observations, and transect walks contribute to the rich data collection process. The study draws upon the socio-technical transition theory to sustainability and the Multi-Level Perspective (MLP) as conceptual frameworks to dissect the digital transformation of the informal waste sector through the lens of the ICT-enabled waste reclaimer system. Findings underscore the potential of this innovative system to foster symbiotic connections between waste reclaimers and stakeholders embedded within the recycling value chain. This, in turn, culminates in enhanced working conditions and augmented income for waste reclaimers. Crucially, the ICT-enabled waste reclaimer system offers mechanisms for waste monitoring and tracking, while concurrently introducing incentives and rewards. By generating precise, secure, and reliable data, this system engenders a paradigm shift from a conventional cash-based payment structure to a virtual and electronic payment mechanism. Preliminary evidence showcases a notable threefold increase in recyclable collection by waste reclaimers compared to municipal efforts. In culmination, this study delivers both theoretical and empirical contributions by shedding light on the integration of waste reclaimers and waste management within the context of a bottom-up smart city approach. The study posits a promising trajectory for future research and ushers in new avenues for the development of bottom-up smart cities within the ambit of developing nations.

# Dedication

This research is wholly dedicated to my beloved two moms (Selina and Sarah), who have been a source of inspiration and strength through their continuous prayers and moral support.

My siblings, Nomandla and Mxoliso, always encouraged and motivated me to finish this study.

And finally, I dedicate this research to the Almighty Father; thank you for your protection, guidance, power of imagination and mind, healthy life, and skills to navigate the impediments till the end. We offer our praise and thanks to you for these and all that. AMEN.

# Acknowledgements

I want to acknowledge and give my deepest thanks and gratitude to my supervisor Prof. Anne Fitchett for your support in making this work possible. I cherish your guidance through insightful feedback and corrections in all the stages of the thesis write-up. In addition, your support in helping me secure funding from Emancipatory Future Studies (EFS) is greatly appreciated. THANK YOU!

To my colleagues, mentors and fellow PhD students in the School of Civil and Environmental Engineering, you are being acknowledged for providing a friendly and collegiate research environment. Mr Awolabi, Mr Dunu, Ms Damilola, Mr Chris, Ms Emelly and Mr Laundry, thanks for the laughing moments and informal discussions we held in our offices and Postgraduate kitchen during coffee breaks.

The study might not have been successful without the financial support from the Emancipatory Future Studies (EFS) and Postgraduate Merit Award (PMA). I would like to thank Prof Vishwas Satgar for funding my research through the Emancipatory Future Studies. The EFS program activities, including presenting my work to other EFS research cohorts and participating in EFS public events, helped develop the thesis. The financial and academic support of the Emancipatory Future Studies Scholarship for this research is hereby acknowledged.

Finally, I would like to thank all the respondents who participated in this study from Cape Town and Johannesburg: waste reclaimers, ICT-enabled waste collectors, experts, the City of Johannesburg, waste reclaimer organisations and government departments for sharing information and providing future alternatives.

## List of Figures

## List of Tables

## List of Abbreviations

| | |
|---|---|
| APP | Mobile application/ platform |
| ARO | African Reclaimers Organisation |
| ASSAF | Academy of Science of South Africa |
| CoCT | City of Cape Town |
| CoJ | City of Johannesburg |
| CSI | Corporate Social Investments |
| CSIR | Council for Scientific and Industrial Research |
| DEA | Department of Environmental Affairs |
| DEFF | Department of Environment, Forestry and Fisheries |
| DSI | Department of Science and Innovation |
| EISD | Environment and Infrastructure Services Department |
| EPR | Extended Producer Responsibility |
| EPRO | Extended Producer Responsibility Organisations |
| GIS | Geographic Information Systems |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning Systems |
| GSM | Global System for Mobile Communications |
| ICT | Information Communication Technology |
| IDP | Integrated Development Plan |
| IoT | Internet of Things |
| MLP | Multi-Level Perspective |
| MSWM | Municipal Solid Waste Management |
| NDP | National Development Plan |
| NGO | Non-Governmental Organisation |
| NWMS | National Waste Management Strategy |
| OECD | Organisation for Economic Co-operation and Development |
| PAYT | Pay As You Throw |

| | |
|---|---|
| PRO | Producer Responsibility Organisation |
| RFID | Radio Frequency Identification |
| S@S | Separation at Source |
| SACN | South African Cities Network |
| SALGA | South African Local Government Association |
| SMMEs/SMEs | Small, Medium and Micro Enterprises |
| SONA | State of the Nation Addresses |
| SWM | Solid Waste Management |
| UNCTAD | United Nations Conference on Trade and Development |
| WIEGO | Women in Informal Employment: Globalizing and Organizing |
| ZWI | Zero Waste Index |

# Table of Contents

# CHAPTER ONE: INTRODUCTION

## 1.1 Introduction

In recent years, new emerging technologies and waste management digital platforms have transformed traditional municipal solid waste management into ICT-enabled waste management to achieve ecological objectives. ICT-enabled waste management seems a promising solution for organised and intelligent waste recycling operations and integrating the informal sector into smart cities' formal recycling value chain (Zanella et al., 2014). However, most cities in developing countries are plagued with poor service delivery, including inadequate solid municipal waste management provision (Dlamine et al., 2019; Childe, 2015). Therefore, governments are increasingly adopting smart city approaches in response to the failures of the traditional and classical local approaches in which municipalities impose top-down solutions on communities that become passive beneficiaries (Alverti et al., 2016). This thesis explores how the bottom-up smart city approach can improve stakeholder participation, civic engagement, social innovation, big data management and urban governance models in the informal waste management and recycling sector.

The bottom-up smart city approach involves the application of ICTs and ICT-enabled waste management digital platforms, intelligent collection of recyclables, incentivising households and funding recycling initiatives, provision of infrastructure (transport, storage and sorting facilities) and integration of informal waste reclaimers (Samson et al., 2020; Stübinger & Schneider, 2020; Godfrey et al., 2016 and Scheinberg et al., 2010). The bottom-up smart city approach establishes a new model for reclaimer integration and a framework for solid waste management by adopting ICT-enabled platforms and associated features. This approach also incorporates a complementary and dual solid waste management system introduced through the Extended Producer Responsibility (EPR) regulation which has shifted the burden for waste management services to the manufacturers. The EPR regulation requires industries and the private sector previously excluded in the former waste reclaimer integration process to integrate informal waste reclaimers into their recycling initiatives. However, the extent to which such 'mandate integration' has been implemented and increased waste recycling performances is explored in this study.

## 1.2 Background

The role of technology in remediating waste management challenges and informal waste reclaimers' inclusion in smart and sustainable cities is an important question that needs to be investigated in smart city discourse.  This is necessitated by the increasing significance of technology in the fourth industrial revolution (4IR), where emerging ICT infrastructures and capabilities offered by computational infrastructure, the Internet of Things and Blockchain technology can be the foundation of an ICT-enabled waste reclaimer collection system. Han et al. (2013) points out that the fourth industrial revolution (4IR) ushered in a new model of waste management offered by the emerging Internet of Things (IoT), which allows for communication, tracking and payment of services between users over the internet. In addition, Blockchain technology not only serves as the platform where the ICT-enabled waste management applications are developed but also creates decentralised public inventories facilitating information sharing through permanent transaction inscription and traceable data among various users within the waste recycling value chain ushering in a new transparent and integrated waste management business model (Esmaeilian et al., 2018). The Internet of Things (IoT), Blockchain technology and ICT infrastructure have disrupted the traditional waste management system and provided an inclusive solution for all stakeholders within the recycling value chain in smart cities toward the zero-waste goal.

Despite acknowledging municipalities' challenges with implementing the smart city approach in integrating waste reclaimers and providing efficient waste management services, research shows that many developing countries fail to adopt it (SACN, 2020) effectively. Consequently, the current top-down smart city approach being implemented by municipalities has limited success in integrating waste reclaimers and improving waste management due to it being predominantly technocentric, limiting stakeholder participation and engagement through the exclusion of households, waste reclaimers and industries from participating in the municipal waste management and recycling initiatives. It is therefore argued that the adoption of innovative bottom-up driven ICT-enabled waste management system for informal waste management through waste management digital platforms can potentially provide alternatives to the challenges of waste management and informal waste reclaimer integration (Xue et al., 2018). Hypothesised as a fashionable concept, the bottom-up smart city approach imagines innovation emanating from the people using the technologies and co-creating with citizens and the private sector (Deen-Swarray et al., 2013). As such, citizens will not be considered passive recipients, merely testers, users, or consumers, but rather co-producers and sources of innovation and creativity (Alverti et al., 2016). Breuer et al. (2014) additionally conceptualise the bottom-up smart city approach as ushering in citizen initiatives and embracing solidarity movements such as waste reclaimer cooperatives and associations (Hamdi, 2004) in the municipal solid waste management sphere. In such a context, a bottom-up driven ICT-enabled waste reclaimer system becomes an enabler to efficient waste management, informal waste reclaimer integration and improved quality of life for households and waste reclaimers grounded on mutual involvement in which citizens, industries and public sector work together (Esmaeilia et al., 2018; Alverti et al., 2016).

As municipalities are struggling to provide waste collection services and landfill spaces are running out, the collection of recyclables offers excellent potential for diverting waste from landfill. In cities in the Global South, the collection of recyclables is mainly undertaken by the informal sector (Wilson et al., 2006), which collects "between 80 to 90% (by weight) of post-consumer paper and packaging, which saved municipalities between R309.2–R748.8 million in landfill airspace, at no cost" (Godfrey et al., 2016:05). This illustrates the achievements of the informal waste reclaimers who have, "been very successful in bridging the service and value chain despite little-to-no integration (of the informal sector) into municipal waste management services" (Godfrey and Oelofse, 2017:06). The integration of informal waste reclaimers globally and in South Africa has been widely researched (Climate Legal, 2020; Samson, 2020; Pholoto, 2018; Sekhwela, 2017; Dlamini, 2016; Godfrey, 2016) but cases, where waste integration has been successful, is rare. Some integration solutions have been framed within a developmental approach (Nzeadibe and Anyadike, 2012), charity approach and poverty reduction lens mainly focused on informal waste reclaimers' economic survival strategies (Scheinberg, 2012). However, this overlooks the informal sector's entrepreneurship, empowerment, social aspects, and sustainability of the informal reclaimers collection model (Samson, 2020). Therefore, a bottom-up smart city integrated waste management model should be designed to include the informal waste reclaimers, industry, households, government and community-based organisations within the recycling value chain towards the zero waste goal.

The application of the current top-down smart city solutions in solid waste management has followed a trajectory of two contrasting, often incompatible approaches. The first approach is the techno-centric view which emphasises the application of technologies with little or no human intervention (Yin et al., 2015). The second is the human-centric view which focuses on improving people's capabilities, skills and livelihoods in solid waste management through the welfare approach (charity model) for employment creation, entrepreneurship and innovation amongst informal waste pickers or waste reclaimers (Neirotti et al., 2014). Unfortunately, neither of the two approaches contextualizes waste pickers as data co-creators and co-system designers of the ICT-enabled waste reclaimers' system already within the smart city waste management system. The general failure of the two approaches suggests the need for a fundamentally different approach to smart waste management, one located within the intersection of the techno-centric and human-centric approaches.

Based on the foregoing, this study explores the influence of a bottom-up smart city approach on waste reclaimers' integration and environmental performance, which is founded on the application of the Internet and Communication Technologies (ICTs) and Internet of Things (IoT) in this research has been named the ICT-enabled informal waste reclaimers system. The concept of an ICT-enabled waste reclaimers system will be used in this research to refer to the digital platforms used by waste reclaimers in the informal collection and recycling sector.

Globally, an estimated 20 million informal waste reclaimers are involved in material recovery and recycling (OECD, 2016), with South Africa's increasing and vibrant informal waste reclaimers estimated between 62 000 (State of Waste Report, 2018) and 215 000 (Godfrey, Muswema and Strydom, 2017). The emerging EPR system and local business innovation provide opportunities and new benefits for integrating waste reclaimers and environmental performance through the ICT-enabled waste reclaimer system. South Africa is experiencing an increased adoption of ICT-enabled waste management digital platforms, which industries such as Coca-Cola, Unilever, Distell, SABS and PETCO have been using to collect recyclable waste. The thesis explores the extent to which the ICT-enabled waste reclaimers system can contribute to waste reclaimer integration and enhance solid waste management.

## 1.3 Problem statement and rationale

Solid waste management in sub-Saharan Africa still lags behind the developed world due to a lack of awareness, absence of appropriate infrastructure and technology, governments' unwillingness to enforce proper waste management strategies, economic deterioration and insufficient skilled personnel (Dlamini et al. 2019; Simatele & Simatele, 2015).

Reclaimers are deeply embedded in municipal solid waste management systems and the recycling economy through their 'separation outside source' system that predates government interest in recycling (Samson et al., 2020). In South Africa, the informal recycling system saves municipalities between R309.2 million and R748.8 million annually in landfill airspace alone (Godfrey et al., 2016). However, municipalities' waste management approaches, for instance, Separation at Source (S@S), exclude the waste pickers and ignore them for partnerships in SWM. For example, PikitUp contracted private companies to provide S@S services in middle and high-income areas and community cooperatives in low-income suburbs (PikitUp, 2018) in opposition to an effective and efficient informal collection sector. Despite awarding contracts to the private sector, the formal system's recycling rate has not improved but has adversely affected the reclaimers' income levels and collection rates (Samson and Sekhwela, 2019.) According to the Final Technical Report on Lessons from Waste Picker Integration Initiatives (2020), the waste pickers' well-functioning recycling system can meet Pikitup's annual targets for collecting recyclables which PikitUp through its formal system is failing to achieve every single year. Thus, there is a local and appropriate bottom-up well, functioning informal system that needs to be explored to understand its operations, improve its partnership with the formal municipal system for sustainable environmental management, and improve waste pickers' quality of life to achieve zero waste and circular economy.

Poverty and unemployment are seen as the drivers of the disenfranchised to seek occupation as informal waste reclaimers as a matter of survival (Bastos, 2008). As a site of innovation, resilience, and a safety net for many unemployed and urban poor, the informal economy has been undervalued in general development approaches and efforts to build the smart solid waste management approach in particular (Smit and Musango, 2015). This sets the stage for socially and environmentally based policies to the extent that informal recyclers contribute to the viability of collecting recyclables economically. Although much has been written about informal waste reclaimers, little is known about the practical impact of technologies directed at them to raise their income, thus reducing poverty and improving urban environmental conditions (Esmaeilian, 2018). In over 20 years of waste management studies, smart city initiatives have been applied in developed and developing countries (Kummitha and Crutzen, 2017). However, literature on the role of smart city initiatives in solid waste management remains polarised between techno-centric and human-centric models. Therefore, there is a need for research on the influence of the bottom-up informal smart city waste initiatives towards the zero waste goal that integrates these two poles (Deakin, 2014). However, in-depth studies on the bottom-up smart city approach to waste management are scarce, especially in developing countries (Behzad et al., 2018). A bottom-up smart city approach examines both the physical components (collection, disposal and recycling) and the governance aspects (inclusivity of users and service providers; financial sustainability; coherent, sound institutions underpinned by proactive policies) (Wilson et al., 2018). The effect of the bottom-up smart city approach in remediating environmental problems in general and waste management is an important question that needs to be investigated in academic research with a particular focus on its potential to improve waste pickers' integration in the formal system while striving towards achieving the zero-waste goal in particular.

Although the role of informal waste reclaimers in solid waste management (SWM) has been studied, no research has been conducted concerning the topic under investigation focusing on the smart city perspective. In addition, the smart city perspective in SWM emphasises the circular economy (CE) emerging in the Global North, focusing on improving resource loops' technology, engineering and governance aspects (Geisdoerfer et al., 2017). Most of the literature on circular economy (Geissfoefer et al., 2017; Korhonen et al., 2018 & Gutberlet et al., 2017) portrays a Global North perspective, yet this perspective needs to be broadened by taking into account the perceptions developed by and collected from initiatives by informal and organized waste pickers from the Global South.

In recent years, there has been the development of Internet and Communication Technologies (ICTs) and the Internet of Things (IoT) in waste management (Wen et al., 2018; Thürer et al., 2016). The ICT-enabled waste reclaimer system for recyclables collection is a new technology applied in the informal sector in Johannesburg and Cape Town. Studies of smart waste collection systems focus chiefly on the technologies and architecture of an IoT-driven system (Thürer et al., 2016) and food waste management (Wen et al., 2018). Previous research in developed countries focuses on designing and developing an efficient automated waste management model in the global north (Gutierrez et al., 2015). Studies on ICT-enabled and IoT-enabled waste management have only focused on the technology themselves but overlooked the business and organisational model of the collection (Reis et al., 2015). Most of the documented smart waste collection systems are in developed countries and are still experimental and prototype (Rada et al., 2013). The applicability of the smart waste intelligent collection system for municipal solid waste management was piloted in Brazil through the Relix Project (Coelho et al., 2019) and explored in China for its applicability for solid waste management (Zhou, 2015) but overlooked the experiences of the informal waste reclaimers (Rada et al., 2013). The respective governments financed all these trial smart city intelligent collection systems through public funds. New ICT-enabled waste reclaimer systems have recently been developed in South Africa due to the EPR regulation and business innovation for integrating waste pickers and efficient environmental performance. This research explores the organisational, social and economic aspects and entrepreneurship model of the ICT-enabled waste reclaimer system in solid waste management of two South African cities.

## 1.4 Aims and objectives of the study.

The research explores the new ICT-enabled waste reclaimer system as an alternative solution for a bottom-up waste management model in smart cities. The thesis assesses the efficacy of the ICT-enabled waste reclaimer system as an alternative bottom-up smart city approach in mediating environmental challenges and waste reclaimer integration. An empirical case study approach is adopted to determine perceptions (Creswell, 2013) on how the ICT-enabled waste reclaimer system manifests within the recycling value chain and waste management system. The case study approach provides a spatial analytical tool enabling pointed and detailed focus on the ICT-enabled waste reclaimer-driven integration processes.

### 1.4.1 Research Objectives.

The research has the following as objectives:

1. **Analysing Bottom-Up Smart City Approaches in Waste Management:** Investigate the concept of bottom-up smart city framing and its specific manifestations within municipal waste management and recycling contexts. This objective aims to deepen the understanding of how this approach can be effectively implemented and its potential implications for sustainable waste management practices.
2. **Examining the ICT-enabled Waste Management Models for Socioeconomic Impact:** Evaluate various integrated waste management models rooted in bottom-up smart city strategies, focusing on their implementation in South Africa. Investigate how these models contribute to the improved welfare of waste reclaimers, considering factors such as income generation, working conditions, and social integration.
3. **Assessing Digital Technologies for Waste Diversion and Environmental Performance:** Examine the role of digital technologies in optimizing waste diversion practices, leading to reduced landfill usage and enhanced environmental performance en route to achieving zero waste goals. Analyse the effectiveness of these technologies in facilitating efficient waste collection, sorting, recycling, and overall sustainability.

## 1.5 Research Questions

To what extent can the ICT-enabled waste reclaimers system integrate waste reclaimers and enhance environmental performance towards the zero-waste goal?

In answering this research question, the following themes will be explored:

1. How is the integrated waste management model being framed, and in what way does the model manifest in municipal waste management and recycling?
2. How do ICT-enabled waste management models, rooted in bottom-up smart city strategies, impact the socioeconomic well-being of waste reclaimers?
3. To what extent do digital technologies enhance waste diversion practices, leading to reduced landfill usage and improved environmental performance within the context of achieving zero waste goals?

## 1.6 Research Scope

The thesis identifies the ICT-enabled waste reclaimer system as an integral approach towards integrating waste reclaimers and improving municipal solid waste management in South Africa. This thesis focuses on the ICT-enabled waste reclaimer system's role in improving waste reclaimers' lives and enhancing environmental performance towards zero waste in South Africa. The thesis is a human-centric assessment of the trajectory of the bottom-up smart city to solid waste management that aims to understand the uses of emerging technology in the integration of the informal recycling sector and provide equitable solutions that can significantly improve waste reclaimers' inclusion and recycling rate. The research is prompted by the current inefficiencies in solid waste management and reluctance by municipalities to fully integrate the waste reclaimers, which hinders an efficient informal collection system in South Africa.

Regarding delineation, the study does not intend to investigate the entire product life cycle in solid waste management but only focuses on the collection and sorting stages of recyclable products by informal waste reclaimers. Three ICT-enabled waste management systems, namely Regenize, Kudoti and BanQu, form the newly ICT-enabled informal waste reclaimer collection model, which is being investigated in this research, and were carefully chosen for their inclusion of informal waste reclaimers and adoption by industries to implement their EPR requirements. Regenize is an emerging ICT software development start-up company that has transformed into an ICT-enabled waste collector and has developed the Regenize system, which is being used to provide free waste collection services in Bridgetown. Kudoti and BanQu are waste management trading platforms which enable waste reclaimers to transact with registered buyback centres in Khayelitsha and Johannesburg, respectively. The ICT-enabled waste reclaimers system has developed a recycling value chain where all the stakeholders from the bottom (households or waste reclaimers) to the top (manufacturers) can interact, track and monitor the performance of their recycling initiatives which is absent in the traditional informal recycling system. This provides new opportunities for applying IoT and Blockchain technology towards "making proper changes in human behaviour and toward pro-environmental behaviour" (Esmaeilian et al., 2018:03).

The study uses primary and secondary data sources, comprising semi-structured interviews of ICT software developers, ICT-enabled waste management companies, waste reclaimer organisations and associations, civil society, government and academics. The respondents who participated in this research fall into various categories, including employees of the targeted technology companies (managers of Regenize, Kudoti and BanQu); waste reclaimers and their association leadership; state institutions (municipalities and national department officials); municipal entity services providers (PikitUp officials), NGOs and experts in smart cities (SC), waste reclaimers integration (WRI) and Extended Producer Responsibility (EPR). The research undertook thirty-seven interviews in three major stages from July 2019 to April 2021. The interviewing process, which initially was scheduled to end in early 2020, was further disrupted by the Covid-19 outbreak and, followed by lockdown regulations, shifted some face-to-face interviews into virtual means through MS Teams, Webinars, ZOOM and Google Meetings. Despite its disruptions, this extended field work stage also allowed the researcher to become acquainted with the ICT-enabled waste reclaimers system, allowing for more virtual meetings with the companies and visits to Bridgetown, Khayelitsha and interactions with waste reclaimers in Johannesburg.

In addition, the virtual mode also allowed the researcher to participate in various smart cities, waste reclaimers integration and EPR webinars. Some of the webinars and virtual meetings include the waste reclaimers' campaigns against the City of Johannesburg's R50 recycling fee organised by African Reclaimers Organisations (ARO), presentations on celebrating women waste pickers and their struggles organised by Women in Informal Employment: Globalizing and Organizing (WIEGO) and Global Alliance of Informal Workers, various Emancipatory Future Studies (EFS) webinars, series on webinars on Waste Picker Integration, presentations on EPR regulation organised by the Department of Environment, Forestry and Fisheries and circular economy webinar with PlasticSA which contributed to the overall understanding of the project. Secondary information was drawn from existing literature on the traditional informal and ICT-enabled intelligent collection systems. Primary and secondary data were analysed manually using thematic content analysis.

## 1.7 Definition of key terminology:

**Smart City:** A smart city employs digital technologies and data-driven approaches to enhance the efficiency of urban services and improve the quality of life for its residents. These technologies include IoT devices, data analytics, and communication networks to manage resources, services, and infrastructure effectively.

**Internet of Things (IoT):** IoT refers to the network of interconnected physical devices, vehicles, buildings, and other objects embedded with sensors, software, and connectivity, allowing them to collect and exchange data over the internet. IoT enables real-time monitoring, data analysis, and remote control of various systems.

**Blockchain Technology:** Blockchain is a decentralized and distributed digital ledger technology that securely records transactions across multiple computers. Each record (or block) is linked to the previous one, creating a chain of blocks. This technology ensures transparency, immutability, and security of data and transactions.

**Circular Economy:** The circular economy is an economic model that aims to minimize resource consumption and waste generation by designing products, systems, and processes to promote recycling, reuse, and regeneration of materials.

**Welfare Approach:** The welfare approach focuses on providing social support and assistance to individuals or communities in need, often with the goal of improving their well-being and quality of life. It may include programs, services, and initiatives that address economic, social, and health-related challenges.

**Charity Approach:** The charity approach involves providing aid, assistance, or resources to individuals or groups in need. It often includes acts of philanthropy or charitable donations to alleviate immediate suffering or challenges without necessarily addressing the underlying systemic issues.

**Rights-Based Approaches:** Rights-based approaches emphasize recognizing and upholding the fundamental human rights of individuals and communities. These approaches seek to empower marginalized or vulnerable groups by ensuring their rights to dignity, participation, equality, and non-discrimination.

While both welfare and charity approaches involve helping those in need, the welfare approach aims for broader systemic change and empowerment, while the charity approach focuses on immediate assistance. By providing clear definitions for these key terms, the thesis can establish a solid foundation for readers to understand the concepts discussed in the study.

## 1.8 Structure of the thesis

The thesis is presented in seven chapters. The literature review analyses smart cities, traditional informal collection models and ICT-enabled collection systems. Conceptual and theoretical frameworks and a detailed explanation of the research methods are presented in the following chapter. The three subsequent chapters present narratives and analysis from selected fieldwork data which respond to different stages, aspects, and scales of ICT-enabled informal waste reclaimers' collection as an innovative process in integrating waste reclaimers and environmental performance. They illustrate the ICT-enabled digital transformation, implementation, and diffusion processes for the ICT-enabled informal waste reclaimers' collection model. The conclusion chapter revisits the research question and concludes by formulating recommendations for policy frameworks and further research. An overview of each chapter is provided below.

Chapter 2 analyses the conceptual and theoretical understanding of 'smart cities and ICT-enabled waste management, waste reclaimers integration processes, the emergence of new technologies for 'intelligent collection systems' and current research about 'ICT-enabled informal waste reclaimers collection systems' in developed and developing countries. The literature review presents key debates on smart cities and ICT-enabled waste management, intending to build an informed picture of future waste management processes in smart cities. It also highlights the knowledge gaps (waste reclaimers' integration, digital transformation, citizen involvement, zero waste, and innovation processes) in current 'ICT-enabled waste management' in smart cities literature that this research addresses by introducing an integrated bottom-up driven ICT-enabled model for waste collection for smart city waste management. The chapter also discusses the integrated bottom-up driven ICT-enabled model for waste collection as an important driver towards sustainable environmental management and waste reclaimer integration in smart cities.

Chapter 3 presents the smart cities' and waste reclaimers' integration processes, institutional frameworks, and various ICT-enabled waste collection models in South Africa. This chapter describes the traditional informal recycling system and how the various municipalities implement or plan to integrate waste reclaimers guided by the programmes, legislative and policy arrangements. This chapter identifies a gap in the integration of the current waste management initiatives and other programmes, which adversely impacts the envisioned integration progress and waste management provisions services.

Chapter 4 outlines the research process of how this interpretive qualitative case study approach research was carried out, such as the process of sampling, data collection, configuring theoretical frameworks, data analysis and ethical concerns. The chapter also provides an overview of this research's theoretical framework, vital for analysing the findings in chapters 5-6.

Chapter 5 presents the framing of the bottom-up driven ICT-enabled model for waste collection models, including the emergence of the ICT-enabled platforms of Regenize, Kudoti and BanQu in South Africa. What is presented in this chapter is how the bottom-up driven ICT-enabled model for waste collection has manifested and how it has integrated waste reclaimers and has provided various opportunities in its implementation towards improving the welfare of waste reclaimers and improved recyclable collection. This chapter shows that the bottom-up driven ICT-enabled collection model emerged as a smart city innovation, resulting in the digital transformation of the informal waste recycling sector. The chapter also investigates the bottom-up driven ICT-enabled model for waste collection's ability to integrate waste reclaimers and enhance environmental performance towards zero waste in South Africa. The chapter further discusses the impact of the bottom-up driven ICT-enabled model for waste collection on waste reclaimers integration and ecological performance. This chapter applies a multilevel conceptual framework based on the socio-technical transitions theory to sustainability to understand innovation and implementation processes. Finally, the chapter reveals mechanisms and challenges in implementing the bottom-up driven ICT-enabled model for waste collection.

Chapter 6 analyses the empirical findings presented and discussed in Chapter 5 relating to the literature reviews addressed in Chapter 2 and Chapter 3. The findings in this chapter review the literature, positioning the research findings in the body of knowledge. Finally, the chapter concludes with recommendations to the government, municipalities, ICT-enabled waste companies and producers to improve the ICT-enabled waste reclaimers system.

Chapter 7 reflects on the innovation of the bottom-up driven ICT-enabled waste reclaimer system for waste collection in South Africa. It then summarises the findings and discussion chapters, positioning the thesis' contribution to the knowledge body. Consideration of future empirical and theoretical research directions follows this.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Introduction

This chapter aims to locate the research within the broader 'smart cities' context. The first section of the chapter will introduce the phenomenon of 'smart cities' and explore the emergence of the 'smart cities' concept, its global adaption and the still ambiguous efforts in defining 'smart cities'. The chapter reviews the current models of 'smart cities' and includes a critique of the conceptualisation of 'smart cities' and the recent shift into the human-centric approach in the field. The second section reviews the waste management practices in 'smart cities' and how they have transformed the informal waste collection system through ICT-enabled waste management systems to provide insights into integrating informal waste reclaimers into the 'smart cities' ICT-enabled waste reclaimers system. The third section of the chapter reviews the ‘bottom-up’ approach in 'smart cities', focusing on waste reclaimer integration and reviewing other best practices worldwide. The chapter further identifies the gaps in the current 'smart city' literature to which the research aims at contributing. The chapter concludes by reviewing the conceptual frameworks underpinning this study.

## 2.2 ‘Future Urban Utopias’

Contemporary cities illustrate the climate change crisis, inadequate service delivery (water, sanitation and waste management), incessant urbanisation and poverty, which promote a fragmented and disconnected society (Mata, 2018). The effects of the crisis experienced in contemporary cities exacerbate this desolate outlook and explain the increased interest in developing new paradigms of cities to provide alternative solutions to these problems. Against this background, the 'smart cities' discourse unfolds as ideal cities "sustained in freedom, equality and coexistence, modernity" (Mata, 2018:203). Ideal and utopian cities were designed as in the case of Thomas More, who defined utopia as “*oú-topos* the non-place and, at the same time, the *eu-topos,* the place of happiness" (Mata, 2018:203). The concept of designing and developing ideal utopian cities created much enthusiasm for intellectuals to design innovative forms of cities. The most important goal was the utopian cities' improved quality of life (Mata, 2018).

Various urban utopias have emerged based on the “dream and imagination to transform cities into liveable cities and harmonious with nature providing resistance against capitalism’s excesses and encouraging citizens to value the reuse of discarded materials to challenge capitalism’s fundamental basis in the creation of ever-vaster quantities of waste” (Dobraszczyk, 2019:196). Antonio Sant'Elia in the *Manifesto of Futurist Architecture,* envisioned the “futurist city like an immense and tumultuous shipyard, agile, mobile and dynamic in every detail; and the Futurist house must be like a gigantic machine” (Asim and Shree, 2018:03). This illustrates a view of the city which can be achieved with advanced technology and presents the urban utopian city in technocentric view. In Graham (1997), an urban utopia comprises an advanced system and communication model that responds in real-time to complex challenges. In *Plug-in-City*, Cook (1964) expresses a dream of an evolving city that adapts and transforms itself to the ever-changing environment resulting in creativity and innovation (Guneri, 2020). The shortcomings, concerns and challenges experienced by society from the late 19th century until the 1960s led to the adoption of utopia as a "tool (but not a goal) appropriate for designing viable and sustainable environments, capable of evolving in an era of expanded risks, scales, complexities, and difficulties" (Guneri, 2020:59).

For Moir *et al.* (2014), the future cities discourse underwent four cycles in the 20th century, inclusive and synchronised with the environment. The most important aspect to note is that these four cycles were based on the after-effects on society caused by:

> …the industrial revolution, economic and technological development; the anguish caused by wars; the efforts to clean up the cities in Europe; the increasingly cosmopolitan character of the great western metropolises; the invention of the automobile and the strong development of the train; the ambient and political sensation of the eternal durability of the energy coming from fossil resources (oil, gas, coal), underlies an ideal-city, characterized by the aspirations of a way of life where speed, connectivity, mutation or urban flexibility, automation, unlimited verticality, the conquest of the land, air and water are part of everyday life (Mata, 2018:204).

Post the Second World War, the discourse of future urban utopias was mainly focused on reconstructing the cities in Europe which had been destroyed during the war. During the 1980s, future cities positioned themselves as global trading sites to support the new cycle of international trade influenced by economic globalisation. The rise of the world wide web, internet and ICTs in the 1990s brought new imaginations and creativity about the future urban utopias. The 21st century challenges faced by cities comprising climate change, population growth, technological development, inequalities and social tensions, depleting resources (food, energy and water), traffic congestion and inefficient solid waste management, require new paradigms which would enable future cities to strategically position themselves and improve the standards of environmental efficiency, citizen health and well-being. The urgency of these crises requires an evidence-based approach and future-oriented solutions (Gabrys, 2014) to address these challenges.

The current academic literature and discourses on urban utopias provide various ideas on designing, developing and constructing future smart cities. Various forms of future cities offer new insights into the urban utopia landscape. As discussed above, the terminology of future city discourses is aligned with specific challenges the future city seeks to remediate. Since the mid-1990s, the 'sustainable city' terminology has frequently been featured in discourses and academic literature to achieve sustainable development articulated in the millennium development goals (de Jong et al., 2015). In the early 2000s, the concept of a 'digital city' gained dominance due to the rise of cellphones, the internet and ICTs but was later replaced by the increased interest and enthusiasm for a 'smart city' towards the end of the decade in 2009. The 'smart city' paradigm has dominated academic usage more than the 'sustainable city' after 2012. Synonymous with the 'smart city' concept, the terms 'resilient city' and 'low carbon city' emerged in 2012 in response to the effects of poor waste management practices and the climate change debate. However, the terms were not widely used in utopian discourses. Although Moir et al. (2014) observed a similar pattern in adopting and using these future city terminologies, their research concluded that 'smart city' terminology dominates the current discourse and academic literature.

The imagination of future urban utopias being transformed by technologies is not a new concept, but the concept has evolved over time, incorporating specific connotations. In the 1960s, ICTs influenced the thinking and imagination of future cities (Forrester, 1970), which resulted in planners and architects (Archigram movement) during that period experimenting with technology to enhance future cities and designing imaginary cities of tomorrow (Crompton, 2012). Beginning in the 1980s, 'network cities' and 'computable cities' frequently appeared in layout designs and architectural plans (Castells, 1989; Graham and Marvin, 2001). During this period, it resulted in the emergence of various terminologies associated with the 'technological cities' such as the 'wired city' (Dutton, 1987), 'information city' (Castells, 1996), 'cyber city' (Graham and Marvin, 1999), 'digital city' (Ishida and Isbister, 2000), ‘ubiquitous city’ (Weiser, 1999; Anthopoulos and Fitsilis, 2010), and the ‘intelligent city’ (Komninos, 2013). These examples illustrate the contextual conceptualisation of ICTs and the cities due to a specific technology adopted during that period. The adoption of the intelligent transport system, sensor-based and ICT-enabled waste management platforms, the Internet of Things, blockchain technologies and wireless technologies (Carvalho, 2014) has reinvented the ‘smart city’ concept as the future urban utopia and “an idea, a model, a system, whose objective is to find alternative solutions for the improvement and evolution of the contemporary city” (Mata, 2018:204).

The current ‘grand technocentric utopia’ in smart waste management concept fails to incorporate the waste reclaimers in the waste management sector. The future of waste management should be inclusive, empower and integrate informal waste reclaimers into waste management systems in future urban utopias where informal waste reclaimers are acknowledged, supported and participate in all municipal solid waste management processes. Aligned to the future city discourse, this research aims to imagine the prospect of a smart city that is neither dystopian nor ambivalent (technocentric) but a smart city that is utopian and inclusive. The research calls for alternative societal futures that can sustain life through research centred on future pathways and systemic change towards the zero waste goal and 'smart cities'.  As towns and cities transition from legacy cities to modern and advanced smart cities, they have adopted the smart city concept to enhance efficient service delivery in transport, water, waste and energy management by deploying ICT technologies. The smart city, more than a utopia of the city of the future, today presents itself as a reality with alternative solutions in an urban world afflicted by severe and complex problems.

## 2.3 Smart Cities: Origins, Definitions and Diffusions.

### 2.3.1 The origins of 'Smart Cities'

Smart cities are not a new phenomenon but may have originated from conversations among scholars and practitioners in the 1980s (Glasmeier and Christopherson, 2015), reflecting on the future of cities whose speed and flexibility in adapting to complex challenges make them more inclusive, efficient and competitive. Vanolo (2013) and Holland (2008) suggest two kinds of academic literature, namely, the New Urbanism literature and the intelligent city debate, both of which are connected to the emergence of smart cities. The New Urbanism literature, which originated in the 1980s in the USA, was mainly concerned with designing, shaping and developing new urban development models based on new technologies and responding to uncontrolled urban development. The New Urbanism suggested building development control and reduced rapid land release to effect planned densities. For Konomi and Roussos (2017), some of the dimensions of smart city smart cities, like 'mobility' and 'environment', can be traced back to this New Urbanism movement. The intelligent city debate is the second academic discourse connected to the origins of smart cities. The intelligent city discourse emerged from the conversation prompted by using ICTs, e-governance, innovation and increased funding towards harnessing new technologies like the Internet of Things and Blockchain technologies by cities (Crivello, 2015).

The New Urbanism and intelligent city discourse have provided insights into the origins of the 'smart cities' concept; however, the current 'smart cities' debate has been advanced outside academia by the global IT industry and technological corporations like Cisco, IBM Corporation, Siemens and Microsoft Corporation. As early proponents of 'smart cities' and manufacturers of technologies and infrastructure for 'smart cities', the global IT industry and technological corporations argue that their technologies enable mobility and liveability for cities. The global IT industry and technological corporations can enhance the quality of life by harnessing technology (Crivello, 2014). The Fourth Industrial Revolution has shaped the current model of 'smart cities' where the global IT industry and technological corporations are planning authorities of 'smart cities' and benefit financially by selling their technologies and products (Hollands, 2008; Moser, 2015).

In addition, international firms such as Apex Avalon Consulting, Cisco, Deloitte, IBM, KPMG and McKinsey have been given key roles in building 'smart cities' (Datta, 2015). Thus the

Fourth Industrial Revolution was mainly focused on digital transformation, the adoption of the blockchain, the Internet of Things (IoT) and big data for real-time services and communication (Nahavandi, 2019). But unfortunately, the Fourth Industrial Revolution did not have a strong aspect of inclusivity; hence experts are now looking towards the Fifth Industrial Revolution for improved integration and multi-level cooperation between humans and technology to enhance collaboration, innovation and creativity of human brains (Shelzer, 2017) which forms the objectives of this research. The prospects of the Fifth Industrial Revolution, especially the collaboration between technology and people, will digitally transform the environment, economy and communities (Shelzer, 2017).

### 2.3.2 The definition of 'Smart Cities.'

There is no universally agreed definition of a 'smart city', and Hollands (2008) contends that the diffusion of 'smart city' initiatives in countries with different needs and contextual conditions makes it difficult to identify shared definitions and common trends at a global scale. A 'smart city' is "a compound construct with two parts, smart and the city" (Ramaprasad et al., 2017:18), with its context-specific application and meaning. The smart city is: "…a high-tech intensive and advanced city that connects people, information and city elements using new technologies to create a sustainable, greener city, competitive and innovative commerce, and increased life quality" (Bakıcı et al., 2018:2). Hollands (2017:307) defines a 'smart city' as: "…an innovative city that uses information and communication technologies (ICTs) to improve the efficiency of urban operation and services, and competitiveness." A 'smart city' is also described as an instrumented, interconnected, and intelligent city (Lazaroiu and Roscia, 2012). The above definitions argue that technology is central in defining a smart city, and city services like water, transport and waste management are provided to citizens using ICT-based solutions or 'smart city' solutions. However, the shortcomings of ICT or technology-based solutions in delivering efficient and effective city-wide services led to adopting of human and sustainability concepts in defining a smart city (Foth et al*.,* 2015).

The digital transformation through the adoption of IoT, blockchain technology and ICT-enabled systems is expected to transform the urban landscape and cities of the future. For Gibson et al. (1992), the term 'smart city' recently dubbed "City 2.0", highlights the harnessing of technology and innovation to drive new urban development. Albino et al.

(2015) provides various definitions and dimensions of the smart city concept, primarily focusing on considering cities as key future elements and key to remediating environmental, social and economic challenges. Various concepts have been used contextually, for example, 'digital', 'interconnected', 'wired' and 'intelligent' to replace the term ‘smart'. With the various uses and dimensions, the term ‘smart city’ is used inconsistently and results in neither a universally agreed 'smart city' framing template nor an all-encompassing definition (O'Grady and O'Hare, 2012). In the early 1990s, when the 'smart city' concept was coined, the focus was on communities becoming smart through incorporating information technologies (Alawadhi, et al.  2012). Cretu (2012:59) identifies two main streams for defining smart cities: "smart cities should do everything related to governance and economy using new thinking paradigms and smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life."  The designing and application of technology are central to defining smart cities in the early phases of smart cities development and framing.

In ‘smart cities’ framing, the strategic direction, vision, or goal is also central in defining a ‘smart city’. Kourtit and Nijkamp (2012) view smart cities as the means to an end or the process/method/technique to address socio-economic and environmental challenges bedevilling cities through the application of ICTs.  "Smart cities result from knowledge-intensive and creative strategies to enhance cities' socio-economic, ecological, logistic and competitive performance. Such smart cities are based on a promising mix of human capital (e.g. skilled labour force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities)” (Kourtit and Nijkamp, 2012:93). Criticism has been raised on adopting a technology-oriented definition of smart cities with a shift into the governance-oriented approach, social capital and relations in urban development (Albino et al., 2015). For Marsal-Llacuna et al. (2014), smart cities seek to improve urban performance and provide efficient services to citizens using ICTs, big data and sensors, allowing for collaboration among various stakeholders resulting in innovation and creativity for both formal and informal sectors. Governments and municipalities are adopting the concept of 'smartness' in the programmes and policies which target environmental protection, improved quality of life for their citizens (smart living) and creativity. Thus, smart cities not only focus on the diffusion of ICT but also incorporate communities and citizen needs.

The technological component is central to defining smart cities for the global IT industry and technological corporations like Deloitte, IBM, Apex Avalon Consulting, Cisco, Siemens and Microsoft Corporation. For example, IBM indicates that the concept "smart city" signifies an "instrumented, an interconnected and intelligent city with the capability of capturing and integrating live real-world data through the use of sensors, meters, appliances, personal devices, and other similar sensors" (Harrison et al., 2010:02). These ICT and intelligent systems are integrated into a computing platform to process the data for optimisation and better operational and decision processes. Thus 'smart cities' have a significant ICT presence in critical service delivery infrastructure components embedded in them for more accurate monitoring and tracking of waste management or energy services (Liu and Peng, 2013). However, Greenfield (2013) critiqued the corporate-designed 'smart cities', for example, PlanIT Valley (Portugal), Masdar City (UAE) and Songdo (Korea), as top-down and corporate-driven initiatives disregarding the human components of smart cities.

As indicated above, one of the key smart components missing in these previous definitions is that of citizens or people. For Thuzar (2011), citizens shape smart cities through continuous interaction, innovation and creativity, one of the key drivers of smart cities. Technology does not offer, on its own, the answer to environmental and socio-economic problems. Sustainability is inextricably linked with economic and social considerations that differ across cultures. Nam & Pardo (2011) define a 'smart city' as a "humane city" with multiple opportunities to exploit human potential and lead a creative life. Caragliu et al. (2011) present the view that a city is smart if it makes "investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure to fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance." A 'smart city' is an environment, platform and space where human needs like employment creation, reduction in poverty and inequality and improved quality of life are achieved through human capacity, skills, innovation, creativity, talent and cultural assets. This human-centric definition puts citizens at the core of defining the 'smart city', and technology is viewed as an enabling approach to solving city-wide challenges like waste management, inequality and unemployment.

Proponents of ‘smart cities’ emphasise the potential for promoting economic prosperity, ecological integrity and social equity, advancing the larger goal of urban sustainability (YU and Gibbs, 2020).

Neirotti et al. (2014) identify the social infrastructure or "soft domains" such as education, culture, knowledge, social inclusion, and learning as central to smart cities. These social elements, such as knowledge and education, are essential to smart cities as they allow for "connecting people and creating relationships" (Alawadhi et al., 2012). Through knowledge and education, the smart city becomes a centre of higher education, generating smart people who are creative and innovative and forming a virtuous circle that makes them smarter (Winters, 2011). Nam and Pardo (2011) use the aspect of 'community' in trying to clarify the concept of a smart city. This leads to the concept of a 'knowledge city', which has emerged from the better-educated citizens and skilled employees working with various institutions to transform their environment. This perspective is bottom-up, as knowledge, innovation, and creativity are community-driven responses to worsening city problems like waste management, traffic congestion and inefficient resource management.

Esmaeiliana et al. (2018) imagine ‘smart cities’ as an alternative for remediating the problems of inefficient solid waste management and environmental protection. A conceptual framework with three interconnected elements based on “product lifecycle, new business models and intelligent sensor-based infrastructure for waste separation and on-time collection" (Esmaeilian et al., 2018:178) is proposed for future waste management in ‘smart cities’. The 'eco-city' concept is connected to the utopian vision of smart cities, which emphasises the potential for promoting economic prosperity, ecological integrity and social equity, advancing the larger goal of urban sustainability (Gibbs, Krueger and MacLeod, 2013). Various models for 'eco-cities' have been identified, such as the "zero-waste and zero-carbon emissions" in the Abu Dhabi Masdar City project (Palca, 2011), the “industrial symbiosis and recycling” of Japanese eco-town projects (Van Berkel et al., 2009), the “economically sustainable, socially harmonious, environmentally friendly and resource-conserving” of the Sino-Singapore Tianjin Eco-city project (Caprotti, Springer and Harmer, 2015). The identified ‘grand technocentric utopias’ in smart city waste management act as engines for ecologically benign strategies so that cities may transform traditional waste management practices toward zero-waste practices (Zaman and Lehmann, 2013).

In expanding the definition of a 'smart city', Nam and Pardo (2011) have identified three dimensions of 'smart cities', namely: 1) the technological dimension, 2) the human dimension, and 3) the institutional dimension of smart cities. The technological dimension of smart cities incorporates various concepts such as 'Digital City', 'Virtual City', ‘Interconnected/Wired City' and 'Intelligent City'. Further expanding the smart city concept past the technocentric approach is the human dimension which focuses on the humane aspects of smart cities, for instance, ‘inclusive cities’, ‘liveable cities’, 'knowledge cities' and 'learning cities'. Finally, the third aspect considered by Nam and Pardo (2011) is the institutional dimension of smart cities which covers concepts like sustainable development and energy efficiency through the adoption of 'eco-city', 'green city', ‘sustainable city', ‘garden cities’, ‘resilient cities’ and 'smart community’. Adopting the narrow and broader sense, Moir et al. (2014: 12) argue that a 'smart city' in "a narrow sense indicates the use of the right hardware, software and technology platforms to solve many urban challenges, while 'smart city' applied in a broader sense often emphasizes good city governance, the empowerment of city leadership, smart citizens, and the right investment in smart technologies." Caragliu et al. (2011) distinguished "smart economy", "smart mobility", "smart governance", "smart environment", "smart living", and "smart people" as six key characteristics and benchmarks of a smart city. This research will be located within the ’smart environment’ and other sub-dimensions of smart cities, namely social inclusion, zero waste goal and circular economy.

The ‘smart city’ concept is largely a strategic vision to reach sustainable futures rather than a description of reality in a current context. UNCTAD (2016) classifies 'smart city' projects into two categories: Brownfield and Greenfield projects. Most 'smart city' projects fall into the category of smart interventions in existing cities and can be classified as Brownfield projects. However, Greenfield initiatives, such as Songdo (South Korea) and Masdar (United Arab Emirates), are projects started from scratch with a vision to create 'new' smart cities. This research will look mainly at Brownfield projects that are emerging and applicable in developing countries in solid waste management since most of South Africa’s cities fall in this category where smart city interventions are being retrofitted and adapted to existing city infrastructure and urban services.

As discussed previously, within the community aspect, the smart city's definitions have evolved from techno-centric to citizen-centric (OECD, 2020). The concept of smart citizenship as an emerging phenomenon in smart cities is undergoing its own transformation. Smart citizenship is a radical shift from the traditional approach of citizens being passive recipients of government policies and drawing closer to citizens being innovators, co-producers and collaborators in public management. As part of citizen collaborations, smart citizens actively participate in local governance affairs through the e-governance process facilitated by new technologies. As the concept of smart citizens evolves towards co-producers, citizens are integrated with the academic and private sectors to generate creativity and innovation for a better quality of life, efficiency or sustainability. Here, the common objective of smart cities is the creation of value for citizens and other stakeholders living in the city. Reflected in this dimension of smart cities are the "ways of doing" that are "smart" (UCLG Smart Cities Study, 2019). This implies that, through collaboration, co-production and co-creation, key stakeholders and citizens use data for decision making, especially in planning, redefining and measuring the efficiency and effectiveness of municipal programmes in transforming communities. Thus, if smart citizens govern the cities in smart ways, they can "achieve a smart economy, smart mobility, smart environment and promote smart citizenship" (UCLG Smart Cities Study, 2019:22).

As argued above, the current techno-centric and human-centric approaches to smart cities are top-down models which have failed to acknowledge the smart citizen role of waste reclaimers in municipal waste management. In this context, this study is located at the intersection of the techno-centric and human-centric definitions of the 'smart city'. The questions that remain, however, are how the emerging ICT-enabled technologies will be positioned in this expanding recycling economy, what benefits they will reap, and what role the waste reclaimers' integration processes within the smart city approach will play towards the transition into a zero-waste, circular economy, while significantly improving waste reclaimers' working conditions. As a site of innovation and resilience, as well as a safety net for many of the unemployed and urban poor, the informal economy has been undervalued in development approaches in general (Cheng, 2010), especially in efforts to build economic, social and environmental sustainability.

### 2.3.3 The diffusion of the 'Smart Cities' concept

The concept of smart cities has gained global consideration and cities in the developing and developed world are adopting it to transform themselves into energy efficient and sustainable cities. Although various factors can be put forward for the popularity of smart cities, Vanolo (2014) attributes this to increased research funding on smart city projects and increased budgets by governments and cities for the digital transformation of waste management and other municipal services. Many 'smart city' initiatives have been developed across the globe. Most 'smart city' projects in developed economies have focused on cutting-edge technological applications as key components (Bibri, 2018). Although earlier 'smart city' projects were mainly focused on mobility and energy efficiency (Martins et al., 2018), a growing concern has emerged in the environmental sustainability aspect of smart cities. The smart city projects and dimensions of environmental sustainability have focused on artificial intelligence and big data and their potential for optimizing energy efficiency and mitigating environmental effects.

As mentioned above, the smart city concept is also prevalent in Asia, for instance, in United Arab Emirates, India, South Korea, Singapore, China and Japan. The 1997 effects of the Asian Financial Crisis led to the creation of the smart city concept in South Korea. The impacts of the crisis prompted the South Korean government to transform its economy from manufacturing into service (Shwayri, 2013). Urban development was considered one of the methods to attract expertise and foreign direct investment. The South Korean government conceived the concept of a 'ubiquitous city' as a response to the financial crisis, for example, the Songdo Smart City. Songdo City is a Greenfield initiative connected to transforming South Korea's economy into logistics services (Shin, 2016). Cisco invested USD$47 million to upgrade the smart city with advanced technologies (Strickland, 2011). Thus, the smart city concept in South Korea was adapted to the economic dimensions.

In addition, several countries in Asia have implemented their own smart city initiatives, with China and India generating the highest number of smart city plans. For both China and India, Saunders and Baec (2015) identified approximately 300 smart city pilot projects currently being implemented. In South Korea and Singapore, experimenting with smart cities is not new since both countries have retrofitted advanced technologies in their urban system since the 1980s (Bibri, 2018). In the 1990s, Singapore, through the policy document entitled: *A* *vision of an Intelligent Island: IT 2000 masterplan,* digitalised all government departments and transformed the country through technological enhancement for improved quality of life and innovation (Hollands, 2008). Several other smart city initiatives followed this, for instance, the 10-year plan, *Intelligent Nation 2015* (2015) and the "Smart Nation" initiative, which established critical infrastructure for the Internet of Things and big data analytics, which forms some components of smart cities (Saunders and Baeck, 2015). Thus, technology was seen as a driver of economic growth and smart living.

There are also smart city projects in Africa that have emerged as a response to Africa's challenges, for instance, climate change, environmental degradation, traffic congestion and pollution and rapid urbanisation (Balkaran, 2019). Estate Cloud (2018:03) identified five Smart City initiatives in Africa, namely: “Konza Techno City (Kenya), Eko Atlantic (Nigeria), Hope City (Ghana), Vision City (Rwanda) and Waterfall City (South Africa).” These smart city initiatives in Africa boast of adopting the latest technologies and infrastructure for rethinking urban development. These smart city projects are believed to reduce inequality, unemployment, and economic disparities and improve living conditions for urban citizens.

The other dimension of a smart city implemented in the United Arab Emirates and Japan has sought to exploit the ability to integrate technology for advancing environmental sustainability through the eco-city concept. This eco-city concept explores the perspective of "rebuilding cities in balance with nature" (McManus, 2016:06). This concept was adopted by the Japanese and UAE governments to achieve future sustainable urban development by considering social, economic, environmental and cultural aspects through changing the production mode, consumption behaviour and decision instruments based on ecological economics and systems engineering (Cao and Li, 2011; Cheng and Hu, 2010; Yu, 2014). Bai and Imura (2000) and Newton (2018) postulate that the eco-city can effectively minimize resource consumption and waste production by encouraging “using resources more efficiently”, “using waste as a resource”, “restoring and maintaining urban environmental quality” and “promoting highly efficient and effective urban and industrial planning, design and management systems.” Various individual eco-cities have emerged, such as the “zero-waste and zero-carbon emissions” in the Abu Dhabi Masdar City project (Palca, 2011), the “industrial symbiosis and recycling” of Japanese eco-town projects (Van Berkel et al., 2009), and the “economically sustainable, socially harmonious, environmentally friendly and resource-conserving" of the Sino-Singapore Tianjin Eco-city project (Caprotti, 2014). Thus, environmental sustainability and resource efficiency have emerged as visions of the current smart city projects.

Several benefits of smart cities have been identified through the implementation of eco-cities, which include efficient land use, habitat preservation and restoration, effective transport management, efficient solid waste management and environmental protection, efficient use of resources, and enhanced quality of life for the occupants (Pansera and Sarkar, 2016). Pansera and Sakar (2016) argue that the ultimate goal of many smart cities is to eliminate all carbon waste, produce energy entirely through renewable sources, and incorporate the environment into the city; however, eco-cities also have the intentions of stimulating economic growth, reducing poverty, facilitating higher population densities, and therefore higher efficiency, and improving health. Furthermore, the smart city emphasizes environmental responsibility and resource conservation, zero waste and zero carbon emission through policy frameworks that allow for ICT-enabled waste collection and sustainable ecological management (Lau et al., 2019). However, current studies disregard the role of big data applications and the IoT in integrating informal waste reclaimers to improve environmental sustainability in smart cities.

## 2.4 Municipal Solid Waste Management in Smart Cities

### 2.4.1 Data, technology and citizens in smart city waste management initiatives.

The fourth industrial revolution has illustrated the more significant role of technology in improving environmental protection and sustainability through the adoption of the Internet of Things (IoT), Blockchain technology and intelligent collection systems. For Khaitan and McCalley (2015), these emerging technologies provide cyber-infrastructure which fosters efficient resource management, a better quality of life and sustainable economic growth. The generation of waste globally is growing, with an estimated 7 - 9 billion metric tons of municipal solid waste generated annually (Kaza et al., 2018). Due to rapid urbanisation, the waste generation rate is estimated to double each decade (UN-HABITAT, 2009). The increase in waste generation is a cause of concern in current cities due to the increased shortage of landfill spaces and the cost of waste collection (Esmaeilian et al., 2018). The IoT-enabled waste management system seems to provide an alternative solution for challenging waste collection, recycling and waste generation reduction (Zanella et al., 2014).

The resulting transformation of urban environments into the smart environment is expected through harnessing data, technology and the citizens. Technology is identified as a key driver to smart city transformation while collecting appropriate citizen data enables innovative solutions which bring changes in waste generation behaviour in smart cities (Deloitte, 2015). The increased number of mobile devices and smartphones allows for citizen-generated data collection in waste generation and disposal rate, forming one of the elements of smart cities. Buyin et al. (2016) indicate that the data collected from citizens is linked to a particular location (geo-referencing) in real-time, informing the individual citizen or household waste generation and recycling trends and behaviour. Thus, IoT systems can generate private citizen data and public infrastructure information from sensors deployed to monitor and manage the environment and pollution levels. Four main devices have been identified by Pan et al. (2013) for collecting waste management data, namely, sensors, mobile devices, smart cards and GPS-equipped vehicles. However, despite these various technologies for collecting data, there is a lack of communication between them, or integrated systems that multiple stakeholders can access (Karim, 2014).

Pan et al. (2013) analyses the purposes for which data collected in smart cities is used. Six purposes from the literature are identified being:

> "(1) prediction of the patterns and models of citizens' behaviour, (2) tracing the citizen data at individual levels, (3) tracing the social relationships and interactions among individual citizens, (4) connection between region characteristics and residents' behaviour of each region, (5) visualization of complex data and dynamics of city evolution, and (6) unwanted privacy issues and personal identity" (Pan et al., 2013:120).

In addition, emerging technologies can potentially change waste generation behaviour towards pro-environmental behaviour (Chourabi et al*.,* 2011). Although citizen decisions influence the waste management system, waste management technologies can influence citizens' waste generation and consumer behaviour (Liboiron, 2014). Thus, as citizens operate these technologies to access urban services, the city is transformed more sustainably.

### 2.4.2 ICT-enabled waste management practices.

This section will initially provide a brief overview of solid waste management practices and later focus on ICT-enabled waste management in smart cities. Waste management studies, in general, have focused mainly on three objectives: 1) waste management practices, 2) waste quantification, and 3) waste characterisation (Gomez et al., 2008; Castro et al., 2017). For De Vega (2008), waste characterisation studies sample waste streams from different regions into plastic, paper and metal categories. Waste quantification studies mainly focus on the estimation of waste generated, recycled, landfilled and incinerated in multiple industries, for instance, construction (Castro et al., 2017), e-waste (Patil et al., 2017) and medical waste (Babanyara et al., 2013). Dornfeld (2013:65) identified three primary waste management practices: "1) prevention practices (e.g. product design), 2) end-of-pipe strategies (e.g. recycling, waste separation, incineration, proper landfill), and 3) environmental restoration practices." The three waste management strategies consist of initiatives like educating citizens to increase awareness, waste minimisation, on-time collection of waste, recycling and separation at source (Ajayi et al., 2017; Wäger et al., 2011; Sukholthaman and Sharp, 2016).

Although much research has been conducted on waste management practices, the concept of ICT-enabled waste management is still in its infancy. Esmaeilian et al. (2018:181) used various studies to classify the ICT-enabled waste management system into four categories, namely:

1. "Development of data acquisition and sensor-based technologies (Glouche and Couderc, 2013; Catania and Ventura, 2014);
2. Development of communication technologies and data transmission infrastructure (Medvedev et al., 2015);
3. Test the capabilities of IoT systems in field experiments (Hong et al. 2014); and
4. Truck routing and scheduling for waste collection operations *(*Anagnostopoulos et al., 2015a; Ustundag and Cevikcan, 2008)."

Studies by Medvedev et al. (2015) and Longhi et al. (2012) discuss the entire IoT architecture of ICT-enabled waste management system for waste collection operations using bins with RFID tags for waste identification purposes and sensors to detect the waste level with wireless network communication systems to transmit data for efficient waste collection. In addition, Anagnostopoulos et al. (2015) integrated the above architecture with GPS-equipped trucks for real-time tracking of waste levels and route optimisation for waste collection.

The review of ICT-enabled waste management has been explored by Zhang et al. (2012), who have classified the technologies into four groups, namely: data/network communication technologies (Wi-Fi. GSM), identification technologies (barcodes and RFIDs), data acquisition technologies (imaging, sensors) and spatial technologies (GPS, GIS). Spatial technologies have been widely researched in waste management, especially for route optimisation and path planning. GIS data has been used by Şener et al. (2010) for identifying a site for landfills. The GIS-based routine model has been used for path planning in solid waste collection using road networks and population densities (Ghose et al., 2006). All this shows that spatial technologies enable proper path planning and identification of future sites for landfill construction.

Various studies (Glouche, 2015; Chowdhury and Chowdhury, 2007) focus on applying and developing data identification technologies, especially barcodes and RFIDs, in smart cities. In the waste identification RFID-based framework developed by Glouche (2015), barcodes/QR codes attached to products are used by households or citizens to correctly sort and place recyclable materials in bins attached with RFID tags. RFID-based technologies have helped municipalities with automated waste weighing, identifying stolen bins and communicating real-time waste management data to households (Chowdhury and Chowdhury, 2007). In Italy, the RFID integrated with the GIS system has enabled efficient separation at the source of waste (Rada and Ragazzi, 2013). Although RFIDs are effective in the automated identification of recyclable material in SWM if not managed well can result in the loss of some valuable materials in the recycling process.

As discussed above, data acquisition technologies are divided into imaged-based and sensor-based for automated waste weighing and detecting bin levels (Elia et al., 2015). Vicentini et al. (2009) and Reverter et al. (2003) designed sensorised bins and point-level capacitive sensors for real-time measurement of the volume and weight of waste resulting in the bin automatically locking itself when it is full. Building upon this model, Medvedev et al. (2015) added cameras to assist with monitoring waste collection in Shanghai. Using the same concept, Rada et al. (2013) used images from the camera to develop algorithms to analyse bin-level detections. The sensor-based technologies have helped municipalities and services providers to avoid collecting empty or partly empty bins and assist in identifying full bins.

Research on waste management practices has also focused on applying and developing communication and data processing technologies. These infrastructures are mainly used by municipalities and waste services providers in developed countries. For example, a web interface was developed by Lata and Singh (2016) to enable local authorities and waste service providers to track trucks for waste collection and monitor bins with data transmitted by sensors using a wireless network. In addition, various communication types in ICT-enabled waste management systems have been explored by Shyam et al. (2017), who have identified machine-to-machine and human-to-machine communication. These communication applications transmit data for bin monitoring and recyclables collection.

Previous studies have revealed the application and testing of emerging technologies in several case studies of MSW management pilot projects in smart cities. For example, in Wuhan City, Tao and Xiang (2010) suggested a conceptual digital platform for recyclable collection and waste management using RFID technology to enhance intelligent waste collection. In the Netherlands, Elia et al. (2015) proposed a design for a Pay-As-You-Throw (PAYT) strategy using RFID cards for data transmission and bin-level detection to reduce household waste generation. For timeous waste collection in South Korea, Hong et al. (2014) designed bins with RFIDs connected to a wireless network that transmit bin levels statuses for timely collection of bin collections. Finally, in Denmark, Gutierrez et al. (2015) piloted an experiment using simulations to ascertain the economic feasibility and efficiency of an automated waste management system connected with RFID systems for waste collection using GIS data accessed from the city's open data portal.

Implementing the 'smart city' concept in developed countries has been focused on a techno-centric approach based on ICT-based integrative development methods, which refer to connectivity and data (Letaifa, 2015; Kummitha & Crutzen, 2017). In Portugal, the municipality of Cascais combined underground waste containers, remote fill-level sensors, adapted vehicles chassis and an integrated web platform that collects and analyses data for smart waste management (RENER Living Lab, 2017). The 'smart waste management system' began to be implemented in 2011 and increased the collection of recyclable material by 274% and the capacity to collect general waste by 40% (RENER Living Lab, 2017). Installing remote fill sensors for data generation linked to an online web management platform report via cellular networks to the management platform to monitor the fill levels of their bins and plans optimized collection routes for their drivers (Smartbin Intelligent Monitoring Solutions, 2015). This approach resulted in a 40% reduction in trips and data collection on route performance and fleet. Between 2013 and 2014, the municipality saw €145,043 savings on fuel costs, €520,087 savings on vehicle repair and maintenance costs and 264 tons of $CO_2$ emissions were avoided due to the reduction in the number of kilometres driven (Municipality of Cascais, 2017). The municipality, however, acknowledged that "using the best available technology is not enough for implementing a successful project; relevant stakeholder groups must be integrated into the implementation process" (Municipality of Cascais, 2017:03).

The research on smart cities mainly focuses on developing advanced technologies, sensor based, IoT and data communication systems and their applications in smart city waste management practices. What can be observed in this section is that the ICT-enabled technologies are mainly used for scheduling problems and waste collection. Therefore, the focus has been on municipalities and private waste providers to acquire IoT and ICT-enabled technologies for bin-level monitoring, route optimisation and adjusting waste collection schedules according to individual municipality demands and context.

Schafer (2014) lamented the privacy and security of data as limiting factors for ICT-enabled systems as it enables municipalities and private waste collectors access to household or citizen data. Household data is shared among all the system's stakeholders for analysis and results generation. Smart cities adopt various systems within intelligent waste management, which can collect data, for instance, smartphones, sensors, RFID and actuators for determining the level of waste in the bin, schedule collections, route optimisations and waste monitoring (Anagnostopoulos et al., 2017). According to Kitchin (2016), this ICT hardware presents a "possible violation of the personal privacy of urban dwellers through increased data surveillance and geo-surveillance." Graham (2011) asserts that the ICT-enabled waste management system might purposely be adopted to target particular audiences and/or social groups. Lange and Waal (2013) identified several smart city projects with some level of surveillance disguised as real-time monitoring and tracking undertaken through big data analytics on households and individual citizens. South Africa has illegal immigrants working as waste reclaimers in the informal sector; due to their illegal status and fear of being deported once the system flags them, they resist adopting the smart city initiatives. These concerns about sharing personal data to create a user profile and surveillance impede waste reclaimers and `households from participating in ICT-enabled waste management projects.

Finally, previous studies on smart cities' waste management practices have now focused on waste monitoring, separation at source and waste collection efficiency by applying IoTs and ICT-enabled technologies. However, the current smart city model is ineffective as it does not consider the integration of informal waste recyclers into the strategies to enhance waste management practices. ICT-enabled waste management systems should focus on route optimisation and scheduling and empower the informal waste reclaimers to schedule collections and improve their working conditions using data from the ICT-enabled systems. Thus, a new bottom-up integrated ICT-enabled system must be developed for waste management in smart cities to facilitate intelligent collection initiatives and integrate and empower the informal waste reclaimers as collaborators in recycling initiatives and the zero-waste goal.

## 2.5 The Zero Waste concept in smart cities.

The previous section ended by advocating for a new and inclusive model for waste collection in smart cities. This section introduces an addition to the conceptualisation of smart cities, focusing on the zero-waste concept. In the current model of smart cities, waste is envisioned as raw materials which need to be reused, recycled and composted, thus resulting in an ideal smart city with no waste (Anagnostopoulos et al*.,* 2017). Esmaeilian et al. (2018) identified "waste prevention, proper waste collection, and finally proper value recovery from collected waste" as the three requirements for cities to transition into zero-waste smart cities. In addition to these three strategies, Rybova and Slavik (2016) and Al-Khatib, et al. (2010) identified management of waste reclaimers, improved legislation and extended producer's responsibilities as factors enhancing the zero-waste concept in smart cities.

Waste management through the zero-waste concept seeks to minimise further depletion of global resources. This requires sustainable consumption and strategic waste management systems based on (1) waste avoidance, (2) material efficiency and (3) resource recovery (Lehmann, 2010). Cities such as Adelaide, San Francisco, Vancouver, Johannesburg, Cape Town and Ethekwini have adopted zero waste goals as a part of their waste management strategies because zero waste stimulates sustainable production and consumption, optimal recycling and resource recovery, and minimises mass incineration and landfilling (Zamman, 2014). The Department of the Environment in San Francisco defines zero waste as "sending nothing to landfill or incineration." (SF Environment, 2011). Despite adopting the zero-waste concept, cities around the globe understand, practice and apply the concept in different ways resulting in different outcomes. For instance, some studies have claimed to achieve the Zero Waste goal through the application of technologies (ICT) such as the internet of things (IoT) and Intelligent Waste Systems, while other studies emphasise the achievement of the concept through innovative human initiatives such as the use of animals for waste management, deterrent policies for disposing in landfills, incentives and effective informal waste reclaimer system. Samson et al. (2020) argue that the bottom-up informal waste management models are the best and most locally appropriate solution in developing countries towards Zero Waste.

Zaman (2014) used the Zero Waste Index (ZWI) tool to measure the resources extracted, consumed, wasted, recycled, recovered, and finally substituted for virgin materials and offset resource extraction by the waste management systems in Adelaide and San Francisco. According to Zaman & Lehmann (2013), the Zero Waste Index is illustrated by the equation below:

$$\text{Zero waste index} = \frac{\sum \text{Potential amount of waste managed by the city} * \text{substitution for the systems}}{\text{The total amount of waste generated in the city}}$$

This equation determines waste management systems' performance towards achieving the zero-waste goal. The equation only provides the overall amount of resources that are recovered from the waste streams and substituted for virgin materials but does not distinguish the waste performances according to sectors, for example, formal and informal. However, this equation is still useful conceptually, and its application helps elucidate new concepts. While the equation was offered and developed as a quantitative tool, this useful analytical methodology cannot fully represent the complexity and richness of technology-human–environment interactions; therefore, a qualitative approach should be integrated into the equation's application. Furthermore, the equation should consider other drivers of zero waste performances like technology, population, quality of life, regulations and the influence of waste reclaimers. Thus there is a need to consider the role of technology towards zero waste and circular economy since technology influences consumption, resource supply problems (and hence environmental impact) and recycling rate (zero waste performance). The bottom-up smart city is built upon the weakness of the current *'smart city'* models, focusing on other drivers like inequality, poverty, state policy, environmental behaviour and the role of informal waste reclaimers. The model acknowledges that a given *smart city* solution cannot simply be transplanted from one geographic region to another, and smart infrastructure concepts need to be made locally relevant and respond to local development needs since context, culture and economics all play a role in this process.

The circular economy seeks to shift from the traditional linear model of extraction and dumping to an alternative circular flow model that emphasizes product, component and material reuse, remanufacturing, refurbishment, repair, and upgrading throughout the product value chain and life cycle (Korhonen et al., 2018). The concept of a circular economy is not limited to optimal recycling or resource recovery; a circular economy also requires eliminating unnecessary waste creation at the first stage of designing a product. Therefore, circular economy design principles go beyond recycling to focus firstly on avoidance and reduction of waste by innovative product design and then recycling and composting/waste to energy through the use of technologies and human innovative skills and strategies (City of Austin, 2018 and Zaman & Lehmann, 2013). There is a need to recognise that in South Africa, a circular economy cannot be achieved without the role of waste reclaimers. Waste reclaimers move large quantities of recyclables into the value chain daily through their existing informal systems. Thus there is a need for a change of perception towards the current informal recycling system and support with resources and infrastructure like better trollies to collect and transport their recyclables, storage facilities and space to store, sort and produce their products from recyclables, for instance,, eco-bricks from green plastic PET bottles. Sekhwela and Samson (2020) argue that there is an urgent need for partnerships between the industry and informal waste pickers to improve an existing system towards an inclusive circular economy. Accordingly, it is argued that 'smart cities' should significantly emphasise innovative partnerships where various sectors and stakeholders unite to promote citizens' entrepreneurship and innovation.

This research perspective on the zero-waste concept in smart cities illustrates a proposed integrated framework comprising three interconnected elements. Esmaeilian et al. (2018) provide a detailed overview of the interdependence of these three elements in ICT-enabled waste-managed practices, as shown in (Fig 2.1.) below. The first element comprises technology and infrastructure for product lifecycle data collection. These product lifecycle data collection systems enable data sharing between various stakeholders in different regions to facilitate real-time separation of waste at source, waste collection and reduction in waste generation. In addition, the zero-waste concept in smart cities envisions recyclable waste being used as raw materials for the remanufacturing industries. Although the earlier review of literature on ICT-enabled waste management systems mainly focused on developing and applying these technologies for efficient collection and separation, the current focus of this research is on ICT-enabled waste reclaimer integration to facilitate improved efficiency in waste reduction, recovery and separation.

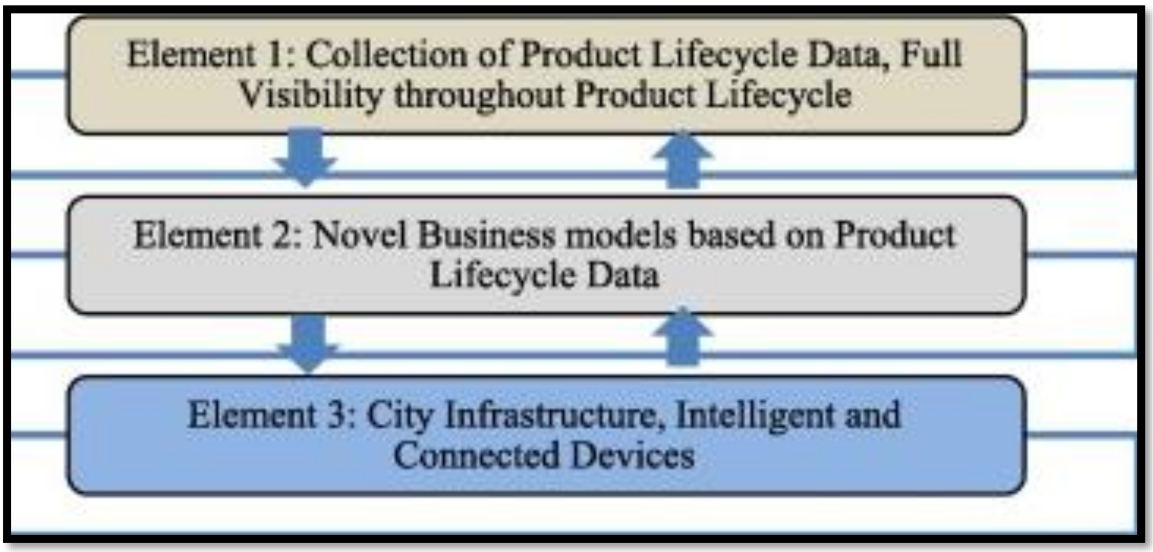


**FIGURE 2. 1.** THREE INTERCONNECTED ELEMENTS FOR WASTE MANAGEMENT IN SMART AND CONNECTED COMMUNITIES. **(SOURCE: ESMAEILIAN, ET AL. 2018).**

The second element for waste management in smart and connected communities comprises the aspect of smart citizens. This element is citizen-centric in that citizens and municipalities are connected and collaborate in sharing household waste generation data and services to facilitate the adoption of innovative ICT-enabled waste management business models for waste prevention, improving quality of life and increased waste recycling initiatives through value creation. The third consists of sensor-based and intelligent systems linked to municipal and city urban service infrastructure to enable on-time scheduled waste collection and proper separation at the source of waste at the end-of-life stage. Thus, the zero-waste smart city views *waste* as a 'resource' focusing on separating waste at source to increase resource recovery and adopt the circular economy concept. Thus, the ICT-enabled waste management practices and emerging value creation paradigm, waste management in smart cities, should reduce waste generation, increase recycling elements, enable stakeholder relations in waste management, improve the quality of life and encourage innovation and creativity.

## 2.6 The Conceptual Critique of the Current Smart Cities Models

Criticism against 'smart cities' came from objections and dissatisfaction around the concept of 'smart city' and its implementation. The current model of smart cities has received criticism due to its conceptualisation of future cities or urban utopias. Zhu et al. (2020) provide a powerful critique of the current smart city design and planning principles which only serves the planners and political elites' utopian fascinations and inclination without considering the contextual realities of the functioning of the cities. For Harvey (2012), the current urban development indicates the capital accumulation process without transforming cities into sites of social inclusion, citizen innovation and creativity, citizen involvement and collaboration through the 'right to the city' (Lefebvre, 1991). Although the ICT-enabled waste management system in smart cities in developing countries is still in the early stages of application, various proposed conceptual IoT and ICT applications are just mere visions for the future and sometimes remain in the experimental phase; for instance, Relix system in Brazil and the BanQu system in South Africa. Holland (2008) observed that global IT companies develop many self-designated smart cities projects in Asia. Thus, smart cities, as a self-designated term, allows cities to brand themselves as such to attract investment and a skilled workforce for entrepreneurial urbanism (Holland, 2014).

Scholars question the implementation of a ‘smart city’ as a result of being connected to IoT (Komninos, 2015) and neoliberalism (Watson, 2013), resulting in reduced social capital (Calzada & Cobo, 2015) and failure to address imbalances (Holland, 2015). 'Smart city' projects across the globe reveal the privatisation of urban space (Hogan, Bunnell, & Pow, 2012) and its failure to recognise or promote bottom-up innovation (Calzada & Cobo, 2015). Furthermore, scepticism has been raised on the planning authorities of 'smart cities' who are corporations like Cisco and IBM (Moser, 2015) who benefit financially by selling their technologies and products, the political agents involved gain from their lobbying and funding, and the actual losers from this practice are the citizens and their communities (Datta, 2015). Furthermore, the 'smart city' has failed to reach out to include in the mainstream various excluded sections of the populace revealed by sharp increases in inequality and poverty levels, including unemployment and underemployment in both Singapore and San Diego (Hollands, 2008), whilst in Malaysia, it is the skilled middle-class citizens, politicians and corporations who are benefiting from 'smart cities' (Bunnell, 2015).

Datta (2015) argues that smart cities are a business model rather than an instrument to achieve larger social objectives such as social justice, social inclusion and sustainable development, as it has been argued that 'smart cities' could accomplish. Cisco is a big player in the building of the "Dholera smart city" and one of the major players in the global IT industry, Cisco significantly benefits from the business opportunities it exploits in India by selling its smart city technologies (Hollands, 2008; Moser, 2015). Smart cities will be remembered for their vendor-push or technology-push nature (Calzada & Cobo, 2015; Hollands, 2008), where technologies are forcibly installed or supplied into cities. In other words, technologies are forced into communities without assessing their needs because big corporations invent them and need a market to sell them. International firms such as Apex Avalon Consulting, Cisco, Deloitte, IBM, KPMG and McKinsey have been given key roles in building 'smart cities' (Glasmeier and Christopherson, 2015). These practices exemplify the market and entrepreneurial context of 'smart cities'.

Kitchin (2015) compared various dimensions of smart city concepts, for instance, 'creative city', 'sustainable city', 'green city', 'intelligent city' and 'resilient city', as new technological versions of future urban utopias. These new versions have emerged as an alternative to city-wide challenges of rapid urbanisation, increased inequalities and social exclusion of marginalised communities. In addition, smart cities illustrate the rise of the neo-liberal urban utopia, which stifles bottom-up citizen participation, innovation and creativity in developing future cities. The current models of smart cities are being illustrated by adopting and retrofitting technologies into urban service systems rather than focusing on citizen needs (Greenfield, 2013; Townsend, 2013). As a result, the technological smart cities view citizens as 'service-users', 'consumers' and 'entrepreneurs' (Ertio and Bhagwatwar, 2017). Lange and Waal (2013) indicate that mobile services Apps with geo-location and reward systems, especially in waste management, might transform citizens or households into 'social sorting' practices. Thus, citizens are reduced to becoming measured objects whose data is used for decision-making and improving efficiency in smart cities.

Kitchin (2013) identifies and explores three main issues of using ICT-enabled data generation systems for real-time tracking in smart cities. First, most ICT-enabled technologies can potentially monitor waste infrastructure, for instance, bin level tracking, automated waste weighing and truck monitoring for real-time waste collection resulting in the functionalist and reductionist approach. Second, although IoT and ICT systems are core in improving efficiency through data collection, technology alone in smart cities cannot resolve deep structural problems prevalent in contemporary cities like deepening inequalities, poverty and social exclusion. Third, most technologies and smart city projects have adopted the 'one size fits all approach’, which ignores various communities' contextual uniqueness and differences.

Vestergaard et al. (2016) use the case of intelligent streetlights as an example of how smart city technologies disempower citizens rather than empower them. Humans use their visual awareness to determine whether to walk in darkness or at night. The street with an intelligent light at night might look dark at a distance, though, at a certain distance, the intelligent streetlight will automatically light the street, under such conditions, the human ability to make an informed decision to use the street might not be possible. Although the intelligent street lighting system is for resource management, especially energy efficiency, on the other hand, it impedes the informed decision-making process for its citizens. Thus, in this example, smart cities merely represent the energy efficiency dimension without including the human element of safety and mobility.

Despite their promise to deliver sustainable outcomes with advanced technology, smart cities are heavily criticised as just a buzzphrase that has outlived its usefulness (Kunzmann, 2014; Shelton et al., 2014; Yigitcanlar, 2016). Sweden is one of the most advanced countries in waste management, and they successfully sort, separate, recycle and incinerate (through waste-to-energy projects) over 90% of the 'unusable' waste in a sustainable manner (Bayat and Biekart, 2009). The success has been attributed to applying several intelligent waste management techniques, automation and strict recycling policies. In contrast, the current techno-centric 'smart city' waste management model advocated by the government of India is now replacing the pre-existing informal waste recyclers system, thereby taking jobs away from the informal waste pickers who earn their livelihood through waste picking and recycling (Coletto and Bisschop, 2017). In India, there is no formal recycling/reuse mechanism (in most parts), but the waste industry in India forms a significant part of its informal economy (UNCTAD, 2016). India recycles at least 70% of PET bottles. This is achieved through a hierarchical and tiered social infrastructure ranging from waste pickers in informal settlements and landfills to small merchants. A few municipalities in India have succeeded at doorstep segregation, but there are locations with limited segregation, as a lot of the waste is incinerated.

Another key challenge confronted by the smart city concept is ensuring all groups of citizens' engagement and promoting inclusivity. The smart city models have been predominantly techno-centric formal systems that fail to recognise the informal sector and other vulnerable groups in their implementation. For example, the Smart City Policies of Barcelona and Amsterdam are silent about social inclusion, and Oslo's Smart City Policy is evasive on social inclusivity (UNCTAD, 2016). In developing country cities, people belonging to the informal economies, who are seldom under government taxation or regulations, also need to be ensured a place, space and opportunities within smart cities. These informal economies account for 48% of the GDP in North Africa, 51% in Latin America, 65% in Asia and 72% in Sub-Saharan Africa (World Bank, 2016). Ensuring inclusivity for these vulnerable groups is essential because there is a high possibility that they will lack the skills to use smart city applications or that their livelihoods might be most affected by smart city applications.

In India, where the techno-centric smart waste management system has been adopted, it has disturbed the hierarchical and tiered social infrastructure ranging from waste pickers in slums and scavengers in landfill areas to small merchants. From the example of Barcelona and Amsterdam, where smart waste management and automation systems have been adopted, UNCTAD (2016) concludes that the techno-centric 'smart waste systems and automated technologies could be perhaps inappropriate and costly in developing countries, primarily due to the social disruptions induced on livelihoods of thousands of people surviving on recycling waste sector. While technology in the form of IoTs and ICT-enabled applications is an integral part of a smart city, it should only be seen as an enabler to meet the needs of the city's people. Therefore, developing and designing a hybrid smart waste management model that is more inclusive of the social infrastructure and in concert with reuse and recycling would be more effective and efficient.

## 2.7 The empirical shift to Human/Citizen-centric Smart Cities

In sharp contrast to the technocentric approach, the human-centric approach sees the ‘smart city’ in a different way. Section 2.2.2 above discussed the citizen-centric dimension within the smart city’s definitions, which have emerged as a response to the shortcomings of the techno-centric perspective in defining smart cities (Buallay, El Khoury and Hamdan, 2021). Proponents of this school of thought (Brenner & Theodore, 2002; Garcia et al*.,* 2016) argue that smart cities must focus on people and their capabilities more than just concentrating on ICTs or technology. Holland (2008) argues that it is not the technologies that ‘smart cities’ need to give significant attention: they need more to focus on enabling citizens to enhance their capabilities, who then utilise their skills and capabilities to invent and promote technology usage while addressing their problems. Accordingly, it is argued that ‘smart cities’ should significantly emphasise innovative partnerships where various sectors and stakeholders unite to promote citizens' entrepreneurship and innovation. This innovation perspective claims that innovative initiatives should be related to the investments in human capital that would transform how people live and interact with each other and then lead to advancements in technological innovation. Investments in communities and their learning capabilities would lead to better yield in innovation and entrepreneurship (Neirotti et al., 2014; Toppeta, 2010; Giffinger and Pichler-Milanovic, 2007). The humanistic elements related to smart communities, including education, social learning and human capital, are crucial for smart city creation (Eger, 2003). The human-centric approach argues for a move beyond a tangible ICT-based approach towards more intangible skills, knowledge, social capital and human capital-based approaches (Neirotti et al., 2014).

## 2.8 The Informal Waste Reclaimers integration and emerging ICT-enabled waste reclaimers systems

### 2.8.1 The informal waste reclaimers' system and waste reclaimers' integration practices

Waste management is a global concern because of its environmental impacts and the high costs of waste collection services in developing countries (Le Courtois, 2012; UN-Habitat, 2010). Despite high costs and inefficiency in collection services, municipalities struggle to integrate various stakeholders engaging in waste management and recycling initiatives. Nowakowski (2017) states that recyclable waste collection from households to buy-back centres and other recycling centres is vital to waste recovery initiatives in a zero-waste smart city. The collection of recyclable material in many developing countries is predominantly undertaken by informal waste reclaimers (Wilson et al., 2006). Although waste reclaimers contribute to resource recycling and waste collection initiatives, their working environment and status are linked with social, health and environmental problems (Ardi and Leisten, 2016). Thus, informal waste reclaimers' integration through ICT-enabled and IoTs seems appropriate as cities move towards inclusive zero-waste smart cities and sustainable resource recycling.

In North America, for instance, in Canada, waste reclaimers are regularly referred to as "*Les Valoriste* (Montreal), Diverters (Victoria), Binners (Vancouver)" (Sholanke and Gutberlet, 2020), play a significant role in informal resource recovery. The Binners' project (2020) discovered that the binners "diverts about 7,000 kg of waste per month, which has been growing by 10% yearly." The bottle depot in Vancouver, operated by *United We Can* (UWC), illustrates entrepreneurial initiatives and social enterprise to empower the binners contributing to poverty alleviation and integration into the municipal waste management systems (Tremblay 2007). Sholanke and Gutberlet (2021) found that about 66% of the binners receive government social assistance and are invited to participate in government-sponsored waste sorting events providing access to recyclables for binners. The Universal Cart Initiative (UCI) is a government and private sector-funded initiative for designing and producing carts which can be either attached to a bicycle or be pushed specifically designed for binners to use in their collection and transportation of recyclable material (Tremblay, 2007). The city government is currently sponsoring a pilot project being done by UCI for the use of a voice recognition system to enhance the ease of access to carts by the binners (Sholanke and Gutberlet, 2021).

Scheinberg (2011:48) defined informal waste reclaimers as: "individuals or enterprises who are involved in private sector recycling and waste management activities which are not sponsored, financed, recognised, supported, organised or acknowledged by the formal solid waste authorities, or which operate in violation of, or competition with, formal authorities." Wilson et al. (2009) explores the critical role contributed by informal waste pickers, which is not even recognised in the currently not-yet-technologically advanced communities where they are the basis of most recycling initiatives and provide raw materials to the industries. Waste reclaimers are located in the bottom tier of the secondary materials supply chain (Wilson et al., 2006), and they recover recyclables from households' bins, street bins, communal kerbsides, open spaces and landfills sites where the recovered materials may be transported to the local industries and exported globally.

The waste reclaimers trade their material at buy-back centres or informal small-scale shops, which buy material from waste reclaimers and supply either the bigger centres or sell to the waste recyclers directly. In this informal value chain, various intermediaries deal directly with waste reclaimers and sell the materials to buy-back centres or waste recyclers, who aggregate the materials for sale to industries. This hierarchical structure reduces the bargaining power of waste reclaimers when they sell their materials, thus ending up being paid low prices due to limited technologies for aggregating their recyclable materials. The buy-back centres in the informal waste recycling initiatives become institutions and centres of integration because of their established relations with waste pickers by providing loans, equipment and sorting spaces (Furedy, 1997). In currently less technologically advanced waste management systems, waste reclaimers experience poor working conditions and deplorable living conditions, with some residing close to the dumpsite (for instance, 'Garbage City' in Egypt) and suffering from health risks associated with scavenging in dumpsites filled with chemicals and injuries from metal and bottle cuts and contact with syringes. In some areas, waste reclaimers are not recognised as they are considered a social problem due to their handling of waste in landfills and household bins.

In developing countries across the globe, the bulk of waste reclaimers consists of cross-border immigrants (Scheinberg and Anschtz, 2006), followed by local citizens who might have migrated from rural areas to urban areas in search of work opportunities and ended up finding themselves undertaking waste collection services to earn an income. In countries like Egypt, the minority Coptic Christians constitute the bulk of waste reclaimers and waste collectors in 'Garbage City'. The Muslim minority comprises most of the waste reclaimers and collectors in India's informal waste recycling system. The Roma gypsies and Afghan refugees are associated with cleaning the streets and working at the landfills in Romania and Pakistan, respectively (Furedy, 1997). Internal or external migration has influenced the informal sector and waste reclaimer integration initiatives globally. For example, Nzeadibe (2009) found that most waste reclaimers in Nsukka, Nigeria, came from rural areas and surrounding states within Nigeria. In Egypt, the Coptic Christians are the major waste pickers and are landless (Scheinberg et al., 2006). In Turkey, most waste pickers are Kurdish, Syrian and Afghan immigrants. These numbers are increasing because it is easier for immigrants to secure employment in informal waste collection than in formal and skilled jobs in Turkey (Gugus, 2019). The nature of handling waste makes waste reclaimers despised in communities and sometimes labelled as criminals or a nuisance (Dias and Junior, 2016). Consequently, as discussed above, applying the smart city concept in current municipal waste management practices seeks to integrate reclaimers in ways that disempower them and force them to exit the informal recycling sector.

### 2.8.2 The welfare approach towards waste reclaimers’ integration practices

Unlike the technocentric approach, which views the informal waste reclaimers as a social problem, the human-centric approach seeks to alleviate environmental pollution, inequality and unemployment through the integration of waste pickers and treat them as economic actors or entrepreneurs in the socio-technical solid waste management and recycling system (Neirotti et al., 2014). Scheinberg (2011:51) identified the three most common approaches which have featured prominently in the human-centric approach, namely: “(1) the welfare-based approach, (2) the development-oriented approach and (3) the rights-based approach within the waste management sector". The welfare-based approach seeks to improve waste pickers' living conditions by focusing on daily needs and welfare problems without addressing the political and social forces influencing their position. In Curitiba, Brazil, innovative waste collection approaches were developed, such as the "Green Exchange Program," to encourage residents of informal settlements to clean up their areas and improve public health by offering bus tickets and fresh vegetables to residents who collect waste and deposit at collection centres and allow children to exchange recyclables for school supplies or toys (LaRue, 2010). The welfare approaches have improved the lives of the residents through access to public transport and reduction in hunger through the provision of vegetable supplies.

### 2.8.3 The development-oriented approach towards waste reclaimers' integration practices

The development-oriented approach is concerned with social and economic interventions such as education, credit and income generation projects focusing on strengthening capacities to facilitate an exit from picking by families involved in waste scavenging. However, the development-oriented approach supports empowerment and enables access to schools or other social continues to ignore the content of waste picking and its contribution to family livelihood. The development approach shares the social framework and vision with the welfare approach and thus gives little attention to pickers' status as informal sector recyclers working on solid waste. Most development interventions neither consult waste pickers regarding priority questions nor engage them in solving their problems (Furedy, 1997; Scheinberg and Anschtz, 2006). In Romania, this lack of consultation has consistently led to Roma waste pickers ignoring projects that would give them housing and schooling opportunities and, in the process creating much resentment in the non-Roma organizations doing the 'helping' (Stanev, Veraart and Popovici 2004).

### 2.8.4 The rights-based approach towards waste reclaimers' integration practices

Finally, the rights-based approach addresses social, political and institutional aspects of waste picking, creating more political room for changing and strengthening pickers' position as a group in society, giving them a voice, making them visible, and stimulating their political participation (Scheinberg, 2011). Various informal waste reclaimers association have emerged at the forefront advocating for the integration of waste reclaimers, improved working conditions and pushing for policies and legislation that empowers and protect waste reclaimers in waste collection and recycling initiatives, for instance: the Global Alliance of Waste Pickers; Association of Waste Pickers of Bangladesh; National Association of Waste Pickers of Venezuela (ANREV); and Women in Informal Employment: Globalizing and Organizing (WIEGO) (Scheinberg, 2011). On the other hand, the welfare and developmental approaches view waste reclaimers as passive recipients of government programmes and end-users of the technologies adopted in smart cities without contextualising waste reclaimers as economic and institutional actors already within the waste management system. For the developmental approach, waste reclaimers are taught skills unrelated to their waste reclaimers and scavenging activities, which leads to an assumption that exit from this system will help, something the waste reclaimers themselves may not concur with (Samson et al., 2020). Thus, the need to ensure inclusivity to the vulnerable groups is critical because there is a high possibility that they will lack the skills to use smart city applications or that their livelihoods might be most affected by smart city applications. Furthermore, a given smart city solution cannot simply be transplanted from one geographic region to another, and smart infrastructure concepts need to be made locally relevant and respond to local development needs since context, culture, and economy varies (Alverti et al., 2016).

The integration of waste reclaimers has been observed in many countries in the Latin Americas, Asia and Africa; however, the processes have not yielded satisfying and precise results (Fei et al., 2016; Linzner and Salhofer, 2014). As argued above, most integration processes have been conceptualised only on poverty eradication and moving the waste reclaimers from the informal waste collection sector but ignoring the collaboration and in-depth ICT-enabled integration models of waste reclaimers' collection systems in smart cities.

## 2.9 The Bottom-up Smart city approach in ICT-enabled waste collection models

The bottom-up approach is a critical departure from the earlier top-down models of smart cities, which are predominantly techno-centric, government-driven and corporate-designed (Alverti et al., 2016). The bottom-up smart city approach seeks to address the waste management issues in urban areas through ICT-enabled digital platforms based on multi-stakeholder, private sector, industries, research institutions, community-based organisations, waste reclaimers and representative organisations, and national government and municipal-based partnerships. Through 'smart environment' cities adopts ICT-enabled waste digital platforms for waste collection tracking, household waste generation monitoring, environmental pollution control, monitoring of the waste diversion rate from the landfills and data creation for future waste management modelling, which results in efficient resource cycling, re-use and substation which serves the zero waste goals (Alverti et al., 2016).

To delve further into the concept of bottom-up smart cities, it is essential to critically engage with African critiques of market-led smart urbanism (Ouma, 2019) and juxtapose them with alternative frameworks of "bottom-up" smart urbanism, such as the "emancipatory smart city" (Odendaal, 2020) and "knowledge-intensive smart urbanism" (McFarlane & Soderstrom, 2017). These perspectives offer valuable insights that challenge and enrich mainstream smart city narratives. These critiques shed light on the potential pitfalls of exclusively market-driven approaches and highlight the necessity of considering local social, economic, and cultural contexts. By examining these critiques in the context of bottom-up smart cities, one gain a deeper understanding of how such an approach can counterbalance the often top-down, technology-focused narratives that dominate smart city discussions.

Within the African context, critiques of market-led smart urbanism emphasise the necessity of contextual sensitivity and social equity in smart city projects. Ouma (2019) draws attention to the potential pitfalls of uncritically adopting Western-centric smart city models in African contexts, highlighting the risk of exacerbating existing inequalities and disempowering local communities. Engaging with these critiques enables a more profound understanding of how market-driven agendas can neglect the unique challenges faced by African cities, ultimately hindering the potential for inclusive and sustainable urban development.

Moreover, exploring alternative framings of "bottom-up" smart urbanism, such as the "emancipatory smart city" proposed by Odendaal (2020), opens a gateway to a more inclusive and socially just perspective. The alternative framing by Odendaal (2020), present a compelling juxtaposition which emphasises social justice and empowerment, focusing on dismantling inequalities and fostering active community participation. Contrasted with the prevailing technocentric discourse, this perspective challenges the status quo by foregrounding the democratisation of technology and knowledge, thereby transcending the mere implementation of solutions to addressing systemic urban challenges. This recalibration encourages a holistic approach that considers the diverse knowledge systems embedded within local contexts, fostering more contextually relevant and effective smart city strategies.

The concept of "knowledge-intensive smart urbanism," as articulated by McFarlane and Soderstrom (2017), introduces another layer of critique. This approach critiques the prevalent fixation on technology as the starting point for smart city initiatives. Instead, it suggests that urban knowledge comprising local wisdom, indigenous practices, and community insights should be the foundation. By initiating smart city endeavours from a position of urban knowledge, this approach not only contextualises solutions but also fosters community ownership and engagement. Contrasting this with traditional technology-driven paradigms highlights the importance of adopting a more comprehensive and people-centred approach. Shifting the narrative from technology-driven solutions to contextually rooted knowledge, this framing aligns closely with the ethos of bottom-up smart cities, emphasising community co-creation and problem-solving.

By comparing these perspectives, a more nuanced understanding of the bottom-up smart city concept emerges. It becomes evident that a one-size-fits-all approach doesn't suffice in addressing the complexities of urban environments. While market-led models might prioritise economic growth, the "emancipatory smart city" and "knowledge-intensive smart urbanism" highlight the significance of social inclusion and contextual relevance. Acknowledging these alternative framings enhances the discourse by introducing a broader range of considerations and possibilities, ensuring that bottom-up smart city initiatives are rooted in the specific needs and aspirations of diverse communities. The expansion of the bottom-up smart city concept through African critiques, the lens of the emancipatory smart city, and knowledge-intensive urbanism injects diversity and depth into the discourse. These perspectives challenge one to question established norms, reconsider power dynamics, and embrace the complex interplay of technology and society in pursuit of truly smart cities.

The bottom-up approach recognises informal waste reclaimers as critical stakeholders and co-producers of waste management data to model waste generation and optimise resource use efficiency and substation. The smart city citizens, including informal waste reclaimers and households, have access to training and education, culminating in citizens acquiring e-skills necessary for working with ICT-enabled waste management platforms. The inclusive environment established through the adoption of ICT-enabled digital platforms for increased social capital and cohesion as various stakeholders in MSW management, together with informal waste reclaimers, "input, use, manipulate and personalise data, to make decisions and create products and services" (Alverti et al., 2016:3). The ICT-enabled digital platforms, which form the core of the bottom-up smart city approach, improve the participation, connection and meaningful engagement between stakeholders and where necessary integrate the informal waste reclaimers, civil society, public and private sector in the recycling value chain for MSW to be managed efficiently and effectively. Thus ICT, through waste management digital platforms, facilitates partnerships and collaboration towards the co-creation of data and decision-making in pursuing the zero-waste goal and integration of informal waste reclaimers.

The bottom-up approach seeks to integrate informal waste reclaimers and improve environmental protection by responding to the shortcoming of the charity, developmental, and welfare approaches and adopting ICTs and smart processes. The bottom-up approach has key attributes which are based on the following:

- “consultative, participatory engagement with pickers as leaders in the process;
- contextualization of pickers as solid waste system stakeholders, both in terms of helping them understand their economic relationship to the municipal solid waste system and in legitimizing and evaluating their activities to the formal solid waste and political authorities;
- an understanding of the specific effects of ecological modernization of waste systems, especially in terms of anticipating new institutional and economic niches, and helping pickers to enter them sustainably; and/or
- a commitment to sustainable improvement in the lives and livelihoods of pickers.” (Scheinberg, 2011:53).

The bottom-up approach recognises the waste reclaimers as co-designers of the ICT-enabled digital platforms and waste management applications through consultative and participatory initiatives by the private sector. The recognition and treatment of waste reclaimers as legitimate waste experts and technical actors in the digitalisation of the waste recycling value provide them with a new status as crucial stakeholders within the recycling sector. The contribution of waste reclaimers can be evaluated and quantified from the data generated by the ICT-enabled waste management digital platforms to ascertain their expertise, economic contribution and role towards the zero-waste goal. Such recognition of waste reclaimers through the bottom-up approach creates a virtuous environment for the waste reclaimers to optimise the collection of recyclables and reduce harassment and arrests by municipal police. Thus, the bottom-up approach, which is participatory and consultative, seeks to:

> "…increase the bargaining power and legitimacy of waste pickers by focusing on the status and social value of the waste management activity. In the process, harassment decreases, and family income and marginal profits often stabilize, creating better conditions for sending children to school" (Scheinberg, 2011:53).

Participation in and consulting with waste reclaimers is central to the design of the ICT-enabled waste platforms, and integrating waste pickers in the digitalised recycling value chain is a sustainable and systematic approach.

### 2.9.1 The modernised mixtures approach to MSW management

The bottom-up approach highlights the development of the 'modernised mixtures approach', which in this research is an intelligent approach to MSW management (Kosoe et al., 2019; Scheinberg, 2011; van Vliet et al., 2013; Oosterveer and Spaargaren, 2010). The 'modernised mixtures approach' refers to the following:

> "…socio-technical complexes of infrastructures, institutions, and payment systems which combine largescale, centralized, high-technological, low citizen-consumer participation models, with small-scale, decentralized, less technologically advanced and more participative models" (Kosoe et al., 2019: 231).

The 'modernised mixtures approach' is a conceptual framework for designing a more locally framed and sustainable solution to contextual urban waste management challenges by integrating environmental infrastructures' economic, technological and social dimensions (Hendriksen et al., 2012). It is important to note that the 'modernised mixtures approach' is stakeholder inclusive and integrates the technological and social-scientific knowledge when designing the ICT-enabled waste management system, which considers the local specific contexts (Kosoe et al., 2019).

The main features of the informal waste sector in most developing countries such as Brazil, Colombia, India and Kenya are low-cost and small-scale technology operating within decentralised systems (Kosoe et al*.,* 2019; Hendriksen et al*.,* 2012). Oosterveer et al. (2010) view the 'modernised mixtures approach' as an "organized eclecticism where various levels of scale, strategies, technologies, payment systems and decision-making structures, combine to create a better fitting with the physical and human systems for which they are designed" (See Figure 2.1 below). This approach used both in Brazil (Coelho et al., 2018) and China (Xue et al., 2018) is referred as a 'mixture' because, "it takes the best features out of both decentralized and centralized systems, and combines them into hybrid solutions which better fit into local situations" (Kosoe et al., 2019:231). Central to the 'modernised mixtures approach' is the “ecological sustainability, accessibility and affordability (for waste reclaimers and households), cultural suitability, and technological flexibility” (Scheinberg, 2011:57) in the design and assessment of efficient ICT-enabled waste management digital platforms. If implemented well, the 'modernised mixtures approach' has the potential for innovative technical systems and participatory institutional arrangement and digital payments models built from the weakness of both the techno-centralised and human-centric systems. Together with the centralised (government) systems with the emerging decentralised ICT-enabled waste management systems, the 'modernised mixtures approach' can be built into new methods which adapt to and recognises the local environment, which is characterised by various spatial arrangements (Kosoe et al., 2019; Scheinberg, 2011 and Oosterveer et al., 2010). In Latin America, Africa and Asian countries, this model appears to be a reflexive response adapted to specific needs and circumstances, offering various waste management technology solutions offering improved user participation and incentives, the highest level of environmental performance, recyclable trading and payment methods.

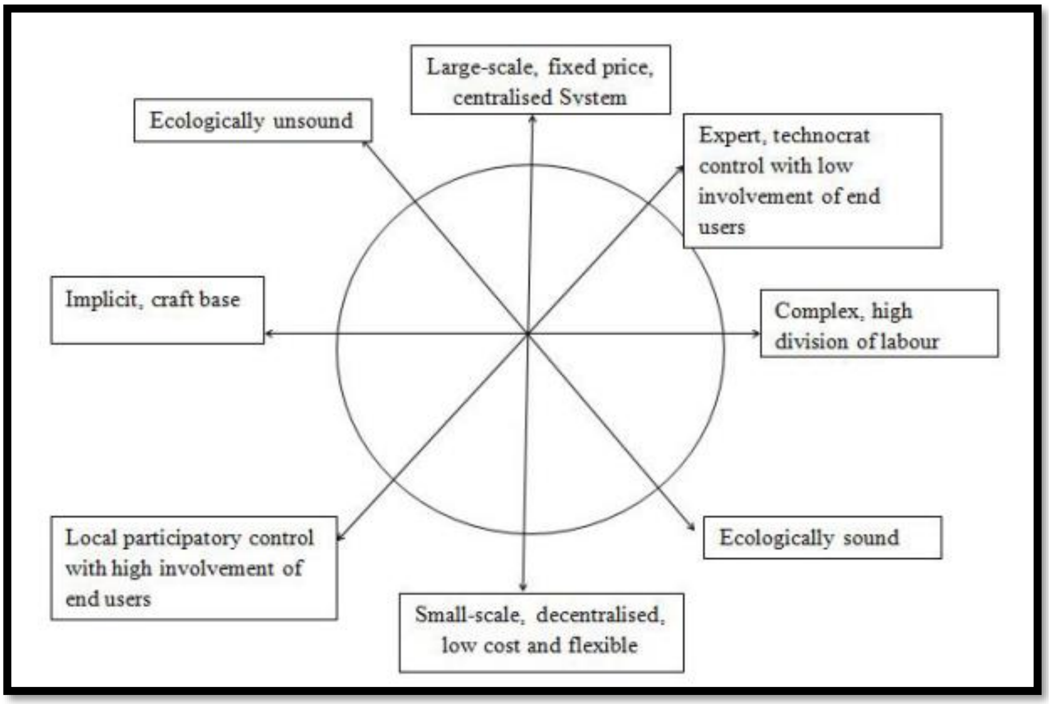


**FIGURE 2 2** THE 'MODERNISED MIXTURES APPROACH' WITH SEVERAL DIMENSIONS OF ENVIRONMENTAL INFRASTRUCTURE **(SOURCE: ADAPTED FROM KOSOE, ET AL. 2018).**

### 2.9.2 Conceptual framework of the ICT-enabled waste management model in smart cities.

Akram et al. (2021) provides the framework of ICT-enabled waste digital platforms to all the stakeholders in the recycling value chain. This includes data for scheduling a recyclable household collection, transportation, and infrastructure for sorting, disposal and analysis of recyclable data. ICT-enabled digital platforms are an effective way to enhance compliance by the industries to the extended producer responsibility, improved household recycling rate and collection of recyclables by the waste reclaimers. The ICT-enabled waste management platforms provide accurate and traceable data regarding the characterisation and quantification of recyclables collected by waste reclaimers from households and landfill sites. However, despite integrating all stakeholders in the recycling value chain, these technologies only permit a few participants, like the companies, industries, government and buy-back centres, to monitor and track the MSW management activities.

In addition, the ICT-enabled digital platforms are developed on blockchain technology, allowing for real-time payment transaction systems of recyclable material and rewarding systems to households and waste reclaimers (Rybnytska et al., 2018). Blockchain technology can permanently record and secure every transaction transparently and in an immutable ledger accessible to all the participants in the recycling value chain. In blockchain technology, data is decentralised, which implies that data is accessible to everyone in the transactional network. Transparency is another important feature that is highlighted through the convenient visualisation of transactions resulting in each party in the transaction network having a copy of the ledger for the number of recyclable materials collected from households, characterisation of recyclables and total amount/fee of recyclables traded, in each transaction. For Pardini et al. *(*2019), what makes ICT-enabled platforms for MSW management critical is that through being developed on blockchain technology, they are tamper-proof, which allows for auditing EPR funds and transactions made with informal waste reclaimers.

Additional features, for instance, security and privacy of data generated MSW activities by waste reclaimers, bring confidence that the data will not be misused against the waste reclaimers but used to benefit both parties in the recycling value chain. Zhou (2015) argues that the technology protects the data co-created in collaboration with waste reclaimers by ensuring that transactions and identities are secure, and access is restricted only to waste reclaimers and other stakeholders in the recycling value chain according to the requirements of the EPR regulations. The consensus mechanism and the smart contract allows the ICT-enabled digital platforms to perform digital transaction between the waste reclaimers and buy-back centres (Akram et al., 2021; Pardini et al., 2019). The digital transaction brought in by the adoption of ICT-enabled platforms allows for virtual currency and the adoption of other electronic payments instead of relying on cash only when trading in recyclables in the informal recycling sector. This has proved effective in China, where virtual currencies and other electronic payments increased the transactions and volumes of recyclables being traded due to various payment options (Xue et al., 2018).

The use of ICT in the informal recycling sector is the focus of Coelho et al. *(*2019) in the Brazilian case of the RELIX App. The RELIX App is an ICT-enabled waste management digital platform adopted in north-eastern Brazil and used by 26 municipalities and more than 45 000 waste reclaimers. It consists of providing and allocating Eco-bikes and a smartphone application for easy communication with households and collection of materials by waste reclaimers, cooperatives and associations. Seetharaman et al. (2019) applaud the RELIX project for improving the quality of life and working conditions of waste reclaimers through the provision of "a kit containing a bag, a sun hat with neck protection, a UV protective shirt, a pair of gloves, a padlock and chain, and a calibration pump" (Coelho et al., 2019:09). Through the use of the RELIX App, waste reclaimers have observed increased income, social inclusion, reduced harassment, better working conditions and recognition as legitimate stakeholders within the recycling value chain. In addition, the App allows households to request the collection of materials by waste reclaimers allowing for interaction and communication between the households and waste reclaimers, opening the way for other activities for reclaimers to earn income, for instance, cleaning yards and cutting grass (Coelho, Hino and Vahldick, 2019). However, despite the associated benefits of adopting the RELIX App to improve the working conditions of waste reclaimers and connect them with households, the App needs a supporting mechanism to enhance its efficiency and effectiveness in improving the household recycling rate and integration of waste reclaimers.

China is experiencing a rapid development of a new "internet +" recycling program that "implements the internet idea, technology, and mode into the way of recyclable resource recycling" (Wang et al., 2018). The private sector implements the "Internet +" recycling program, especially ICT companies that become waste collectors and design innovative systems using "internet + resource recycling website and applications to connect households, waste reclaimers, sorting centres and industries (Wei, 2016 and Wang, et al. 2015). For example, the new "internet + resource recycling" recycling program developed by Dafeng in Hunan has more than 30 000 households using the platform since 2015, increasing the door-to-door collection to fifty per day (Wang et al., 2018). The residents who request Dafeng to collect recyclables from their households are being rewarded with a payment of between 15 – 60 yuan (Song et al., 2016), and also the platform is saving the municipality an estimated "50% of municipal waste transportation and disposal fees" (Wang et al., 2018). In addition, using ICT-enabled platforms has reduced the distance for waste reclaimers due to online appointments and improved the transportation logistics to collect and transport recyclables from households to the sorting centres by waste reclaimers.

Finally, countries like Colombia, India, China and South Korea have adopted a new collection model known as the 'intelligent collection' in which the recyclable materials "are collected with the assistance of Internet and Communication Technologies (ICTs) and Internet of Things (IoT) tools" (Xue, Wen and Bressers, 2018:309). The adoption of ICT-enabled systems in Colombia and China highlights two models of integration, the 'collaboration' and 'in-depth' integration of waste reclaimers (Xue, Wen and Bressers, 2018; Wang et al*.,* 2018; Song et al., 2016). For in-depth integration, the waste collector companies employ experienced waste reclaimers already familiar with the informal recycling system, provide them with smartphones, Eco-bikes or tricycles, intelligent devices, training in intelligent collection techniques, welfare benefits and social security provided by the companies or waste collector companies (Xue et al., 2018). In China's Beijing and Hangzhou areas, the HG Company and INCOME Company have integrated more than 1233 waste reclaimers and 450 waste reclaimers, respectively. A collaboration integration model is an approach where a waste reclaimer joins the ICT-enabled platform as a user, not an employee, to get collection requests from households and record transactions at the buyback centres. In Colombia, the industries have adopted the BanQu App in collaboration with the waste reclaimers and municipalities to track and monitor their compliance with the requirements of the EPR regulations.

The ICT-enabled digital platforms in MSW management appear promising in the informal sector within the smart city waste management in that the digital platforms provide a systematic and organised collection system for waste reclaimers and act as an enhancement to the formal MSW collection system through the provision of household separation at source services (Song et al., 2016; Xue et al., 2017). The waste collector companies using the ICT-enabled platforms are now the institutions of waste reclaimers' integration and environmental sustainability. Companies in Colombia, Brazil and China are collaborating with local municipal solid waste management systems to improve and achieve separation of waste at source and household recycling targets. Recently, developing countries have adopted the ICT-enabled platforms within the EPR framework to establish an intelligent collection model, for instance, Shanghai (Wu et al., 2017). The ICT-enabled platforms combined with the EPR framework promise to provide an effective and efficient solution for high resource efficiency recycling and intelligent collection (Aparcana, 2017).

Finally, 'big data' is another feature that illustrates the level of innovation brought into the informal sector through the adoption of ICT-enabled waste management digital platforms in MSW management. Brown et al. (2011) argue that 'big data' can significantly transform the informal recycling sector and provide entrepreneurship solutions. Data on the contribution of waste reclaimers was absent, and big data has provided an opportunity to collect, store and analyse data on MSW activities. The ICT-enabled digital platforms "create, receive and collect machine and/or sensor-generated data" (Aswani et al*.,* 2018), which drives the material recycling process in the informal sector through detailed patterns and insights on household waste characterisation and income levels for each waste reclaimer (Shirdastian et al., 2017). Big data enhances organisational performance for waste reclaimer organisations, cooperatives and association and empower the waste reclaimers to tackle various business challenges (Yaqoob et al., 2016) and knowledge co-creation involving other stakeholders in the recycling value chain (El-Kassar & Singh, 2018). This would guide the waste reclaimer integration process and payment of waste reclaimers using evidence-based decision-making (Rehman et al., 2016).

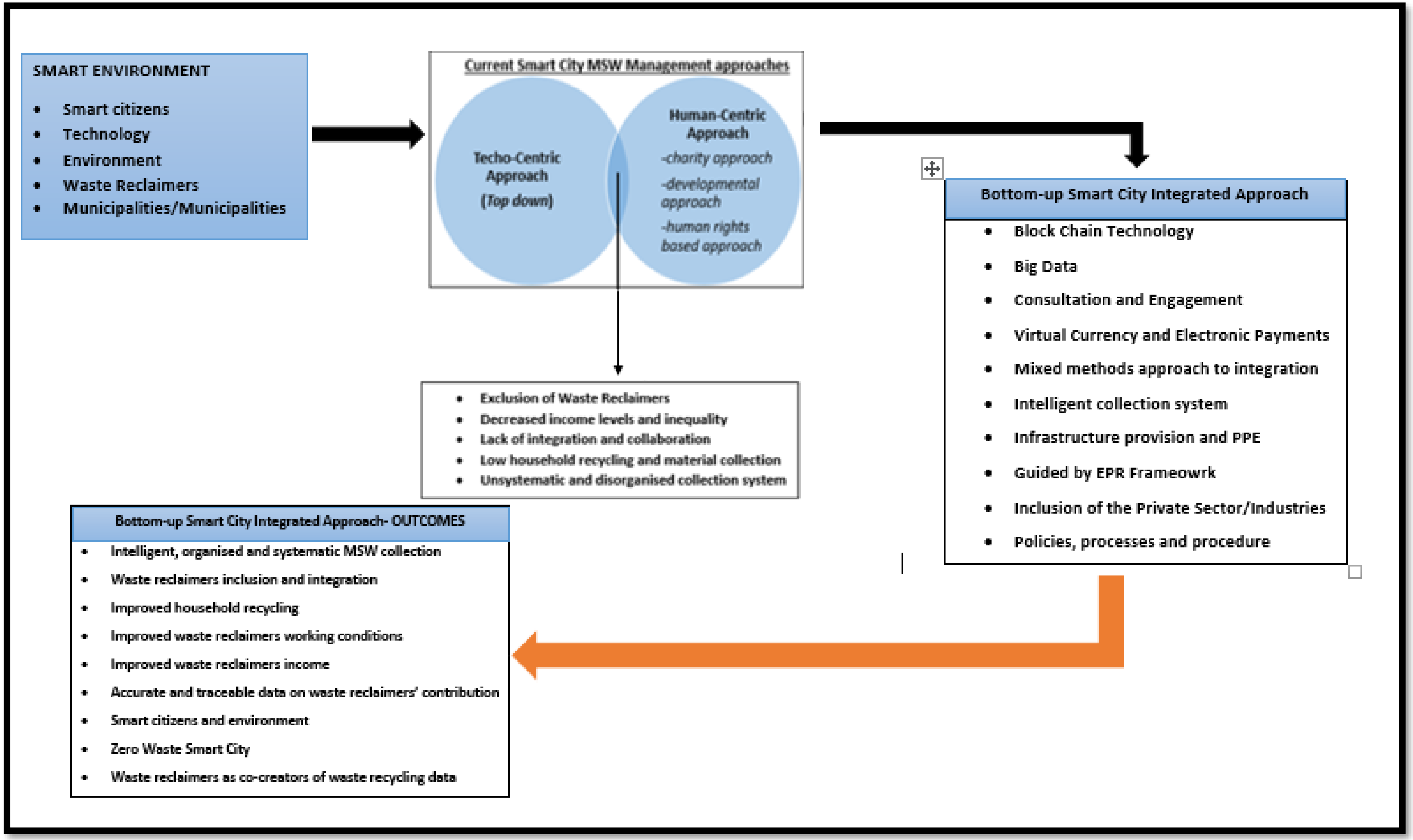


**FIGURE 2.3.** CONCEPTUAL FRAMEWORK OF THE BOTTOM-UP SMART CITY INTEGRATED MODEL BASED ON LITERATURE REVIEW. **(SOURCE: AUTHOR, 2021).**

## 2.10 The research gaps in the current Smart city approach in ICT-enabled MSW management.

This chapter has illustrated some waste reclaimer integration models adopted by municipalities and national governments in the current smart cities: top-down approaches framed within the poverty reduction and charity approach. These strategies do not acknowledge the emerging ICT-enabled applications through the EPR framework. Using experiences from 20 cases of waste reclaimer integration in China and Latin America, Aparcana (2017) concludes that the policy and institutional frameworks were the barriers to most of these integration attempts as they ignored the private sector initiatives in the integration processes. The EPR framework has brought in the private sector, which has invested in applying ICT-enabled platforms and the Internet of Things (IoT) in MSW activities resulting in a new ICT-enabled and intelligent informal collection system for recyclable material. ICT-enabled platforms and the Internet of Things (IoT) have facilitated the digitalisation of the informal recycling sector through Internet-based recycling, allowing households to request recyclables collection and get incentives for recycling (Sun et al., 2018). This adoption of the ICT-enabled platforms and Internet of Things (IoT) in the informal recycling sector leads to the following questions: What are the key features of the ICT-enabled waste reclaimers' system, and how is the model contributing to the integration of informal waste reclaimers and environmental sustainability?

The bottom-up smart city approach in MSW management is built upon the weakness of the current smart city models, and this research seeks to assess the influence of the ICT-enabled waste reclaimers system in the integration of informal waste reclaimers. The ICT-enabled waste reclaimers system acknowledges that a given smart city solution cannot simply be transplanted from one geographic region to another, and smart infrastructure concepts need to be made locally relevant and respond to local development needs since context, culture and economics all play a role in this process (Alverti et al., 2016). The ICT-enabled waste reclaimers system advocates for cities to consider solid waste management problems holistically before selecting appropriate smart technology solutions and balance the top-down and bottom-up governance approaches between various participants (such as universities, the private sector, civil society and local and municipal governments). In designing the ICT-enabled waste reclaimers system, the research seeks to answer the following questions: To what extent does the ICT-enabled waste reclaimers system interfere with and change the largely informal recycling systems in the urban centres in low-income South Africa? The research seeks to investigate how the ICT-enabled waste reclaimers system can enhance the integration of the informal recycling sector into the formal recycling structures and establish the significance of digital transformation in the informal sector for the waste reclaimers for which informal recycling forms a major livelihood asset.

Currently, there is a lack of permanent, accurate and traceable data regarding the contribution and role of waste reclaimers in MSW management and recycling activities (Srivastava et al., 2015), and where available, it is based on ambiguous data and extrapolation (Samson et al., 2020). Researchers and policymakers have suggested blockchain technology to solve these challenges in the informal recycling sector (Memon et al., 2019). Blockchain technology can record and track all the activities in the informal recycling value chain, analyse the data trends regarding waste quantification and characterisation, and even record all the payment transactions. Thus, there is a need to assess the extent to which blockchain technology has impacted informal waste reclaimers and buyback centres through a "complete record of transactional ledgers in an immutable and transparent manner" (Chen et al., 2019). How does transparency enhance the integration processes and enable the tracking and monitoring waste diversion and recycling targets determined by the regulations?

Apart from assessing the role of ICT-enabled digital platforms, this research addresses the aspects of citizen consultation and participation in designing the ICT-enabled digital platforms and the challenges faced in using these platforms. As discussed in the conceptual critique of 'smart cities', it was highlighted that bottom-up smart city planning is absent as citizens and waste reclaimers are passive recipients and mere users of the platforms to benefit the private companies. On the other hand, bottom-up approaches to smart cities allow waste reclaimers to co-design the platforms due to their technical knowledge and expertise of the informal recycling value chain and co-creators of data together with all participants in the network. Thus there is a need to investigate the extent of waste reclaimer participation and identify the challenges waste reclaimers and private companies face when engaging with each other. By following the socio-technical theory to sustainability, this research will bridge the gap in citizen participation.

## 2.11 Conclusion

This chapter locates this research in the context of the "bottom-up smart cities waste management approach", exploring the ICT-enabled platforms as instruments for facilitating the waste reclaimers' integration processes and achieving the zero-waste goal. The research gaps were identified in this chapter in the current state of smart cities and their approaches to municipal solid waste management. The following chapter (Chapter 3) will locate this research within the South African context, looking at the status of implementing the smart city and why it is necessary for this research to be carried out in South Africa. The research will discuss the current smart city initiatives and waste reclaimer integration processes in South African cities to position this research. Within Chapter 3, theoretical frameworks will be used to respond to the research questions and answer the gaps identified in Section 2.8. A detailed review of the theoretical frameworks is provided in the next chapter.

# CHAPTER THREE: SOUTH AFRICAN CONTEXT

## 3.1 Introduction

This chapter presents literature on the South African perspectives on 'smart cities' and informal waste reclaimer integration practices. International experiences inspire the 'smart city' trajectory and waste reclaimers integration models in Brazil, India, Colombia, the Balkans and China. The chapter will introduce the South African context of smart city definition, drivers and the trajectory of implementation within MSW management. The chapter further reviews the South African municipality-led and consultancy-driven models of 'smart cities', which includes exploring barriers that impede the digital transformation of the informal recycling sector. The second section reviews the current waste reclaimer integration practices and how they have failed to transform the informal waste collection system. The third section of the chapter explores the Extended Producer Responsibility (EPR) regulation resulting in the emergence of ICT-enabled waste management digital platforms towards the waste reclaimer integration and zero waste goal in South Africa. The chapter also reviews the socio-technical transitions theory to sustainability as the theoretical framework underpinning this study (Geels and Schot, 2010). The chapter concludes by positioning the research in South Africa, particularly the prospects of the current Extended Producer Responsibility (EPR) and Waste Picker Integration Guideline for South Africa and Corporate Social Investments (CSI) practices on the ongoing integration of informal waste reclaimers' process and the digital transformation of the informal recycling sector through the use of ICT-enabled waste management digital platforms.

## 3.2 South Africa's Smart City Perspectives

This section reviews various policies, current practices and legislation on Smart City and MSW management at both national and local levels through cases of bottom-up smart city examples in Johannesburg and some instances from the City of Cape Town. The smart city agenda has been adopted for urban services delivery by cities in South Africa to respond to their local challenges (Mosco, 2019). In both the 2019 and 2020 State of the Nation Addresses (SONA), the impact of the smart city agenda and the Fourth Industrial Revolution (4IR) in resolving the challenges of urbanisation in South Africa was highlighted by President Ramaphosa. The interest in the smart city agenda gained momentum after the SONAs, with different players developing silo projects and responses to city-wide challenges, mostly business-led, consultancy driven and top-down approaches (Siwawa, 2020). The current top-down and techno-centric smart city approach has led the excluded and marginalised stakeholders in urban services provisions to question the role of smart cities as a panacea to the problems of waste management, poverty, transportation, housing and unemployment (Arreff, 2019). Marrian (2020) notes that compounding the scepticism about smart cities is the fact that South African cities have different approaches to engaging with the smart city concept. Therefore, before examining the influence of the bottom-up smart city approaches and model, it is crucial to understand the smart city model in a South African context, given that cities, policy, legislation and literature have not defined this understanding. The smart city concept is understood as a *glocal* phenomenon that considers the universal context and the local features that influence the implementation of the smart city concept in South Africa, ravished by inequality, poverty and poor living conditions.

Nationally, within the South African context, the smart city perspective focuses on citizen connectivity, smart service governance, and mega infrastructure projects driven by the politicians/elites and top-down (Forster, 2020). This is illustrated in the 2019 State of the Nation Address (SONA) by President Ramaphosa, in which he outlined the smart city vision of South Africa encompassing “high-speed trains” connecting “megacities and the remotest areas of our country” and “to build a new smart city founded on the technologies of the Fourth Industrial Revolution” (SONA, 2019). However, the citizens of South Africa were not consulted on whether this was the kind of smart city development they desired and what smart city development meant within the South African context. The 2019 State of the Nation Address (SONA) does not mention a national framework nor provide a strategy for citizens to engage with technologies and smart services. Although smart city development is seen as a panacea to current city-wide challenges, unfortunately, the policies are primarily developed without citizen participation or with limited stakeholder engagement.

As South Africa embraces the fourth industrial revolution (4IR) brought about by ICT and digital internet connectivity, the concept of a smart city has been brought to the forefront. Municipalities in South Africa are adopting ICT in response to city-wide challenges and enhancing liveability through an efficient internet connection and intelligent provision of services (Hubbard et al., 2017). Balkran (2019) identifies high-speed internet connectivity as a fourth essential utility in smart cities after water, electricity and gas. Although the smart city concept is gaining traction in South Africa, municipalities are far off compared to Masdar, Songdo and Abu Dhabi smart cities. Municipalities are currently grappling with inefficiencies in various sectors such as waste, water, social development, transport, energy and housing (SACN, 2016), which requires stakeholders' buy-in, making smart cities a misplaced priority (Arreff, 2019). For a successful smart city roll-out in South African cities, it requires multi-stakeholder engagement, political support and leadership with a clear vision, but often the reality is mismatched with the vision. The reality of inequality, exclusion of informal waste reclaimers and the apartheid legacy coupled with incompetence have perpetuated South Africans to reside on the periphery of society (Ramphele, 2019).

## 3.3 The Smart City Model – South African Context.

The conversation on the concept of smart city agenda in South Africa dates back to the early 2000s with a series of wide-ranging concepts that allowed cities to implement tailor-made local approaches in responding to local challenges (Mosco, 2019). However, since then, the smart cities' conversations and projects have been made in silos at the municipal level with differing outcomes, resulting in different contextual meanings of a smart city in South Africa. Despite the absence of a universally agreed definition of smart cities, ASSAF (2019) defined a smart city as: "the diffusion of science and technology within the local spheres whilst creating an enabling environment for the deployment of local technologies to address the local challenges whilst improving the quality of life of South Africans." For South African Local Government Association (SALGA), smart cities, "are not only based on technology and automation but involved socio-economic, legal, political and environmental dimensions and addressed municipal functions in the various sectors" (ASSAF, 2019).

The South African Cities Network (SACN, 2020) pointed out that there is a challenge in finding a common definition of smart cities in South Africa, and the lack of an integrated national smart cities policy or strategy further exacerbates the situation. This absence has consequently resulted in the move towards smart city status largely being implemented in the local government sphere. However, in the local government sphere, the Municipal Integrated Development Plans (IDPs) do not relate to the concept of smart cities as the IDP framework was designed decades ago and thus needs to be replaced with a new mandate for local government that focuses on raising competitiveness (ASSAF, 2019). Therefore, most municipal IDPs and national legislation like the National Development Plan (NDP) ought to be revisited to incorporate the Fourth Industrial Revolution (4IR) and become the leading strategic agenda of South Africa.

South African Local Government Association (SALGA) is a membership-based body of all municipalities in the country and represents, promotes and protects the interests of local government in various forms and on many different platforms. SALGA is mandated to strengthen local government in terms of efficient service delivery. During the ASSAF Smart City Forum in 2019, Mchunu from the South African Local Government Association (SALGA) presented the "SALGA Smart Cities Development Framework", which aimed: "to address the modernisation and transformation of municipal functions and operations through the use of smart technologies" (ASSAF Smart City Forum, 2019. Although technology is the foundation of the SALGA Smart Cities Development framework, other aspects were included, for instance, the environmental, legal, political and socio-economic dimensions to address and strengthen local government service delivery initiatives. Figure 3.1 clearly defines the SALGA Smart City Maturity Framework, as it identifies the municipal functions which will be improved through the adoption of ICT, IoT, and citizen participation, which would result in smart city outcomes, and the city will be rated according to their level of maturity in smart city strategy.

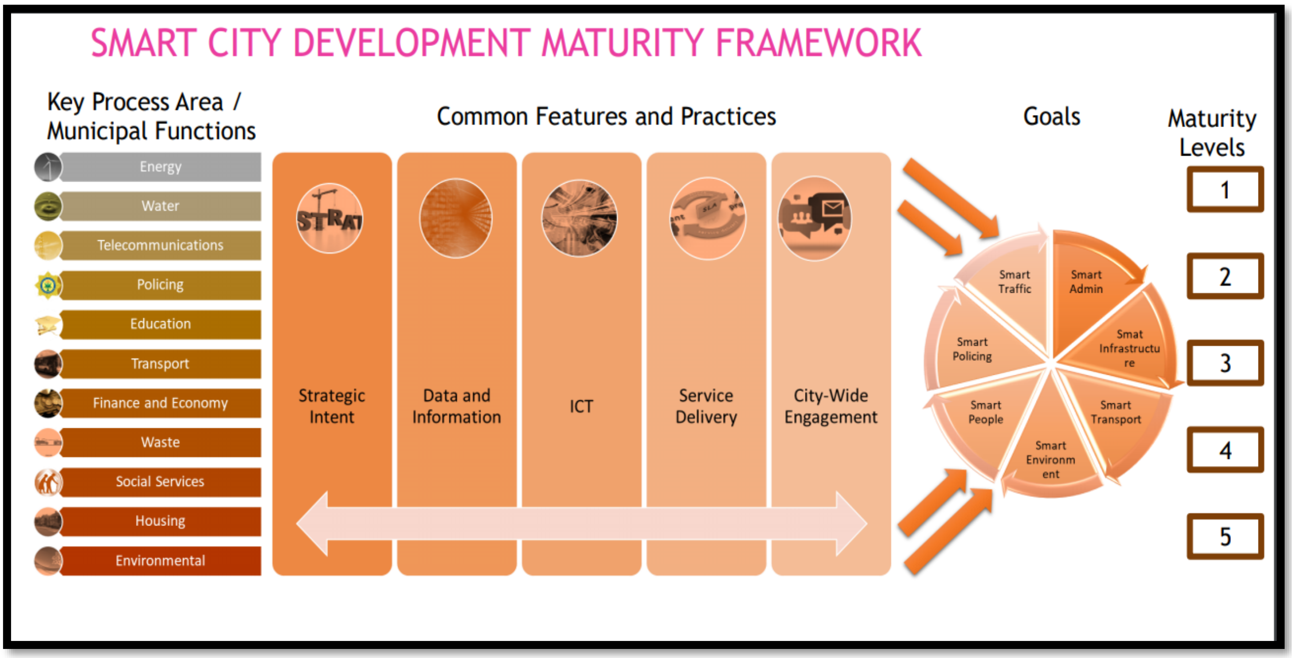


**FIGURE 3. 1.** THE SALGA SMART CITIES DEVELOPMENT FRAMEWORK: DESIGN. **(SOURCE: SALGA, 2019)**

In waste management (Figure 3.1), the SALGA Framework emphasizes the adoption and use of ICTs and IoTs to attain a Smart Environment ultimately. The techno-centric approach to MSW management is illustrated, and in its design, it ignores the already existing role players in the recycling and waste management sector. Although municipalities like the City of Johannesburg and the City of Cape Town ultimately aim to adopt automated waste management systems, it will disrupt the current informal waste recycling sector and might not be applicable considering the existing inequalities within CoJ and CoCT. The smart technologies SALGA advocates (see Figure 3.2) for smart waste management require advanced infrastructure, architecture and networks, which cities in South Africa currently do not have. In addition, the current inequalities between suburbs and informal areas will pose a huge challenge in adopting smart technologies in waste management.

Smart Technologies - Waste Management

| Smart Technology | Description | Use Case | Smart City Dimension | Technology Enabler Class | Architecture Layer |
|---|---|---|---|---|---|
| Smart Trash | Intelligent identification, sorting and recycling process. | Prevent the wrong stuff from finding its way into areas where they can cause harm | **ICT, Smart Environment** | Artificial Intelligence | Information Technology |
| Waste Collection Apps (My-Waste and Rubicon) | Local waste collection with waste and recycling information | Garbage and waste collection | **ICT, Smart Environment** | Smart device, Internet | Technology Infrastructure |
| IoT-Related Solutions | Network of devices connecting trash bins and smart devices | Offer communication solutions between the trash bins, the citizens, and the garbage collection agencies | **ICT, Smart Environment** | Internet, Electronics, Software, Smart Devices, Computers | Technology, Infrastructure |
| Fill-Sensors | Capacitive fill-level sensor for soiled media | Sends real-time data to city cleaning agencies | **ICT, Smart Environment** | Sensors, Monitors, Smart Devices, Computers, Internet | Technology, Infrastructure |
| Ultrasonic fill-level Sensor | Wireless ultrasonic fill-level sensor | Secures monitors in containers and sends real-time data to city cleaning agencies | **ICT, Data, Smart Environment** | Sensors, Monitors, Smart Devices, Computers, Internet | Technology, Infrastructure |

**FIGURE 3.2.** SALGA SMART CITIES DEVELOPMENT FRAMEWORK: WASTE MANAGEMENT. **(SOURCE: SALGA, 2019)**

Smart cities aim to harness new data-collecting technologies and advanced infrastructure to provide safe and more efficient service delivery for their citizens (Henreckson, 2018). The SALGA Smart Cities Development Framework is an excellent example of waste management services. The maturity levels in SALGA Smart Cities Development Framework (Figure 3.3) sought to measure smart city implementation towards smart city outcomes. The maturity level framework positions South African cities to their levels of achievements and implementation of smart city initiatives. Despite having this framework from SALGA, which should have been the point of reference for all municipalities, it is disappointing to note that during the 2019 ASSAF Smart City Forum in Pretoria, municipalities like the City of Johannesburg and the City of Cape Town were unaware of the SALGA Smart City Development Framework. This clearly illustrates the disjuncture between SALGA and its member municipalities towards implementing the smart city framework resulting in silo smart city projects in various cities in South Africa. The lack of a national framework further impeded smart city implementation in South Africa, resulting in the absence of proper coordination and silo smart city initiatives by municipalities. The lack of consultation between SALGA and member municipalities in the SALGA Smart Cities Development Framework production illustrates the silo approach to smart city implementation, which is disconnected from the local government and the grassroots people.

SMART CITY DEVELOPMENT MATURITY FRAMEWORK

| Level | Description |
|---|---|
| Level 1 – Non-Existent/Ad-hoc/Chaotic | *In this level there **are no discernible smart city features in a municipality**. There is no focused and municipal-wide **strategy** and planning for implementation of smart city capability. Activities and products implemented and used by the municipality that resemble **smart city features are ad-ho**c, un-coordinated and exist in isolation.* |
| Level 2 – Defined / Systematic | *In this level municipality has a defined enterprise-wide strategy to implement smart city capability. This is irrespective of the completeness of the strategy in covering comprehensive list of smart city dimensions, performance areas and goals. The strategy includes **practical and systematic implementation approach with multiple streams and implementation phases. An implementation programmes has been established, resourced and functional.*** |
| Level 3 – Purposeful / Repeatable | *Armed with a clearly defined and implementable Smart City Strategy, in this level the municipality is purposefully implementing their smart city strategy as per their plan. **There is a city-wide smart-city implementation programme which successfully coordinates the implementation of smart city capabilities across people, process and tools/infrastructure**. The programme harnesses lessons learnt from previous implementation phases for improved results in subsequent phases. There are successful smart city capabilities the municipality can show case in at lead 2 key process areas.* |
| Level 4 – Managed / Operationalised / Capable | *In this level a municipality has **implemented smart capabilities in varying degrees of success and efficiency across the municipal value chain in almost all smart city dimensions** where applicable. In this level the municipality has **achieved its smart city goals** for smart administration, service delivery, governance, economy, environment, technologies and citizen engagement.* |
| Level 5 – Optimised / Efficient | *At this level the municipality is fully smart city and **continuously improves and enhances** its smart capabilities resulting in high efficiencies, productivity and citizen satisfaction levels.* |

**FIGURE 3.3.** SALGA SMART CITIES DEVELOPMENT FRAMEWORK: MATURITY LEVELS. **(SOURCE: SALGA, 2019).**

However, while SALGA's initiative is a notable driving force, it is essential to examine the broader context of glocal (global-local) conversations and relationships that have contributed to the introduction of smart city concepts in South Africa. Insights from Astrid Wood's work on the Bus Rapid Transit (BRT) system in Cape Town and Odendaal (2020)'s research on smart cities shed light on these dynamics. The integration of the BRT system, as discussed by Wood, exemplifies a glocal approach where global concepts are adapted to local contexts, potentially influencing the introduction of smart city ideas. Similarly, Odendaal (2020)'s work on smart cities reveal connections between global smart city discourses and their translation into the South African context.

These glocal conversations and relationships could serve as conduits for the transfer of knowledge, ideas, and best practices related to smart city development. By exploring the intersections between SALGA's endeavours, local initiatives like the BRT system, and the insights of researchers like Odendaal (2020), a more comprehensive understanding of the genesis and evolution of smart cities in South Africa can be attained. This holistic perspective enables us to discern how global smart city narratives are adapted and applied within local contexts, shedding light on the intricate interplay between global influences and local realities in shaping smart city initiatives. These studies provide lens through which to examine how external ideas, influenced by glocal dynamics, interacted with local urban planning agendas and contributed to the introduction of smart city concepts in South Africa. The convergence of these perspectives helps illuminate the intricate interplay between global discourses and local contexts, ultimately shaping the trajectory of smart city initiatives within the country.

In their analysis of Smart Cities as misplaced priorities in South Africa, Musakwa and Mokoena (Undated) argue that the smart city initiatives in South African cities are top-down strategies implemented without considering the citizens' actual interests and needs. For example, in terms of smart mobility, Gautrain, which serves Johannesburg, Ekurhuleni and Tshwane in Gauteng, transports more than 1.5 million passengers a month from 300 000 when it started in January 2012 (Gautrain Management Agency, 2015). Still, Gautrain is considered exorbitant and appropriate for the affluent and middle class as it does not cater to most poor who need cheap transport (Donaldson & van der Westhuizen, 2011). Thus, developing a high-tech rail system and harnessing technology entrenches inequalities already existing in South Africa. Furthermore, even though the implementation of a smart city strategy is at the local level, what is disappointing is that most smart city projects' implementation and outcomes are departmentalised. Even at the local government level, cities adopt a contextual approach guided by the IDPs towards smart cities. This is exemplified by cities sharing boundaries and in the same province, for instance, the City of Ekurhuleni, the City of Johannesburg and the City of Tshwane in Gauteng Province, which all have smart cities strategies that are different in approach and do not complement each other.

### 3.3.1 The City of Tshwane

The Tshwane Vision 2055 seeks to reposition Tshwane, the administrative capital of South Africa, "as an e-Capital of excellence and a driver of education in the country, aligned to the creation of a Smart City and a knowledge economy" (Tshwane Vision 2055, 2013). The Tshwane Executive Mayor, Cllr Kgosientso Ramokgopa, has stated that the smart city strategy in the Tshwane Visio 2055 is about "the remaking of South Africa's capital city, creation of a new identity and ensuring that our City becomes a 'well connected, well-governed and managed City'" (Tshwane Vision 2055, 06). Smart cities' critical feature and component is "knowledge transfer and partnership" in best practices for urban services provision (SALGA, 2015). In 2005, the CoT was twinned with the Oulu City of Finland as the early smart city initiative in knowledge transfer and partnership. In 2009, the CoT launched the "e-Health Project", a digital platform that "provides health-care services by using ICT for information-gathering purposes to develop the development of electronic health records to be used in clinics" (SALGA, 2015). In addition, CoT, through Project Isizwe and Free TshWi-Fi, has rolled out some 783 Wi-Fi zones to date, offering free internet access to schools, clinics, informal settlements, libraries, and educational institutions, representing coverage to over 2 million people (Draft Tshwane Metropolitan Spatial Development Framework (TMSDF), 2019). Thus at the core of the smart cities strategy, digital transformation and technological solutions are at the centre of being adopted to improve service delivery in Tshwane.

Further to Waste Management, through the TshWi-Fi app, CoT encourages communities to access knowledge, skills, and tools to be innovative and develop their local tailor-made solutions for service delivery. According to the Draft Tshwane Metropolitan Spatial Development Framework (2019:78), the TshWi-Fi app provides citizens with "urgent announcements regarding other municipal service offerings from the City and offers access to new online skills and learning advancement features." In their findings, Caragliu et al. (2011) and Ramaprasad (2017) present the view that a smart city provides and uses information and communication technologies (ICTs) to improve the efficiency of urban operations and services. CoT has improved internet access and invested in human capital and modern (ICT) communication infrastructure to fuel high quality of life through participatory governance. In Waste Management, CoT, by 2055, seeks to adopt a "waste management infrastructure which supports separation at source and recycling through smart technologies investment programmes and incentives" (Tshwane Vision 2055, 2013). SALGA (2019) contends that the Tshwane Vision 2055, which seeks to transform and relocate Tshwane as a "well-connected and well-governed city", is influenced by globalisation and the neoliberal concept as Tshwane competes with other cities in South Africa. The smart city initiatives have been prevalent in education and knowledge, which seeks to improve access to knowledge and education, thus resulting in "smart people", one of the human-centric approaches to the smart city paradigm. In as much as the Tshwane Vision 2055 set a platform for recycling, not much has been implemented on the ground to create and develop such infrastructure for the circular economy. Thus at CoT, the concept of the smart city is a process, or a means to an end, where it is implemented to reposition CoT and improve access to education, empower the citizens and allow citizen participation.

### 3.3.2 The City of Johannesburg

The City of Johannesburg first mentioned the smart city concept in the 2013 Integrated Development Plan (IDP) as a strategy for transforming the city's governance and enabling the citizens to meaningfully participate in the urban services provision governance process (City of Johannesburg, 2013). However, in its 2017 IDP document (City of Johannesburg, 2017), smart governance was only confined to gathering data on citizens' expectations, unlike the 2013 IDP document, which viewed smart city initiatives as mechanisms for the provision of efficient urban services sustainably. The City of Johannesburg defined a smart city as "a city that makes decisions and governs through technologically enhanced engagement with its citizens who have universal access to services and information, where socio-economic development and efficient service delivery is at its core" (CoJ Smart City Strategy, 2014). For the City of Johannesburg, central to providing services and city governance is adopting ICTs systems and intelligence instruments for optimum citizen engagement and universal access to service provision.

CoJ seeks to evolve into a digitally enhanced and sustainable smart city by undertaking a program of Digital Transformation through:

1. "Connectivity, Smart Technology, and Access (for ease of communication, mobility, and access to basic services including broadband enabled through smart technologies),

2. Digital Service Delivery (Digital and 24Hours Online Citizen Services: e-Services, eHealth, e-Learning, e-Indigent Register, E-Central Customer Identity Verification, Smart Walk-in-Centres, Mobile Self Service Portals, e-Voting and e-Public Participation),

3. Digital Governance (big data and data governance, paperless council, smart boardrooms e-public participation, e-voting, etc.),
4. Digital Smart Citizen (digital literacy, internet access at homes, schools, public buildings, e-public participation, e-voting, etc.)" (CoJ Smart City Strategy, 2014).

For the City of Johannesburg, smart city initiatives have been implemented through digital transformation processes where the city can provide services through different city portals. In addition, to support the digital transformation and improve access to the internet, CoJ rolled out a free Wi-Fi drive throughout the city to improve public participation in city programmes. In addition, since smart city strategies are influenced by neoliberal policies (SACN, 2020) and the privatisation of public services, the city adopted this strategy and rolled out services through city-owned entities like Joburg Water, City Power, City Parks and PIKITUP. The South African local government context denotes a smart city as a process and a strategy to provide efficient service delivery in areas of their jurisdiction. Interesting to note is that technology is at the core of their smart city strategy towards efficient service delivery. Technology has impacted social groups in different ways in their bid to access services from their respective municipalities.

The smart city vision for the City of Johannesburg is located within the IDP document and a separate Smart City Policy document providing set objectives and smart city initiatives. What is clear from this context is that the IDP is used as the smart city guiding framework for developing and implementing smart city initiatives in South African municipalities (SACN, 2020), and citizens are involved as recipients and users of municipalities' smart city infrastructure for data collection and access. However, the weakness of the IDP is that the document is limited to the local level and is not connected to other levels of government in smart city planning and development (Fuo, 2013). For example, in Johannesburg, the smart city concept has adopted ICT initiatives connected to the city's strategic vision and priorities.

The 2017 IDP for the City of Johannesburg defined the smart city concept within the technocentric approach, which advocated using ICT technologies and data to sustainably provide efficient urban services (SACN, 2020). This strategy is evidenced by the city launching an Integrated Intelligence Operations Centre (IIOC) to "integrate all municipal data on a single platform in a bid to improve decision-making on critical service delivery issues, using technology" (City of Johannesburg, 2019). The city's Integrated Intelligence Operations Centre (IIOC) seeks to create an integrated effort towards service providers and enable the city to "have a single integrated platform for critical municipal data for the benefit of the city's population and economy, thereby enabling the City to make informed decisions based on accurate data generated from citizens" (City of Johannesburg, 2019). Currently, the IIOC focuses on Inner-City safety, security and reducing crime in Johannesburg. The city's future vision is that residents will be able to send images of damaged infrastructure and uncollected refuse/waste to the IIOC to initiate response and improve service delivery in Johannesburg.

The Smart City Office in the City of Johannesburg is housed in the Mayor's Office, and the 2013 Mayoral Committee adopted the Smart City initiatives within the IDP. Locating the Smart City Office within the Mayoral Office illustrated the level of commitment by the political leadership and how it prioritised the implementation of smart city projects in the city. Smart city projects require various departments and stakeholders to collaborate with financial, infrastructure and human resources jointly, hence its strategic location within the Mayor's Office. However, despite its strategic location within the Mayor's Office, much is required to fully implement and make an undertaking that the Smart City strategy is fuelling the activities of all the city departments.

### 3.3.3 The City of Cape Town (CoCT)

The City of Cape Town is identified as one of the pioneers of the smart city concept, and this concept was first started in the City of Cape Town's 2002 IDP document. Although the 2003 and 2008 IDP documents were silent on the smart city concept, the City partnered with the private sector to harness ICT by creating technology hubs and open data portals for its citizens (Pollio, 2020). From 2013 onwards, there has been a shift in the City of Cape Town's smart city dimension from the economic growth perspective into ICT for efficient service delivery perspective linked to waste provision and transport management (SACN, 2020). The City of Cape Town's smart city dimension focuses on ICT integration, emphasising ICT operations and digital infrastructure. Unlike the City of Johannesburg, which is focused on smart city development, the City of Cape Town adopted the digital city strategy that:

> "use[s] ICT to improve service delivery, stimulate innovation and improve citizen-government interaction. The aim is to improve digital infrastructure through a government-provisioned fibre network and to improve digital inclusion; and the focus is on rolling out IT infrastructure in public spaces such as municipal libraries. The goal is for Cape Town to be the most connected city in Africa, and the four pillars of focus are digital governance, digital citizen, digital infrastructure and digital inclusion" (SACN, 2020:32).

The City of Cape Town defines itself as a smart city through "digital transformation", and technology is at the core of the smart city definition by the City of Cape Town (IDP 2017 - 2021, 2017). The CoCT Digital City Programme (IDP 2017 – 2021, 2017:71) lays the foundation of the smart city agenda in Cape Town, which aims "to use digital technology to transform Cape Town into the most digital city in Africa through investment in digital infrastructure, growing the digital economy, emphasising digital inclusion and enhancing the City's digital government capabilities," (SACN, 2020:30). The City Of Cape Town, widely regarded as the pioneer of smart and open governance in South Africa, was the first municipality to launch an Open Data Portal (https://odp.capetown.gov.za/ ) in 2015, which has enhanced interactive public engagement and stakeholders meeting using its digital citizen interactive platforms. The CoCT, through its digital platforms, has availed city data to all its citizens and public, "thereby increasing the administration's transparency and assisting innovation by entrepreneurs and organisations" (City of Cape Town, 2017: 72). As a champion of digital transformation in South Africa (IDP 2017 – 2021), the CoCT has implemented the SmartCape Initiative which is designed to bridge the technological divide by improving access to free internet and computer courses for the disadvantaged residents in Cape Town.

The Infrastructure Branch's Information and Technology Services (I&TS) department, housed within the Corporate Services Unit, is the driving force for the smart city initiatives within the City of Cape Town. The Corporate Services Unit is also responsible for implementing the city strategy and coordinates how data is used for city governance and urban service provision. The location of the digital strategy within the Corporate Services Unit illustrates its focus on infrastructure services rather than viewing the smart city strategy as driving the entire city's direction. SACN (2020) observed that implementing smart city initiatives is impacted by “less leadership, and efforts are more likely to be disorganised and uncoordinated.”

## 3.4 Municipal Waste Management Platforms in South Africa

### 3.4.1 The Waste Recycling App (WRAPP)

South Africa is experiencing the increased use of e-waste-based applications for household, business, industrial, construction and demolition waste in areas where municipalities fail to provide municipal waste collection services, emerging and gaining momentum. The creation and use of waste-based digital applications (Apps) have been rising in South Africa, the region, and globally. The waste management apps in the region have followed the approach of an "uber” or “Taxify" in the form of "Uber for Waste", where a household would request waste collection services since the municipality has failed to collect waste from their households. The individual would log into the digital application and request a waste service provider to come and collect the waste. This aspect of using waste management digital platforms is prevalent in Kenya, Rwanda and Ghana.

In South Africa, a similar digital platform called WRAPP focuses on household waste and provides waste collection services to all waste streams. WRAPP is a digital platform operated by private sector businesses that seek to complement the government in providing waste management services in South Africa. WRAPP digital platforms are not only for household waste but include all other kinds of waste from "small businesses, construction companies, shopping centres, renovators, housing complexes, homeowners and more [the client would] book their truck or skip, and local drivers and loading teams collect the waste for responsible disposal" (WRAPP, 2021). For example, if a client has building rubble or any waste, they will log in to the app that they have building debris and request a service provider to come and collect the rubble. After logging the request, a service provider will collect the waste. However, the weakness of these digital platforms is that the client will assume that the waste collection service provider disposes of the waste at the designated site or landfill because there is no tracking of the waste after collection from the household. It can be argued that, without tracking, the service provider might dump the household waste in undesignated areas, open spaces or by the roadside such that the client has inadvertently contributed to the illegal dumping of waste.

The CoCT Digital City Programme further aims to empower waste reclaimers within the MSW system through their open digital platforms as a tool and opportunity that improves their working conditions, increases their income and provides an opportunity for social inclusion. CoCT, as a hub of digital transformation through harnessing technology for optimum urban service provision, has allowed the development of urban services Apps, especially in solid waste management. The CoCT developed digital tools to manage and provide solid waste management through partnerships with other waste collectors registered within the CoCT Provider List. For example, the City of Cape Town launched and is currently utilizing the Waste Recyclers Digital Tools, namely the Waste Recyclers App and IWEX App, which are hosted on the Department of Waste Management website. Both digital Apps are hosted by the CoCT website and located within the Department of Waste Management. This illustrates that providing services through digital tools is at the core of municipal waste management and waste provision in the CoCT.

### 3.4.2 The IWEX App and Waste Recyclers App

The CoCT Digital City Programme further aims to empower waste reclaimers within the MSW system through their open digital platforms as a tool and opportunity that improves their working conditions, increases their income and provides an opportunity for social inclusion. CoCT, as a hub of digital transformation through harnessing technology for optimum urban service provision, has allowed the development of urban services Apps, especially in solid waste management. The CoCT developed digital tools to manage and provide solid waste management through partnerships with other waste reclaimers registered within the CoCT Provider List. The City of Cape Town launched and is currently utilizing the Waste Recyclers Digital Tools, namely the Waste Recyclers App and IWEX App, which are hosted on the Department of Waste Management website. This illustrates that providing services through digital tools is at the core of municipal waste management and waste provision in the CoCT. The digital transformation has enabled the CoCT to deliver services efficiently and effectively by bringing together recyclable material buyers and waste collectors into the same space, thereby improving business.

**IWEX** is based on industrial symbiosis, exchanging material waste from companies' production processes. This is apparent in the construction industry, where waste material is used in another sector, for example, offcuts of carpets, which can be used in the automotive industry. This is an exchange platform of waste materials between companies and industries so that it never becomes waste in the first place. The IWEX App provides freely available services to anyone who generates or uses waste, including companies, individuals, institutions, schools, NGOs, and community groups (CoCT, 2020). Waste collectors and buyers create their profiles by selecting the waste category that they specialise in, and this approach enables waste collectors to identify where they can find recyclable materials for collection and also locate buyers/intermediaries that offers excellent prices for their recyclable at competitive price, thereby improving their revenue income. However, despite the benefits of using this app, it has shortcomings as a top-down approach: it ignores the socio-economic dynamics and inequalities in Cape Town and South Africa. Furthermore, not all informal waste reclaimers have internet access and have challenges registering in the IWEX user Platform, despite the CoCT rolling out more than 100 new Wi-Fi zones and installing Wi-Fi access through the SmartCape across Cape Town.

Although the CoCT has a register of waste reclaimers and collectors, it is the city's policy to work with cooperatives and SMMEs/SMEs rather than individual waste reclaimers (CoCT, 2017). This approach is also similar to that of the City of Johannesburg, in which PikitUp partners with waste reclaimer cooperatives and SMMEs/SMEs so that they can be able to apply for the CoCT waste management tenders or partner with the private sector in the provision of solid waste management. This approach encourages waste reclaimers to form cooperatives and SMMEs/SMEs to be awarded contracts for collecting recyclable material.

### 3.5 Barriers to Bottom-Up Smart Cities transformation in South Africa

South Africa's drive towards digital transformation faces many barriers which require urgent remedial actions to accelerate the process of transforming South African cities into smart cities. Balkran (2019:20) identified "outdated and complex regulatory frameworks, gaps in digital infrastructure, lack of skills in the new city and, most importantly, a constant supply of power or energy" as barriers that impede digital transformation in South African cities. Backhouse et al. (2020) identify the absence of a South African contextual definition of smart cities and possible solutions at the grassroots level, which are not being captured. The techno-centric approach to smart cities, which many municipalities adopted, has led citizens to dispute the transformative role of smart cities in contrast to South African cities' challenges (Marrian, 2020; Horber, 2019). Amplifying the suspicion about smart cities is the silo implementation of the smart cities concept and different approaches by South African cities when engaging with the smart city concept. The current South African regulations, policies, legislations, literature and cities have not yet defined the understanding of smart cities.

The current approach in South Africa, particularly the application of ICTs, sensors and smart digital utility meters on water and energy management, mainly focuses on reducing resource consumption and improving commercial enterprise in providing city services (Deloitte & Touche, 2015). The smart city approach in South Africa is municipality driven through consultancies contracted to design the smart city policies and agenda where ICT systems and interconnected infrastructure can play a significant role in future development trajectory. Data, a critical component of smart cities (Lammel et al., 2016), plays a vital role in the daily functions and is collected from various affected stakeholders (citizens, developers, waste collectors, associations, cooperatives, consultants, city entities and city departments). However, the data collected by the city lacks maturity and depth and is still in the infancy stages, coupled with the absence of coherence and consistency across various municipalities.

The absence of accurate, coherent and sustainable urban data impedes the municipalities from adopting an inclusive and bottom-up smart city transformation as cities fail to make evidence-based and informed decisions (Thakuriah, 2017). The lack of accurate and sustainable urban data is attributed to the absence of an open data portal in cities and little emphasis on adopting a data-driven decision-making approach coupled with an inefficient data collection system that does not permit the measurement of data progress, especially in waste management towards zero waste goal. In addition, municipalities in South Africa are faced with the absence of an integrated, centralised and coordinated data management system that connects all city departments for collecting, reporting and analysing data. South African Cities Network (2020) note that in some municipalities in South Africa, a similar system in some departments is often executed in silo formats within a specific department that cannot be connected to other departments. Despite municipalities executing silo systems, the systems are inherently inefficient due to a lack of experts and capacity to champion urban data management in service provision.

The suburban-informal settlement standard of living illustrates high levels of inequalities within the existing economic system and the socio-political realities of South Africa. For Balkran (2019), the increasing inequalities in many South African municipalities have been ignored in many cities for technological advancement and innovation. South African Cities Network (2020) concur with the above sentiments by acknowledging that smart city initiatives will fail without first addressing the urbanisation problems towards providing better living conditions. In contrast to Xu & Geng (2019), who proposed for cities first to achieve the people's needs and quality of life, which will simultaneously transform cities towards smart cities, South African cities are adopting smart city initiatives to bridge the inequality divide and support the realisation of the citizens' needs.

The absence of a standard smart city theoretical framework in most South African cities is another barrier to the transformation of bottom-up smart cities (Jokudu and Wilson, 2020). Cities are not fully equipped to understand urban data's concepts, ideologies, methods and approaches towards developing visions of future cities and connections to environmental sustainability. ASSAF (2019), notes that the political leadership does not prioritise smart cities' infrastructure, data and intelligent systems. In addition, smart city initiatives are not clearly defined and explicit within various city departments. The silo implementation of smart cities is illustrated in various city departments having specific data portals for reporting and collecting data, resulting in inconsistent and inaccurate data. The silo approach emanates from different techniques used to collect data from stakeholders, citizens and service providers, leading to inconsistent urban data coverage of all cities' service dimensions. These further forces the municipalities to engage the private sector and consultants to source data from these private data providers at a cost that impacts the integrity and reliability of data if the municipality fails to pay for the complete data set.

The local government sector, mandated with the rolling out of smart city initiatives, has inadequate skilled personnel and councillors who are unaware of the value of data in smart city development (Thakuriah, 2017). Consequently, municipalities have no qualified experts in data management, which leads to municipalities sourcing data from external contractors and service providers for analysis at a substantial cost. In addition, some departments are resistant to sharing data within the municipality, while the national and provincial departments are often unwilling to share data with municipalities. For Balkrans (2019) and SACN (2017), these are the missing key components towards innovative city development in South Africa. This culture is entrenched through various legislations like the POPI Act, which restricts data sharing. SACN (2017) and Thakuriah (2017) identify the municipality's differing mandates as a cause for inconsistent reporting, duplication of duties and fragmented silo implementation of smart city initiatives. This clearly illustrates a lack of data integration and protocol sharing between government departments and municipalities. Thus, without an enabling environment and supportive legislation, access to data will be limited between other branches of government and municipalities, resulting in the citizens shouldering the costs of securing data from external and private service providers. Furthermore, in some instances where data can be sourced from the private sector, there is a lack of strong partnerships and coordination among various stakeholders to benefit from and access the data.

The implementation of the smart city initiatives is hampered by the absence of a national coordinating or regulatory body and supporting legal framework that regulates and facilitates the smart city rollout in South African municipalities (Balkran, 2019; ASSAF, 2019). This is visible, for example, in fibre networks and internet fibre trenching in various municipalities where different companies trench the same pavement. This duplication of fibre cable laying by different companies on the same pavement is manifested by the absence of national regulation to enable a coordinated rollout of this infrastructure. In addition, strong partnerships and coordinated leadership are crucial in many municipalities f to adequate planning for a step-by-step process for smart city development (Xu & Geng, 2019). Thus, without the guiding national smart city framework, coordinating body, partnerships, and coordinated leadership, smart city projects in South Africa will be fragmented, haphazard and sporadic, resulting in increased inequalities and a digital divide.

## 3.6 Informal Waste Recycling and Informal Waste Reclaimers' Integration Initiatives in South Africa

This section provides an overview of informal waste recycling and informal waste reclaimers' integration in South Africa post-1994 era. Zia, Devadas, & Shukla (2008) identifies the informal and formal sectors as two citadels of urban economy in developing countries. Despite acknowledging the growing and established informal sector as a centre of resilience and livelihood in African cities, Smit and Musango (2015) lament the failure of the government to value and support the informal sector in its contributions to the circular economy and waste management services. Although there is growing recognition for the integration of the informal sector into municipal waste management services (Brown and McGranahan, 2016; DEFF and DSI, 2020; Samson et al., 2020; Godfreys, 2021), the question of how the ICT-enabled digital platforms will transform the informal sector requires much attention. The initial point will be to discuss the current informal waste reclaimers' integration initiatives which all have played a central role in adopting ICT-enabled digital platforms in the informal sector. This section will provide an overview of the informal waste recycling and informal waste reclaimers' integration initiatives in South Africa and argue for the need for ICT-enabled digital platforms towards the Zero Waste goal prescribed in the Polokwane Declaration (Taiwo, Otieno & Venter, 2008).

### 3.6.1 Informal Waste Reclaimers and their role in Municipal Solid Waste Management (MSWM)

Historically, South Africa is lagging behind developed countries in sustainable MSW which focuses on zero waste to landfill through waste reclaimer integration initiatives, recycling, reuse, prevention, reduction and recovery (Godfrey and Oelofse, 2017). Medina (2000) alleges that waste reclaimers are in the lower part of the informal recycling chain and are individuals involved in waste picking for survival.

"Waste pickers", "waste collectors", and "waste recyclers" are terms used by Marello and Helwege (2014) to define people collecting and selling recyclable waste materials for a living. In South Africa, waste pickers are also known as "reclaimers", "scavengers", "garbage pickers", and "informal recyclers" (Schenck and Bleeuw, 2011; Samson, 2010) who earn income through salvaging recyclables from landfill sites, streets, and households bins for reuse or sale to the waste collectors (middleman) or buyback centres. In South Africa, Samson et al. (2020) identify two categories of waste reclaimers: individuals operating in landfill sites or the streets. The former category is in constant conflict with the municipal police in the landfill as they hinder the compaction of waste (Medina, 2008) and the latter conflict with the households, motorists and the municipal police for littering open spaces after sorting their waste and causing traffic congestion with their trolleys (Guya, 2019). Therefore, the name "reclaimer" will be adopted in this thesis as an emphasis on "the revival and reclamation of value inherent in the practice of waste-picking" (Samson, 2017).

The informal waste reclaimers who operate in the streets are the most visible participants in the informal recycling value chain; however, for Mitchell (2008) and Samson (2009), waste reclaimers are harassed and marginalised within the MSM system. Due to their physical appearance, which is 'undesirable, posing problems to society' (Sentime, 2011: 1), waste reclaimers are framed as a nuisance to motorists and criminals to society (Simatele and Dlamini, 2016). In South Africa, "most people prefer not to see the [waste collectors] and look down on them for doing such dirty work; many municipalities consider them to be a nuisance and are trying to get rid of them" (Samson, 2008:3). Without recognition and legitimacy, waste reclaimers are exploited in the informal recycling value chain by waste collectors and buyback centres. During a webinar presentation on ***Collaborating with Reclaimers for Waste Picker Integration*** on September 13, 2021, the African Reclaimers Organisation (ARO) lamented that waste reclaimers were constant victims of threats, harassment and loss of recyclable materials from private waste collectors contracted by the municipality for separation at source projects especially in affluent suburbs in Johannesburg. Consequently, due to this perception, waste reclaimers endure stigmatisation, marginalisation and harassment (Samson, 2009), which defeats the various efforts to improve their living and working conditions.

One of the characteristics of waste reclaimers is that most waste reclaimers are either internal or external immigrants (Yigits, 2015 and Sentime, 2011). Theron (2010) identifies waste pickers as poor individuals, migrants with no access to resources and protection whose livelihoods are based on garbage collection from households, landfill sites and market places. Landau (2014) concluded that foreign immigrants employed in the informal waste recycling sector are twice as many as the locals. The African Reclaimers Organisation (ARO), an active waste reclaimer organisation in Johannesburg, has an estimated 6 000 members and "a lot of our members are foreign nationals, some who have papers and some who may not" (ARO, 2021). Research in South Africa (Sentime, 2011; Mamphitha, 2011; Schenck and Blaauw, 2011) did not produce definite results on foreigners but found that most immigrants in South Africa come from the SADC region and more than half from South Africa.

Foreign migrants who moved to South Africa and failed to secure formal employment resort to waste reclaiming to earn a living, generate income, and remittances back home (Schenck et al., 2012). In South Africa, the majority of waste reclaimers are foreigners without identity documents or work permits (Simatele and Dlamini, 2016; Gregson et al., 2016), which explains the government's treatment of waste reclaimers as unregularised and illegal residents posing a danger to society (Sentime, 2011). As a result of being unregularised and illegal immigrants without legal protection, waste reclaimers face social exclusion, manipulation and exploitation within the recycling value chain (Schenck et al., 2012; Samson, 2010). In addition, the job of being a waste reclaimer is risky, strenuous and exposed to health hazards which are described by Scheinberg (2011:49) as follows:

> *"[*they] face injuries from dogs, rats, and other vectors, combined with chemical and biological health risks due to contact with toxic substances, health care wastes, faecal matter, body parts, used syringes and other materials in the waste stream. In the best of situations, pickers report ergonomic problems due to the physically taxing nature of the work and psychological and social disadvantages stemming from their low social status*."*

Waste reclaimers do not enjoy benefits that accrue from formal work or are covered by labour regulations (Holt and Littlewood, 2017; Schenck, 2011; Viljoen, 2012). Like other informal workers, waste reclaimers are "largely denied access to social benefits such as health insurance, pensions and unemployment insurance" (WIEGO, 2012). The absence of access to resources, for instance, credit, impedes their access to technologies to improve their working conditions and economic viability (Wilson et al., 2006), which consequently reduces their bargaining power in the informal recycling chain as a result of collusion between private contracted waste collectors, middleman and buyback centres (WIEGO, 2012). More so, the MSWM system is evasive towards integrating waste reclaimers into the formal waste management system since waste reclaimers are perceived as competitors for jobs and recyclable materials (GIZ, 2011). Thus access to recyclable materials and social services to waste reclaimers is limited due to their social status in the recycling value chain.

Most waste reclaimers have no access to protective wear (PPE), thereby being exposed to working in harsh environmental conditions. Consequently, “severe and chronic occupational health problems” (Matter, Dietschi and Zurbrugg, 2013) are common among waste reclaimers. Dias (2000: 1) conceptualised the waste reclaiming process as demeaning work because of scavenging through the bins. Waste reclaimers were referred to as 'disposables' by the state police in Colombia, and this extreme stigma resulted in ‘social cleansing’ where the state police killed thousands of waste reclaimers (Ordonez, 1996). In addition, waste reclaimers work in unsafe environments: for instance, trolley pushers working in streets and residential neighbourhoods are susceptible to being crushed or run over by vehicles (Schenck et al., 2012). In some residential neighbourhoods, waste reclaimers are exposed to used syringes and sharp objects like razor blades which cut their fingers or poison their hands due to contact with toxic chemicals or germs (Gutberlet, 2016). This is due to waste reclaiming not being identified as a distinct category of work (Sentime, 2011), making waste reclaimers less recognised and highly vulnerable (Sekhwela, 2017).

The second part of this section sought to analyse the contribution of waste reclaimers in the MSWM systems despite harsh working conditions and the restrictive working environment to which they are exposed. South Africa has an increasingly active and large informal sector, with waste reclaimers estimated to be between 60 000 – 90 000 waste reclaimers operating in landfills (State of Waste Report, 2018; Department of Environmental Affairs, 2017). However, another estimate of the size of waste reclaimers in South Africa is approximately 215 000 (Godfrey and Oelofse, 2017), earning income through recycling activities. Scheinberg et al. (2006) state that the "numbers of waste pickers fluctuate because of population growth and economic conditions. If economic conditions worsen, the numbers tend to grow. Waste picking can (re)appear during particularly stressful situations such as war and severe economic crises leading to extraordinary circumstances and scarcity.” The increased visibility and estimates of waste reclaimers result from rising unemployment in South Africa and new immigrants resorting to waste reclaiming to survive.

Like other developing countries with less technologically advanced MSWM systems, waste reclaimers in South Africa collect and reclaim recyclable waste to generate income and improve environmental protection by diverting large volumes of waste away from landfills. In addition, informal waste reclaimers subsidise municipalities by providing alternative free collection services and reducing disposal costs (Godfrey et al., 2016). For example, Godfrey, Strydom and Phukubye These recycling achievements illustrate the significant role of the informal waste recycling sector, which has "been very successful in bridging the service and value chain despite little-to-no integration (of the informal sector) into municipal waste management services" (Godfrey and Oelofse, 2017). For example, the diagram below (Figure 3.1) from Godfrey and Oelofse (2017) illustrates the role of waste reclaimers bridging the service chain (what municipalities do) and the value chain (recycling economy) by diverting waste from landfills into recycling.

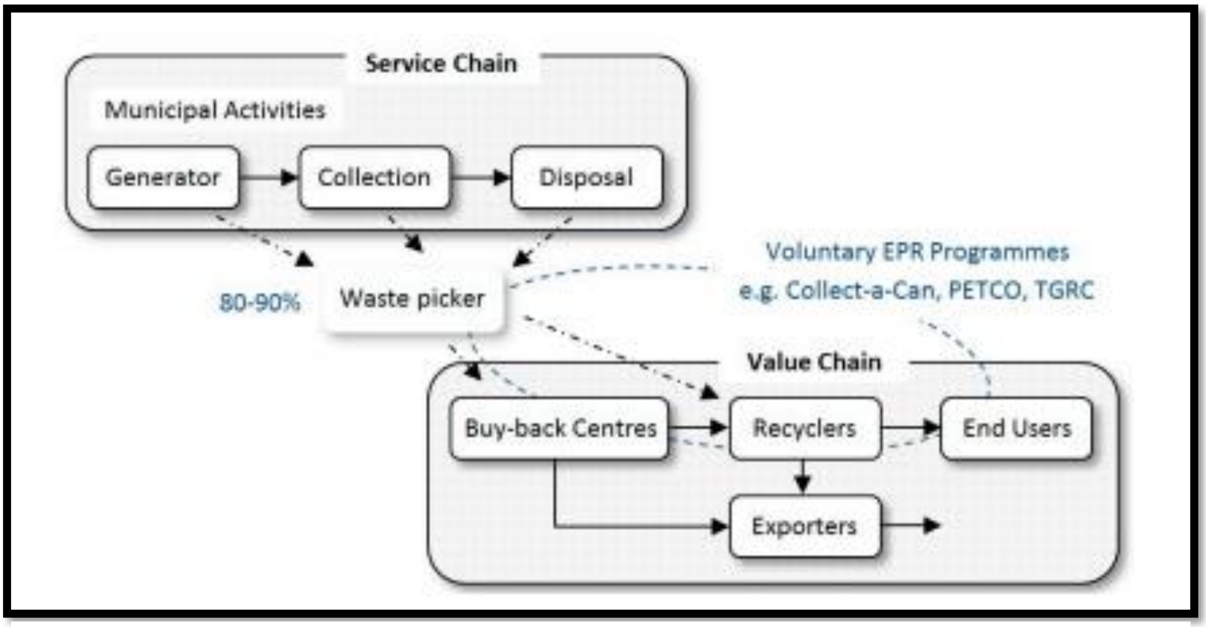


**FIGURE 3.4 .**THE ROLE OF WASTE RECLAIMERS AS A BRIDGE BETWEEN THE SERVICE CHAIN AND THE VALUE CHAIN. **(SOURCE: GODFREY AND OELOFSE, 2017).**

The active informal waste reclaimers in South Africa have been at the forefront of collecting recyclable material and diverting recyclable waste from landfill sites for recycling, reuse and recovery well before the municipalities and government adopted recycling projects (Samson, 2020). However, WIEGO (2019) assert that waste reclaimers are subsiding municipalities and government without compensation for the collection and transportation services they undertake in the recycling value chain. To date, waste reclaimers are only paid the resource value of recyclables they sell at buyback centres and to middlemen, unlike the formal waste collectors and contract waste companies who are paid both the collection services fee and resource value of sold recyclables. The compensation of these "free labour services" by informal waste reclaimers has been a subject of pilot projects (BanQu Project) in Johannesburg and is also addressed in the Waste Picker Integration Guideline for South Africa (Godfrey, 2021.) South African producers, and recyclers are not willing to compensate waste reclaimers for these services due to the absence of traceable data on the actual role of waste reclaimers in collecting and transporting the recyclable waste to buyback centres. Thus, the ICT-enabled digital platforms significantly provide accurate and traceable data for waste reclaimers' compensation. The starting point is how these ICT-enabled waste management platforms transform the informal recycling value chain and provide adequate and traceable data to guide the government and industries in determining the compensation of waste reclaimers.

According to Godfrey (2021), informal waste reclaimers play a crucial role in diverting paper and packaging recyclables away from landfills, contributing significantly to recycling efforts. The infusion of private sector investment into the local recycling economy has yielded direct and indirect job opportunities and improved the overall livelihoods, particularly within the well-established and effective informal waste sector. This private sector involvement has also indirectly supported municipal waste diversion strategies, resulting in cost savings for municipalities in waste collection and disposal. By effectively diverting recyclable materials from landfills, waste reclaimers contribute to mitigating the environmental impact of these sites, including reducing greenhouse gas emissions, preventing soil and water pollution, and preserving habitats.Furthermore, waste reclaimers' collection and recycling activities, encompassing materials such as paper, plastic, and metal, have a positive impact on conserving natural resources by lessening the need for virgin materials extraction and processing. The role of waste reclaimers as a vital source of income is particularly significant for those facing unemployment and poverty in South Africa. Their ability to collect and sell recyclable materials enables them to earn a sustainable living and support their families. Additionally, their work often extends to the local community, providing a valuable service by keeping streets clean and facilitating waste collection.

Another notable contribution of waste reclaimers is their role in reducing illegal dumping of waste, which can have severe implications for public health and safety. By creating jobs, generating income, and actively reducing waste management costs for municipalities, waste reclaimers actively contribute to the local economy. The private sector's investment in the recycling economy has proven instrumental in achieving these socio-economic benefits. Consequently, waste reclaimers are a pivotal element in South Africa's recycling landscape, offering a comprehensive array of environmental, social, and economic advantages. Through their efforts to divert recyclable materials, create employment opportunities, and alleviate waste management expenses, waste reclaimers significantly advance the cause of sustainable development in the country.

Various studies have explored the tonnage of recyclable waste collected by waste reclaimers (Godfrey, 2021; Godfrey, Strydom and Phukubye, 2016; State of Waste Report, 2018); however, similar to other developing countries, traceable and accurate waste data in the actual contribution of informal waste reclaimers is limited in South Africa (UNEP, 2015; Godfrey and Nahman, 2007.) The current research by Godfrey (2021) sourced the South African waste data of paper and packaging recyclable tonnages collected in 2012 and 2017 from the industries (BMi Research, 2012; PETCO, 2016). The waste data collected by informal waste reclaimers in South Africa is limited; however, Godfrey (2021:3) asserts that "none of the Producer Responsibility Organisations (PROs) was able to provide accurate figures on the percentage of paper and packaging collected by informal waste reclaimers." Plastic SA (2012) reported that waste reclaimers in the informal sector are central to the increased collection of recyclable plastic waste, from an estimated 58% in 2012 to 74% in 2017. PET plastic collection by waste reclaimers is recorded as higher because of its high-value price. However, this data is based on extrapolation, and its uncertainty impacts the actual amount of recyclable waste collected by waste reclaimers.

### 3.6.2 Informal Waste Reclaimers' Integration Initiatives in South Africa

The networks for cooperation and inclusion between the informal and formal MSWM systems are apparent in South Africa for efficient MSW management. The integration of waste reclaimers, if undertaken appropriately, offers sustainable environmental management and social and economic advantages, improves the effectiveness of the MSWM system in municipalities (Dias and Alves, 2008) and improves the welfare of waste reclaimers. Kashyap & Visvanathan (2014) assert integration is context-specific and is determined by individual municipalities' objectives. Scheinberg (2012) and Velis et al. (2012) view integration as incorporating waste reclaimers into a more sustainable and formal MSWM system. Strategies for waste reclaimer integration vary and have included approaches to "recognise, organise labour that propagates the support of informal recyclers, by getting them acknowledged by stakeholders and society at large, as economic agents who are a crucial part of the waste management system" (Scheinberg, 2012). From the social perspective, integration offers models inclusion which is focused on transforming the working conditions of reclaimers which includes, "empowerment, recognition, protection and job security as well as personal growth of reclaimers within the waste sector" (Kashyap & Visvanathan, 2014) and enable waste reclaimers to be organised and be formalised into SMMEs (Godfrey et al., 2016).

As in many developing countries, the integration and empowerment of the informal sector in providing efficient waste management services is one of the challenges that the government of South Africa is grappling with (SACN, 2020). The waste reclaimers undertook collectivism, protesting against exclusion (Climate Legal, 2020) as indicative of the failures of government policies, inefficient policy implementation and process management on how smart cities should be inclusive and improve the quality of life of their citizens. South Africa's undertaking of the bottom-up smart city integrated waste management model is broadly informed by the sound overarching Waste Picker Integration Guideline for South Africa and the Extended Producer Responsibility (EPR) as crucial policy instruments for waste reclaimers' integration towards the zero waste goal. The National Waste Management Strategy (NWMS) obligates the government to: "… guide municipalities and industry on measures to improve the working conditions of waste-pickers" (DEA, 2011: 27). The Waste Picker Integration Guideline for South Africa (DEFF and DSI, 2020:03) emphasises that: "…as South Africa moves forward in achieving sustainable development goals (SDGs) related to recycling and EPR, we need to harness and capitalize on this existing strength for the benefit of waste pickers, the environment and the economy." Most of the research to date has aimed to: "…improve the working conditions and livelihoods of the informal waste sector and better to integrate waste pickers into the country's waste economy" (DEFF and DSI, 2020: i). However, the research focusing on the role of technology in integrating informal waste reclaimers in South Africa is limited (SACN, 2020).

Despite the policy and regulatory commitments made by the state and municipalities to improve working conditions and integrate informal waste reclaimers, little has been achieved in South Africa (WIEGO, 2021). The integration and improving the working conditions of informal waste reclaimers in developing countries are rare, with few success stories in the Balkans, India and Latin America (Chikarmane, 2012; Chintan, 2014; IADB, 2013; Scheinberg et al., 2018). In the same vein, in South Africa, most integration processes have relied on top-down public policy approaches within the municipal formal system while overlooking the waste reclaimers and industries, which are key stakeholders in the waste management and recycling value chain. The South African policies and municipalities' approach to informal waste reclaimers tends to be focused on eradicating them from landfills and removing them from the streets (Samson and Sekhwela, 2019).

Integrating the informal waste reclaimers within the formal MSWM system illustrates the importance of reclaiming recyclable materials and how informal recycling has evolved within South Africa's waste management systems. According to Brown and McGranahan (2016), the integration of waste reclaimers indicates the 'inclusionist' approaches adopted by municipalities in general to participants in the informal recycling sector. However, there are few success stories of waste reclaimer integration in South African municipalities, suggesting the need for more inclusive systems for integrating informal waste pickers in the urban informal sector. Dias and Samson (2016) propose four stages towards waste reclaimer integration through their 'integration ladder' summarised in Figure 3.5. Dias and Samson (2016) further advocate for municipalities to independently engage and negotiate with waste reclaimers to develop integration processes. This is meant to ensure that the integration process is inclusive, empowers the waste reclaimers and recognises the socio-technical contexts of each municipality's SWM systems.

| Stage of Integration | Characteristics |
|---|---|
| *1. No formal integration* | Lack of support from local government and the prevalence of dismissive or repressive policy. |
| *2. No formal integration with some degree of tolerance and minimal support* | Although there is a lack of formal acknowledgment and support of reclaimers' service, there is an environment of tolerance (in some cases the city owns buy-back centres, providing waste pickers with a structured way to commercialize their materials). |
| *3. Transition to formal integration* | Former repressive measures are replaced by supportive measures, yet there is still uncertainty as to the consolidation of support and acknowledgment of reclaimers. |
| *4. Formally integrated* | A formal, legal agreement exists between the local government and reclaimers organisation(s) wherein the city provides several support mechanisms including public awareness campaigns for source separation and respect for reclaimers; infrastructure for sorting, storage, waste processing, transport; compensation for environmental/municipal service rendered. Reclaimers may still operate informally or in the informal economy. |

**FIGURE 3.5.** THE INTEGRATION LADDER: STAGES OF FORMAL INTEGRATION OF WASTE RECLAIMERS**. (SOURCE: DIAS AND SAMSON, 2016).**

Despite excellent policy frameworks for waste reclaimer integration guidelines and policies, the integration of waste reclaimers into the MSWM systems in South Africa faces delays due to several challenges. Samson (2020) identified the following challenges as impeding the waste reclaimer integration processes: "dismissive and derogatory attitudes toward reclaimers, limited capacity of local authorities to respond to local economic development requirements and limited formal organisation of reclaimers amongst themselves." As a result, waste reclaimers are discriminated against, which erases their important role in environmental protection as they are often referred to as 'hawkers' and 'scavengers', enabling private contracted waste collectors and municipalities to exploit them. Samson (2015) provided exceptional theoretical insights on the role of waste reclaimers and that municipalities should initially recognise their work of reclaiming and salvaging recyclable materials and diverting waste from the landfill when developing an appropriate process for integrating reclaimers.

Creating waste picker organisations, associations, and cooperatives is one of the initiatives towards waste reclaimer integration in South Africa. Most waste picker organisations or cooperatives help organise waste pickers in various regions into groups as a sign of social solidarity and support for their work. In South Africa, among the many informal waste picker organisations and associations, the South African Waste Pickers Association (SAWPA), Women in Informal Employment: Globalizing and Organizing (WIEGO) and African Reclaimers Organisation (ARO) are active in advocating for the recognition and integration of waste reclaimers in the SWM systems in South Africa. The National Waste Management Strategy prescribed employment creation in the informal waste recycling sector through: "formalising the role of waste pickers and expanding the role of [small and medium-sized enterprises/SMMEs] and cooperatives in waste management" (DEA, 2011). Hence the discussion of waste reclaimer integration has been focused on the creation of cooperatives and SMMEs since this is the most favoured municipal approach towards integrating waste reclaimers, even though research has shown that there is little success by the cooperatives model in informal recycling in South Africa (Satgar, 2007; DTI, 2012). Godfrey and Phukubye (2016) assert that "recycling cooperatives have a 92% mortality rate, one of the highest rates of failure for all cooperatives in any sector, nationally."

Municipalities in South Africa have adopted the separation at source (S@S) model, which does not acknowledge or recognise reclaimers' expertise and assumes that reclaimers should participate in programmes designed by consultants and government officials. As a result, the separation at the source model and the welfare approach does not meet the reclaimers' core needs and relegates them to the peripheral zones of the recycling supply chain, thereby negatively affecting their livelihoods and the existing informal recycling system. Furthermore, the privatisation of SWM through separation at source (S@S) contracts awarded to private waste companies has dispossessed reclaimers and worsened their incomes, working conditions, and relationships with residents (Samson et al., 2020). This was even though reclaimers began salvaging recyclables long before the government entered this terrain and are already deeply integrated via their well-functioning informal recycling system. Therefore, a sustainable, efficient and effective solid waste management approach is needed through a bottom-up smarty city integrated waste management model that can contribute to an improved livelihood approach, inclusion, integration and environmental sustainability through ICT-enabled digital platforms.

## 3.7 The Shift to ICT-Enabled Waste Management Digital Platforms for Waste Reclaimers' Integration

The shift to ICT-enabled waste management digital platforms for waste reclaimers' integration has been ushered in by implementing the EPR regulation in South Africa. Most developing countries in the world have adopted the EPR as a viable alternative for raising money to fund essential municipal waste management services, as well as developing

SMMEs/SMEs for the informal recycling sector, thereby enabling job creation (Godfrey & Oelofse, 2017; OECD, 2016). Climate Legal (2020) defines EPR as “a regulatory intervention that holds producers responsible for their product at the post-consumer use (waste disposal) stage of its lifecycle.” OECD (2016) states that EPR imposes “the responsibility upon producers for their products, from design-to-disposal, thus compelling producers to internalise some of a product’s end-of-life costs and incentivising product-design that includes waste minimisation measures as a means to facilitate final disposal.” EPR offers the opportunity to reduce the financial burden of managing waste from municipalities and the amount of waste destined for the landfill while improving the recycling rate in the informal sector.

As noted in chapter two, previous waste reclaimer integration processes failed due to the absence of private sector producers and industries in the integration processes by municipalities. Climate Legal (2020) points out that the EPR Regulation identified the brands/industries through EPROs or EPR Schemes previously excluded and side-lined in the previous municipalities-led integration processes for safeguarding waste reclaimers recognition and integration. The South African EPR Regulation, which was gazetted on 6 May 2021, reinforced the increased recognition of the role played by waste reclaimers in recycling initiatives and the zero-waste goal in South Africa. The EPR Regulation established markets for recyclable materials, prescribed compulsory integration of waste reclaimers into the EPR Schemes or EPR organisations and proposed compensation of waste reclaimers for the collection services they are undertaking without compensation by November 2022. This is a shift from the charitable municipality-led approach to acknowledging waste reclaimers as innovators and entrepreneurs in the recycling value chain.

The gazetted Regulation 8 of the EPR Regulation (DEFF, 2021) provides requirements for the EPR ‘scheme’ and PRO to “collect, record, manage and submit data to the South African Waste Information System of their quantities which have been collected, sorted, recycled and recovered against the published targets.” Consequently, the EPR ‘scheme’ and PRO adopted ICT-enabled waste management digital platforms to integrate waste reclaimers and ultimately be able to collect data on recycled materials against set annual targets for annual reporting to the government. The adoption of technologies with the involvement of the private sector in the informal waste recycling value chain is key to the digital transformation of the recycling practices for waste reclaimers and municipalities. For Chikarmane (2012), integration can be done by adopting technologies that open avenues for other payment modalities besides cash payment directly to reclaimers with receipts like the electronic fund transfers (EFTS) and money transfer systems like e-wallets for payment of waste reclaimers. Integrating waste reclaimers into the digital payment systems improves their access to income when cash is not readily available and positively impacts their livelihoods and welfare.

Innovative technologies in the form of ICT-enabled waste management digital platforms offer new integration mechanisms for waste reclaimers through digital payment schemes, which provide opportunities for reclaimers to be compensated for the services they render to municipalities. Currently, there is uncertainty on the actual data of waste being collected and transported by individual reclaimers for recycling, and ICT-enabled waste platforms help to fill this gap through daily recording of the amount of waste collected and the distance travelled by waste reclaimers. Furthermore, the adoption of ICT-enabled platforms further affects the waste reclaimers' eligibility for payment schemes using the data from their profiles, allowing for waste reclaimers' census and access to credit from the banks.

Zheng & Walsham (2008) identify the various roles in society that technology can play, and Zamani (2017) notes that technology enables 'social inclusion' and provides access to multiple opportunities.  A broader debate on the role of ICT as beneficial and inherently desirable to society is prevalent (Zamani, 2017; Njoki & Wabwoba, 2015; Zheng, 2009). ICT can be adopted to mitigate challenges of social exclusion, create jobs and promote the participation of the previously excluded groups. In the informal recycling value chain, ICT allows the informal waste reclaimers to forge new communication networks and provides ICT-mediated value spaces (Andrade & Doolin, 2016). Integrating waste reclaimers into the digitally transformed informal value chain requires the application of technologies and tools that foster connectivity, productivity and co-production of waste data (Wilding, 2009). The impact of ICTs in transforming the informal sector may still be limited due to the limited access to smartphones, data and internet access by the waste reclaimers who might not be able to afford internet-capable smartphones.

## 3.8 Conclusion

The chapter has presented the South African context of the smart city phenomenon as implicitly provided in the literature, particularly emphasising informal waste reclaimers' integration processes. I reviewed the literature on the smart city concept in South African cities to demonstrate its growing interest in urban services provision projects. Despite adopting the smart city concept, there is an absence of a South African agreed definition of smart cities and a lack of regulative bodies to govern this emerging aspect. Previous attempts to integrate the waste reclaimers in South Africa through the current informal integration initiatives have failed due to several factors, including reliance on top-down public policy approaches within the formal municipal system while overlooking the waste reclaimers and industries who are key stakeholders in the waste management and recycling value chain. However, given that the Guidelines for Waste Picker Integration in South Africa were only published in 2020, it might be premature to declare the efforts as a failure, as the actual outcomes and impacts could take more time to materialize and should be assessed over a longer period. The ICT-enabled waste management system provides opportunities for digital transformation and integration of the informal recycling sector, thereby improving the working conditions and welfare of waste reclaimers in South Africa.

# CHAPTER FOUR: METHODS, CASES & THEORETICAL FRAMEWORK

## 4.1 Introduction

The chapter aims to frame the research design and methods adopted for this empirical research. The chapter starts by providing the rationale for using interviews to establish a relevant understanding of the digital transformation of the informal waste recycling sector through the application of ICT-enabled waste management digital systems from the perspective of various stakeholders, among them the waste reclaimers, policymakers, waste reclaimer association officials, academics/experts, social movements, government officials and ICT waste collection companies. Next, the case study approach adopted in this research is discussed together with the delimitations of the study. Next, the chapter introduces the three ICT-enabled digital platforms, namely, BanQu, Kudoti and Regenize, as the case studies with BanQu operating in Johannesburg while KUDOTI and Regenize are in Cape Town. It then explains the reasons for choosing BanQu, Kudoti and Regenize as bottom-up smart city integrated waste management projects for this research and the procedure for investigating the sites and engaging with the respondents within the case of these ICT-enabled digital systems.

The following section discusses the sources of data and the sampling techniques for both primary and secondary data. Semi-structured key informant interviews of purposively sampled respondents, complemented by the researcher's observations of the realities of digital transformation in the selected case studies, formed the primary data source. For secondary data, the researcher used media reports, official documents, policies, and global and local literature on smart cities and ICT-enabled waste management systems. This is followed by explaining the procedures for undertaking semi-structured interviews, data management and data analysis from the primary sources in the field. The chapter also presents the Socio-technical Transition Theory to sustainability as the study's theoretical framework. The theoretical framework is helpful in this research as it contributes to the complex innovation process of ICT-enabled waste management digital platforms in South Africa. Finally, this chapter addresses the ethical considerations of this research and how the researcher navigated some of the challenges that potentially constrained the study.

## 4.2 The initial approach: Qualitative case study approach and research instruments

To elicit primary data, the research adopted a qualitative design and inductive methodology to answer the three sub-themes which are linked to the main research question: To what extent the ICT-enabled waste management system can improve the lives of waste reclaimers, divert large amounts of waste from the landfill, and enhance environmental performance towards zero waste? The research adopted a qualitative research design because of its exploratory approach, which necessitated a naturalistic inquiry and probes for an "in-depth understanding of underlying reasons, opinions and motivations behind social phenomena" (Creswell, 2013). As will be shown in Chapter 5, the qualitative approach established significant insights into the role of ICT-enabled waste management systems in improving the welfare of waste reclaimers and environmental management through digital transformation in Johannesburg and Cape Town through the adoption of multiple approaches of inquiry, namely the transect walk, the key informant interviews, case studies and participant observations (Creswell, 2013; Lincoln et al., 2011). Furthermore, Lincoln et al. (2011) validated the qualitative methodology for its capability to explain and interpret social reality, which is appropriate for exploring socio-technical transitions to sustainability.

### 4.2.1 The philosophical assumptions of this research

This section introduces the philosophical assumption of this research and illustrates how the philosophical assumption influences the procedures for finding data to respond to the research questions and subthemes (Creswell, 2013). Mertens (2019) refers to the philosophical assumptions as 'paradigms' such as 'positivism, post-positivism, social-constructivism, critical inquiry, feminism, and postmodernism' (Crotty, 1998). This section only addresses the most suitable paradigm for this research, the social constructivism paradigm (Creswell, 2013). Social constructivism suggests that "individuals seek understanding of the world in which they live and work. Individuals develop the subjective meaning of their experiences - meanings directed toward certain objects or things" (Creswell, 2013: 8). This philosophical assumption is premised on the 'ontology' that "reality is socially constructed through lived experiences and interactions with others" (Mertens, 2015). The social-constructivism philosophical assumption is the most appropriate because the research aims to explore the innovative and transformative process of a smart city project in the digital transformation of the informal recycling sector in detail. The aspect of a 'smart city' is an emerging worldview phenomenon, with various actors having different perspectives about the concept of a 'smart city' itself. Thus, there are multiple realities concerning the 'smart city' concept. The research study findings might be able to identify the various actors and their perceptions of the innovation process.

### 4.2.2 Case study as the research design

This research adopted a case study approach embedded in two South African municipalities, namely the City of Cape Town and Johannesburg. This was imperative for studying the 'smart city concept' as the bottom-up smart city through an ICT-enabled waste management model in the informal recycling sector manifest between the waste reclaimers, tech companies (innovators), industries (EPRO and PRO) and the government. Adopting the social-constructivism approach enabled the researcher to understand the innovation process of a specific bottom-up smart city innovation through interactions with the respondents exploring practices, processes and details. The three case studies of ICT-enabled waste management digital systems and their role in transforming the informal waste recycling sector formed the case study setting for this research. The three ICT-enabled waste management digital platforms are introduced in this chapter, including the justification for their selection in this study.

The research seeks to understand the role of the ICT-enabled waste management digital systems in the informal waste recycling sector by exploring the socio-technical transition process of this bottom-up smart city innovation. Exploring the socio-technical transitions involves understanding various stakeholders' (innovators, social movements and waste reclaimers) collective perspectives, interpretations and meaning concerning the bottom-up smart city concept. Hennink et al. (2020) highlight that case studies not only rely on key interviews with respondents to collect data and respond to the research purpose but sometimes use participant observation to collect data. The case study approach is most appropriate for this research, and Creswell (2013) asserts that case studies explore processes and details of people's daily interactions with a system or artefacts. Barry (2001) validates the relevance of the cases in exploring the process of technological innovation and science at the micro level to understand the smart city phenomenon.

### 4.2.3 Literature Review

The researcher undertook an extensive desktop review of academic published literature pertinent to smart cities, ICT-enabled waste management systems and waste reclaimer integration initiatives to acquire adequate data to understand how the bottom-up smart city integrated waste management has transformed the integration processes of waste reclaimers and enhanced environmental protection through the application of ICT-enabled waste management systems in South Africa. Filtering literature was conducted manually to identify literature relevant to the South African context and the thesis topic. Systematic document analyses were also applied to electronic and printed documents, as Bowen (2009) recommended. From the selected documents, data were examined as Corbin & Strauss (2008) recommended for the research to generate meaning and understand the realities and practices in case studies. This document analysis of this research involved the review and analysis of national policies, legislations and guidelines on smart cities, waste management and waste reclaimer integration guidelines, and other academic research reports on waste reclaimer integration initiatives in several South African municipalities.

### 4.2.4 Using qualitative interviews as a research instrument

The in-depth semi-structured interviews formed the key qualitative research instrument and data collection method used in the present research. Punch (2009:144) asserts that interviews are a "very good way of accessing people's perceptions, meanings, definitions of situations, and their constructions of reality". The use of in-depth semi-structured interviews in case study research locates the researcher in the broader context of what the researcher observes and sees (Punch, 2009). The researcher was engaged in formal and informal communication with respondents to elicit subjective views on the transformative nature of the ICT-enabled waste management system in the informal waste management sector. Hennik et al. (2011) identify informal and formal interviews as relevant to case study research. Each form of the interview solicits information from respondents (Hennik et al., 2011), for instance, the semi-structured interviews to understand the digital transformation of the informal recycling sector. The researcher managed to arrange interviews with officials from the City of Johannesburg and DEFF to understand their role in enforcing the waste reclaimer guidelines and EPR regulations towards integrating waste reclaimers into the recycling value chain. In addition, the researcher interviewed the management of the three case-study platforms, BanQu, Kudoti and Regenize, to understand the digital transformation of the recycling sector and how it has improved the conditions of waste reclaimers. The researcher interviewed a senior employee from Distell, management from a social movement, an academic and experts in waste reclaimer integration, waste management and smart cities from Witwatersrand University and CSIR. These interviewees were regarded as expert informants because of their knowledge and expertise in the subject under study or their position in government/municipalities/organisations/communities. As such, these expert sources provided deep insights into the digital transformation of the informal waste management sector. The selection of the expert informants was purposive and based on the informant's position in the organisation, for instance, managers, academics and professional experts in the field. The full range of respondents/interviews is shown in Table 4.1 below.

The primary data source comprised in-depth semi-structured interviews with nine groups of respondents, altogether resulting in thirty-seven interviews (Table 4.1). The respondents represent six broad categories, namely the institutional (national and provincial departments), local government (municipalities and municipal-owned entities), experts and professionals, waste reclaimers, social movements (informal waste reclaimer organisations) and innovators (technological companies) and EPR scheme (Distell). Respondents from the ICT-enabled waste management innovators (companies) represented another significant group, with eighteen respondents. This was followed by the City of Johannesburg and its municipal-owned entity (PikitUp), which comprised seven respondents. In most cases, especially the waste reclaimers' formal interviews, they tended to be conducted alongside participant observations of how they use the technology.

| ICT-ENABLED WASTE MANAGEMENT SYSTEMS CASE STUDIES IN SOUTH AFRICA | | | CITY OF JOHANNESBURG | |
|---|---|---|---|---|
| **BanQu** | **Data Sources** | **No. of Respondents** | **Data Sources** | **No. of Respondents** |
| | Senior Officials | 1 | **Environmental Infrastructural Services Department** | 3 |
| | Waste Reclaimers | 6 | | |
| **KUDOTI** | Senior Officials | 1 | | |
| | Waste Reclaimers | 5 | **Municipal Owned Entity (PikitUp)** | 4 |
| **REGENIZE** | Senior Officials | 2 | | |
| | Waste Reclaimers | 3 | | |
| | **Subtotal** | **18** | | **7** |
| **STATE INSTITUTIONS AND OTHER** | | | | |
| **National Government** | **Data Sources** | **No. of Respondents** | | |
| | DEFF (EPR & Waste Reclaimer | 1 | | |
| **Gauteng Provincial Government** | Department of Agriculture and Rural Development. | 1 | | |
| **Experts or Professionals** | Smart Cities | 3 | | |
| | Waste reclaimer integration | 2 | | |
| | EPR Policy Implications | 2 | | |
| **Non-state Actors** | Waste Reclaimer Organisations | 2 | | |
| | Socio-Economic Rights Groups for Informal workers | 1 | | |
| | **Subtotal** | **12** | | |
| **TOTAL** | | | | **37** |

**TABLE 4.1.** GROUPS OF INTERVIEW RESPONDENTS.

The initial interview schedule was, to begin with state institutions; however, this was changed, beginning with ICT-enabled waste collection companies (innovators) and waste reclaimers at various operation sites. This was necessitated by the fact that most municipal and government officials are difficult to schedule a meeting with, and it is often delayed as they await approval from their heads of department. Moreover, the state institutions took time to respond, unlike the ICT-enabled waste companies and waste reclaimers, who were generally less difficult. Commencing the interviews with the waste reclaimers and ICT-waste management companies armed the researcher with the realities and on-the-ground facts on waste reclaimer integration processes and prepared the researcher for reflective academic interviews with municipalities, municipal-owned entities and state officials. The semi-structured interviews allowed the researcher to ask specific questions to the participants while, on the other hand, being flexible to probe further information that emerged from the interviews. Denscombe (2010) asserts that semi-structured interviews allow the researcher to interrogate further issues, unlike rigidly structured interviews. Although the researcher developed a semi-structured interview guideline, the order of questions was not always systematically adhered to but was deliberately guided by the respondents' introductory responses and the researcher's reflections on the subject matter based on previous responses/findings.

The semi-structured interviews were undertaken on agreed dates based on appointments with the respondents. However, some scheduled meetings had to be postponed or cancelled due to the respondents citing other commitments and some not arriving for the interviews. In some instances, the expert informant requested the semi-structured interview guidelines but did not participate. Some interviews with senior officials in the Smart City Offices fell through after many attempts, including the Smart City Leader's intervention. These circumstances are perceived as unwillingness by other City Officials despite preliminary interest in the research and permission from the City of Johannesburg and PikitUp. Despite follow-up emails with these officials, the efforts were fruitless. In some instances, despite the meeting being scheduled and agreed to participate, some officials from PikitUp did not attend the interviews. Despite this, what is important is that three meetings were conducted between the researcher, officials from EISD and PikitUp. All the participants signed the consent forms and permitted the researcher to record the entire interview process, and in some instances, the researcher resorted to writing notes. Most of the ICT-enabled waste collectors were enthusiastic to know that their innovations were under study even though they were at their inception stages, and this helped in establishing good relations with them, resulting in the researcher being allowed to visit some of the waste hubs, sites of operation, participate in their 'trial applications' so that the researcher can fully comprehend the operations of the ICT-enabled waste management system. This further helped the researcher secure permission to photograph the hubs during transect walks and use some of the material on the company websites.

The researcher generated an adapted interview schedule with a list of questions for each category of respondents. The interview schedule for each category of respondents is provided in the Appendix. The in-depth interviews provided crucial information about the digital transformation of the informal waste collection sector in relation to the integration of waste reclaimers and enhancing environmental management in South Africa. Although the interviews were planned for thirty minutes, due to the researcher's interactive nature and further probing, some interviews ranged from one hour to one and a half hours, especially with key informant participants allowing the researcher to gain more information on the topic under study. For waste reclaimers, the interviews were about two to three hours long as they involved participant observation and transect walks on case study sites. Initially, the interviews were conducted through face-to-face sessions in 2019, but this was disrupted by the COVID-19 pandemic, which imposed restrictions as of March 2020 on gatherings and meetings. Therefore, the meetings with the officials from the City of Johannesburg and PikitUp, waste reclaimers in Johannesburg, Bridgetown, and Khayelitsha, were all conducted face-to-face before the COVID-19 restrictions. The second and third set of interviews with officials from PikitUp and the City of Johannesburg was conducted online (MS Teams and Zoom), while meetings with Kudoti and BanQu officials were conducted via Google Meeting, and Regenize was conducted via Whereby meetings.

### 4.2.5 Webinar as a research instrument

Webinar sessions were another crucial research instrument the researcher adopted to collect data on EPR policy implications, waste reclaimer integration initiatives and the waste reclaimers' responses to municipality policies towards integration. The outbreak of the COVID-19 pandemic impeded the collection of data using the traditional way, forcing the researcher to adopt alternative digital systems through the use of the web-based seminar (webinar) as a new data collection method for a qualitative research study on the digital transformation of the informal recycling sector. A webinar is “a form of one-to-many communication: a presenter can reach a large and specific group of online viewers from a single location” (Company Webcast, 2021). Tiong et al. (2020) argue that advances in ICT offer new opportunities to conduct qualitative research in the webinar. Braun et al. (2017)

assert that the webinar platform is cost-effective and spans a large geographical spread as it can complement and replicate the traditional data collection methods. Unfortunately, some webinars were disrupted due to ESKOM load shedding and delayed internet connectivity, some of the interactional and practical issues associated with using Webinars (Seitz, 2016). To combat this, the hosts uploaded the recordings on YouTube or sent all participants the recording of the entire Webinar, which was an advantage to those who might have missed the session. The researcher attended fourteen webinars which explored the role of waste reclaimers and integrations processes currently underway, as listed below (see Table 4.2 below.)

| WEBINAR NUMBER | TOPIC | DATE |
|---|---|---|
| **1** | ***Goethe Institute: Sustainable Together- Precious Waste***. Conversation about recycling and the work of reclaimers in South Africa. | 28 July 2020 |
| **2** | Webinar: How Cities Prevent Litter & Reduce Waste Through Data | 08 Apr 2021 |
| **3** | R50 recycling fee online discussion with Brixton Community Forum and African Reclaimers Organisation | 29 Apr 2021 |
| **4** | PolySA EPR Webinar | 19 May 2021 |
| **5** | Voices from the grassroots: WEBINAR: Successful waste management and recycling business innovations | 27 May 2021 |
| **6** | The Power of Data in Today's Smart Cities | 21 July 2021 |
| **7** | SEED - Waste Reclaimers and recycling in South Africa | 31 Mar 2021 |
| **8** | Webinar Celebrating Women Waste Pickers and their Struggles | 11 Aug 2021 |
| **9** | Waste Picker Integration Webinar #2 - Partnering with Reclaimers/waste pickers for integration | 13 Sept 2021 |
| **10** | Webinar on waste pickers and EPR - Pune case study | 30 Sept 2021 |
| **11** | Waste Picker Integration Webinar #3 - Integrating Landfill Reclaimers Webinar | 19 Oct 2021 |
| **12** | Waste-pickers Contribution for a Cleaner Planet at COP26. | 09 Nov 2021 |
| **13** | Learning with Waste Pickers / Reclaimers | 18 & 19 Nov 2021 |
| **14** | Enhancing the social value of the circular economy in Latin America: What is the potential of Informal recyclers in circular economy initiatives? | 26 Jan 2022 |

**TABLE 4. 2.** LIST OF WEBINARS ATTENDED BY THE RESEARCHER.

### 4.2.6 Photography as a research instrument

Besides the use of semi-structured interviews and participant observation as data collection instruments, the researcher also used photographs, as recommended by Lowe et al. (2018), that photography plays a significant role in case study research. Photographs confirm the researcher's presence on a particular case study site. Besides demonstrating the researcher's presence, photographs depict objects, communities, places and processes which the researcher might find difficult to describe. The researcher used his smartphone to take pictures at the case study sites for this research. Photographs were taken to aid in capturing notes, especially during webinar presentations, PowerPoint slides, processes, activities and sites. The photographs are used to support the narratives in this thesis. The researcher also used photos to capture some technologies and artefacts to illustrate how the ICT-enabled waste management platforms operate, as shown in the case studies section. The researcher paid more attention to the Regenize Infrastructure site, the technological components of ICT-enabled waste management systems and other artefacts like tricycles and scales. The images captured the actual settings and activities on the sorting hub and documented the smartphones with the Regenize software. The researcher was also permitted to create a profile as a participant in Regenize and BanQu systems to have a more detailed understanding of the operations of these ICT-enabled waste management systems (See Chapter Five).

### 4.2.7 Participation observation and transect walk as research instruments.

Transect walks and participant observation are key data collection methods in case study research to generate reliable and accurate field-based knowledge on the waste reclaimers' lived experiences and interactions with the innovation processes emanating from the digital transformation of the informal waste recycling sector. Two transect walks in Bridgetown and Khayelitsha were conducted during the interview process, which allowed the researcher to observe the application of the ICT-enabled waste management systems, the use of the infrastructure (tricycles, hand scales, storage and sorting hubs) and other activities in general connected to the digital intelligent informal collection system. One of the senior staff of Regenize and Distell accompanied the researcher to Bridgetown and Khayelitsha areas, where they are undertaking these recycling projects, which allowed me to ask questions about my observations. Crivellaro et al. (2015:1) note that participant observations and transect walks allow ''for the situated discovery of issues connecting [waste reclaimers] with the processes and mechanism[s] at play'. This allowed the researcher to record the spatial differences that influenced the adoption and acceptance of these innovations by various residents who were observed during the walks prompting explanations from the respondents. Four levels of fieldwork participation were identified by Gold (1958), namely; "'complete participant' (researcher completely participates in the event), 'participant-as-observer' (researchers research the field and participate fully in the field), 'observer-as-participant' (participation in the field is limited while the researcher's identity is at the forefront), and 'complete observer' (researcher completely observes the event)" (Crivellaro et al., 2015). During the fieldwork, the researcher's role was interchangeable as determined by the activity or event between 'participant-as-observer' and 'observer-as-participant.' In Waste Reclaimer webinars and Smart City Forum, the researcher took on the role of a 'participant-as-observer' by actively participating in the discussions while in some practical fieldwork at the sorting hubs and using the ICT-enabled waste management systems. The researcher took the role of the 'observer-as-participant' to enable him to observe and listen to the respondents as they demonstrated their interactions with the technology. During the South African Cities Network's Smart City Papers Series Workshop, the researcher was a 'complete participant' as I fully participated by presenting a paper on "Smart Governance of Waste in the City of Johannesburg." As a fully participating researcher, I sat on the panel of presenters during this workshop, which resulted in me being a full participant.

## 4.3 Data analysis

The researcher applied sorting and electronic data coding as qualitative methods to analyse primary and secondary data. The researcher did this manually using an MS Word processor without third-party analysis software. For secondary data sources, the researcher analysed the relevant sources of documents concerning legislative frameworks for smart cities, informal waste integration policies, programmes, EPR regulations and plans. The researcher used different colours to highlight themes emerging from the data to generate a new document with two columns for additional analysis. The two columns comprised recurring themes, texts from the field, and new issues that emerged during the analysis. Focusing on primary data, the researcher transcribed all the respondent interviews recorded during the fieldwork (See Table 4.1). The data was organised according to thematic analysis and tabulation sources. Finally, the researcher analysed and compared data collected from the three case studies, allowing the researcher to prepare for interviews and select the person to be interviewed. The analysis was an ongoing process that "is tangled up at every stage of research including the research design, data collection, data handling (e.g. coding, indexing, sorting, retrieving), theorising, and writing" (Coffey and Atkinson, 1996).

As discussed above, the initial stage of data analysis is organising huge amounts of empirical data by the researcher through sorting and coding. The process of sorting data entails putting data into various categories, and in this study, the researcher sorted the data into five categories; (a) ICT-enabled waste management systems, (b) Informal recycling sector to ICT-enabled informal waste recycling system, (c) Blockchain technology for organised value chain, transaction and traceable data (d) the ICT-enabled informal waste collection infrastructure, (e) the performative role ICT-enabled waste management systems on municipal waste management. The data collection and data analysis process informed the five categories identified. After sorting data into various categories, the researcher began to code it. Coding data is a continuous process, which means the researcher had to re-order and constantly re-code the data as new themes emerged from the field and during analysis. Therefore, the researcher used thematic analysis to code the data. Braun and Clarke (2006) identify two types of thematic analysis: ' inductive thematic analysis' and 'theoretical thematic analysis.' Inductive thematic analysis requires that the researcher generate themes emerging from the data, while theoretical thematic analysis entails the researcher applying a theoretical framework to search for corresponding components within the data. The researcher adopted the 'inductive thematic analysis' and 'theoretical thematic analysis' as shown in empirical chapters five and six. After addressing the data analysis process, the research in the next section responds to the relationship between Socio-technical Transition Theory for sustainability and data analysis.

## 4.4 Case study selection of the bottom-up smart city integrated waste management project

The absence of an integrated national smart city strategy in South Africa has resulted in municipalities, particularly the metros, for instance, the Ethekwini, the City of Johannesburg and the City of Cape Town, emerging as drivers of smart city projects. For the researcher to fulfil the desired research objectives, selecting the cities where ICT-enabled waste management systems are being implemented in partnership with waste reclaimers was important. In Chapter Three, the study explored how the smart city of the smart city concept has evolved and is being implemented at the local government levels in Cape Town and Johannesburg. The contextual chapter illustrated the trajectory of smart city implementation in the two metros and articulated how the smart city concept in the two metros has evolved differently, guided by the IDPs of the two metros. Figure 4.1 presents the smart city concept's trajectory in Johannesburg and Cape Town from the early 2000s to the current phase. For the City of Johannesburg, the aim of the smart city programme is "not only improving service delivery but also enhancing pro-poor socio-economic development" (SACN, 2020:35), while for the City of Cape Town, the aim of the smart city programme is "emphasising digital rather than smart strategy, intending to improve service delivery and citizen-government interaction through ICT but without a clear link to urban and social development priorities" (SACN, 2020:35). In both cities, the smart city project is limited to using ICT-based tools to improve urban service delivery. Through their smart city incubation programme, both cities have developed technological hubs (Pollio, 2020).

The work involving the three case studies and two cities in the thesis is primarily characterised as a multi-site exploration rather than a strict comparative analysis. While the thesis examines three distinct ICT-enabled waste management systems across the cities of Johannesburg and Cape Town, the emphasis lies on understanding the unique attributes, strategies, and outcomes of each individual case, as well as their contribution to the broader context of digital transformation within the informal waste sector. The rationale behind adopting a multi-site exploration lies in the uniqueness of each case and city, particularly in terms of their objectives, stakeholders, technological configurations, and partnership dynamics. The Brixton-Auckland Park BanQu Pilot Project in the City of Johannesburg involves collaboration with the African Reclaimers Organisation (ARO), emphasizing partnership-driven innovation. In the City of Cape Town, the Kudoti and Regenize projects showcase distinct applications of smart city concepts, with Kudoti aligning with Extended Producer Responsibility (EPR) regulations and Regenize operating as an ICT-enabled waste collector with a particular focus on Bridgetown.

Given these differences, a multi-site approach allows for a deep dive into the contextual nuances that shape the implementation and outcomes of each initiative. Comparative analysis might inadvertently oversimplify the intricacies and potentially overshadow the unique contributions of each case and city. By treating each case individually, the thesis is better positioned to uncover insights into how ICT-enabled waste management systems are tailored to address specific challenges and opportunities within their respective environments. This approach resonates with the holistic exploration of complex socio-technical phenomena and recognizes that the benefits of a multi-site approach lie in the depth of understanding it can offer for each case, fostering a richer appreciation of the digital transformation of the informal waste sector.

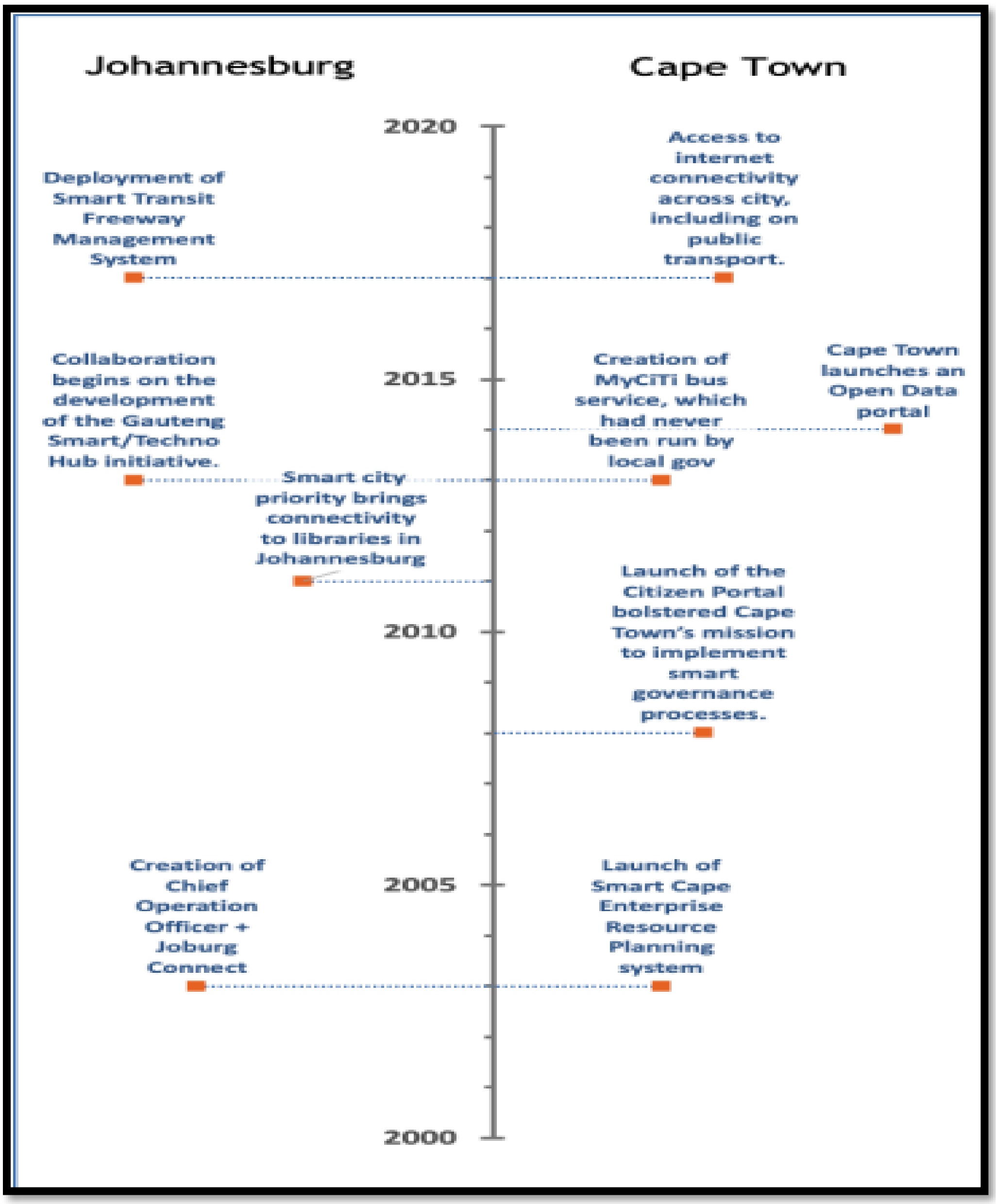


**FIGURE 4.1.** DEFINING MOMENTS IN SMART CITY DEVELOPMENT IN JOHANNESBURG AND CAPE TOWN. **(SOURCE: SACN, 2020)**

### 4.4.1 Selection of the three ICT-enabled waste management systems case studies

In research, there is no universally agreed way of selecting a case study for research. However, there are several factors a researcher has to consider in identifying an appropriate case study site to answer the research questions. Lowe et al. (2018) point out that the researcher can select a case study site based on 'foreshadowed problems' or distinct research problems. In this study, the researcher first considered cities in South Africa already implementing smart city projects and selected the City of Johannesburg and the City of Cape Town. For the City of Johannesburg, it was not merely because it was convenient, but there is a Brixton-Auckland Park BanQu Pilot Project in partnership with waste reclaimers from African Reclaimers Organisation (ARO).

Secondly, the City of Cape Town was chosen because of the implementation of two smart city projects with waste reclaimers, namely in Khayelitsha (Kudoti) and Bridgetown (Regenize). Notably, the Kudoti smart city project is being implemented through Distell's CSI strategy in compliance with the EPR regulations. Regenize is an ICT-enabled waste collector company that designed a waste management platform for business innovation and partnered with waste reclaimers in various Cape Town suburbs but implemented a 'Free Collection Service' in Bridgetown. These two unique smart city projects in Cape Town provided an opportunity to explore the smart city phenomenon in two different research settings.

The researcher applied the snowball method to discuss these waste management digital platforms with people who were aware of them on Facebook, LinkedIn, Twitter and other platforms. From these discussions and interactions with various people and online material, the Regenize App appeared to make an appropriate case study site for this study and provided an excellent opportunity to answer the research questions. However, KUDOTI and BanQu were also included to enrich the findings of this study further.

BanQu, Kudoti and Regenize demonstrate unique smart city projects that deserve attention in the digital transformation of the informal waste sector. The ICT-enabled waste management systems area joint partnerships between various stakeholders, including the waste reclaimers. Regenize, for instance, provided the infrastructure and resources for waste reclaimer integration, and BanQu and Kudoti installed the Internet of Things, blockchain technology and smart applications as conventional smart cities technologies. This ICT-enabled technological configuration aims to effect the transition from the current way the city operates to the existing regime in the informal sector. Cognisant of previous municipality-led and top-down approaches, BanQu, Kudoti and Regenize meaningfully engaged with the waste reclaimers in developing the platforms and allocated roles for each stakeholder, thereby putting citizen engagement at the core of smart city implementation. Finally, both the citizen engagement and technological configuration identified BanQu, Kudoti and Regenize as suitable case studies for investigation and have the potential to enrich our understanding of the digital transformation (smart city concept) of the informal waste sector. Samson et al. (2020) argue that there is an urgent need for partnerships between the industry and informal waste pickers to improve an existing system towards an inclusive circular economy. Accordingly, it is argued that 'smart cities' should significantly emphasise innovative partnerships where various sectors and stakeholders unite to promote entrepreneurship and innovation between the industry, universities and waste pickers.

### 4.4.2 The Regenize Project – Bridgetown, Cape Town

Several factors motivated the researcher to select the Regenize platform as one of the three ICT-enabled waste reclaimer systems. Regenize is an ICT-enabled waste management company based in Cape Town, which provides paid collection and free waste collections services to all residents who have signed up on the Regenize APP. What initially aroused my interest in Regenize was its background in IT, specifically focused on providing programming, software and other IT services to waste management companies. Regenize ventured into waste collection and recycling services due to the unwillingness of the industries and companies to offer incentives to households involved in recycling. The municipality-led separation-at-source household recycling projects had failed due to the lack of incentives to motivate households to participate in these recycling projects. As a result, Regenize designed a digital platform streamlining the recycling process, making it easy for households to sign up for a service and maintain the service by rewarding them for being part of the recycling initiative through the Regenize APP. The Regenize APP will also be referred to as REMALI APP (See Figure 4.2) in this research.

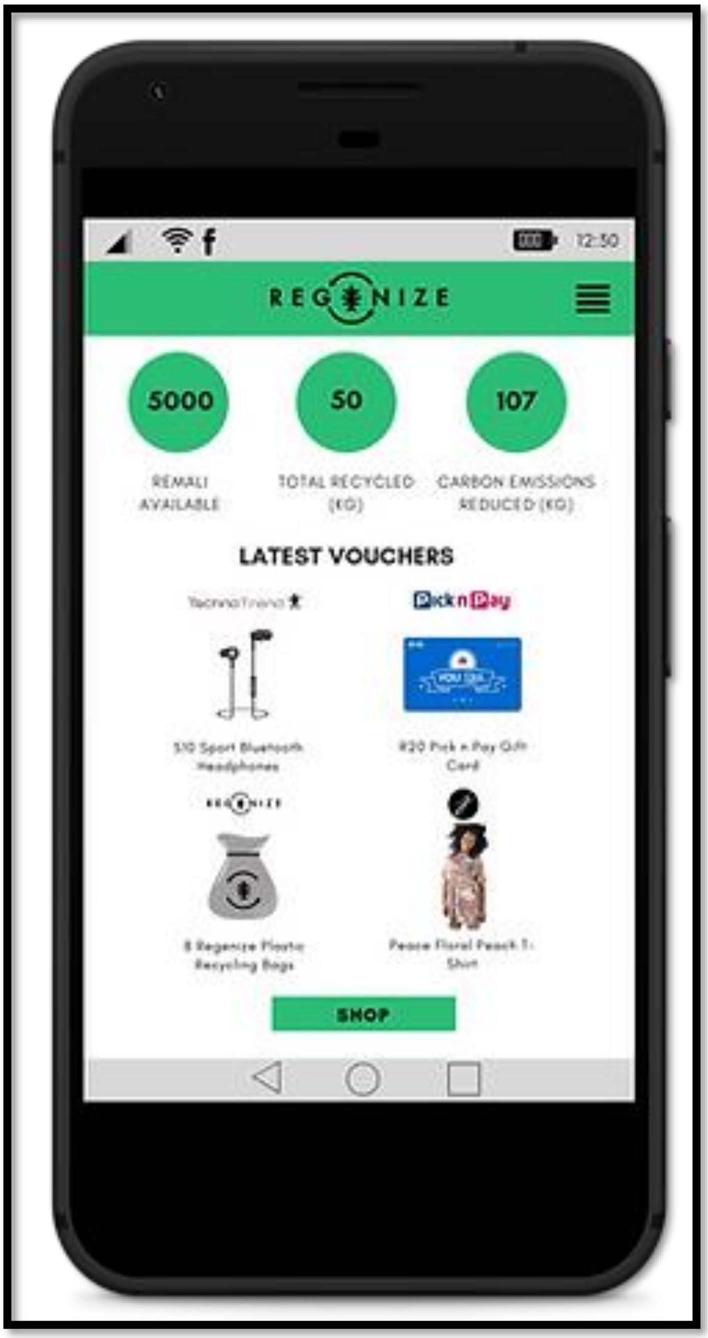


**FIGURE 4.2.** REGENIZE PLATFORM AND FEATURES **(SOURCE: REGENIZE, 2021).**

The features of the Regenize APP generated questions on how the technology has integrated waste reclaimers and households into the informal recycling value chain. Regenize Project in Bridgetown encourages recycling in communities in partnership with waste reclaimers towards improved welfare and Zero Waste Goal. In Bridgetown, through the Regenize Project, “we decided to start a pilot project, a free residential recycling collection service, which is still currently running in the Bridgetown community. We preferred not to use vehicles to perform collections, as we wanted to partner with waste pickers & the unemployed to perform these collections using tricycles" (REG01). The Regenize Project involved a set of awareness campaigns, education programmes and presentations to engage communities who want to participate in the recycling activities in Bridgetown. The digital platform is an ICT-enabled waste management APP that allows industry and corporates to invest in smart city projects that would enable them to inspect, track and monitor in real-time the impact their waste collection services and recycling projects are having in communities.

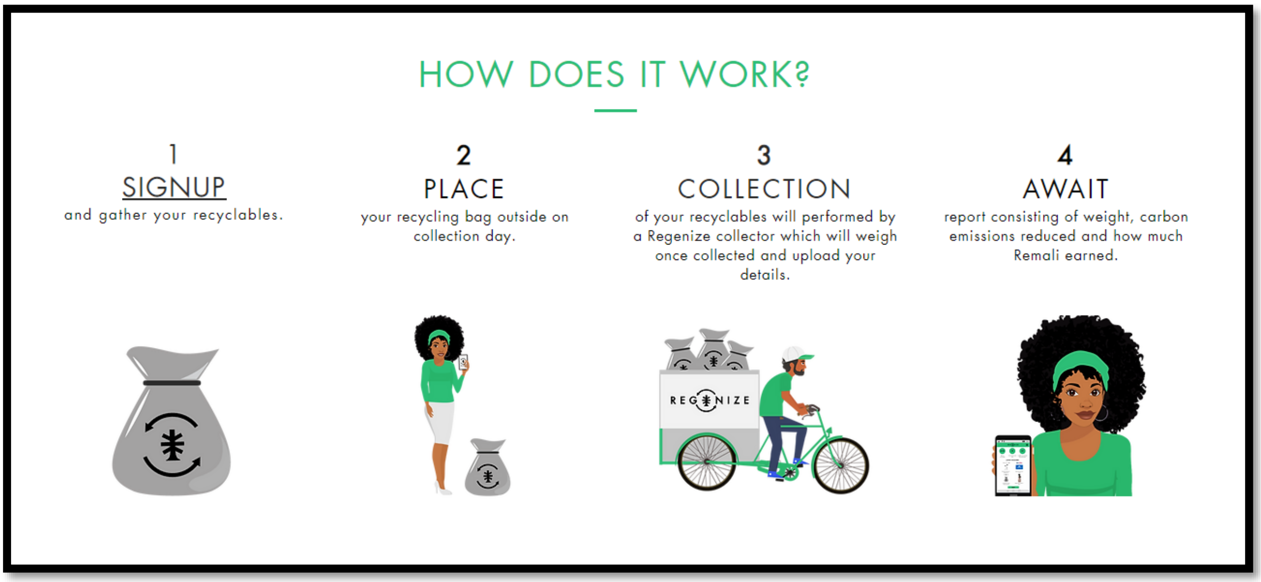


**FIGURE 4.3.** STEPS ON HOW REGENIZE WORK. **(SOURCE: REGENIZE, 2021).**

The collection of recyclables by the waste reclaimers through the aid of ICTs is referred to as the household to ICT-enabled waste reclaimer collection system. The Regenize APP is a mobile application that can be downloaded on any smartphone and allows users like the waste reclaimers, households and Regenize staff, waste collectors and other institutions to access a customer profile that is only available to them (REG02, REG03 and REG04). Households are required to register by creating a profile/account on Regenize APP through the smartphone application (APPs) developed by the ICT-enabled waste collection company. The household to ICT-enabled waste management system (Regenize APP) allows the "households to log in and request recyclable collection service and the GPS location of the household address is used by the smartphone to direct the household location and also specify the shortest route from the location of the local hub or waste reclaimer to where the household is located. The households can request collection services through the digital platform. These features are embedded within the Regenize APP and are accessible only through the cellphone." (REG01). Thus the household-to-waste reclaimer intelligent collection system consists of four steps (See Figure 4.3):

1. "Household requests waste collection through smartphone APPs about the collection time and items.
2. Schedule a list of households to be collected daily, and the system assigns collection orders to the nearby waste reclaimer based on location.
3. Waste Reclaimer collects recyclables at the door/gate of the specified house and manually input information on the collected recyclables, including the images, weight and types.
4. Information is sent to the household profile/account with a report informing them how much they have recycled, how much carbon emission they have saved, and the Remali that the household can redeem for either groceries or airtime once the collection is accomplished" (REG01).

Several ICT tools are used in the household to waste reclaimer intelligent collection systems. Both the waste reclaimer and household use smartphones as the hardware ICT infrastructure and Regenize APP as the software component of the intelligent collection system. The waste reclaimer is responsible for identifying and submitting detailed information and uploading the images/photos of the recyclables on their Regenize App profile. This data communication process is transacted through the provided internet data and GPRS location system.

Regenize, as a waste collection company, adopted Bridgetown's household waste reclaimer intelligent collection system. In this intelligent collection model, three waste reclaimers provide collection services for a suburban area. Each day, the waste reclaimers receive daily collection schedules and a list of households where they will provide collection services. Regenize in Bridgetown operates on a decentralised model where reclaimers are placed in local hubs linked to big storage containers placed strategically throughout the community. Each container can service between 600 and 1000 households and is manned by a three-person team, translating to two waste reclaimers and one sorter (REG02, REG03 and REG04). In Bridgetown, Regenize established a collection service station for 1500 households to collect dry recyclables like wastepaper, PET bottles, cans and cardboard boxes through the support of the ICT-enabled waste management system.

### 4.4.3 KUDOTI - Distell's recyclable waste programme in Khayelitsha

Distell is a liquor-related company involved in the 'production, marketing, and distribution of alcoholic beverages' rooted in South Africa (Distell, 2021). As part of Distell's sustainability objectives, it launched the GreenUp "a progressive community change initiative focused on a cleaner environment, as well as on establishing and formalising effective value chains of operation in the collection, separation and processing of recyclable post-consumer waste within the Western Cape's Khayelitsha informal settlement" (Distell, 2019). The project sought to formalise the waste reclaimers in Khayelitsha's informal recycling value chain, help alleviate socio-economic challenges, and empower the individuals with resources working in informal settlements. Khayelitsha is the sixth-largest informal settlement in South Africa and has an estimated population of 450 00 people and an average annual growth of 2% per year (City of Cape Town, 2017).

Khayelitsha is identified as one of the poorest townships in Cape Town, with many individuals working in the informal sector, and because of its large consumer base, it was selected for the implementation of Distell's GreenUp corporate social investment project. The GreenUp project aims to support recycling services through mentorship, empowerment and skills transfer. The project supports the recyclable waste buy-back centres (BBCs) and waste reclaimers in Khayelitsha with necessary training and resources for waste recycling, sorting and collecting businesses. The project plays a crucial role, especially in collecting data on recyclable waste collected by the waste reclaimers through applying Kudoti, an ICT-enabled waste management system. As an ICT-enabled waste-based APP, the waste reclaimers refer to KUDOTI as GreenUp APP in the Khayelitsha project. The APP was an outcome of engagement and consultation between Distell and Kudoti to customise the APP and design it to ensure that Distell can track the amount of waste being recycled or diverted from the landfills and the amount of income waste reclaimers get from their recyclable material for reporting purposes and to track the impact (DIS01).

Distell partnered with KUDOTI to manage glass bottle collections for reuse and establish ICT-enabled waste collection enterprises in Khayelitsha. KUDOTI introduced “a full traceability and an integrated waste supply chain to collect over 100 tonnes of materials per month” (Kudoti, 2021). KUDOTI works with various stakeholders to establish a digital circular economy comprising the following activities (See Figure 4.4.):

1. *“Sponsoring of ecosystem partners*
2. *Tracking and tracing of materials*
3. *Trading of materials*
4. *Setting up and disbursement of rewards and incentives.”* (Kudoti, 2021)

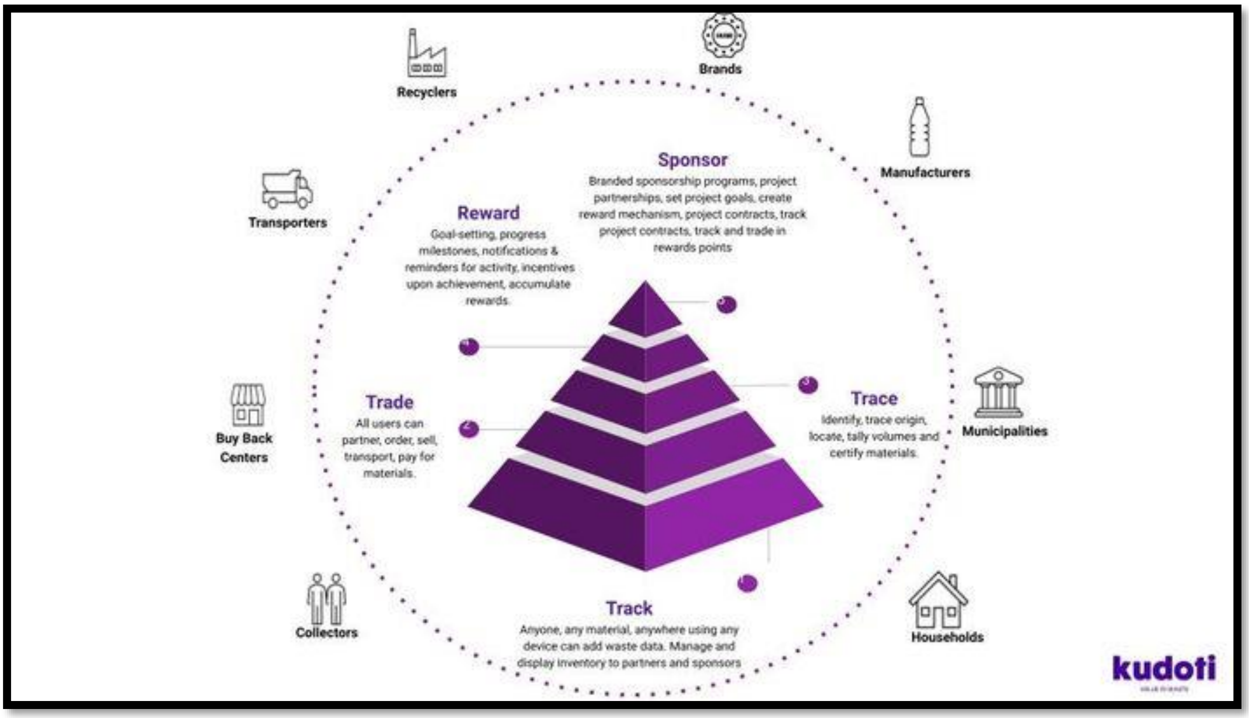


**FIGURE 4. 4.** KUDOTI’S DIGITAL DESIGNED CIRCULAR SUPPLY CHAIN. **(SOURCE: KUDOTI, 2021).**

The KUDOTI APP operates by reporting, tracking and monitoring on the Distell Side, while the integration of waste reclaimers into KUDOTI platforms is done through registration and information capturing daily at the buyback centres. The buyback centres are institutions of integration as they register any interested waste reclaimer. It is important to note that, unlike Regenize, KUDOTI does not interact directly with households or waste reclaimers but interacts with buyback centres that use KUDOTI to integrate waste reclaimers into the ICT-enabled informal recycling value chain. In Khayelitsha, Distell has three buyback centres participating in this ICT-enabled recycling smart city project. The steps for participating in this project are as follows:

1. "Waste reclaimer shows interest in participating in the project and goes to the registered buyback centre for registration.
2. The waste reclaimer is registered on the digital platform, and the buyback centre will approve the individual profile in the system and automatically register them.
3. After registration, waste reclaimers collect and ferry their recyclable materials to the registered buyback centre, where their recyclable materials is weighed on the scales.
4. After getting the exact weight of the materials, the buyback centre will determine the materials' price value based on the recyclables' weight and waste stream.
5. The weight, waste stream and price value of the recyclable are manually entered into the APP by the buyback centre owner resulting in the waste reclaimer getting paid and receiving a receipt for the transaction.
6. For Distell, they can login into the platform to observe the number of waste reclaimer transactions on a particular day and see how much money they got from the buyback centre. This data is only available to Distell for monitoring, tracking and reporting purposes in graphical and tabular formats as this data is not accessible to the buyback centres or informal reclaimers" (DIS01).

KUDOTI transformed the data collection system of Distell from a basic Ms Excel spreadsheet to blockchain technology, where the data is secure, reliable and traceable. The KUDOTI APP has been developed for Distell to track and produce reports on their waste management processes in Khayelitsha (DIS01; KUD02). Thus the KUDOTI APP is being adopted by Distell in partnership with waste reclaimers as an agency to integrate waste reclaimers into the recycling value chain and secure more support for their activities with resources and funding. Generally, the ICT-enabled waste management platforms like KUDOTI are being adopted to support the company's compliance with the EPR legislation by presenting evidence of the work which Distell is currently doing using the KUDOTI APP for instance, the recycling targets and informal waste reclaimers jobs they have created (KUD02; KUD01).

### 4.4.4 BanQu – The Coca-Cola, Unilever and PETCO Project in Johannesburg

The Coco-Cola Foundation funded the BanQu Project in Johannesburg, which is being rolled out by PETCO, a South African PET Plastic Producer Responsibility Organisation (PRO). For PETCO, this "innovative technology to track, trace and record the trading in recyclable materials is being rolled out across South Africa. The move is set to empower recycling SMMEs, strengthen the value chain and promote the economic inclusion of the informal sector" (PETCO, 2021). Adoption of digital platforms provides for the digital transformation of trading of recyclable waste in South Africa. Besides integrating waste reclaimers, BanQu assists, "buy-back centres accurately record and track their recycling transactions with waste pickers as well as trace the origins of the recycling while providing a real-time business management tool enabling them to understand better and manage their businesses" (PETCO, 2021). The BanQu platform has allowed waste reclaimers to be bankable and have a record of transactions, as shown in Figure 4.6. In South Africa, BanQu is being used to assist brands like Coca-Cola and Unilever in meeting the Extended Producer Responsibility Regulation requirements. "

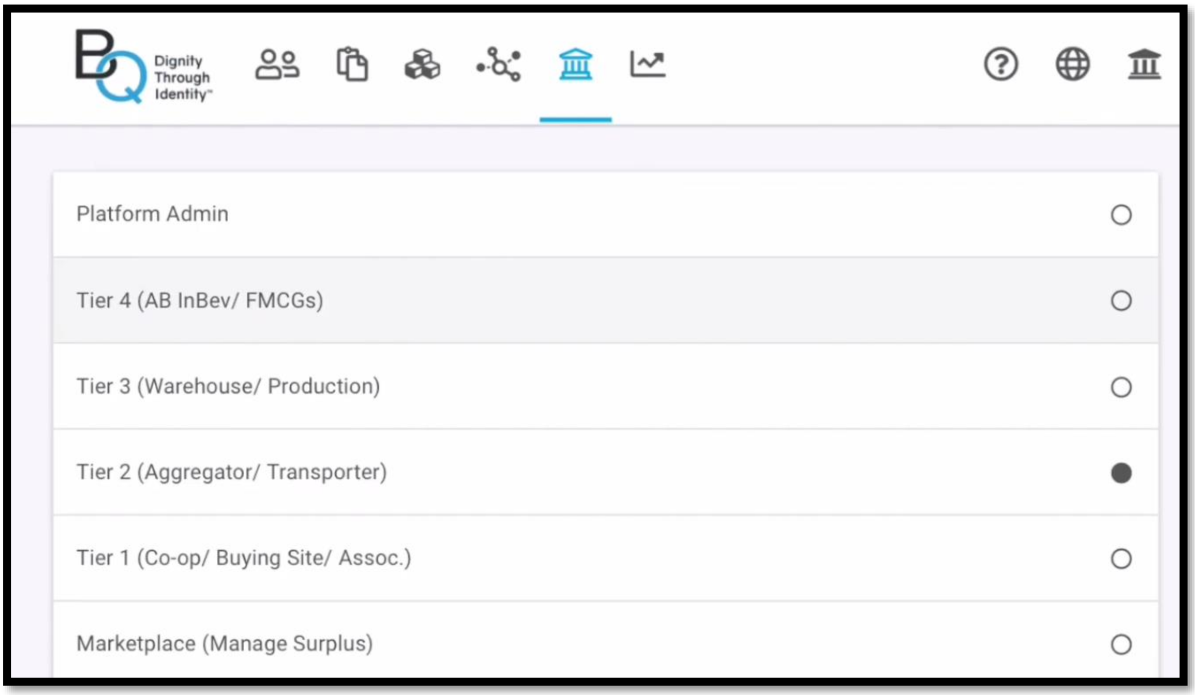


**FIGURE 4.5.**THE BANQU APP WITH VARIOUS TIERS (STAKEHOLDERS) IN THE SUPPLY VALUE CHAIN. **(SOURCE: BANQU, 2021).**

The BanQu Top-Up Project targeted was a pilot project which targeted waste reclaimers in Johannesburg under the African Reclaimers Organisation (ARO). The project was piloted in Brixton and Auckland Park, where waste reclaimers participating in the project were paid R0.50c per kg of recyclable material traded in registered BanQu buyback centres. Currently, more than ten buyback centres are operating, and these buyback centres are key institutions in the integration of waste reclaimers by registering them in the BanQu system. The BanQu process is the following:

1. "As part of the recycling chain, PETCO introduces BanQu to waste reclaimers and buyback centres. At the buyback centres, BanQu engages with owners of and explains to them the benefits of adopting this innovative technology in their recycling business and the benefits they will gain from the brands/producers of material they are trading. Buyback centres are the first to be registered into the system.
2. Waste reclaimers are registered into the BanQu through the buyback centre, or buyback centres submit to BanQu their database, for instance, in MS Excel or spreadsheet format with names, surnames and phone numbers for bulk registration through uploading the data into the BanQu system. In other cases, waste reclaimers are registered into the system as they come to trade their recyclables.
3. Waste reclaimers trade their recyclables at registered buyback centres, where the buyback employees manually input the weight and prices of recyclable material submitted.
4. The transaction is approved weight, and the waste reclaimer instantly gets an SMS notification as a receipt, which has the amount paid, the weight of recycles, and the types of recyclables sold. "The waste pickers, in turn, receive an SMS receipt for each transaction and can digitally track their income earned through sales to various buy-back centres" (BanQ02; BanQ03).
5. For waste reclaimers, they can monitor and track their transactions and generate weekly or monthly reports of their contribution to the circular economy, thereby enhancing transparency. The data is private and is only accessible to

stakeholders on the value chain for monitoring, tracking and reporting purposes in graphical and tabular formats" (BanQ01).

BanQu is a software company whose model is Software as a Service (SAS), which is mainly used in informal supply chains, such as waste recycling or agriculture. BanQu started in agriculture connecting small holder farmers to the brands like ABC Index Brewery and Coca-Cola (BanQ01). BanQu is currently operational in forty-one countries, mainly in more than half of Africa and the Middle East Africa, with little presence in South America and Europe (BanQu01). The BanQu platform works as an APP on a smartphone and is a multi-tier software for supply chain precisely, and the user can map any number of tiers (stakeholders) in the recycling supply chain, as shown in Figure 4.5. BanQu connects the whole supply chain from the brand to the recycling companies to the aggregators, resulting in four or seven tiers eventually leading to waste reclaimers at the bottom of the recycling chain. Various stakeholders are ranked according to their importance, with waste reclaimers on the lower tier of the recycling value chain. Unlike KUDOTI and Regenize, BanQu allows waste reclaimers to generate reports on their quantity of recyclable material traded, the prices paid, and the location of the buyback centre (BAnQ01). As of October 2021, BanQu, through PETCO, registered ten buyback centres that integrated more than 1 400 waste pickers on the BanQu system (PETCO, 2021). More than 2 350 tonnes of recyclable material has been diverted from the land fill and traded on the BanQu platform in transitions worth more than R5.7 million (PETCO, 2021). BanQu is free for registered waste reclaimers and buyback centres, and brands like Coca-Cola and Uniliver are responsible for paying the annual subscription fees.

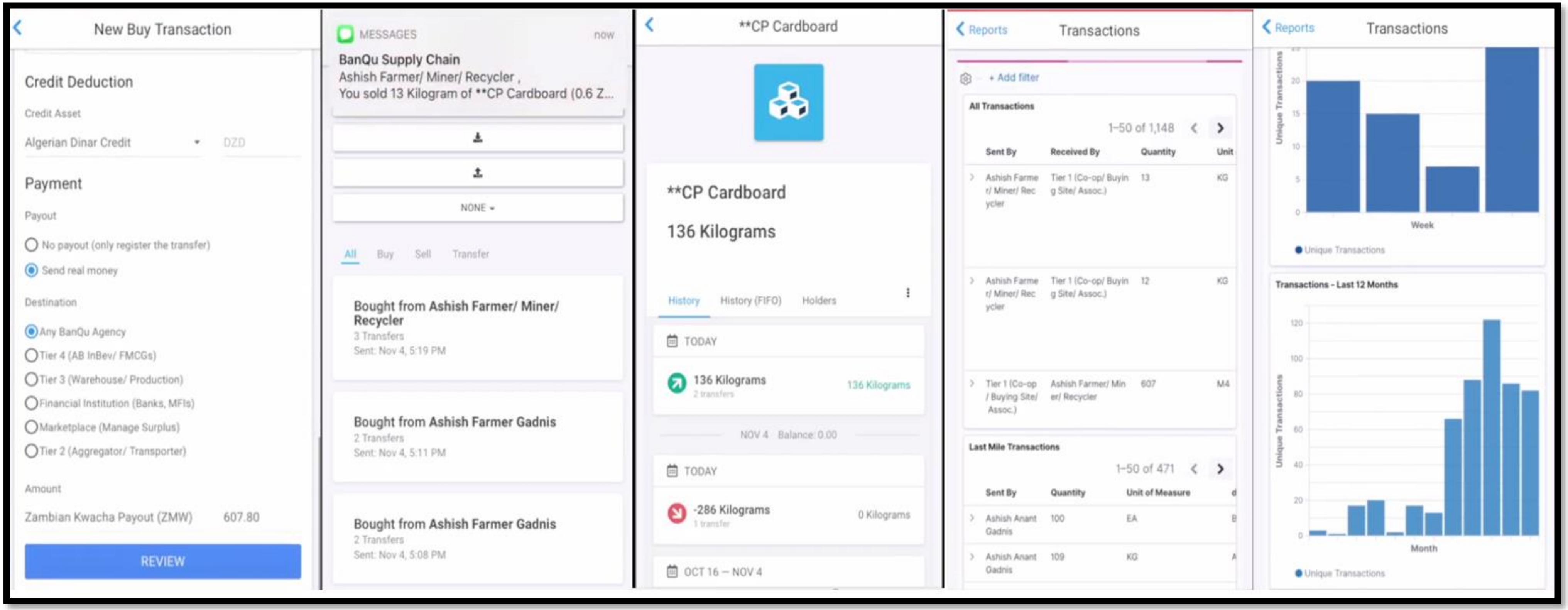


**FIGURE 4. 6.** THE BANQU APP WITH VARIOUS TRANSACTION PHASES AND REPORT GENERATION WITHIN THE SUPPLY VALUE CHAIN. **(SOURCE: BANQU, 2021).**

## 4.5 The theoretical framework for this research

This section presents the theoretical framework underpinning this thesis, drawing on the socio-technical transitions theory to sustainability within the environmental sustainability and waste management transformation debate. The adoption of the socio-technical transitions theory to sustainability as the central theoretical concept is a departure from previous research on the role of ICT in the informal sector, which adopted the social shaping of technology (Mackenzie & Wajcman, 1985), and the structuration theory (Giddens, Cabral, & Morissawa, 1989). Section 4.4.2 presents the key concept of the socio-technical transitions theory to sustainability that underpins this research. It is critical to note that some of the more detailed aspects of the socio-technical transitions theory to sustainability warranted empirical context but will be briefly explained and expanded in both the data presentation and data analysis chapters.

The researcher adopted the Socio-Technical Transition Theory for sustainability as the most applicable conceptual tool for the empirical data. The Socio-technical Transition Theory for sustainability frames socio-technical transitions as a consequence of the entire configuration of technology, citizens, policy and regulations, cultural meaning and market. The Multi-Level Perspective (MLP), the analytical tool for the socio-technical transition theory for sustainability, helps understand the digital transformation of the informal waste sector by applying ICT-enabled waste management digital systems. The researcher adopted the Socio-technical Transition Theory for sustainability as a theoretical framework for this study because the bottom-up smart integrated waste management project in the ICT-enabled digital transformation of the informal sector encompasses a transition goal. This is reflected by the design of the ICT-enabled waste management system, which seeks to establish ICT-intelligent waste collection and a programmable platform which enables stakeholders in the recycling value chain to deal with waste management and recycling issues.

As a system of innovation, the ICT-enabled waste management systems aim to transform the informal sector into an intelligent collection system from its current model. Secondly, the Socio-technical Transition Theory for sustainability illustrates the structure in which ICT-enabled waste management systems are embedded. At the core of the Socio-technical Transition Theory for sustainability is the MLP, which considers the transition into the digital transformation of the informal waste sector due to the interaction between the three analytical levels: niches, regimes, and landscape. The digital transformation of the informal waste sector and the emergence of ICT-enabled waste management systems result from the interactions between the local and meso levels (regime). The MLP further enables the researcher to distinguish between the global and local niches, thereby shedding more light on the diffusion of the ICT-enabled waste management systems in the informal waste sector. Finally, the research adopted the Socio-technical Transition Theory for sustainability as the theoretical framework for this study.

### 4.5.1 The socio-technical transitions theory to sustainability

The socio-technical transitions theory to sustainability emerged as a response to persistent sustainability challenges in cities and communities, such as rapid urbanisation, resource depletion, environmental pollution and climate change (Geels, 2011). These city-wide problems are denoted as crises. The socio-technical transitions theory postulates that addressing the worsening and persistent environmental challenges involves "fundamental changes in these systems, which are conceptualized in shorthand as 'socio-technical' since the fulfilment of societal functions involves not only technologies, but also situated consumer practices, cultural meanings, public policies, business models, markets, and infrastructures" (Geels, 2011:187).

Socio-technical transitions research is "an overarching term covering different, but similar, theoretical approaches that analyse the development of socio-technical transitions. Here, 'socio-technical' refers to the co-evolution of social and technological relationships while 'transitions' refers to the dynamics by which fundamental change in these relationships occur" (Geels, 2011: 188). Grin et al. (2010) distinguish three schools of thought in the socio-technical transitions research, namely: 'governance perspective' (Grin, 2010), 'transition management' (Loorbach and Rotmans, 2010) and the 'socio-technical transition' (Geels and Schot, 2010). The 'socio-technical transition' is hinged on successful case studies of sustainability transitions in waste, water, mobility and energy. Darnhofer (2015) asserts that research in this school of thought is focused on understanding the development and diffusion of technologies in society. Geels (2002) identifies the mobility transitions referring to steamships replaced by sailboats and fossil fuel cars replaced by automated and electric cars. These historical cases allow researchers to theorise how transitions are embarked on

(Darnhofer, 2015; Twomey and Gaziulusoy, 2014). Based on modern research, the ‘transition management’ and ‘governance perspective’ steering transitions into sustainable pathways focused on bottom-up systems which empower marginalised groups and enable participatory approaches (Darnhofer, 2015). ‘Co-evolution’, ‘multi-level perspective’, ‘multi-phases perspective’, and ‘learning’ are key conceptual tools shared by the three socio-technical transition approaches. Considering the aim of this research, Socio-technical Transition Theory to sustainability is adopted as the most appropriate for analysing the bottom-up smart city integrated waste management model in South Africa.

In the socio-technical transitions theory to sustainability, according to Markard et al. (2012), the primary focus is studying the innovative processes that precipitate an integral transformation in a ‘socio-technical system’. Firstly, the socio-technical transitions theory to sustainability considers the process of transitions as a 'co-evolution' process that require not only the complete ‘configuration’ of technology but overarching policy frameworks, markets and an enabling environment (Geels, 2019). Zamani (2017) and Wilding (2009) consider technology as powerless if it is not connected to a human agent. Secondly, the socio-technical transitions theory to sustainability considers the process of transitions as a multi-stakeholder process which comprises the participation and involvement of various social groups with varying capabilities, roles and interests, such as the municipalities, private waste collectors, waste reclaimers, NGOs and the private sector which includes the industries and businesses (Geels, 2019). Finally, radical transformation is regarded as the third aspect of transition in the socio-technical transitions theory to sustainability. Radical transformation not only illustrates the disruptive nature of technologies but also illustrates the shifts from one socio-technical configuration into another. Coenen et al. (2010) provide the fourth aspect of transition, which unfolds over more than twenty years.

The ICT-enabled waste reclaimers system (BanQu, Kudoti and Regenize) matches the first three conceptual tools of the socio-technical transitions theory to sustainability; for instance, the identified ICT-enabled waste digital platforms are a novel ‘socio-technical configuration’ which encompasses various stakeholders and has dreams to transform the current waste management sector and informal recycling industry. The researcher observed the early transition since these technologies are in their inception stages. This limitation does not necessarily mean the unsuitability of the socio-technical transitions theory to sustainability but acknowledges that despite time constraints, the theory provides rich theoretical perceptions of the innovative processes entrenched in a larger socio-technical context. Within the socio-technical transitions theory to sustainability, the Multi-Level Perceptive (MLP) is adopted to analyse the technological artefacts and structure the bottom-up smart city waste management model embedded within it. The Multi-Level Perceptive (MLP) contributes to a detailed understanding of the smart city innovation process of the bottom-up smart city integrated waste management model.

The current waste management system can be construed as a hybrid socio-technical configuration that has transpired through niche innovations introduced by waste reclaimers. This depiction signifies an amalgamation of established formal municipal waste collection practices and inventive approaches pioneered by waste reclaimers. This interpretation is congruent with the dynamic nature of socio-technical systems, wherein innovation and adaptation transpire across both technological and social dimensions. Within this context, the endeavours of waste reclaimers can be viewed as pivotal niche innovations that have engendered a hybridised waste collection framework, effectively bridging the chasm between conventional municipal waste collection and the progressive practices of waste reclaimers. This hybridised framework embodies an intermediary phase, suggestive of a potential trajectory towards a more sustainable waste management paradigm. This perspective underscores the significance of acknowledging and valorising waste reclaimers' inventive contributions as pivotal drivers in shaping and advancing sustainable waste management practices within the context of the socio-technical system.

### 4.5.2 Multi-Level Perspective (MLP)

The Multi-Level Perspective (MLP) is at the centre of the socio-technical transitions theory to sustainability. The origin of the MLP is attributed to various scholars (Geels, 2005; Schot, 1998; Rip and Kemp, 1998) who desired to connect the Evolutionary Economics theory and Science and Technology Studies (STS). The MLP integrates concepts from Neo-institutional theory, Evolutionary Economics theory, Structuration theory and Science and Technology Studies (STS). Despite having different roots, "their understanding of the process of technological change are very similar" (Grin, 2010: 30). MLP is multidisciplinary and creatively collates the best components from the four theories identified above in a comprehensible theoretical framework that is built to address the weakness of each theory.

Furthermore, MLP provides for harmonisation between the phases of transitional transformation. As a heuristic framework, the MPL is adopted in this research to analyse transitions defined as “processes of profound regime reconfiguration resulting in a shift” (Bui et al., 2016) from one socio-technical system (traditional informal waste collection system) to another (the ICT-enabled informal waste reclaimers system).

### a) MLP’s three analytic levels

Geels (2019) and Rip and Kemp (1998) postulate that MLP comprises three analytical levels, which are: ‘the niche (the locus of radical innovations), the socio-technical regime (existing practices and rules), and the social-technical landscape.’ Lawhon and Murphy (2011) view them not only as essential levels but also as analytical concepts. This is hinged on the assumption that alignment across different levels and within levels triggers the transition. Geels (2002) demonstrates the relationship between these three levels in a nested hierarchy depicted below in **Figure 4.1**.

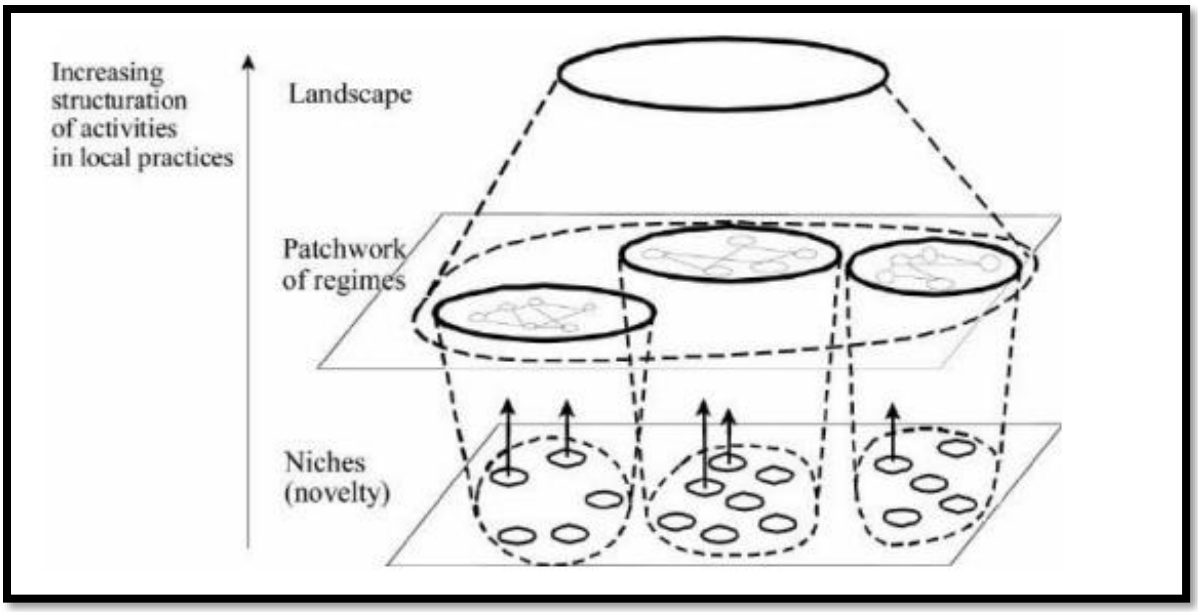


**FIGURE 4.7.** THE NESTED HIERARCHY OF MLP’S ANALYTIC LEVELS. **(SOURCE: GEELS, 2002: 1261)**

Socio-technical regimes are depicted as the meso-level of the nested hierarchy (Geels, 2002; Geels, 2011). Geels (2005) suggests that the regime consists of three interlinked dimensions: “(1) networks of actors and social groups; (2) formal, normative and cognitive rules that guide the activities of actors; (3) material and technical elements” (Verbong & Geels, 2007: 1026). For Geels (2005), a socio-technical regime consists of three rules: ' cognitive, regulative and normative.’ Agendas and belief systems are examples of cognitive rules, while regulations, standards and laws are examples of regulative rules and norms, and behaviour and values are examples of normative rules (Geels, 2005). The socio-technical regime is stabilised by these rules for the innovation to occur in an incremental trajectory resulting in an incremental technological path (Grin et al., 2010). The incremental trajectory is confined to the technological facet and relates to other aspects such as stakeholder preference, markets, politics, culture and science. These various dimensions of regimes also can create friction with the regime.

Niches form the micro-level of the nested hierarchy in Socio-technical regimes and are spaces for a small network of innovators to develop their technologies at the regime's margins (Geels, 2002; Geels, 2011). The ICT-enabled waste collection system is very congruent with the concept of the niche since it encompasses technological evolution. Similarly to the concept of niche, the ICT-enabled waste collection system illustrates that informal waste reclaimers and various network supports new technologies. Kemp et al. (1998) define niches as "breeding spaces" protected from the mainstream market where learning enables actors to develop a new set of practices and rules around the new technology. This set of new rules and practices are regarded as innovative socio-technical configurations and considered incubators for regime change (Geels, 2011). Berkhout et al. (2011) assert that niche development is fundamental but fails to prompt a regime change. Key to the socio-technical transitions is the concept of niche-regime interaction through integrating new practices and rules within the regime, resulting in further regime reconfiguration. Elzen et al. (2012), in their analysis of the regime's constituent elements where the niche-regime interaction occurs, identified institutional, technological and network as the three models that portray this interaction's nature.

The notion of waste reclaimers as niche innovators within the realm of sustainability presents an opportunity to transcend traditional conceptions of innovation. These individuals, often operating informally at the fringes of established waste management systems, play a crucial role in the transition towards more sustainable practices. While their contributions may not align with conventional technological advancements or high-tech solutions, their resourceful approaches serve as a distinct form of innovation that resonates with Clapperton Mavhunga's alternative definitions of technology and innovation. Mavhunga (2017) challenges the dominant discourse that confines innovation to technological breakthroughs, highlighting that innovation can manifest in various forms, including indigenous knowledge systems, practices, and local adaptations. Waste reclaimers, through their adept salvage and recycling practices, epitomize such non-conventional innovation. Their initiatives effectively extend the lifecycle of discarded materials, reducing the burden on landfills and conserving resources, which aligns with sustainability goals (Dias & Alves, 2008).

This underlines the need to broaden the scope of innovation beyond the confines of high-tech interventions and acknowledge the diverse pathways through which sustainable change is realized. Drawing from McFarlane and Soderstrom's (2017) concept of "knowledge-intensive smart urbanism," an alternative perspective emerges. This viewpoint emphasizes the centrality of knowledge and intelligence in urban transformations, as opposed to a narrow focus on technology. Waste reclaimers' practices align with this framework, as they leverage experiential knowledge and localized strategies to achieve significant waste reduction outcomes. This discourse challenges the conventional tech-centric narrative by advocating for a more inclusive understanding of innovation that encompasses knowledge-rich, community-driven initiatives.

Expanding on this argument theoretically, the Multi-Level Perspective (MLP) on sustainability transitions, often criticized for its tech-centric bias, could benefit from a recalibration. By acknowledging the role of waste reclaimers as agents of change within socio-technical systems, the MLP could evolve into a framework that embraces diverse forms of innovation. This evolution could help transcend the dichotomy between technological and non-technological innovation and enable a more holistic understanding of transition dynamics. Waste reclaimers' innovative practices represent a paradigm shift in how innovation is conceptualized within sustainability discourse. By aligning with Mavhunga's alternative notions of technology and embracing knowledge-intensive smart urbanism, a broader and more inclusive understanding of innovation emerges. Integrating such perspectives into established theoretical frameworks like the MLP can enrich our comprehension of sustainability transitions and offer a more comprehensive roadmap towards a more sustainable future.

The macro-level of the nested hierarchy is formed by the socio-technical landscape (Geels, 2002; Geels, 2011). Urbanisation, population growth and climate change are long-term external trends within the socio-technical landscape that influence the niches and regimes. Geels (2011) identifies the socio-technical landscape as an external context of the regime and niche which directly influence actors. Geels (2011) distinguishes the two forms of change at the landscape levels as being 'slow change', such as demographic and/or cultural changes and more rapid change, for instance, economic depression or commodity prices.

Niche, regime and landscape are the three analytical levels that structure the theoretical core of the MLP, a design that illustrates these components interacting and assembled with a nested hierarchy (See Figure 4.2). The decade-long term configurations of the three analytic levels are interpreted as a consequence of "social (inter)actions within semi-coherent rule structures that are recursively reproduced and incrementally adjusted by interpretive actors" (Geels 2010:505). Therefore, in this sense, the socio-technical transition research is "interested in uncovering how socio-technical configurations that might work become configurations that do work among a plurality of transition pathways" (Smith et al. 2004). Transitions in the socio-technical system encompass dynamics between several stakeholders on various levels, and this thesis intends to discover and capture these dynamics.

### b) The Multi-Level Perspective on the socio-technical transition to sustainability

The MLP is a "process theory which illustrates in detail the overall trajectory of socio-technical transitions and a 'local model' component, which addresses-specific activities and causal mechanisms in multi-level interactions" (Geels and Schot, 2007). MLP demonstrate that transition is not a linear process but varies between countries and domains although there are common patterns: "a) niche-innovations gradually build up internal momentum, (b) niche-innovations and landscape changes create pressure on the system and regime, and (c) destabilization of the regime creates windows of opportunity for niche-innovations, which then diffuse and disrupt the existing system" (Geels, 2011: 29). Figure 3.7 presents an ideal transition that emerges through the interaction between various levels (landscape, system and niche).

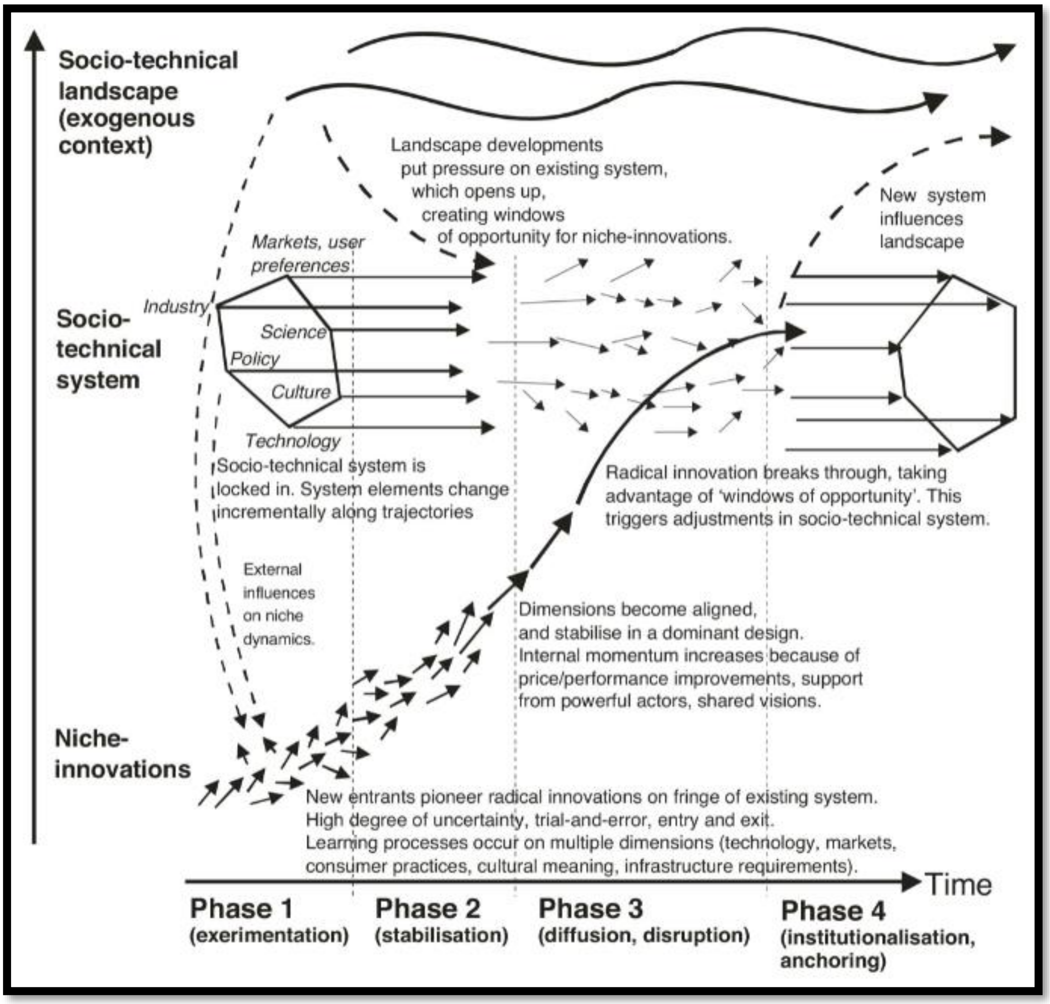


**FIGURE 4.8.**THE MULTI-LEVEL PERSPECTIVE ON SOCIO-TECHNICAL TRANSITIONS. **(SOURCE: GEELS, 2002: 1263)**

The trajectory of socio-technical transitions is split into four phases, with key activities and struggles taking many decades. The first phase of the trajectory encompasses pilot projects and trial-and-error learning with the new technologies (Sengers et al., 2019; Schot and Geels, 2007). The cities, living laboratories and pilot projects act as foundations of niche innovations (Geels and Raven, 2006), creating a learning environment for the innovators about the acceptance, feasibility and performance of the newly introduced technologies. During this phase, there is a prevalence of failures, uncertainty and competing objectives for both the end-users and owners (Schot and Geels, 2007). The main challenge of sustainability technologies is to "overcome the current fragmentation of initiatives, and their tendency to remain isolated or short-lived, which ultimately reduces their potential for lasting and wide-ranging change” (Turnheim, 2018:237). As new technologies, they may be perceived as unfamiliar with deep uncertainties, undermining their social acceptance and legitimacy.

In the second phase, technological innovation establishes a grip and stabilisation in the market niches, offering users more reliable access. The stabilisation of the new technology into the market enables it to be a dominant design if “sequences of projects build on each other through the circulation of experiences, learning processes, and dedicated aggregation activities such as codification, standardization, and model building, which articulate best practices, product specifications, and design guidelines “ (Geels and Raven, 2006). Various stakeholders in ICT, engineering, academia and industry sectors interact with each other to regulate the market and entrance of new technologies as they record, codify and archive lessons learnt from previous projects and provide them as inputs for new technologies. As end-users interact with the technology, innovation may occur during its localisation and transform them into familiar artefacts entrenched in their daily practices and routines (Lie and Sørensen, 1996). However, some social groups may oppose such technology due to its adverse impact on their daily practices and not being consulted while producing it. Such resistance to new technology may impede further development resulting in conflicts and stalemates (Devine-Wright et al., 2017). These activities are essential in gradually stabilising the innovation trajectories in the socio-technical transition process, as illustrated in Figure 4.3.

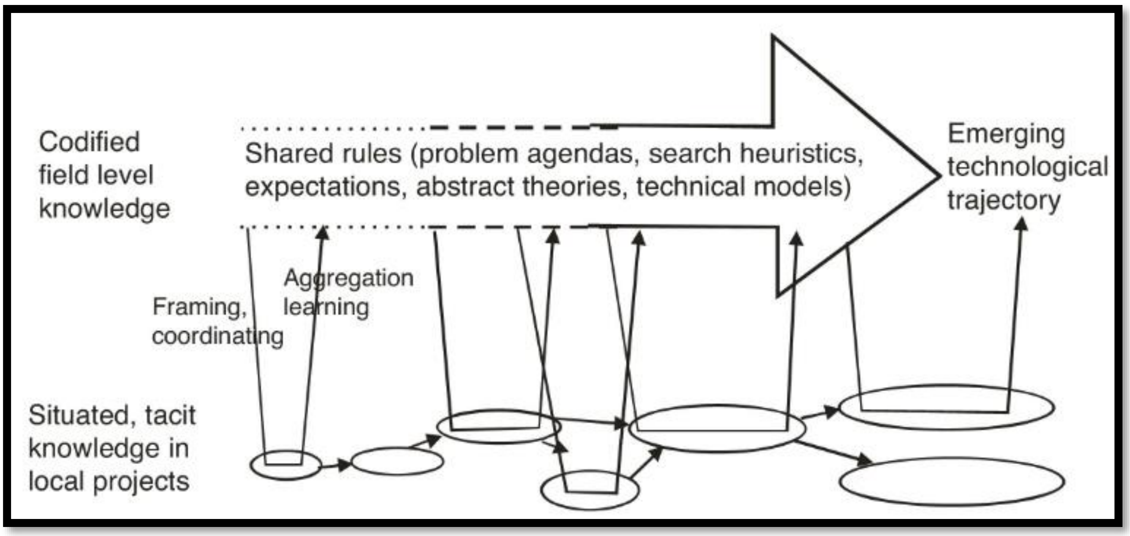


**Figure 4.9.** Innovation trajectory emerging from sequences of local. **(Source: Geels and Raven, 2006: 379).**

The third phase is characterised by the innovation or technology being diffused into the mainstream markets, “on the one hand driven by niche-*internal* drivers such as price/performance improvements, economies of scale, development of complementary technologies, and support from powerful actors, and, on the other hand, taking advantage of structural windows of opportunity created by landscape developments that pressure the regime, leading to tensions and regime destabilization” (Geels, 2002). During this diffusion phase, struggles between the innovators and the existing regime are prevalent in various dimensions. For example, there maybe be economic competition between the current technologies and new technology, business struggles between new ICT-enabled waste collectors against the old buyback centres, which might lead to the downfall of existing buyback centres, political conflicts as a result of power struggles between the informal waste reclaimers and privately contracted waste collectors and industries over the "agenda-setting, problem framing, and adjustments in subsidies, taxes, and regulations" (Meadowcroft, 2009) for integrating waste reclaimers into the formal recycling value chain. These power struggles also involve municipalities, waste reclaimer organisations, industries, academia, NGOs, policymakers and other social groups affected by the new technology. However, whether the niche innovation will overcome these struggles remains uncertain, and some technologies ultimately suffer setbacks.

After countering and overcoming such struggles, the niche innovation enters into the fourth and final phase of the trajectory of the socio-technical transition. During this phase, the new socio-technical system supersedes the components of the old system and “becomes institutionalized and anchored in regulatory programmes, user habits, and views of normality, professional standards, and technical capabilities” (Geels, 2019:192). The new technology is fully embedded into society and succeeds over the competition resulting in a socio-technological regime change.

The socio-technical landscape of this study, in Multi-Level Perspective (MLP) terminology, encompasses the intricate interplay between technological configurations, social actors, institutions, and their contextual settings within the realm of ICT-enabled waste management systems. The case study selection process is guided by both distinct research problems and the presence of ongoing smart city projects. The chosen case studies—BanQu, Kudoti, and Regenize—represent unique smart city initiatives, each embedded within the broader socio-economic and environmental contexts of the City of Johannesburg and the City of Cape Town. Place plays a pivotal role in shaping the ICT-integration process within this study. The difference in the two cities' contexts contributes to variations in the implementation and outcomes of the smart city projects. The City of Johannesburg's Brixton-Auckland Park BanQu Pilot Project, for instance, is influenced by the African Reclaimers Organisation (ARO) partnership, reflecting the specific socio-political dynamics of the city. Similarly, the City of Cape Town's smart city initiatives—Kudoti in Khayelitsha and Regenize in Bridgetown—respond to localized waste management challenges, with Kudoti operating within Distell's corporate social investment (CSI) strategy and Regenize adopting an innovative business platform.

The unique socio-economic conditions, regulatory frameworks, and waste management landscapes in Johannesburg and Cape Town shape the way waste reclaimers are integrated into the technological configurations of the ICT-enabled waste management systems. This interplay between contextual factors and technological implementations highlights the significance of place-specific considerations. For instance, the alignment of the Kudoti project with Distell's CSI strategy and compliance with Extended Producer Responsibility (EPR) regulations underscores the impact of place on project design. Ultimately, the socio-technical landscape of this study is a dynamic tapestry of technological innovation, citizen engagement, stakeholder partnerships, and the distinct socio-political and economic attributes of Johannesburg and Cape Town. This landscape underscores the importance of context-sensitive approaches to smart city projects, emphasizing the role of multi-stakeholder collaboration in shaping ICT-integration processes to address local waste management challenges and catalyze transitions toward a more inclusive circular economy, as advocated by Samson et al. (2020).

### 4.6 Criticism of the Multi-Level Perspective (MLP) of the socio-technical transition theory

Criticisms have been levelled against the Multi-Level Perspective (MLP) of the Socio-technical Transition Theory in sustainability research (Smith et al., 2010). The first criticism of the MLP focuses on the actual meanings of the theoretical concepts in socio-technical transition studies. For example, Raven et al. (2010) identified five meanings of ‘regime’, and ‘niche’, he found six different meanings and four meanings for ‘landscape’. The second criticism focuses on the lack of acknowledging the political and social struggles in defining socio-technical transitions (Shove and Walker, 2007). The third criticism highlights that MLP is insensitive to local context and spatiality in that it locates the country as the key context in which the regime and niche are based (Shove, 2002). Furthermore, Vasileiadou and Safarzynska (2010) argue that the framework has a conceptual gap between agents and systems dynamics, leading to a high level of simplification and generalisation inherent in the theory.

Later developments of the Socio-technical Transition Theory to sustainability and the MLP have addressed some of the criticisms raised. To address the shortcomings of the MLP, Geels (2002) developed an updated MLP referred to as the multi-scalar MLP perspective. Despite the criticism that MLP lacks spatialities, researchers have used the MLP spatial level (Raven et al., 2012), tracing the spread of Rapid Bus Transit in Bangkok (Senger and Raven, 2015), exploring geographical unevenness of transitions processes (Coenen et al., 2012) and studying the role of the city (Huston and Marvin, 2009) in socio-technical transition. Many studies on socio-technical transition have been located in developed countries focusing on energy efficiency, smart mobility and low-carbon systems (Lawhon and Murphy, 2011). In response to the lack of agency, Geels (2011) argues that agency is not explicitly shown in the MLP framework but that social groups introduce the trajectory and alignments at each level. Various types of agency are incorporated into the MLP, such as culture, power and social movements (Grin et al., 2010; Geels and Verhees, 2011).

## 4.7 Ethical considerations

The research complied with the University of the Witwatersrand’s ethical guidelines for conducting research, as explained by the university’s Non-medical Human Research Ethics Committee. The guidelines required the researcher to seek Ethics application approval before conducting the research and the approval was granted on 09 September 2020. The University Ethics Clearance Certificate is attached in Appendix A, and also attached is the Certificate of Competence in Research Ethics (See Appendix B). The researcher was granted permission to undertake research in selected case studies, as shown in the attached permission letters (See Appendix C – F). Ethical considerations permeate every phase of case study research, ranging from negotiating access to the case study sites to the research write-up stage. The researcher was fully aware of the ethical considerations throughout the research, which are addressed below.

### 4.7.1 Informed consent

A researcher is expected to attain consent from the respondents. For this research, informed consent comprised permission to undertake semi-structured interviews and participant observation. Since the data collection process consisted of participant observation at the SACN Smart City workshop, ASSAF Smart City forum, webinars, informal and formal interviews, the researcher used informal and formal consent for the research. The researcher designed two documents, the consent form (See Appendix J) and the participant information form (See Appendix I), as specified by the University's ethical guidelines. The participant information sheet provided the respondents with enough information concerning the research and the implications for the respondents if they participated. The consent form guaranteed that the respondents understood how their data would be used in the research and also articulated their rights. For all face-to-face interviews, the researcher issued consent forms which were signed by each respondent, which authorised the researcher to undertake the interview, record the interview proceedings and take photographs in case studies. The researcher used both forms to receive formal consent during formal interviews and participant observations.

The COVID-19 pandemic and subsequent lockdown regulations altered the traditional approach to data collection, resulting in the researcher adopting digital platforms like ZOOM, Google Meetings, MS Teams and Whereby to conduct interviews. Since the researcher could not meet with the respondents, consent forms, participant information sheet and the interview schedule guideline were sent before the interview meeting for the participant to be appraised of the documents, which the researcher read again before the online interview. The respondents agreed that the researcher read out the contents of the consent form and participant information sheet at the beginning of the online interview session and agreed to participate in the research interview. During the interview sessions, the researcher informed the respondents that they were not compelled to answer any question they wished not to respond to and were permitted to withdraw at any moment during the interview session. During the entire online interview session, the researcher did not encounter any incidents where the respondents were hesitant to respond to questions.

Regarding the participant observations, there were three main sites: the Webinars, the SACN Smart City workshop and the ASSAF Smart City forum. The SACN Smart City workshop was limited to the project participants, while the Webinars and ASSAF Smart City forum were accessible to everyone who wanted to attend. For the SACN Smart City workshop, every participant signed a consent form with the host organisation, which permitted other participants to observe and ask questions regarding the presented topics. The consent of participants of the Webinars and ASSAF Smart City forum was gained by signing up and agreeing to participate in the forum and webinars, which meant that the hosts could record the proceedings of the meeting and share the recordings with all the participants. However, during these webinars and forums, the researcher managed to undertake some informal interviews with experts on smart cities and waste reclaimer integration, and the researcher introduced himself and his research to gain oral consent before the interviews. In other instances, the respondents requested consent forms to be emailed to them to sign and email back to the researcher.

### 4.7.2 Confidentiality and anonymity

The researcher ensured that the respondents were guaranteed anonymity in any research paper or report emanating from this study. Confidentiality is defined by Lowe et al. (2018) as relating to everything the researcher gets from the participants. 'Case study research rarely involves damaging consequences, but researchers should still carefully consider the likely effect on people who are involved in the research' (Petty et al., 2007). This research study concerns real people and ICT-enabled waste management projects in South Africa and can potentially affect the people, organisations, institutions and suburbs involved in the research. In response to this, the researcher adopted anonymity to disguise the respondents and used pseudonyms. In other cases, the researcher used the title of the person, for instance, an official from the City of Johannesburg, rather than a pseudonym to provide the readers with necessary information concerning the source while safeguarding the individual's identity. Finally, the researcher was cautious not to offer false hopes and guarantees to the respondents concerning solving the issues associated with the digital transformation of the informal waste sector.

## 4.8 Limitations

The first anticipated limitation was a potential language barrier associated with specific local languages. However, even in Cape Town, where the researcher had anticipated this potential limitation, all the participants were conversant in English, and any further clarification was done in vernacular language, for instance, Xhosa (Khayelitsha) and IsiZulu (Johannesburg), which the researcher is conversant with. The other limitation is related to adopting only the three ICT-enabled waste management systems in the digital transformation of the informal waste recycling sector. It is crucial to note that the qualitative approach does not essentially seek to be entirely representative, but the three ICT-enabled digital platforms were purposively selected for exploring the digital transformation of the informal recycling system and integration of waste reclaimers in the informal recycling value chain.

The COVID-19 pandemic and subsequent lockdowns postponed the scheduled work, initially planned for October 2019 to August 2020. The induced hard lockdown due to the outbreak of COVID-19 impeded the researcher's access to office work space at the university campus. More importantly, it prevented the scheduled visits to the two case study sites in Cape Town due to restrictions on inter-provincial travel. As such, the researcher had to reschedule planned visits, and the length of the study was extended. Furthermore, the researcher resorted to online interviews to collect data from the respondents, especially with the ICT-enabled waste management collectors or companies. This enabled the researcher to understand better how the ICT-enabled waste management systems operate before visiting the sites.

The other limitation was gaining access to the case study research sites and the respondents. Bryman (2012) agrees that gaining access to the research site by a researcher is a challenge; however, the researcher was fortunate to benefit from the contacts established during the October 2019 ASSAF Smart City forum and February 2020 SACN Smart City workshop before the fieldwork commencing. Burgess (1984) cautioned that accessing sites involves several steps of negotiations and renegotiations. Nevertheless, the ICT-enabled waste collectors or companies promptly responded to my requests for interviews as they viewed this as an opportunity for their business for researchers to explore their contribution to the digital transformation of the informal recycling value chain.

The request for permissions to conduct interviews with officials from the City of Cape Town (CoCT) was diligently pursued. However, despite the researcher's efforts, the process of seeking permission at CoCT unfortunately did not yield approval. This might have been due to the intricate and time-consuming nature of the approval process, which potentially posed challenges for timely execution within the research timeline. This outcome illustrates the complexities that can arise when engaging with public institutions for research purposes. Despite the researcher's proactive approach in securing permissions, external factors beyond their control might have influenced the final outcomes The researcher's commitment to thorough and ethical research is evident in their efforts to secure permissions and their transparency in documenting the outcomes of their engagement with CoCT and CoJ.

## 4.9 Conclusion

This chapter presented and provided the rationale for the qualitative inductive research methodology consisting of multi-steps and organised research methods and activities to understand the digital transformation of the informal recycling sector by applying ICT-enabled waste management systems. The chapter presented Socio-technical Transition Theory to sustainability as the study's theoretical framework. The theoretical framework is useful in this research as it contributes to the complex innovation process of ICT-enabled waste management digital platforms in South Africa. The researcher used the case study design that focused on South Africa’s three ICT-enabled waste management platforms and justification for selecting BanQu, KUDOTI and Regenize as suitable bottom-up smart city integrated waste management projects in South Africa. The chapter also discussed the instruments used in data collection, including data analysis and the theoretical framework. The chapter also reflected on the limitations navigated by the researcher to gain access to the research case study sites and key ethical issues. Finally, the researcher also addressed the reconfiguration of the Socio-technical theory for sustainability as the critical theoretical framework for this study.

# CHAPTER FIVE: PRESENTATION OF FINDINGS

## 5.1 Introduction and Background

Technology, policy directives and globalisation are frequently transforming urban service provision in South African Cities. Innovative models enabled through ICTs have emerged in municipal solid waste management, disrupting the existing traditional approach towards the zero-waste goal. South Africa is experiencing an influx of digital waste management platforms that remedy environmental problems, waste reclaimers integration and circular economy. Kudoti and BanQu are employed for the EPR regulation and CSI strategy of corporates. These innovative digital tools can connect the waste generator and service provider, which is critical towards the zero waste goal. Regenize, Kudoti and BanQu Apps use the ground-breaking model that brings together technology, education, rewards/incentives and sustainability to raise awareness about recycling (EXPT-SC02). How is the bottom-up smart city approach understood within the South African informal recycling management system? The context, design and cognition of the ICT-enabled waste reclaimers system (Kudoti, BanQu and Regenize) will be used as case studies to understand how the bottom-up smart city approach is being framed and in what way the model is manifesting in recycling and municipal waste management.This chapter responds to the three sub-themes to gain an in-depth understanding of how the Bottom-Up Smart City Integrated Waste Management Model integrates waste reclaimers and enhances environmental performance towards zero waste. Based on the interview engagements with the stakeholders and organisations outlined above, the chapter presents the results wherein the outcomes are examined in the context of theoretical and conceptual frameworks underpinning the identified thematic areas.

## 5.2 Framing of the bottom-up smart city integrated waste management model and how the model manifests in informal waste collection system.

### 5.2.1 The ICT-enabled waste management platforms for grassroots informally driven integration processes.

Industries and producers like Coca-Cola and Distell have adopted technologies that aim to integrate waste reclaimers in their design and operation in various waste recycling projects in South Africa. Thus, we are seeing an increase of these APP-based technologies being able to go beyond linking the waste generator and waste service provider, which is critical to the implementation of the EPR scheme. We are now seeing bottom-up smart city strategies through the EPR Scheme, where innovative digital tools like Regenize, BanQu and Kudoti have incorporated informal waste reclaimers in waste management. These three digital applications have consulted waste reclaimers in their implementation in partnership with multinationals like Coca-Cola and Distillers, who have purchased the licenses to use these digital platforms. These waste-based technologies are being adopted within the CSI strategies of the industries in compliance with the EPR Regulation. Thus, this section seeks to analyse the role of these digital platforms in improving the welfare of informal waste reclaimers and the Zero Waste Goal.

> "The most important aspect about these platforms is that these waste-based technologies have managed to link the manufacturers, buyback centres and waste reclaimers who are the service provider for waste collection in communities within the EPR framework. Smart cities advance the digital transformation of cities and provision of services through digital APPs and technological systems in which the ICT-enabled waste management platforms are part of the smart city solutions in terms of smart cities, clean cities, and zero waste and circular economy" (EXPT-SC01).

**TABLE 5. 1.** MAPPING OF DIFFERENT ICT- ENABLED WASTE RECLAIMERS SYSTEMS IN TWO SOUTH AFRICAN CITIES.

| Nr | Company name | Year started | City located | Service targeted | Items collected |
|---|---|---|---|---|---|
| **1** | Regenize | 2018 | Cape Town | Residential | Recyclables |
| **2** | BanQu | 2015 | Johannesburg | Residential | Recyclables |
| **3** | Kudoti | 2018 | Cape Town | Residential | Recyclables |

These platforms have managed to bring together most waste management stakeholders into the same platform to improve the waste management processes; for instance, buyers and sellers are brought into the network. The socio-technical transitions theory to sustainability is used to analyse the impact of technology towards the zero waste goal while integrating waste reclaimers recycling value chain in South Africa. Here, the use of technology will be analysed according to groups, perceptions and context from the dimensions of context, process, and content.

## 5.3 Two models of ICT-enabled waster reclaimer collection systems

Chapter two discussed the intelligent collection systems in the informal sector and acknowledged that in sub-Saharan Africa, the ICT-enabled waste reclaimer system was not yet fully explored as the implementation of the digital platforms is in the inception stages. The collection of recyclables involves several steps "from household to waste reclaimer; to the waste collector; to middleman; to the buyback centres; and the recycling plants finally" (EXPT-SC01). In South Africa, the ICT-enabled waste reclaimer system illustrates two forms of ICT-enabled recyclable collection: 1) waste reclaimer to ICT-enabled system and 2) household to ICT-enabled waste reclaimer system, as shown in Table 5.2.

| **Collection forms** | **Companies that adopted the forms** |
|---|---|
| Waste Reclaimer to ICT-enabled Waste Reclaimer system | KUDOTI and BANQU |
| Household to ICT-enabled Waste Reclaimer system | REGENIZE |

**TABLE 5.2.** ICT-ENABLED RECYCLABLE COLLECTION AND PLATFORMS ADOPTED.

### 5.3.1 Household to Waste Reclaimer ICT-enabled collection system.

The collection of recyclables by waste reclaimers through the aid of ICTs has resulted in several models based on each phase of waste recyclable collection. The first approach is the household-to-waste reclaimer ICT-enabled system. The household-to-waste reclaimer ICT-enabled system depicted in the Regenize platform allows users like households to request collection services from waste reclaimers (REG01; REG-WR01; REG-WR02 and REG-WR03). Households are required to register by creating a profile/account on the Regenize platform through a smartphone application (APPs) developed by Regenize, an ICT-enabled waste collection company. The household-to-waste reclaimer intelligent platform (Regenize APP) allows:

> "households to log in and request recyclable collection service, and the GPS location of the household address is used by the smartphone to direct the household location and also specify the shortest route from the location of the local hub or waste reclaimer to where the household is located. The households can request collection services through the digital platform. These features are embedded within the Regenize APP and are accessible only through the cellphone." (REG01).

Several ICTs tools are used in the 'household to waste reclaimer' intelligent collection systems. Both the waste reclaimer and household use smartphones as the hardware ICT infrastructure, and Regenize APP is the software component of the ICT-enabled waste-based collection system. The waste reclaimer is responsible for identifying and submitting detailed information and uploading the images/photos of the recyclables on their Regenize App portal. This data communication process is transacted through the portal-provided internet data and GPRS location system.

### 5.3.2 Waste Reclaimer to ICT-enabled waste based collection platforms

The second model is the waste reclaimer to ICT-enabled waste-based collection platforms. It mainly focuses on waste reclaimers, collectors and buyback centres and needs several ICT tools to implement. Each waste collector has a unique code that identifies their profile and a section/tab where the waste reclaimer can upload images of the types of waste collected to their account. The current system in South Africa is not fully developed and technologically advanced, like the automated intelligent waste recycling machines with sensors, radio frequency identification (RFIDs) and barcode readers to identify the waste type, volume and value (R5). Hannan et al. (2015) identified five ICT tools applied in the automated intelligent collection 1) spatial technologies, including Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Remote Sensing (RS). 2) Identification technologies involving barcodes, Radio-frequency identification (RFID). 3) Data acquisition technologies, including sensors and imaging devices. 4) Data communication technologies relying on Global System for Mobile Communications (GSM)/GPRS.

The waste reclaimer to ICT-enabled waste-based collection platforms applies spatial and data acquisition technologies. Unlike the highly advanced models, a waste reclaimer using the Regenize system uploads images of various waste streams collected in the imaging device and manually inputs the weight of the recyclables. The sensors and imaging devices monitor the recyclable data uploaded and transmit it to the company server through GSM/GPRS (REG01, REG-WR02 and REG-WR03). For waste reclaimers using BanQu and Kudoti, the buyback centre inputs the weights and recyclable waste streams on the waste reclaimers' accounts/portals (KUD-WR04 and BANQ-WR04). Experts in waste reclaimer integration (EXPT-WRI01) and smart cities (EXPT-SC02) note that the system also works as a backdoor inventory for the waste reclaimer, waste collectors and buyback centres to ascertain and monitor their stock status for different recyclable materials. Thus, the waste reclaimer to ICT-enabled waste-based collection platforms consists of five steps:

1. The waste reclaimer uploads images of waste types and manually inputs the weight of the recyclables following the sequence of steps provided on the Regenize system.
2. The waste reclaimer will deliver the recyclable material to the buyback centre (Kudoti and BanQu), or the waste collector will collect at the decentralised hubs where waste reclaimers are operating (Regenize)
3. The system will provide the amount payable for the recyclables by SMS to the waste reclaimer and a transaction registered in the waster declaimer's account.
4. The waste reclaimer will be paid and can choose the mode of payment, either through electronic payments or cash. (EXPT-SC01, EXPT-WRI01 and EXPT-EPR01).

| | ICTs tools adopted | Applicability | Forms |
|---|---|---|---|
| **Informal collection** | N/A | All recyclables | Waste reclaimer collects randomly through separation outside source and salvaging in landfills.<br>Trading of recyclables is done in cash. |
| **Waste Reclaimer to ICT-enabled waste based collection platforms** | Imaging devices, APP, Sensors, Smartphone device | All recyclables | Collected information on recyclables is uploaded via the machine.<br>Trading of recyclables can be either electronic currency or cash |
| **Household to Waste Reclaimers collection** | APP, Imaging device, GIS, GSM/GPRS Smartphone device | All recyclables | Waste collection by reclaimers is scheduled or collected by request at the gate or door.<br>Trading of recyclables can be either electronic currency or cash. |

TABLE 5. 3. COMPARISON OF INFORMAL COLLECTION, HOUSEHOLD TO WASTE RECLAIMER AND WASTE RECLAIMER TO MACHINE COLLECTION SYSTEMS.

### 5.3.3 ICT-enabled and organised informal waste reclaimer collection system

The ICT-enabled informal waste reclaimer collection system is highly organised and systematic whilst enabling waste reclaimers integration through ICTs. Fig.5.1 explains the schematic organisation of the organised ICT-enabled informal waste reclaimer collection system and unsystematic informal reclaimer collection. The informal waste reclaimer collection system is unsystematic, and collections are random as waste pickers and reclaimers salvage at landfills and from trash bins. Waste reclaimers typically start their day around 0300hrs and walk long distances to salvage material in affluent suburbs and travel back with a heavy load of recyclable waste in their trolleys (KUD-WR03; REG-WR02 and BANQ-WR05). Reclaimers sometimes do not have a particular time of working or lunchtime, and they collect everywhere, including affluent suburbs, townships, open spaces, zoos, lakes and informal settlements without municipal collection services. In areas where there are municipal services, reclaimers leave early to areas where they will search for recyclables and wait for households to put their bins outside for municipal collection. Once the bins are out, the reclaimer immediately scavenges through the bins for material before the municipal or private waste service provider truck arrives (BANQ-WR). Xue et al. (2019) argue that time, place, items, and price are random within the informal waste collection system. The underlying root cause for challenges experienced by waste reclaimers is attributed to the randomness in this sector.

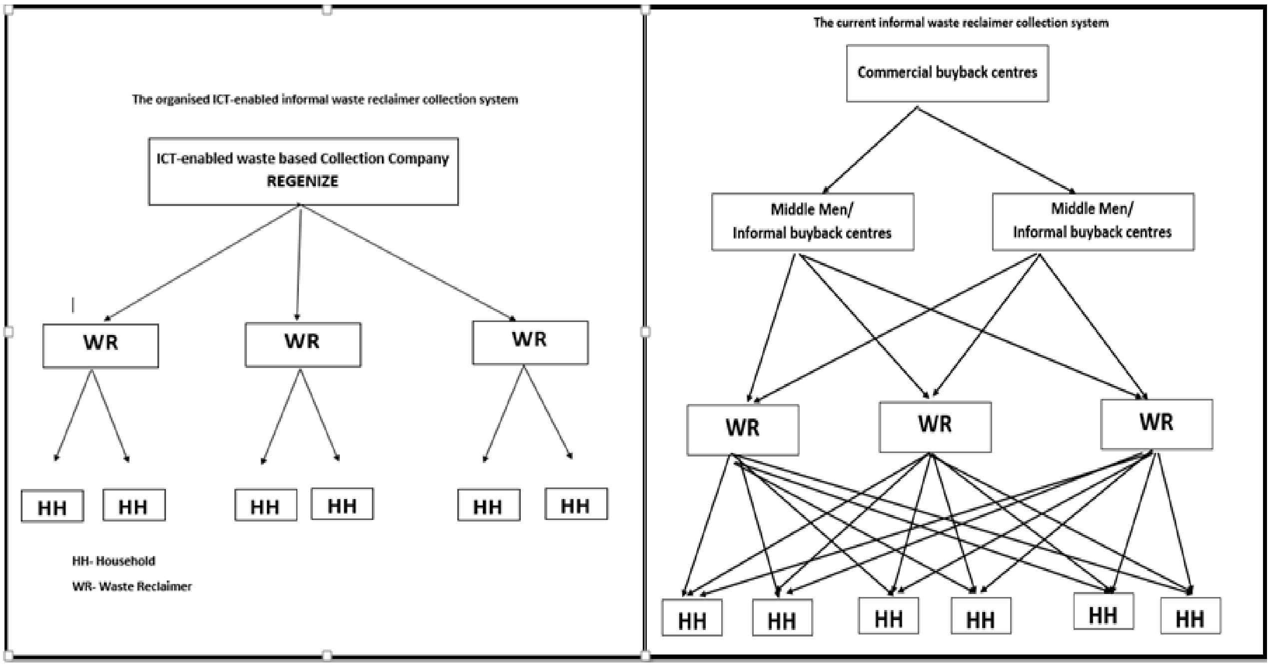


**FIGURE 5. 1.**THE ORGANISED ICT-ENABLED INFORMAL WASTE RECLAIMER COLLECTION SYSTEM AND UNSYSTEMATIC INFORMAL COLLECTION. **(SOURCE: AUTHOR, 2021).**

In the ICT-enabled informal waste reclaimer collection system, the use of ICT applications and infrastructure avails opportunities to organise, regulate and monitor the collection process of recyclables and reduce the unsystematic and random nature of the current informal waste reclaimer collection. The digital platforms enable a systematic and consistent collection of recyclables through recorded daily collection schedules for households, suburbs, time of collection, type and amount of waste collected and frequency, which becomes consistent and systematic. The mobile device has the Regenize APP, allowing the reclaimer to capture the weight and images of the collected waste. In addition, the smartphone device has daily collection schedules and a list of households where the reclaimer will collect waste (REG-WR02). The digital platform produces a scheduled list of household collections per day for recyclables collection and uses GPS locations for route optimization (REG-WR03). The ICT-enabled waste collection model adopted a decentralised model where waste reclaimers are fixed to specific suburbs/areas, establishing a regular collection relationship with households.

> "The Regenize Project in Bridgetown operates on a decentralised model where reclaimers are placed in local hubs linked to big storage containers placed strategically throughout the community. Each container can service between 300 and 500 households and is manned by a three-person team, translating to two waste reclaimers and one sorter. What is important about the strategic location of local hubs where these containers are fitted and placed is that the waste reclaimers operate within a 1-2km radius, and all the households would be within that range. Relationships have been created between us and the household we interact with while collecting recyclables." (REG01).

The Kudoti and BanQu model of ICT-enabled collection is fixed between the waste reclaimer and the registered buyback centre. The Kudoti and BanQu models are not operational at household-to-waste reclaimer levels, as these platforms only work with buyback centres and waste reclaimers, excluding households from the recycling value chain (BANQ-WR03; KUD01 and KUD-WR02). At household levels, collection by waste reclaimers is still disorganised and similar to the traditional informal collection systems where waste reclaimers collect recyclables in landfill sites, residential household bins, kerbsides and illegal dumpsites. In addition, the sorting of recyclable materials is sometimes conducted in open spaces, salvaging through the bins and "undesignated areas resulting in some form of illegal dumping when waste reclaimers leave their unwanted material after sorting, which the municipality workers have to collect or clean up the area" (CoJ-PIK01 and CoJ-EISD02). The researcher, during data collection, observed that the waste reclaimers in Braamfontein Metro Centre were hastily transporting their stored and sorted recyclable materials to the buyback centres as the municipality had informed the waste reclaimers that the area was prohibited from dumping (See Fig.5.2 below). This clearly illustrates that the Kudoti and BanQu model exhibits some features of the traditional informal collection system, and the application of ICTs or digital platforms only happens during trading of recyclable materials to record the transactions between the waste reclaimer and buyback centre. The City of Johannesburg, through PikitUp, strives to be a clean city (CoJ-PIK02) and "takes pride striving to keep the city clean, some of the sorting spaces used by waste pickers remain undesirable as the municipality is struggling to manage where waste pickers can sort and store their materials while enforcing the city by-laws when it comes to illegal dumping" (CoJ-EISD03)


**FIGURE 5.2.** WASTE RECLAIMERS TRANSPORTING THEIR MATERIALS FROM AN UNDESIGNATED SORTING AND STORAGE SITE IN BRAAMFONTEIN METRO CENTRE. **(SOURCE: AUTHOR, 2021).**

## 5.4 Shared Blockchain approach

### 5.4.1 Organised value chain, recyclable material flow and transactions.

The ICT-enabled informal waste reclaimer collection system illustrates an efficient and organised value chain, recyclable material flow and transactions. Fig. 5.3 (below) demonstrates the recyclable material flow, organised value chain and cash flow in the current waste reclaimer collection model and the ICT-enabled informal waste reclaimer collection system. In the current waste reclaimer collection model [Fig. 5.2 (1)], the recyclable material is moved and transacted in several phases from the household to the waste recyclers. The price of recyclable material rises as the recyclable material goes up the value chain, and in each stage, the recyclable material is sorted to the buyer's requirements (BANQ-WR05). The transaction-for-cash environment of the informal sector is attributed to being one of the factors that result in inefficiencies, as trading cannot be done without cash. Fei et al. (2016) point out that this exerts tremendous pressure on buyers, middlemen and buyback centres, to consistently have cash, making them susceptible to being robbed by criminals.

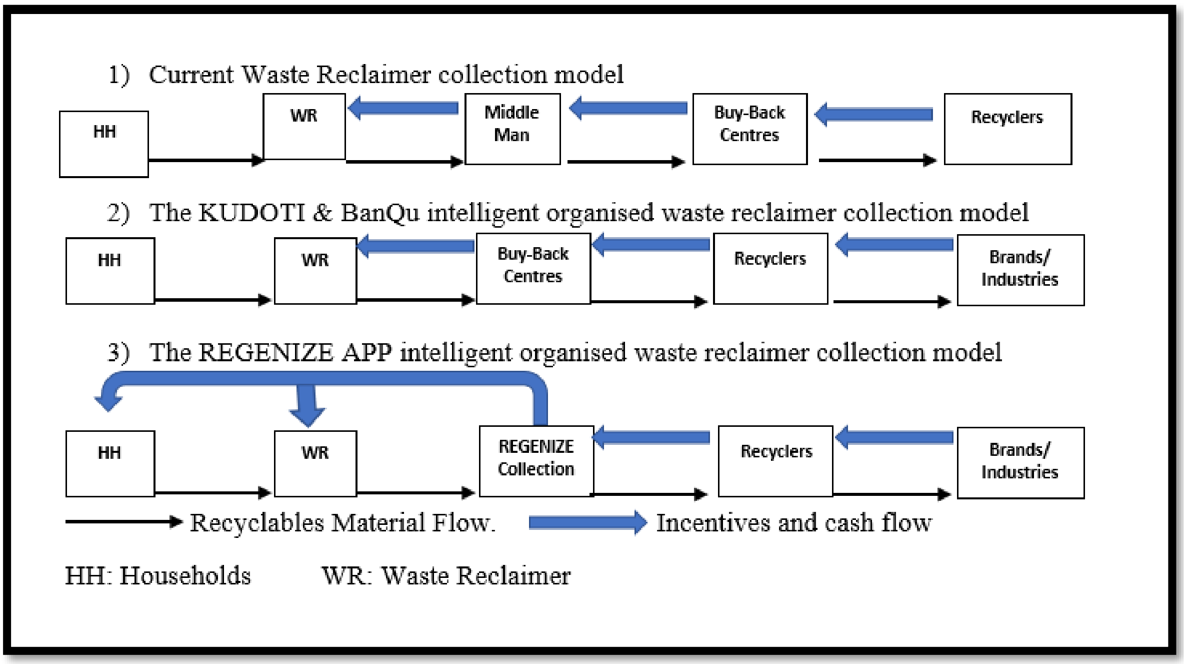


**FIGURE 5.3.** RECYCLABLE MATERIAL FLOW, ORGANISED VALUE CHAIN AND CASH FLOW IN THE CURRENT WASTE RECLAIMER COLLECTION AND THE ICT-ENABLED WASTE RECLAIMER SYSTEM. **(SOURCE: AUTHOR, 2021).**

In Fig 5.3 (2 &3), there are two models of ICT-enabled informal waste reclaimer collection system where there is a clearly defined value chain which includes the industries/manufacturers/brands (Coca-Cola, Distillers and SABS Breweries), technological companies (Kudoti & Regenize) becoming waste collectors and transaction money flow from the brands/industries cascading down to the household/waste generator which is absent in the current informal collection system. Unlike in the informal recycling model, where the transaction trade is undertaken in three phases, in the Kudoti and BanQu ICT-enabled informal waste reclaimer collection system, transactional trade is done in three stages with the inclusion of the producers/brands/EPRO and the removal of the middlemen as waste reclaimers trade their materials directly with registered buyback centres (EXPT-EPR01; KUD01 and BANQ01). The trade is done in four phases in the Regenize ICT-enabled informal waste reclaimer collection system. Regenize company own the sorting centres; they control and monitor the collection process from the household until the sorted materials are collected from the waste reclaimers and sold to the recycling companies (REG01). Regenize replaces the buyback centres and incorporates households in the recycling value chain. Thus, the informal recycling sector's digital transformation through ICT-enabled waste management digital platforms has included households, ICT waste collector companies, and producers previously excluded in the municipality-led integration process.

The transactions traded in the ICT-enabled informal waste reclaimer collection system are electronic, and this eliminates pressure on recycling companies and buyback centres to consistently have cash for them to buy the recyclables (Xue et al.  2019). The consistency in collecting recycles, and various payment possibilities make the intelligent system more efficient, systematic and sustainable. Waste-based digital APPs and ICT tools create opportunities for increased trades in recyclables, route optimisation, and information collection in recyclables and payment transactions (EXPT-SC02).

> “When recyclables have been collected, information is sent to the household’s Regenize APP profile/account with a report that informs them how much they have recycled and how much carbon emission they have saved and the REMALI (incentive) that the household can redeem for either groceries or airtime once the collection is accomplished” (REG01).

> “BanQu and Kudoti are the most efficient platforms for waste reclaimers to implement and track the EPR targets in collaboration with the EPRO, buying back centres, producers or all the stakeholders in the supply chain, to track and see the transactions as they happen, it brings a degree of transparency to the system” EXPT-EPR01).

### 5.4.2 Blockchain technology for permanent, accurate and traceable data in the informal sector.

The ambiguity of the contribution of waste reclaimers to the city's waste management and recycling initiatives is identified as the primary factor behind the government and cities failing to adopt inclusive approaches to waste recycling systems. The waste reclaimers' contribution is not acknowledged, "and given the fact that they are informal, is that they have kind of flown under the radar, and there has not been any kind of reliable data on them, where they work, and how much waste they're recycling" (EXPT-EPR02). Schenk and Blaauw (2019) argue that waste reclaimers can collect ten times the municipality's amount.

Despite this data, some of the quantifications, for instance, on landfill savings and the amount of waste being collected by waste reclaimers, are based on extrapolation and uncertain data. The waste reclaimers, middlemen and informal smaller buyback centres neither have an adequate system in place to record, monitor their transactions, nor track their stock for recyclables. One respondent (EXPT-WRI01) explained that waste reclaimers rely on the receipt of payment while smaller buyback centres use paper and Excel system, which is full of inefficiencies and inaccurate data which can be easily altered. An official from Regenize pointed out that "as we strive to design and build better waste management systems, there is still one major issue of 'data'. Without large amounts of precise data, we will struggle to find appropriate solutions that empower and support the existing system of waste reclaimers" (REG01). Thus, data is critical to designing and creating an appropriate technology and measuring waste reclaimers' impact on recycling initiatives.

The ICT-enabled informal waste reclaimer collection systems, namely Kudoti, BanQu and Regenize, are software programmes developed on blockchain technology (EXPT-SC01). Blockchain technology has been commended as a solution to the informal recycling sector, especially for EPR projects, because of its security advantages, consensus model and traceability (EXPT-EPR01). Blockchain technology offers an easier way to complete transactions without online banks and third-party applications, which is highly applicable in the informal sector (EXPT-SC01; REG01 and BANQ01). Wu et al. (2017) note that blockchain technology allows the informal recycling sector to facilitate payment transactions, communicate and keep detailed trading data on all stakeholders in the value chain. As already shown in Section (5.4), the possibility of scheduling daily collections, monitoring the collection and route optimization by the technology offers opportunities for real-time data which is accurate and traceable. The ICT-enabled informal waste reclaimer collection systems, which are anchored on blockchain technology, can provide detailed records of transactions and provide accurate data on the role played by waste reclaimers towards the Zero Waste goal (EXPT-SC01). Detailed and statistical information on the transactions and recyclables traded can be provided at any particular moment. This allows for transparency and helps solve the challenge of inadequate and uncertain data on the actual role of waste reclaimers.

> "There are benefits of using blockchain technology in terms of traceability because the permanent inscription of transactions eliminates [tampering] with data since once the transaction has been concluded, no one cannot go back and erase it. …BanQu and Kudoti enable smaller buyback centres to understand their businesses better using automated recording and tracking of transactions. BanQu and Kudoti's online automated supply chain tracking and payment system uses blockchain technology to track and trace recycled material across the value chain, providing buyer and seller price transparency" (EXPT-WRI02).

Despite its security advantages, the technologies adopted within the informal recycling sector are criticized for their reliance on individuals at buyback centres or waste reclaimers physically capturing the data. Respondents (REG01 and KUD01) acknowledge that the ICT-enabled systems experience challenges when a waste reclaimer during household collection or the buyback centre sometimes manually records inaccurate data. This is observed during routine reporting when the Distell or Regenize discover that the information entered was incorrect as it did not tally with the transactions of recyclable material sold. This makes the technology not foolproof and susceptible to human errors during data input into the system (EXPT-EPR02). However, systems have been put in place to deal with instances of human error. For BanQu, the consensus model where the waste reclaimer and owner of the buyback centre verify the information entered into the system before approving the transaction reduces human error (BANQ01). Regenize and Kudoti have a procedure to cross-check and verify that the data entered is correct by comparing the total weight of recyclables collected and sold against the information entered during the collection of recyclables (REG01; KUD01). Even though demands have been made for an automated system, it is important to note that the current system, undergoing further developments, has laid the foundation for a highly advanced automated informal waste reclaimers' collection model.

The recently gazetted EPR Regulation requires that brands, industries and manufacturers take responsibility for managing their products through the dedication of funding to collect and process their products at the end of use (DEFF01). Furthermore, the EPR Regulation has set annual targets that each industry or sector should attain regarding recycling their products. The brands, industries and manufacturers have adopted ICT-enabled informal waste reclaimer collection systems to generate data which will be used to report to the government towards their EPR targets as mandated by the EPR Regulation. Three uses of technology within the EPR model are identified concerning payment of funds, auditing of the spent funds by the EPR organisation and tracking targets, which they have to achieve in the next few years on a certain percentage of their product that does not go to the landfill (DEFF01). For such, technology is important in that it allows the stakeholders in the value chain to track objectively: what waste reclaimers have sold, the number of recyclables recovered, and the price they are being paid for the recyclables (EXPT-SC01). Furthermore, the technology has enabled the waste reclaimers' visibility, integration and recognising the tracking of transactions.

> "BanQu, Kudoti and Regenize for small black businesses offer them the back-end ability to know what they are buying from the waste reclaimers, how much stock they have, who they are selling to and how much they are selling for. It's some inventory software where the buyback centres can see how much they have bought, sold and what's remaining in their stock" (EXPT-SC02).

This section has comprehensively responded to the first sub-theme aimed at understanding how the bottom-up smart city model is manifesting and being framed in the informal waste collection and recycling sector. The waste reclaimers in South Africa have benefited from implementing waste-based digital platforms/APPs to provide a waste collection and recycling value chain. The ICT-enabled informal waste reclaimer collection systems have created a value chain with all the stakeholders from the bottom tier of the recycling value chain to the top tier being the producers absent in the informal sector. The benefits of the digital transformation and intelligent collection system towards improving waste reclaimer welfare and environmental performance are addressed extensively in the next section.

## 5.5 Varied impacts of integration .

This section presents the benefits brought about by the integration processes through the digital transformation of the informal recycling sector. To fully understand the bottom-up smart cities model in waste management, it is imperative to understand the current model of smart cities waste service provision, which is predominantly technocentric and formal, but has failed to integrate waste reclaimers into municipal solid waste management.

### 5.5.1 Waste Picker Integration Guideline for South Africa and the Extended Producer Responsibility (EPR) as a key policy mechanism for waste reclaimers' integration and zero waste goal

The Waste Picker Integration Guideline for South Africa and its related waste management instruments are important programmes under which arrangements for designing bottom-up smart cities with integrated waste management models and integration of waste reclaimers should be implemented and administered. South Africa has vibrant regional waste management policies, strategies, regulations and legislation; however, they lack efficient implementation and adequate enforcement. In 2016, the Department of Environmental Affairs (DEA) reported that municipalities provided the collection of waste services to 61% of households, whilst 33% disposed of the waste themselves (DEA, 2016a). Collection services differ according to municipalities, as some are provided by contracted private management companies, waste pickers (cooperatives or individuals) and municipalities. The waste reclaimers integration process must "value and improve the present role of reclaimers, and the strength of the informal systems and include waste pickers as key partners in the design, implementation, evaluation and improvement of waste pickers work as well as the political, social, economic, legal and environmental integration of waste pickers" (Samson et al., 2020:30). Thus, the bottom-up smart cities model in informal waste management should harness opportunities provided by digital platforms, ICTs and APPs to involve various stakeholders, sectors, multilevel perspectives and stimulate grassroots smart waste development.

The Waste Pickers Integration Guideline has created a bottom-up process for citizen and waste reclaimers' participation in the integration processes within the informal recycling sector. The technologies adopted in implementing the EPR schemes allowed waste reclaimers to be involved in designing and developing the Regenize, BanQu and Kudoti technologies. OECD (2016) argues that in cities of the global South, reclaimers are often the only people who know how the existing recycling system works, how it can be improved and what technologies are suitable for their system. The participatory processes allowed the industry and waste reclaimers to work together to find alternatives to create a system that seeks to complement the waste pickers' system rather than creating a new system which will result in fewer recyclables being collected and job losses for waste reclaimers. The most important aspect of the ICT-enabled waste management platforms is that they were conceived after intense engagement and consultation with waste reclaimers. Waste reclaimers using the ICT-enabled waste management platforms stated, "I am happy about the Kudoti digital platform because it came from us after we informed them how we would want the digital platform to function and operate. The digital platform came from us, and we were involved and consulted in designing features we want" (DIS01). The Smart APPs and digital platforms involved industries/manufacturers who are the waste producers and waste reclaimers who are both end-users of the platform in the value chain of informal waste collection system, thereby enabling collaboration and stakeholders' buy-in, which resulted in the success of the technologies.

The EPR Regulation, which was gazetted on 6 May 2021, reinforced the increased recognition of the role played by waste reclaimers in recycling initiatives and the zero waste goal in South Africa. The EPR Regulation established markets for recyclable materials, prescribed compulsory integration of waste reclaimers into the EPR Schemes or EPR organisations and proposed compensation of waste reclaimers for the collection services they are currently undertaking for free by November 2022 (EXPT-EPR02). This is a shift from the charitable municipal approach of acknowledging waste reclaimers as entrepreneurs in the recycling value chain. The EPR Regulation identified the brands/industries through EPROs or EPR Schemes previously side-lined in the municipal smart waste management as instruments for safeguarding waste reclaimers recognition and integration (EXPT-EPR01). The EPR Regulation not only empowers the waste reclaimers but further “encourages local dialogue, tailored solutions and flexible approaches to integration, working with what is already in place but also seeking to improve challenges and impediments to integration. This accommodating approach also allows for the case-by-case implementation of the various distinct pilot programmes between individual producers, EPR Schemes, EPROs, waste reclaimers and technological companies" (EXPT-WRI02). This allows for multiple flexible and inclusive approaches of all stakeholders, allowing for potential scaling up of the initiatives if they are gaining momentum and success.

The EPR Regulation lacks clarity on how the waste reclaimers will be integrated into the recycling value chain. What is interesting to note is that the EPR Regulation has created a dual waste management system being the municipality-led and EPRO/EPR Scheme managed (EXPT-EPR02). During the PolySA EPR Webinar on 19 May 2021, a concern was raised about the interaction between producers and municipalities preventing sorted waste from ending up in the same collection system, negating the separation at the source system. This concern was in trying to understand and demarcate the actual role of municipalities within the EPR schemes. The EPR Regulation, left to the producers' discretion, established EPROs to engage with municipalities without clearly defining the procedures and delineating the responsibilities of producers and municipalities within the EPR Regulation and implementation (EXPT-EPR01). The OECD (2016) notes that there may not be a one size fits all approach of either formalisation or total informalisation and that the best-functioning systems tend to be those which embrace an open strategy that includes both informal collectors and the existing [private] value chain enterprises in the system

### 5.5.2 ICT-enabled waste reclaimers' integration models in Cape Town and Johannesburg

The adoption of technology in the informal recycling sector has resulted in the ICT-enabled grassroots informally driven integration processes: two approaches of integration have emerged, namely collaborator integration and depth integration. Xue and Bressers (2020) identified depth integration and collaborator integration as manifesting in China's digital transformation of the informal recycling sector. For Xue and Bressers (2020:313), depth integration is an approach where the ICT-enabled waste collector company "hires experienced collectors from the informal sector, equips them with smartphones and intelligent devices and trains them with methods of intelligent collection. The waste reclaimers, through using digital platforms, can access welfare benefits provided by these ICT companies." Regenize Company has hired waste reclaimers to provide a collection of recyclables in Bridgetown and provided waste reclaimers “uniforms, PPEs, boots, goggles, hand scales, gloves, sorting and storage hubs, tricycles and smartphones” (REG-WR03). Similarly to Kudoti in Khayelitsha, it has intervened by providing PPEs, goggles, and plastic refuse bags to separate recyclable material (KUD-WR01, KUD-WR03). Waste Reclaimers in Bridgetown and Khayelitsha who are using Regenize APP and Kudoti APP are accessing resources that have improved their working conditions and improved their income (REG-WR01, REG-WR02, KUD-WR02 and KUD-WR03). These intervention mechanisms by Regenize and Kudoti have improved the waste reclaimers' status and working conditions (REG01 and KUD01). The mentioned benefits accrued from Regenize and Kudoti were absent in the traditional informal waste collection model, where waste reclaimers were not provided with resources.

The second approach that has also emerged is the integration between the waste collection company and the waste reclaimer. In the collaboration integration model, Xue and Bressers (2020) explain that the waste reclaimer uses the intelligent/technological waste collection company’s digital platform as a collaborator or user instead of being a fully-boarded employee. Through this platform, the waste reclaimer only uses the payment features and sometimes receives incentives from the system. Waste reclaimers using the BanQu digital platform are collaborators in creating transactions and data that producers need to report on their performances towards the EPR regulation waste recycling targets. Regenize and Kudoti have taken the first approach in South Africa, while BanQu has adopted the second approach to waste reclaimer integration. As of October 2021, Kudoti had integrated more than 300 waste reclaimers in Khayelitsha, while Regenize has integrated more than 800 waste reclaimers in several suburbs in Cape Town, and BanQu has collaborated with “10 buy-back centres and registered over 1 400 waste reclaimers in Johannesburg” (PETCO, 2021).

### 5.5.3 Multiple improvements for ICT-integrated waste reclaimers

The digital transformation of the informal recycling sector through the adoption of ICT-enabled informal waste reclaimer collection systems has dramatically changed the welfare and working conditions of the waste reclaimers who are part of the project (BANQ-WR03, KUD-WR02; REG-WR2). The important aspect of digital transformation is that it adopted a decentralised model in that the ICT-enabled informal waste reclaimer collection systems allowed waste reclaimers to be integrated not only around waste management but also within their community (EXPT-WRI01; WRO-01, WRO-02). The ICT-enabled waste reclaimers system not only uplifted the confidence of waste reclaimers in Johannesburg and Cape Town but further enhanced collections of household materials. The ICT-enabled waste reclaimers system incorporated GIS and GPS applications resulting in route optimisation, efficient, recyclable collection and an organised value chain. The three ICT-enabled informal waste reclaimer companies intervened uniquely in their various areas to improve some of the conditions experienced by waste reclaimers in their sector, as discussed below.

#### a) Provision of vehicles and tricycles to transport recyclable materials

Waste Reclaimers are seen as a nuisance on the roads for causing accidents, deaths and slowing traffic leading to traffic congestion with their makeshift trolleys when transporting waste recyclables. Notably, transportation challenges have been addressed with the introduction of co-produced recycling tricycles and a donated truck, enhancing collection efficiency and empowering waste pickers within their communities (EXPT-WRI01; WRO-01, WRO-02). This transition from makeshift trolleys to purpose-built tricycles and trucks exemplifies a participatory design approach, reflecting the project's commitment to waste reclaimers' input and technological suitability (REG-WR02). Figure 6 shows the makeshift trolleys and bags used by reclaimers to collect the recyclable materials and transport them to the sorting areas and buyback centres. The recycling tricycles are used for the collection of recyclable material and used by waste pickers who are participating in the recycling project. The intervention mechanism was part of the project's social design, which needs to provide technology that considers the realities of informal waste reclaimers. One of the realities was the challenge of transportation which resulted in Regenize providing recycling tricycles.

**FIGURE 5. 4.** WORK CONDITIONS OF WASTE PICKERS BEFORE THE REGENIZE PROJECT. **(SOURCE: AUTHOR, 2021)**

The design of the recycling tricycle was developed after engaging with the waste reclaimers. Before the delivery of tricycles, waste reclaimers used to "spend 3 hours going to a suburb to go and collect some material, and spend another three hours coming back, with a heavy load of recyclable materials" (REG-WR02). Engaging waste recyclers to identify what they need in the design process of the tricycle is essential in the project's sustainability and ensuring that the end-user benefits from this technology.

> "This illustrates that we engage with our stakeholders, unlike one municipality which decided to give trolleys to waste reclaimers without initially consulting them to ascertain if it was the technology they needed and the specifications of the trolleys. For instance, CoJ designed a trolley that didn't have handles and was too heavy. So, the waste reclaimers could not use it, dismantled the trolleys and sold the metal scrap for cash centres" (EXPT-WRI02).

To determine the appropriate technology, it is vital to consult waste reclaimers on the right technology to empower them. The African Reclaimers Organisation (ARO) also faced challenges transporting recyclable materials. In partnership with other donor agencies, ARO received a truck (Fig.5.6) to enable them to transport their materials from various collection points to the buyback centre (WRO-01). UNIDO donated the truck to empower waste reclaimers, improve their working conditions and enable them to move large amounts of materials from the landfill


**FIGURE 5. 5.** INFORMAL WASTE RECLAIMERS ON TRICYCLES PROVIDED BY REGENIZE FOR USE IN THE RECYCLING PROJECT. **(SOURCE: REGENIZE, 2021).**


**FIGURE 5.6.** INFORMAL WASTE RECLAIMERS LOAD THEIR MATERIALS ON A LORRY DONATED BY UNIDO TO TRANSPORT THEIR RECYCLABLES. **(SOURCE: AUTHOR, 2021).**

### b) Provision of Personal Protective Equipment (PPE)

In the traditional informal collection system, most waste reclaimers operate without adequate protective gear (EXPT-WRI02). The waste pickers do not use protective equipment when collecting material in the streets or open-air dumps, which exposes them to health risks. During the inception and design phase, Regenize and Kudoti in Bridgetown and Khayelitsha, respectively, to gain the confidence and trust of the waste reclaimers, provided waste reclaimers with uniforms, boots, goggles, hand scales and gloves. This intervention sought to improve the reclaimers' status and working conditions (REG02; KUD01). The waste reclaimers who operate in landfill sites are exposed to extremely harsh conditions that make them susceptible to health risks. The lack of adequate PPE means that reclaimers are forced to work under extreme conditions to make a living, yet this is working towards South Africa's recycling goals and diverting waste from the landfills as municipalities in South Africa run out of landfill space. The provision of PPE enhances their working conditions and acknowledges the great role reclaimers play.

c) Decentralised Hubs for sorting and storage of Recyclables

Waste reclaimers do not have adequate space to sort and store their recyclable materials, and in most cases, they store their material on illegal land like open spaces, parks, unused buildings and under bridges. The materials stored in open spaces and parks are seen as waste either confiscated by the metro police or burnt, resulting in waste reclaimers losing their income (WRO-02). Furthermore, during the lockdown in 2020, when all buyback centres were closed, reclaimers continued going to work, and with the ban on alcohol, glass had no value then, but reclaimers collected and stored them. One of the reclaimers asked: "Now that we are in level 1, and alcohol consumption is permitted, the glass companies have opened, and now we are supplying these glasses. Tell me, what would have happened if we had not stored these bottles in our storage facility?" (BANQ-WR03). As discussed in section 5.3.3, waste pickers using Kudoti and BanQu model, sort and store their materials in undesignated and undesirable spaces (CoJ-EISD03). Figure 5.2 (Section 5.3.3) and Figure 5.9 below show some of the sorting spaces in Johannesburg that become illegal dumping sites, resulting in conflicts between waste reclaimers and the city.


**FIGURE 5. 7.** ILLEGAL SORTING AND STORING SPACES USED BY WASTE PICKERS BEFORE REGENIZE PROJECT. **(AUTHOR, 2021).**

The Regenize model is advanced in its design and operation because Regenize controls the whole system and operates hubs/sites for sorting and storing recyclable materials (REG-WR01). The container is used not only for sorting and storing collected recyclable materials but also for storing tools, tricycles and smartphones (REG-WR01). The local hubs and route optimisation has reduced the long distances travelled by waste reclaimers to collect recyclables. In addition, this further gives waste reclaimers sufficient time to collect, transport and sort the materials at the local hubs. After the waste reclaimers have sorted the materials according to waste streams, the ICT-enabled waste collector (Regenize) would collect the sorted materials in all local hubs and sell it to commercial buyback centres and recyclers (REG01).

**FIGURE 5. 8.** REGENIZE HUB WITH A STORAGE CONTAINER FOR SORTING, STORING AND COLLECTING OF MATERIAL WITH A COMPANY VEHICLE. **(SOURCE: REGENIZE, 2021).**

d) Provision of hand scales and baling machines for recyclable waste quantification.

Waste reclaimers using the ICT-enabled informal waste reclaimer collection systems have been provided with various resources to enable them to operate efficiently, including scales and baling machines for weighting and compressing materials for resale to the buyback centres (KUD01; REG01). Distell note that for “waste pickers that worked with our registered buyback centres, we would give them PPE and the buyback centres we would give them scales, machinery and other equipment for them to start working in the project” (KUD01). Waste reclaimers are provided with hand scales (Fig 5.12) so that they may know how much they have collected in terms of weight, while Distell and Regenize would be able to have an idea of how much waste is being collected daily and determine the exact weight of waste that is being sorted and stored at the storage container and sold at the buyback centres. For waste reclaimers using Regenize APP, after getting the weight of waste from each household, the exact weight is manually entered into the digital platform by the waste reclaimer (Fig 5.12), and Regenize gets the information on the number of waste recyclables being collected per household each day by the waste pickers (REG02). Thus, the waste reclaimers collect, weigh the recyclables and manually input the figures on the mobile device and return to the container after completing collecting recycles from all the households to offload the materials at the container where they have access to bulk bags and general space to work and sort the recyclables (REG-WR02). When reclaimers have finished sorting, they contact Regenize, who has the truck that collects sorted recyclables from reclaimers and then pays the reclaimers according to the prevailing market prices of recyclables.

**FIGURE 5. 9**. ONE WASTE RECLAIMER WEIGHS THE RECYCLABLES WHILE THE OTHER IS MANUALLY INPUTTING THE DATA IN THE SYSTEM. **(SOURCE: REGENIZE, 2021).**

### e) Medium of interaction and communication between households, waste reclaimers and buyback centres.

The ICT-enabled informal waste reclaimer collection systems supported the informal waste reclaimers and were built on an effective recyclable collection system of waste reclaimers that had existed before municipalities began collecting recyclables. The digital transformation of the informal waste recycling sector is based on a system that allows waste reclaimers to register, supporting reclaimers with resources and infrastructure which would move reclaimers from sorting in the public spaces resulting in illegal dumping of waste, into designated areas provided in the project (REG01). For waste reclaimers, the ICT-enabled informal waste reclaimer collection systems have also become a medium of interaction and communication between the community, waste reclaimers and other stakeholders involved in the project. Waste reclaimers who are part of the project pointed out that this is a participatory process designed to include the waste reclaimers in consultation with the residents (REG-WR01; REG-WR02; KUD-WR02). Before the project interventions, both the waste reclaimers and buyback centres experienced inconsistency with the recyclable material inflow, and the project resulted in a consistent amount of recyclable materials. The system has built functionalities that allow waste reclaimers to log in digitally, make transactions and connect both the buyer and seller (KUD01; BANQ01). This has increased the demand for recyclables as waste reclaimers can choose different buyers who offer favourable prices for the recyclable material. This automatically translates to improved working conditions, increased income levels and recognition of their professional work.

The ICT-enabled waste reclaimer systems also benefit the community by facilitating the exchange of recyclable materials between households, buyback centres and waste reclaimers. The project provided free waste recycling collection services in Bridgetown, where recycling services were not being provided, and, in the process, incentivised the households to participate in the return of depositing their recyclable materials to the waste reclaimers who are working for Regenize. The platform is like a marketplace where different people connect, sell and buy materials from each other (BanQ01). This has created a direct relationship between waste reclaimers, waste collectors, buyback centres and the communities; for instance, the households can know their contribution to waste management and the waste reclaimers have the correct and up-to-date data on their contribution towards recycling. The project also benefits all the residents who are not participants but are part of the community where the project is being implemented. These residents can also request collection services for waste recyclables, but they will be paid. Only households registered in the system receive free services, but anyone can call Regenize to collect their recyclables for a fee if they are not in the system (REG01; REG02). This approach to providing a service for a fee is meant to subsidize the free collection service in Bridgetown.

The ICT-enabled informal waste reclaimer collection systems have put together households, reclaimers, buyback centres, waste collectors and sponsors in the same platform and created avenues for collaboration. The previous initiatives for waste reclaimers' integration failed because they were top-down and did not allow for collaboration amongst the various stakeholders in waste management. Collaboration is minimal within the informal recycling space as individual stakeholders operate independently. Through the ICT-enabled informal waste reclaimer collection systems, households collaborated with waste reclaimers by providing recyclable materials. When reclaimers and buyback centres log in the data of waste collected and sorted, the platform will show the available waste within the ICT platform. Any waste collector on the platform could purchase it or come and collect the recyclables. One waste collector explained, "I find this app helpful because in the recycling industry, as I would call it, everyone is doing their things in their corner. It's like we are all doing the same thing, but nobody knows who is doing what, where and who has what. This platform is bringing us together to exchange material and support reclaimers by buying the materials/things I need to get my business moving forward" (KUD01). This has enabled the different stakeholders to transact with each other directly and ensure the optimal collection of recyclables in various suburbs of Cape Town. Furthermore, some partners have availed resources like redeemable vouchers at a supermarket or airtime and provided plastic/refuse bags used for recycling. The project sponsors have also provided funding for PPE used by waste reclaimers and tricycles.

#### f) Physical fitness and respect through ICT-enabled informal waste reclaimer collection systems

The aspect of technology in practice reveals the different dimensions of technology as it is being used and its intended and untended use of different technology artefacts. The Regenize project provided waste reclaimers with a tricycle, smartphone, sorting hub and PPE to improve their working conditions and ensure they get more income from participating in the project. Different benefits have been identified, and respondents vary in the extent of emphasis. Although the tricycles were intended for collection and transporting recyclables from households to the sorting hubs by waste reclaimers, some reclaimers mentioned that the regular use of tricycles had improved their physical fitness and allowed them to have an alternative cheaper mode of transport to and from work. Some waster reclaimers mentioned that they view cycling as part of physical exercise resulting in weight loss and making them strong (REG-WR01; REG-WR02; REG-WR03).

Besides physical wellbeing, waste reclaimers participating in ICT-enabled informal waste reclaimer collection systems began to "feel more integrated because they had a better way of presenting themselves to society in uniforms, tricycles and smartphones" (REG-WR02; REG-WR3). Reclaimers had resources to earn more income, and Regenize sold recyclable material for waste reclaimers to buyers who offered better rates (REG01). Waste reclaimers have begun to operate and salvage materials in communities that were outside of their initial reach (BANQ01; REG-WR01). With PPE, vehicles and tricycles, waste reclaimers observed that even in traffic, they were now respected and no longer seen as a nuisance caused by makeshift trolleys which reclaimers were using before the interventions of ICT-enabled informal waste reclaimer collection systems (REG-WR01; REG-WR02 and BANQ04).

The community now respects them, and the waste pickers perceived significant benefits to social inclusion due to the ICT-enabled informal waste reclaimer collection systems. One reclaimer said that when they salvage extra resources to get cash, they can now negotiate for better prices than ordinary reclaimers before the project (REG-WR02). The ICT-enabled informal waste reclaimer collection systems are seen as a perfect solution to waste reclaimers as they are now equipped with resources and infrastructure to perform better and earn more money from their recyclables. Furthermore, with established relations, waste pickers are offered other piece work, for instance, cleaning the yard and removing discarded materials, for extra income. Waste reclaimers also take away small discarded items for a fee in Bridgetown (REG-WR03). In Brixton and Auckland Park, waste reclaimers are sometimes requested to assist with moving discarded materials and cleaning the yard for a fee (BANQ03).

g) Optimum materials collection and increased income

The ICT-enabled informal waste reclaimer collection systems have opened opportunities for waste reclaimers and capacitated them with infrastructure, technology and resources to increase their income and better working conditions. It has created an environment where waste pickers use technology to collect recyclable material efficiently, allowing them to work less in terms of distance travelled, reducing the fatigue that comes with working and travelling long hours. The Regenize APP has strategically positioned waste reclaimers by reducing the distance travelled by reclaimers since they are operating in a smaller area, and this has created more time for reclaimers to sort the materials, thereby maximising the collection of materials in one particular area (REG01). The Regenize APP allows households to be rewarded with data and groceries, enabling them to access the internet, communicate with relatives, and access nutritious food (REG-WR01). The income levels of the reclaimers have improved, with one reclaimer saying that they used to earn between R10 and R40 on a typical day and sometimes R50-R80 on a busy and good day (KUD-WR02). The Regenize APP has improved the collection rate of waste pickers by maximising collection in one area, increasing the demand for collection per day and making an average of R150 to R230 per day (REG-WR03). This amount depends on how well they work in terms of efficiency and as well of the type of waste they will get from the households (REG01). Furthermore, the waste reclaimers are now being recognised through the project and operating in areas they initially were not permitted to collect recyclables.

Once the information is entered into the system, ICT-enabled informal waste reclaimer collection systems can track and monitor the project's performance. The ICT-enabled informal waste reclaimer collection systems allow daily manual input of data for waste collected, sorted, and sold at the buyback centres. This enables waste reclaimers to get information from the waste pickers. All the data is reported and analysed in graphs or other forms regarding expenditure, collection and recycling rate. Through the ICT-enabled informal waste reclaimer collection systems, Coca-Cola, Regenize and Distell can track and monitor waste reclaimers' performance and distinguish performers from non-performers. The ICT-enabled informal waste reclaimer collection systems platform also helps producers identify reclaimers that should be rewarded with PPE and more resources because of the number of recyclable materials they bring (KUD01; BANQ01). Some reclaimers in the project claim that they are working, but when the officials check the system, they see the actual amount of waste being delivered, with some reclaimers delivering less than 5kg of recyclable waste for the whole month (KUD01). Thus, the app is also used to track the waste being delivered and see who is doing what work.

#### h) Access to various payment platforms and channels for sending remittances

In South Africa, the estimated majority of waste pickers “typically had no record of their earnings and so remained largely unbanked and unable to access the kinds of services available to those who were self-employed or had a record of employment in the formal sector” (EXPT-WRI01). The ICT-enabled informal waste reclaimer collection systems have availed various payment platforms that were initially unavailable to reclaimers, for instance, electronic transfers and bank deposits. Through the ICT-enabled informal waste reclaimer collection systems, waste reclaimers can now access their monies through electronic funds and e-wallet (BANQ-WR032; REg-WR01). For BanQu and Kudoti, waste reclaimers receive an instant electronic funds transfer in their profiles/portals, while for Regenize, reclaimers had to wait for a week or two to be paid a lump sum amount into their bank accounts and with the use of bank cards, they are encouraged to integrate into society (REG01). A reclaimer said, "Now, I have to go into the bank, PnP, or mall to withdraw my money " (REG-WR02). The project has managed to equip reclaimers with resources that would enable them to benefit from getting a bank account. For BanQu, waste reclaimers are now building a permanent history that can be used as proof of income or funds with transactional history necessary to open a bank account, access credit and sign a cell phone contract (BANQ-WR03). Furthermore, waste reclaimers can send remittances back home to their families and children, which was lacking in the traditional informal recycling system. The challenge of BanQu APP on remittances is that it only works with specific supermarkets and banks, which might not be available in some countries and provinces (BANQ-WR02).

i) Increased visibility of waste reclaimers through ICT-enabled informal waste reclaimer collection systems.

The aspect of usage negotiation is seen in the waste reclaimers' influence exerted in the process of using the digital platform. The ICT-enabled informal waste reclaimer collection systems have increased the visibility and interaction of waste reclaimers in communities when collecting recyclables. What is most significant about these projects is that it has also increased the volume of waste recyclable materials, and demand for their material has also increased after the implementation of the projects. The ICT-enabled informal waste reclaimer collection systems have also increased social awareness of the importance of waste reclaimers and community partnership initiatives in recycling, waste reclaimer image linked with the project, better working conditions of waste pickers, and an alternative source of income for households. The increased visibility of waste reclaimers in partnership with ICT-enabled informal waste reclaimer collection systems has changed the community's perception towards waste reclaimers and made it easier for households to contact waste reclaimers to collect and gather more material.

Technology in the form of an ICT-enabled informal waste reclaimer collection system has played a crucial role in linking all the stakeholders in the informal recycling value chain and allowing for the potential transfer of data and flow of funding. The EPR regulation allows for the compensation of waste reclaimers for the services they provide in waste collection and recycling which necessitated the creation of the national registration database system of informal reclaimers. EXPT-EPR01 pointed out that the National Treasury has permitted the development of the National Informal Reclaimer Registration System, which will be the master list of all informal reclaimers working in South Africa. Currently, various manufacturers and industries have implemented different EPR models. For instance, Coca-Cola and Unilever have used PETCO and BanQu to fulfil Coca-Cola's extended producer's responsibilities. Distell has used Kudoti through their CSI unit to meet their extended producer responsibilities in Western Cape. The money provided by the industry is meant to address the failing MSW management system by subsidizing the value chain and making it profitable to recyclers (EXPT-EPR1). Thus ICT-enabled informal waste reclaimer collection systems enable Distell or Coca-Cola to generate reports on the expenditure and the tonnes of materials recycled, and the number of waste reclaimers who benefitted from the project. Although ICT-enabled informal waste reclaimer collection systems are developed on blockchain technology, which makes it difficult to tamper with information inputted into the system, it relies upon the waste reclaimer manually inputting the data or entering the information, unlike in other sectors where information can be captured remotely or through other mechanisms where there is no human interference.

### 5.5.4 The interpretive use of the ICT-enabled informal waste reclaimer collection systems by various groups in the value chain.

Different social groups such as waste reclaimers, households, ICT companies, buyback centres and other institutions have been identified as using the platform, and they interpret the project intervention differently, as shown in the table below with the summary analysis. The different social groups have access to specific features which are particularly relevant to themselves hence having different interpretations of the scheme depending on how the various users perceive the technology. The summary of the interpretive analysis of the various social groups is presented in Table 5.1.

| *Social Group* | *Who are?* | *Interpretative frames* |
|---|---|---|
| *Waste Reclaimers* | The main stakeholders using the ICT-enabled informal waste reclaimer collection systems (BanQu, Kudoti and Regenize) | BanQu, Kudoti and Regenize are platforms that integrate waste pickers, empower them and provide an opportunity to increase their income. |
| *Buyback Centres* | The beneficiaries who use the ICT-enabled informal waste reclaimer collection systems (BanQu, Kudoti and Regenize) | BanQu, Kudoti and Regenize are platforms that provide inventory, trading and payment services for recyclable materials. |
| *BanQu, Kudoti and Regenize* | The developers of the platforms who manage and monitor the platforms | BanQu, Kudoti and Regenize provide waste collection and recyclable transactional trade services in South Africa |
| *Community/Households* | The beneficiaries who participate in the project | Regenize help in collecting recyclable material and an opportunity to get some vouchers as incentives or rewards. |
| *Business & Industry* | The sector that partnered with and funded the projects | BanQu, Kudoti and Regenize help track and monitor the impact of their waste management initiatives. |
| *Government* | State and local governments that create an enabling environment for the project | BanQu, Kudoti and Regenize are technological tools that benefit waste management policies and innovation. |

**TABLE 5. 4.** DIFFERENT SOCIAL GROUP USING THE ICT-ENABLED INFORMAL WASTE RECLAIMER COLLECTION SYSTEMS.

The rules for waste reclaimers to participate in the ICT-enabled informal waste reclaimer collection systems were designed to involve any participant who is either an individual waste reclaimer or cooperatives who are interested in using the platforms. The approach to identifying the waste reclaimers and the rules of participation are not uniform as they vary depending on a specific city and or communities (REG01; BANQ01 and KUD01). For Regenize, "it varies by area, it depends on what area you're in, and every area will determine the type of waste pickers you will come across with; for example, in high-income areas, you will find out that waste pickers in these areas might be more knowledgeable or experienced since they were people who have been down and out and they just somehow ended up being waste pickers unlike in low-income areas" (REG01). For BanQu and Kudoti, the approach is similar: buyback centres act as key institutions of integration by registering any interested waste reclaimer (KUD01 and BANQ010). This approach clearly shows that the rules for participation are flexible and can be adjusted to ensure that everyone is catered for. Researching the area before approaching the waste pickers is crucial since this enables Regenize to design context-specific methods that apply to the community and waste reclaimers. Thus, research enables the project implementers to decide on the rules and method of participation depending on the area and type of waste pickers within that area.

The ICT-enabled informal waste reclaimer collection systems operate twofold in registering waste reclaimers and providing reports on the amount of waste recycled and the amount received by the waste reclaimer for each transaction. After identifying a waste picker, they will undergo training for using the ICT-enabled waste management platforms, smartphones and tricycles before being registered on the APP (EXPT-WRI01). Once the waste reclaimers have completed the training, Regenize or the buyback centres will approve them and automatically register them. BanQu, Kudoti and Regenize undertake training on the technological aspect of using smartphones for waste reclaimers to get comfortable using the ICT-enabled waste management platforms and how to manage data and capture the images and information (REG01).

### 5.5.5 Multiple challenges and contestations to the ICT-enabled informal waste reclaimer collection systems in the informal recycling value chain.

One of the barriers experienced by ICT companies when coming to the waste industry is understanding the landscape and the whole value chain. This approach is a shift from the top-down approach of imposing digital solutions without first consulting and involving the waste reclaimers and community who are the end-users of the technology. The informal waste reclaimer system has various phases and stages at different levels that need to be identified to design an inclusive and applicable system through the whole value chain (REG01). In a community where recycled materials are collected, "you will find a waste picker who collect[s] the recyclables, and there is a collector who is either semi-formal, informal or some formal who is competing with a waste picker, and then you have a buyback centre, and after the buyback, you have the waste collector, then the waste processor and manufacturer” (REG02). Hence a significant barrier is designing a model that could fit in without disrupting any of these stakeholders or the whole system.

The ICT-enabled informal waste reclaimer collection systems threaten the traditional model of waste collectors, and waste pickers themselves could be side-lined, resulting in loss of materials and income (REG02). Regenize was faced with trying to design and create a model that would allow them to partner with the waste reclaimers, waste collectors and other buyback centres that are not partnering with ICT-enabled informal waste reclaimer collection systems but also operating in the area. Furthermore, the decentralised model being implemented involves incorporating waste pickers paid according to the weight of recyclables they sort and link them to the buyers. "Now, those waste pickers that are selling to the local buyback centre decide to sell the recyclables to us, we become enemies with the buyback centre and push that buyback centre from business" (REG01). To maintain harmonious relations with existing buyback centres, the ICT-enabled informal waste reclaimer collection systems model entails that recyclables of the entire area are sold to a partnering local buyback centre where the waste pickers would normally go to sell their materials and, in addition, negotiate a fee with them (BANQ01, REG02). Thus, it is a challenge to find solutions that make the ecosystem peaceful and do not disrupt stakeholders in the recycling industry, such that every player and partner is gaining value through ICT-enabled informal waste reclaimer collection systems.

a) Barriers to gaining the trust of waste reclaimers.

Gaining the trust of waste reclaimers and bringing them on board is one of the daunting challenges currently faced in other communities where ICT-enabled informal waste reclaimer collection systems are being implemented. “It's a huge task for a corporate or private company to go into a community in a township and inform them about a waste recycling project that households should participate in; obviously, there is going to be scepticism within the community due to the mistrust that exists” (KUD01). Waste reclaimers and communities do not trust companies; in the process, they need to know the benefits of the project before participating. "We still struggle to get them on board even today because there are a lot of social aspects embedded there; depending on which area you are in, you will get different results. It depends on where you are, your market, the method you want to use, and the type of waste pickers. Once you can break the barriers and understand the waste pickers, you can switch your model to suit the end-users" (REG01). In other projects, for instance, in Khayelitsha and Johannesburg, the project implementers work directly with owners of the buyback centre to register and approve waste reclaimers on the digital platform. Kudoti is a digital platform focusing mainly on the buyback centres since they already have relationships with informal waste reclaimers. However, this approach of focusing on buyback centres reduces the ability of the App designers to create a system that empowers the reclaimers and closes more avenues of collaboration open when they directly engage with them.

b) Barriers to maximising the value of waste

The ICT-enabled informal waste reclaimer collection systems are facing challenges in trying to maximise the value of waste to ensure that the project benefits both the community and waste reclaimers. The informal waste recycling industry is a highly contested space and harsh, especially for waste reclaimers concerning the rates or price they will get when selling the recyclable materials as a waste picker, which is why these rates are not made public and constantly fluctuates. Most reclaimers are paid low prices when they sell their materials at a formal buyback centre. One respondent gave an illustration: "If I go to a buyback while driving a bakkie and I bring in a kilo of PET bottles, normally the buyback centre is going to give me R2, 50/kg because I am driving a bakkie which brought the material and I will be paid instantly. But if I push a makeshift trolley and have a black bag, I might be offered something from R1.20 to R1.50. You see, there are a lot of discrepancies in this industry" (REG01). This clearly shows the injustices and distortions which exist in the recycling industry, where reclaimers are paid different rates due to their perceived social status. Faced with this scenario, designing a system that can make things equal and improve waste pickers' welfare and working conditions such that they are even compensated for the services they offer to municipalities for free proves to be a daunting task (EXPT-WRI01). Despite having other innovative ICT-enabled informal waste reclaimer pilot projects being implemented in Cape Town and Johannesburg, it is difficult to make this uniform and applicable nationally. Furthermore, generating value from waste is difficult for waste reclaimers due to complexities and working with as many partners as possible to pull together resources to lobby for increased rates (REG01; REG02). Regenize has managed to reclaim and sort different waste streams and connect directly with the manufacturers for process design approaches to get higher rates for their recyclers.

c) Social difference between reclaimers and the absence of adequate data

The social differences between informal recyclers is vital when designing and introducing any programme to benefit the informal waste recyclers. Different communities determine the appropriate social design of the ICT-enabled informal waste reclaimer collection systems appropriate to waste reclaimer in terms of providing resources and tools to use. For instance, in Bridgetown, each reclaimer was given a tricycle and a smartphone to improve their working conditions. By contrast, in Khayelitsha, the engaged reclaimers informed the team that phones and bicycles were not crucial to them, and they only wanted a system that supported what they were doing by becoming more efficient and allowing them to make more money (KUD01). However, building such an efficient and effective system that benefits them requires getting data on their operating system. “Most projects have failed to be effective because they lacked the data on what's happening in the system in terms of who produces what, who is moving what and the remainder where is it going” EXPT-WRI01). There is a need to focus on getting credible data in one system as this will help give the government, waste reclaimers, and industry a holistic picture of what is transpiring on the ground towards the zero waste goal.

The ICT-enabled informal waste reclaimer collection systems have caused uncertainty in some waste reclaimers since the implementation depends on transforming their traditional work process. Before the project, waste pickers travelled 20-40 km daily to collect and transport recyclables, whereas the ICT-enabled informal waste reclaimer collection systems decentralised them in specific areas. Traditionally, waste reclaimers do not want to be passive but want to operate freely and even travel for 15km outside the project requirements to get more recycled materials to earn an extra income each day. One respondent (REG01) pointed out that the waste reclaimers do not want to be packaged into operating in a specific area only but want to be allowed to roam freely anywhere, looking for recycles. Some waste reclaimers are still uncertain about the use of technology, distrust using the ICT-enabled informal waste reclaimer collection systems for electronic payment, and still prefer cash payments (BANQ-WR05).

Another barrier is the issue of waste pickers who do not have the proper paperwork. During the Waste Pickers Integration Guideline workshop, one of the things that became clear when developing the guidelines was that the national registration system needed to be inclusive. EXPT-WRI01 pointed out that: "the issue of documentation affects both South African citizens and foreign nationals who do not have proper documentation … because if we are not being inclusive, we won't be able to get accurate and updated data on the role of waste reclaimers' waste management." "Initially, the Regenize platform would reject reclaimers who wanted to participate in the project because they lacked proper documentation. However, the management is trying to be inclusive; they tried to make the process more informal to register the waste reclaimers, and once they are in the system, they are further helped to acquire national I.D. and even open a bank account" (REG02). In Khayelitsha, working with waste reclaimers without documentation was not feasible. The initiative focused on working with people with formal documentation since Distell was working with the government as a partner (KUD01). This barrier still exists in many poor communities where households lack documents that would enable them to participate in the implementation of ICT-enabled informal waste reclaimer collection systems.

Three interconnected but different ICT-enabled waste management systems in the informal waste recycling sector generated important dynamics in the digital transformation of the informal sector. One most important observation is that the ICT-enabled informal waste reclaimer collection systems' integration approaches have improved the waste reclaimers' working conditions. However, within the ICT-enabled informal waste reclaimer collection systems, the absence of municipalities further complicates the integration process of waste reclaimers into the formal municipal waste management system. The following section considers how BanQu, Kudoti and Regenize platforms are improving the diversion of waste from landfill and enhancing environmental performance towards zero waste.

## 5.6 Impacts on landfill diversion and municipal waste flows

### 5.6.1 Increased recycling rate through incentives and rewards in the ICT-enabled informal waste reclaimer collection systems

The ICT-enabled informal waste reclaimer collection systems have digitalised the informal sector resulting in an efficient and organised smart waste management model and improved the recycling rate. The digitalisation of the informal sector activities and processes to fit into the smart city concept has incorporated other stakeholders, including producers, households and ICT waste collector companies, to improve the recycling sector (EXPT-SC01). The creation of door-to-door collection in the Regenize model promotes household participation in a voluntary separation at source model, which the municipalities failed to implement due to the lack of rewards and incentives to motivate residents. In addition, the door-to-door free collection services reached more than 100 collections a day and an increase in households registered to participate in the Regenize project (REG01).

The Regenize model has registered more than 1800 households in Bridgetown whom they "incentivise through the Regenize APP for groceries, airtime and data" (REG01). "We found out that in terms of our recycling active rate compared to us, the municipality contracted waste collectors were managing at the time, I think 28%, and we (Regenize) were coming in at 67% here in Bridgetown" (REG01). For Kudoti, the recycling rate increased due to waste reclaimers being rewarded for trading more recyclables (KUD-WR01), while for BanQu, the Top-up project improved the recycling rate (BANQ-WR01). This increase in recycling rate through the application of ICT-enabled informal waste reclaimer collection systems has been attributed to a new emerging model illustrated in Fig 5. 13. This model has reduced distances travelled and ensured that waste reclaimers maximise their specific areas. Furthermore, using tricycles to replace trolleys is one of the objectives of smart cities.

### 5.6.2 Access to data on household recyclables generation and recycling behaviour.

The Regenize ICT-enabled informal waste reclaimer collection system provides opportunities for the generation of big data, especially targeting the household waste streams, consumption rate and the recycling attitude of households. The data generated helps the retailers, waste collectors, producers and government to comprehensively record the amount of recyclable material collected at a particular time and place. For Regenize, the system enables households that are participating in their projects to generate a statistical report which shows the amount of recyclables collected and determines the carbon emission saved, providing accurate data on household performance on recycling activity which can be generated into weekly and or monthly statistical reports (REG-WR02). Figure 5.10 below shows the statistical performances of an individual participating in the Regenize project. The Regenize model has an efficient separation at-source model, which households implement, enabling waste reclaimers to collect sorted recyclable materials. This removes the need for reclaimers to salvage from the bins and further pollute the environment as they dispose of waste on the ground.

Contrary to the Regenize model, which has household performance data, Kudoti and BanQu provide statistical reports of waste streams and the amount of recyclables traded at the buyback centre according to locations or suburbs on the waste reclaimers' profile (BAnQ-WR02; KUD-WR01). The transaction report is sent to the waste reclaimers, enabling the reclaimer to view his weekly and monthly performances in terms of diverting waste from the landfill (Fig 5.10). This information allows the producers and other enterprises to analyse and track household beverage consumption (Distell and Coca-Cola) and design an incentive to improve household recycling.  This helps the producers to determine the amount of waste being diverted from the landfill and the amount of carbon emission averted. The central aspect observed by reclaimers using digital platforms is the ability to trace the recyclable material waste streams at the household level, improving the overall efficiency of the collection system. This data sheds new light on the contribution of households towards the zero waste goal in South Africa. With the data on households being generated, the ICT-enabled informal waste reclaimer collection systems provide the basis for refining more systematic and reliable ICT-enabled informal waste reclaimer collection models.

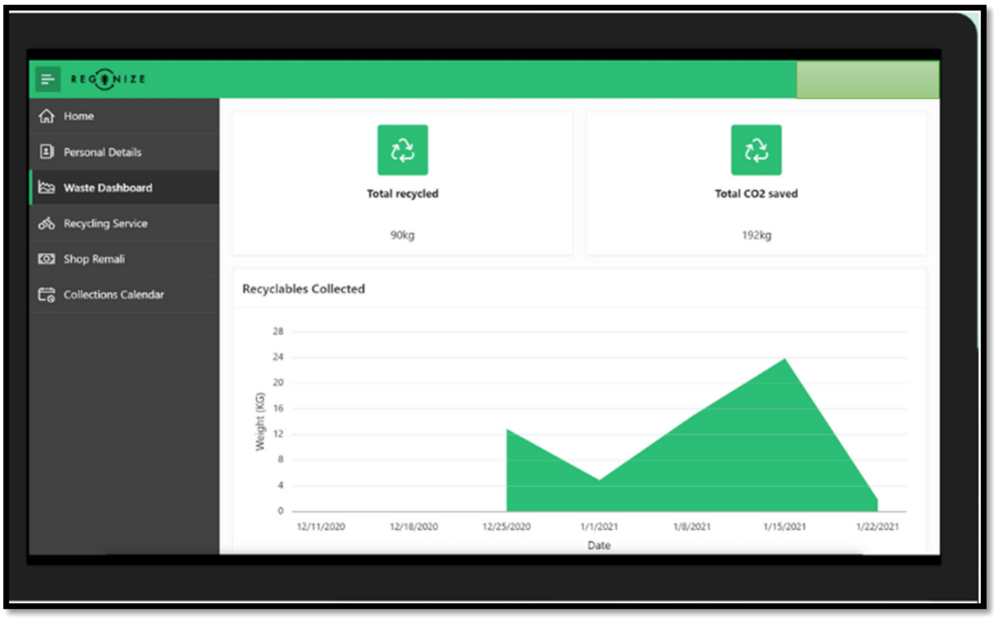


**FIGURE 5. 10.** REGENIZE HOUSEHOLD PORTAL SHOWING WITH RECYCLING PERFORMANCES DATA. **(SOURCE: REGENIZE, 2021).**

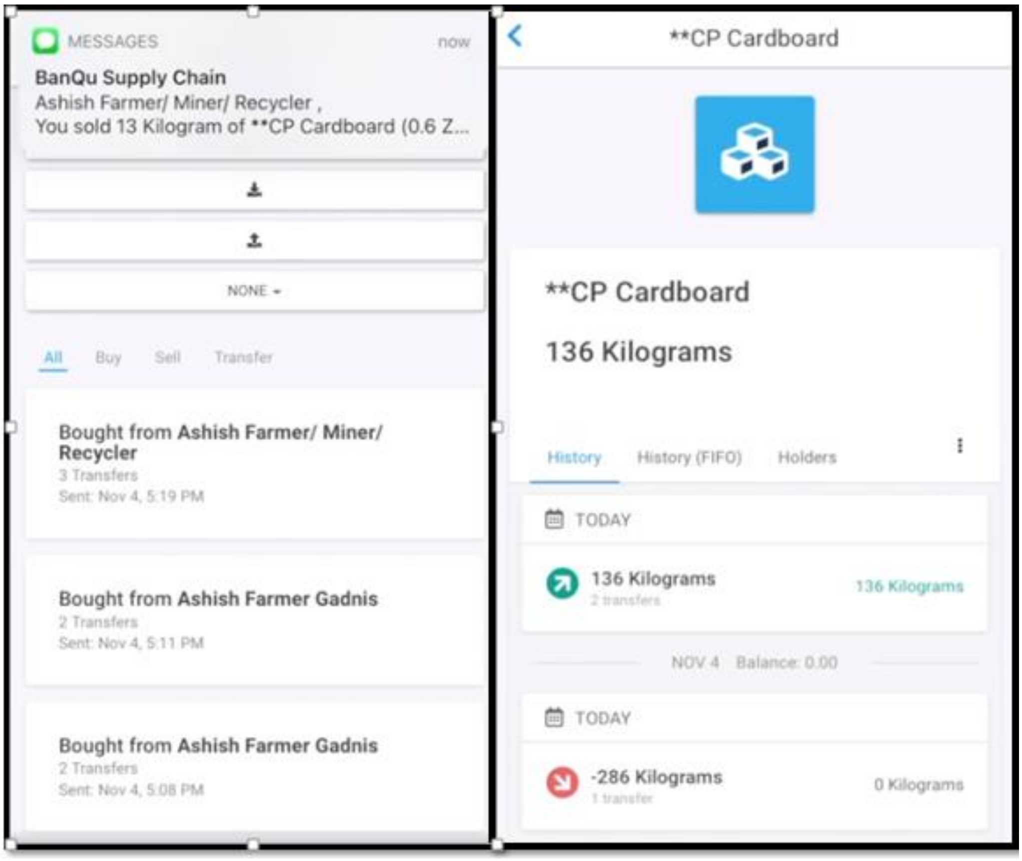


**FIGURE 5.11.** BANQU WASTE RECLAIMER PORTAL SHOWING RECYCLING PERFORMANCES DATA. **(SOURCE: BANQU, 2021).**

### 5.6.3 Automated data for daily collection schedules and route optimisation

In addition to the tricycles, Regenize gives the waste reclaimers smartphones installed with REMALI APP and allows the waste reclaimer to access some of the internal features like daily collection schedule with a list of households and the map of the households.

One of the waste reclaimers who uses the Regenize APP explained that their average daily collection list usually is made of about 100 households per day, where they will go to collect the recyclable materials and with the assistance of the map with the route optimization guiding them and showing the distance (REG-WR03).

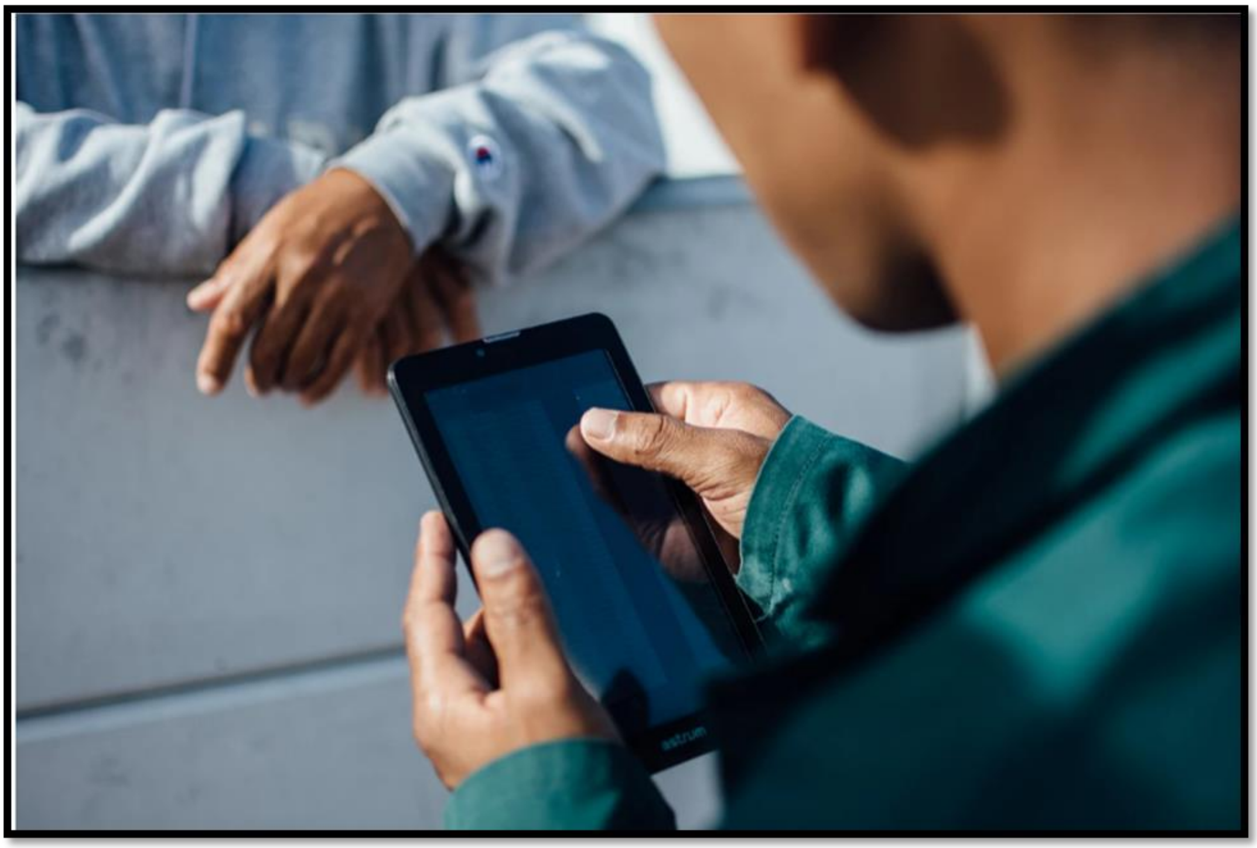

**FIGURE 5.12.** SMARTPHONES WITH A DAILY COLLECTION SCHEDULE USED WASTE PICKERS IN THE REGENIZE PROJECT. **(SOURCE: REGENIZE, 2021).**

Waste reclaimers used to sleep in open spaces, parks and on sidewalks to collect recyclables in the morning before the municipal or private contractor truck arrived to collect waste. This exposes the reclaimers to mugging, confiscating their material by metro police and health hazards like pneumonia. A reclaimer pointed out that before the Regenize project, "I used to walk about 15km each trip to collect and transport recyclables to their sorting spaces, and due to the load and distance, I could only make one trip per day instead of two or three trips a day so that my income can increase" (REG-WR02). The use of a daily collection schedule list and route optimization has resulted in waste pickers waking up around 0700hrs to go to the decentralised hub to start their work, and this meant that waste reclaimers no longer need to compete with a municipal or private waste contractor truck for recyclables (REG02). The Regenize also link the waste reclaimers to the households that are participating in the recycling project, and "this has eliminated the aspect of waste reclaimers having to walk long distances, as well as digging and salvaging through the bins since there is no need for that anymore with this Regenize APP" (REG-WR02; REG-WR03). This has also increased the daily incomes of waste reclaimers. Hence, the technology must be adopted to ensure that each suburb is collected and reclaimers' routes optimised, thereby improving their working conditions.

### 5.6.4 Tracking the performance of recyclable waste.

The city is considered smart if it monitors the levels of environmental pollution based on waste collection targets set by the city government using data generated from ICT-enabled waste-based management systems. Phillips et al. (2011) defined the zero waste goal as “a simple way to summarize targets as far as possible in reducing the effect of waste on the environment. This is a visionary goal that prevents garbage, conserves resources and restores material value." Many activities towards zero achieving zero waste encompass “sustainable waste management systems including avoiding, reducing, reusing, redesigning, re-generating, recycling, repairing, re-manufacturing, reselling and redistributing waste resources” (EXPT-SC01). As identified above, ICT-enabled waste reclaimer collection systems have enabled waste reclaimers to record and generate reports on their transactions and collection rate which is absent in the traditional informal collection system.

Due to the waste companies’ policy on data, Kudoti (Distell) did not provide the researcher with data on waste recyclables collected by waste reclaimers in Khayelitsha. For Regenize, data on recyclables collected from October 2018, when the project commenced, to December 2020 (Fig 5.13) in Bridgetown is estimated at 229 tonnes (REG01). As of 2021, the respondent (REG01) pointed out, “We are averaging 3.4 tonnes a week per local hub.” For BanQu participants in Brixton and Auckland Park from January 2021 until March 2022, the system has “registered a total of 75 830.1 tonnes in 2021, and between January and March 2022, the system has registered a total of 34 833 tonnes of recyclable material” (BANQ-WR03). Figure 5.14 presents data from waste reclaimers operating in Brixton and Auckland Park.

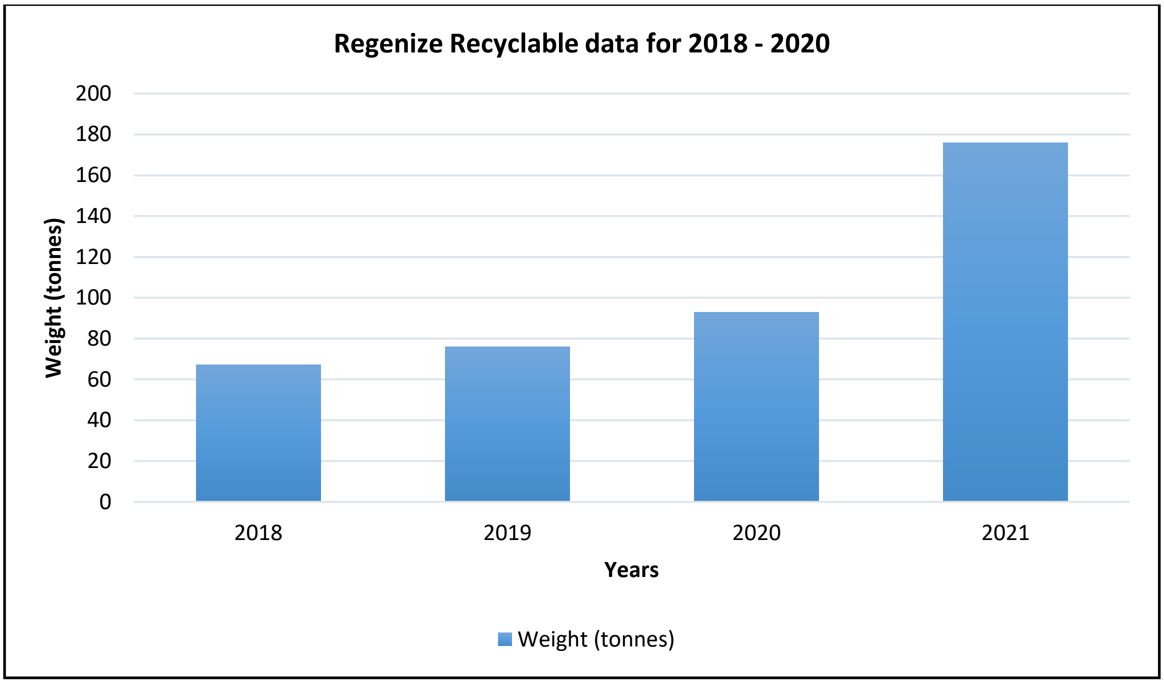


**FIGURE 5.13. QUANTITY OF RECYCLABLES COLLECTED IN BRIDGETOWN FROM 2018 -2020. (SOURCE: REGENIZE)**

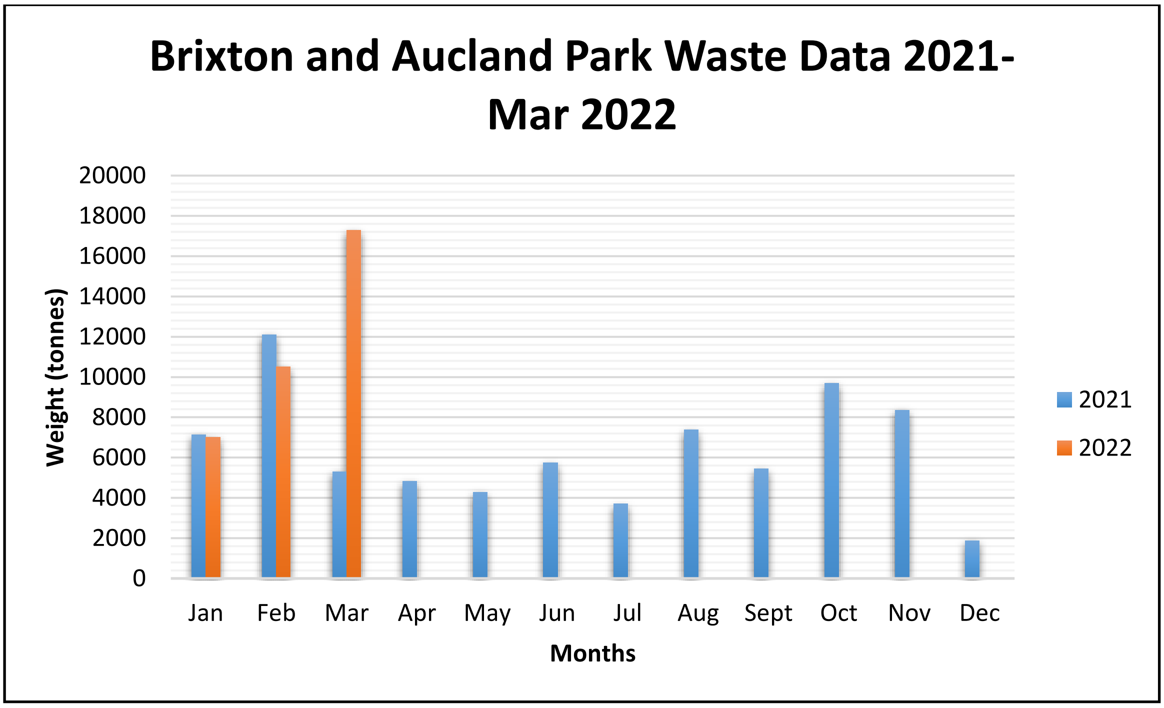


**FIGURE 5. 14. QUANTITY OF ALL RECYCLABLES COLLECTED IN BRIXTON AND AUCKLAND PARK FROM 2021 – MARCH 2022. (SOURCE: AFRICAN RECLAIMERS ORGANISATION)**

### 5.6.5 Waste Reclaimers' performance in Johannesburg against Pikitup annual targets.

This section seeks to determine the performance of the ICT-enabled waste reclaimer collection system against Pikitup's annual targets. This comparison is a crucial indicator adopted to assess the efficiency of the ICT-enabled waste reclaimer collection system. An expert in waste reclaimer integration (EXPT-WRI01) pointed out that "every single year

PikitUp sets goals and targets for itself of how many recyclables it wants to collect and it never meets those numbers, even if it lowers the target numbers, for instance in 2019/2020 they initially planned to collected 55 000 tonnes however reduced it to 38 000 but they ended up missing that target" (See Table 5.2). It is clear that while working with private contracted waste collectors and cooperatives to collect recyclables, the City of Johannesburg has not met its target despite having adequate infrastructure and resources.

| **YEAR** | **TARGET (TONNES)** | **ACTUAL (TONNES)** |
|---|---|---|
| 2017/18 | 40 000 | 29 258 |
| 2018/2019 | 50 000 (reduced to 32 550) | 25 991 |
| 2019/2020 | 55 000 (reduced to 38 000) | 30 812 |

**TABLE 5. 5.** PIKITUP'S ACTUAL RECYCLING PERFORMANCES AGAINST ANNUAL TARGETS**. (SOURCE: PIKITUP, 2018; 2019 & 2020).**

In contrast to PikitUp, where actual data is available, Godfrey (2021) acknowledges that similarly to other developing countries, correct and reliable data on waste reclaimers' performances in South Africa is limited. Most of the data on the actual role of waste reclaimers is acquired from the industry sector and EPROs. Now, with the adoption of ICT-enabled waste reclaimer collection systems, waste reclaimers are able to generate accurate, authentic and reliable data on their performances per waste stream (EXPT-WRI02). The data generated from waste reclaimers is similar to the industry's as both stakeholders generate their data from the same system and are incorporated in the same ICT-enabled waste reclaimer recycling value chain (BANQ01). Presented below in Tables 5.3 and 5.4 is the tonnages of various waste streams of recyclables collected in Brixton and Auckland Park from January 2021 until March 2022. Based on the data from waste reclaimers' figures which has a membership of 5 500 informal waste reclaimers in Johannesburg, "in Brixton and Auckland Park, waste reclaimers collect an average of 126kg/day. Hence if you multiply the average quantities collected per day and the total number of our members (126kg x 5500), you will find that waste reclaimers can meet Pikitup's annual targets in 4 months." (ARO-01).

| Material | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Plastic - HD | 426.5 | 797.5 | 244 | 518 | 510 | 695 | 118 | 514 | 427 | 849 | 603 | 303 |
| Plastic - PET | 1086 | 1551 | 1025 | 478 | 1134 | 1011 | 362 | 1161 | 971 | 1111 | 825 | 290 |
| Plastic - PP | 669.5 | 1188.5 | 774 | 483 | 613 | 892 | 447 | 456 | 607 | 778.5 | 777 | 237 |
| Plastic - Mixed | 604 | 916 | 294 | 180 | 252 | 233 | 277 | 601 | 771 | 408 | 800 | 87 |
| Plastic - Clear | 415 | 711.5 | 377 | 180 | 273 | 342 | 100 | 430 | 264 | 301 | 501 | 123 |
| Glass | | | | | | | | | | | | |
| HL1 | 962.5 | 2140 | 753 | 583 | 351 | 572 | 478 | 788 | 393 | 678.5 | 496 | 80 |
| Aluminium | 242.5 | 341 | 387.8 | 343 | 62 | 479 | 55 | 286.5 | 76 | 333 | 196 | 77 |
| K4 | 2358 | 4078.5 | 1388 | 1783 | 748 | 1197 | 1093 | 2771 | 1587 | 4680 | 3628 | 480 |
| Steel | 362 | 379 | 64.8 | 282 | 210 | 116 | 478 | 174 | 152 | 139 | 209 | 92.5 |
| Sub Grade | | | | | 123 | 198 | 216 | 135 | 152 | 267 | 179 | 65 |
| Cap | | | | | | | 57.5 | 62 | 21 | 80.5 | 59.5 | 22 |
| PVC | | | | | | | 16 | 12 | 30 | 66 | 78 | 14 |
| **Sub-total/month** | **7126** | **12103** | **5307.6** | **4830** | **4276** | **5735** | **3697.5** | **7390.5** | **5451** | **9691.5** | **8351.5** | **1870.5** |
| **TOTAL** | | | | | | | | | | | | **75830.1** |

**TABLE 5 .6.** BRIXTON AND AUCKLAND PARK'S MONTHLY RECYCLING DATA FOR 2021 IN TONNES.(SOURCE: AFRICAN RECLAIMERS ORGANISATION)

| Material | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Plastic - HD | 387 | 688.5 | 999 | | | | | | | | | |
| Plastic - PET | 988 | 1259 | 1701 | | | | | | | | | |
| Plastic - PP | 456.5 | 609 | 820 | | | | | | | | | |
| Plastic - Mixed | 451 | 501 | 700 | | | | | | | | | |
| Plastic - Clear | 231 | 422 | 692 | | | | | | | | | |
| Glass | | | | | | | | | | | | |
| HL1 | 847.5 | 1023 | 3202 | | | | | | | | | |
| Aluminium | 199.5 | 321.5 | 544.5 | | | | | | | | | |
| K4 | 3120 | 5201 | 7850 | | | | | | | | | |
| Steel | 298 | 311 | 415 | | | | | | | | | |
| Sub Grade | 32 | 55 | 108 | | | | | | | | | |
| Cap | 10 | 21 | 59 | | | | | | | | | |
| PVC | | 109.5 | 200.5 | | | | | | | | | |
| **Sub-total** | **7020.5** | **10521.5** | **17291** | | | | | | | | | |
| **TOTAL** | | | | **34833** | | | | | | | | |

**TABLE 5. 7.** BRIXTON AND AUCKLAND PARK'S MONTHLY RECYCLING DATA FOR THE 1ST QUARTER OF 2022 IN TONNES. (SOURCE: AFRICAN RECLAIMERS ORGAN ISATION)

Based on the current data from January 2021 to March 2022, waste reclaimers in Brixton and Auckland Park can exceed both Pikitup's set annual target and actual achieved targets. The data from Brixton and Auckland Park in 2022 alone of 34 833 tonnes exceeds the actual targets achieved by PikitUp from 2017 to 2020. In addition, the annual target of 75830.1 tonnes in 2021 exceeds the annual targets set by PikitUp for 2017 to 2020. Thus, ICT-enabled waste reclaimers collection systems allow reclaimers to compare their performance and role in municipal solid waste management against the city' annual targets. What is observed from the data presented above is that PikitUp has failed to collect a significant amount of recyclable materials to meet its annual targets and that the ICT-enabled waste reclaimer collection system has enabled waste reclaimers to be much more efficient and effective in collecting the recyclable materials.

In addition, the above data can be used to analyse the performance of various waste streams annually. The data for 2021 shows that there is no data on glass, which might be attributed to the impact of Covid-19's National State of Disaster regulations, which limited the consumption of alcohol and further reduced the demand for bottles (BANQ-WR03). "Glass is difficult to for someone going to Rosebank because its heavy, that's why most of the reclaimers are not collecting glass" (BANQ-WR02). Another respondent (BANQ-WR01) pointed out that not only did Covid-19's National State of Disaster regulation impact the demand side but also resulted in the dropping of prices for some recyclables materials resulting in waste reclaimers specialising in recyclables with better prices hence the reason why other recyclables performed better.

### 5.6.6 Assessing the Waste Diversion Rate in Brixton and Auckland Park.

The comprehensive data of recyclable materials collected by waste reclaimers is used in this research to determine the waste diversion rate in Brixton and Auckland Park for 2021. The waste diversion rate is a key component in determining the recycling performance of the city's municipal solid waste management. The waste diversion rate is defined as "the percentage of total waste that is diverted from disposal at permitted landfills and transformation facilities such as incineration, and instead is directed to reduction, reuse, recycling and composting programs" (Zaman and Lehman, 2013:126). For the "weight of garbage" the researcher will adopt the figure in the Gauteng Waste Information System

(GWIS) for the total waste generated in the city of Johannesburg. Without an updated report for 2021, the researcher used 1 467 697 tonnes acquired from Gauteng Waste Information System (GWIS) as the total waste generated in Johannesburg (GWIS, 2022). The equation for determining the waste diversion rate is as follows:

$$\text{Waste diversion rate} = \frac{\text{Weight of recyclables}}{\text{Weight of garbage + Weight of recyclables}} \times 100\%$$

$$= \frac{75830.1}{(1\,467\,697 + 75830,1)} \times 100\%$$

$$= \underline{\mathbf{4,91\%}}$$

So 4, 91% is the total diversion rate achieved by waste informal waste reclaimers in Brixton and Auckland Park in 2021. This diversion rate only focuses on the suburbs of Brixton and Auckland Park and includes all the recyclable waste streams collected during 2021. Thus, with the aid of ICT-enabled waste reclaimers collection systems, waste reclaimers in Johannesburg can now determine and evaluate their waste diversion rate from the data generated in the system. The total diversion rate demonstrates that waste reclaimers significantly divert large amounts of waste from landfills.

## 5.7 Conclusion

The chapter demonstrated the implementation of the ICT-enabled waste reclaimer collection systems in the informal recycling sector. The chapter provided the background of the ICT-enabled waste reclaimer collection systems, which have emerged as an innovation and business model for Regenize and for implementing the EPR regulation in South Africa (BanQu and Kudoti). Four significant themes in this chapter have provided a deeper understanding of how the bottom-up smart city model emanates in the informal sector and how waste collection services are provided through an ICT-enabled waste reclaimer collection system. Overall, the finding in this chapter indicates the digital transformation of the informal sector, which has resulted in a systematic ICT-enabled waste reclaimer collection system and reliable data on the performance of waste reclaimers in the recycling value chain. The next chapter discusses and analyses the empirical findings presented in this chapter.

# CHAPTER SIX: DISCUSSION OF FINDINGS

## 6.1 Introduction

The chapter delves into the transformation of the informal recycling sector through the integration of ICT-enabled waste reclaimer systems within the context of smart cities. This discussion engages with a broad spectrum of literature, the multifaceted implications of ICT-led interventions on waste management practices including case studies local, regional and international case studies. Guided by the sociotechnical transitions framework, the chapter scrutinises the evolution of waste reclaimer perspectives, data sharing mechanisms, recycling rewards, waste material flow tracking, and the co-creation of the ICT-enabled systems. By drawing insights from international ICT-integration models, this chapter not only addresses the practical implementations in South Africa but also contextualises them within a global discourse on urban sustainability. This chapter lays the foundation for future critiques of smart city paradigms, ultimately aiming to offer a comprehensive perspective on the potential and limitations of ICT-enabled waste reclaimer systems in driving societal change. Additionally, this chapter not only contributes to the scholarly discourse on smart cities but also offers insights for future research, opening avenues for critical evaluations and discussions on the sustainability and equity of digital transformations in waste management practices.

## 6.2 Empowering informal waste reclaimers through digital innovation

The digital transformation of the informal recycling sector through the ICT-enabled waste reclaimer collection system emerged as the response to the inefficiencies of the municipality-led recycling initiatives and waste reclaimer integration processes. Warschauer (2003) argues that technology enhances social inclusion by creating opportunities for people to participate in their societies fully. Zamani (2017) asserts that ICTs can be utilised to minimise the exclusion of some social groups and help individuals overcome challenges which may impede their access to resources. The ICT-enabled waste reclaimer collection system was developed to remediate environmental challenges, improve the waste diversion and recycling rate and integrate informal waste reclaimers by exploiting ICT according to the local needs of the communities. In addition, technology can be used to build networks through the design and performance that meet the expectations and needs of disadvantaged groups (Zamani, 2017). The Regenize model intervened with the provision of tricycles, smartphones, PPEs, local hubs, hand scales and gloves. BanQu and Kudoti models provided PPEs, bailing machines and trucks for transporting the recyclable materials. This is similar to the Relix project in Brazil, where the government provided waste reclaimers with "a kit containing a bag, a sun hat with neck protection, a UV protective shirt, a pair of gloves, a padlock and chain, eco-bikes, a smartphone and a calibration pump" (Muniz, 2016). Through these interventions, waste reclaimers' working conditions and well-being have improved.

## 6.3 Data sharing and stakeholder collaboration through an ICT-enabled waste collection system

Through blockchain technology, the Internet of Things (IoT) provides a permanent solution to waste management inefficiencies prevalent in the informal recycling sector (Steenmans, Taylor and Steenmans, 2021). The current technologies and systems in the informal recycling sector are paper-based, centralised and manual (MS Excel), making the waste-related data easy to tamper with or alter from the system Ahmad et al. 2021). In the traditional informal recycling model, data on waste reclaimers was unreliable and inconsistent (EXPT-WRI01), making it difficult to determine their exact contribution to diverting waste from the landfill. The ICT-enabled waste reclaimer collection systems, namely BanQu, Kudoti and Regenize applications, are developed on blockchain technology, allowing for "close coordination and collaboration among the involved stakeholders such as households, informal waste reclaimers, waste collectors, buyback centres, recyclers and producers" (EXPT-SC01). The ICT-enabled waste management systems have allowed the sharing and access of waste-related data in various phases of the informal recycling processes between stakeholders in the value chain. As discussed in chapter five, adopting the ICT-enabled waste management systems in the informal recycling sector has opened up avenues for a transparent, verifiable, secure and effective data-sharing process.

Contrary to the Relix Model in Brazil (Coelho et al. 2019) and Internet$^{++}$ recycling in China (Xue et al. 2019), where government and municipalities are part of the recycling value chain, the South African ICT-enabled waste reclaimer collection systems have provided a well-defined recycling value chain which excludes the municipalities and government while incorporating households, waste reclaimers, waste collectors/buyback centres, recyclers, financial institutions and the producers. The exclusion of other waste management stakeholders like the government and municipalities, mandated by legislation to provide waste management services, impedes the integrative model and waste management data sharing between municipalities and other stakeholders. The absence of the government in this ICT-enabled waste reclaimer collection system may be attributed to the EPR regulation, which has transferred the responsibilities of waste reclaimer integration to the producers. Incorporating the government would entail that all the waste reclaimers need to produce legal documentation and show that they have legal status to be allowed to work in South Africa, thereby demotivating the majority of immigrant waste reclaimers who are operating in Johannesburg and Cape Town without adequate documentation and illegally working in South Africa. The other reason for the absence of the municipalities and government is attributed to the EPR regulations, which are evasive on the specific role of municipalities in managing waste products bearing EPR responsibilities. The absence of municipalities consequently results in municipalities failing to adequately report quantities of waste recovered, reused and recycled in line with their integrated waste management plans.

### 6.4 Recycling rewards and waste reclaimers payments through cryptocurrency

The traditional informal sector is mainly a transaction-for-cash environment which results in inefficiencies, as this places tremendous pressure on buyers, middlemen and buyback centres to consistently have cash and makes them susceptible to criminal elements (Fei et al., 2016). Unlike the traditional informal sector, the main improvement of the ICT-enabled waste reclaimer system is the payment of recycling rewards/vouchers and waste reclaimers payments through cryptocurrency in the informal recycling sector. Since BanQu, Kudoti and Regenize are developed on blockchain technology, they adopt cryptocurrencies in virtual payments and vouchers to facilitate payments to households and waste reclaimers, transforming the system into more efficient, systematic and sustainable. In Argentina, the government developed a JellyCoin platform to reward citizens participating in recycling and waste collection services through the virtual currency token J*ellyCoin* (Steenmans et al. 2021). Similarly to the initiative adopted by the Bounties for the Oceans to reward citizens who pick waste and clean the oceans with their virtual currency, *Dai,* a virtual currency is linked to the value of the United States Dollar (Steenmans et al. 2021), Regenize model adopted the *Remali* (the virtual currency is linked to the South African Rand) to reward households participating in the household recycling in Cape Town. Thus, the ICT-enabled waste reclaimer collection systems through blockchain technology present a unified platform for “cryptocurrency-based recycling rewards and vouchers for households, cryptocurrency-based payments for waste reclaimers and monitoring and tracking of waste from producers to landfills” (Kirchherr et al. 2017). Virtual currencies in *Dai,* J*ellyCoin* and *Remali* are adopted to facilitate payments for recycling and waste materials enabling secure and instant payments.

Rewards must be paid in virtual currencies and consider other non-digital services and initiatives (Lofthouse and Prendevill, 2017). In Curitiba, Brazil, innovative waste collection approaches, such as the “Green Exchange Program,” were developed to encourage households in informal settlements to clean up their areas and improve public health (LaRue, 2010). The municipality of Curitiba provides bus tickets and fresh vegetables to residents who collect waste and deposit recyclables at collection centres and allows children to exchange recyclables for school supplies or toys. The study in section 5.4.1 of Chapter 5 presented that the Regenize model not only uses the *Remali* to reward households but also provides vouchers that can be redeemed for groceries, stationery for children, airtime/data for communication and food parcels for waste reclaimers. The African Reclaimers Organisation (ARO) provides vegetables and food parcels to its members in Johannesburg. These approaches have improved the well-being of households and waste reclaimers through access to airtime/data and reduced hunger through redeemed groceries, vegetables and food parcels and stationery supplies for school children, thereby enlarging human capital.

Furthermore, some of the rewards and incentives implemented in the ICT-enabled waste reclaimers system in South Africa are focused on enhancing the working conditions and welfare of waste reclaimers. In contrast to the *Dai,* J*ellyCoin,* and *Remali* virtual currency focused on households/citizens, the Kudoti and BanQu applications also incentivise waste reclaimers with money and resources. In Auckland Park and Brixton, Unilever and Coca-Cola have piloted a top-up project of rewarding waste reclaimers with R0.50c per kilogramme of recyclable material sold using BanQu to disburse and track the payments. For instance, if a reclaimer collects 300kg of recyclable materials at the buyback centre, the reclaimer will be paid both the value of recyclables traded and the top-up fee of the 300 kilograms sold amounting to R150, which improves the income of waste reclaimers. Distell in Cape Town has used Kudoti to reward performing waste reclaimers with PPEs, gloves and scales to improve their working conditions resulting in waste reclaimers collecting more recyclable materials. This mechanism to incentivise waste reclaimers and citizens participating in circular waste management practices improves the recycling rate and household participation in separation at source initiatives whilst reducing waste going to the landfill.

In the traditional informal recycling sector, payment transactions are cash-based. The waste reclaimers are given a paper payment receipt with the amount paid according to the recyclable quantities traded. Besides facilitating rewards payments to households, the ICT-enabled waste reclaimer systems also provide various models for payment transactions of waste reclaimers in electronic payments and cryptocurrency (Shojaei et al., 2021). The South African ICT-enabled waste reclaimer systems allow buyback centres to pay waste reclaimers through electronic payments, such as "e-wallet and cash sent" linked to financial institutions like FNB, Capitec Bank and Standard Bank. This is in contrast to the Jay Phillips Partnership and Prismm Environmental initiatives, which make and accept payments in Bitcoin (Kim et al. 2021). Adopting electronic payments and cryptocurrencies in the South African informal recycling sector is economically viable in that it eliminates bank charges associated with transaction fees and ensures an instant secure payment with the waste reclaimer receiving confirmation of transaction details of monies paid and recyclables traded. This ICT-enabled waste reclaimer system in South Africa has developed a digital currency payment mechanism accessible even to waste reclaimers who are excluded from the mainstream banking system. The application of BanQu, Kudoti and Regenize platforms in the informal recycling sector demonstrates how the bottom-up integrated smart city concept support circular economy activities through social motivation, incentives and environmental protection. Furthermore, waste reclaimers are given paper-based receipts and digital receipts in the form of text messages with payment details of money received and waste quantities traded. Through transaction records, waste reclaimers in South Africa can now access credit facilities to acquire goods and sign contracts to purchase smartphones, as they are now bankable and can produce proof of income.

## 6.5 Intelligent scheduling, tracking and monitoring of waste material flow

The ICT-enabled waste reclaimer system in South Africa records and captures data on transactions at each phase in the informal sector. This is an inherent feature of Regenize, which provides a schedule of household collections to waste reclaimers for each day resulting in route optimisation, thereby minimising the distance travelled by waste reclaimers. The waste collection in smart cities involves several stakeholders, from households to municipalities incorporating socioeconomic and environmental factors in route planning and optimisation (Ahmed et al. 2021). This research has demonstrated the possibility and efficacy of scheduling household collections and route planning in the informal collection sector by applying the ICT-enabled waste reclaimers system in South Africa. This is a departure from the traditional informal recycling system, where waste reclaimers travel long distances to collect waste recyclables whilst competing with municipal trucks (Samson et al. 2020). Through data collected from household recyclable collection requests on the Regenize platform, pick-up schedules can be generated to maximise waste collection in the area. In addition, emerging technologies can change waste generation behaviour towards pro-environmental behaviour (Chourabi et al. 2011).

The ICT-enabled waste reclaimers system has enabled stakeholders in the informal recycling sector to track the quantities of waste collected, information about the waste reclaimer who has collected it, the area/suburb where the waste has been collected and the final location of the local registered buyback centre where the waste has been traded. For França et al. (2020), the ability of the ICT-enabled waste-based management platforms to schedule and track waste material flow activities enhance transparency in the collection activities, which guarantees that the waste materials are collected timeously by legitimate waste reclaimers. In France, where the ICT-enabled waste-based management platforms are adopted, AREP (French Railways Company) relies on bin sensors for scheduling collections once the bins are full, thereby optimising waste materials collection at each station (Arep, 2017). However, in South Africa, the ICT-enabled waste reclaimers system is still in its developmental phase and not fully automated to use bin sensors and actuators; hence it relies on household requests for intelligent scheduling. This Regenize initiative is similar to Parry & Evans in Bangalore, who, besides improving municipal waste collection, uses ICT-enabled waste-based management platforms to fast-track resolving waste management grievances reported by citizens on the platform ( Ahmad et al., 2021). Similarly to the Bangalore initiative, the ICT-enabled waste reclaimers system in South Africa, Regenize, which has household scheduling and collections services, is also being used to enhance collection services by using the platform to report uncollected recyclable materials. Buyin et al. (2016) indicate that the data collected from citizens is linked to a particular location (geo-referencing) in real-time, which informs the individual citizen or household waste generation and recycling trends and behaviour.

ICT-enabled waste reclaimer model can be used for tracking responsibilities which are key to ensuring compliance and enforcement with national regulations and policies (Steenmans et al., 2021). The data from grievances and household reports provide the accountability of relevant personnel responsible for recyclable waste collection services. The ICT-enabled waste reclaimer systems used by EPROs and EPR schemes collect data to determine the level of compliance and performance of their products against the annual recycling targets set by the government. Adopting BanQu, Kudoti and Regenize in South Africa contributes toward achieving the yearly waste reduction targets and increasing the recycling targets of various materials. For instance, in California, where the manufacturers are required to comply with the 75% waste reduction of single-use packaged products, ICT-enabled waste management platforms support these measures by providing "permanent, immutable ledgers onto which to record tracking lifecycle status information on a virtual distributed ledger" (Akbarieh et al. 2020:195). In South Africa, the data generated from the ICT-enabled waste reclaimers systems are used for reporting purposes on behalf of the manufacturers in compliance with the EPR Regulations. Adopting an ICT-enabled waste reclaimer system in the informal recycling sector has increased the efficiency and accuracy of generating reports while reducing human errors (Akbarieh et al., 2020). The ICT-enabled collection systems allow efficient monitoring and controlling of waste collection services from household levels to the buyback centre. The traceability feature in BanQu, Kudoti and Regenize ensures that waste management in smart cities efficiently tracks the end-of-life of waste products in line with the EPR regulation. Thus the ICT-enabled waste reclaimer model can be effectively adopted to integrate the municipal waste management system and the EPR-driven waste collection systems to improve the entire waste management systems in South Africa.

## 6.6 Data co-creation, responsibilities compliance and co-design of the ICT-enabled waste reclaimers system.

The current ICT-enabled waste reclaimer collection systems in South Africa establish stakeholders from various sectors participating in adopting waste-based digital platforms to manage waste in smart cities. While in other countries, for instance Brazil, Colombia, Netherlands and China, the central government and municipalities have steered the development of such initiatives in waste management (Ayeleru et al. 2020). In South Africa, the ICT-enabled waste reclaimer system is a product of multiple stakeholders in the business and informal sectors previously excluded in municipality-led top-down initiatives. Data is key to waste management in smart cities, and various stakeholders generate it in every waste management phase. The Regenize ICT-enabled waste reclaimer system allows the waste reclaimers to collect data on the amount of waste generated per household together with the quantities of recyclables per waste stream and upload it on the platform. For Kudoti and BanQu, the data is generated at the local registered buyback centres. Thus, the research has demonstrated that waste reclaimers are not only passive recipients of the ICT-enabled waste reclaimer system but are also co-creators of data which is central in guiding policy and improving the efficient collection of waste in smart cities.

For EPR regulations, the current ICT-enabled system is not yet fully developed but has the potential to enforce compliance with the governance of waste management practices. For Steenmans and Taylor (2018), the ICT-enabled waste management platforms can trace the responsible manufacturers of the products dumped in the landfill using barcodes or QR codes linked to the ICT-enabled waste management system. This data from the system would be used to identify the manufacturers who are not complying with the EPR standards and impose fines for failure to adhere to waste regulations. Furthermore, the data collected from the platforms also enable manufacturers and buyback centres to forecast the future household waste generation rate and help municipalities to monitor any community disease outbreaks (Steenmans and Taylor 2018). However, for Regenize, waste reclaimers upload images of various waste streams collected at each household, which helps identify the manufacturer responsible for managing the end-of-life phase of these products. Although the ICT-enabled waste reclaimers system can track responsibilities, as shown in this research, Steenmans et al. (2021) argue technology does not fully enforce compliance with responsibilities without complementary mechanisms. Steenmans et al. (2021) suggest that ICT-enabled waste management systems must be adopted as facilitative mechanisms for improving circular waste management in smart cities.

Within the EPR framework, the ICT-enabled waste reclaimers system is being developed in a sector with various stakeholders. The interest observed by the researcher is that waste reclaimers, buyback centres, collectors, recyclers and manufacturers were engaged in the design and development of the ICT-enabled waste reclaimers system. The ICT-enabled waste reclaimers system is a co-designed model emerging from the participation of waste reclaimers and other stakeholders in the waste management sector. This is a departure from the top-down government and municipality-driven technologies, which Atanasova (2020) argue were costly in India, especially due to the social disruptions on thousands of people's livelihoods. BanQu, Kudoti and Regenize engaged with reclaimers on the platforms' design model, thereby enhancing waste reclaimers' role from being passive recipients of smart city initiatives into being key participants in the co-designs of ICT-enabled waste reclaimer systems. Thus this research has illustrated that waste reclaimers are key stakeholders and participants in the co-design and co-creation of data in smart cities' waste management initiatives.

The South African ICT-enabled waste reclaimer model differs from the Relix model in Brazil (Coelho et al. 2019), where the government controlled the design, identified the participants and implemented the project with waste reclaimers as recipients of government smart city initiatives. The waste reclaimers identified the government's direct role as a barrier to implementing the Relix model. The government only implemented an ICT-enabled waste management system without changing their working conditions. The government-identifying participants further excluded waste reclaimers not part of government projects. However, South African ICT-enabled waste management is being driven by producers, ICT companies and waste reclaimers, making it a more integrative and inclusive approach. This research has confirmed that Virgolin et al. (2016) and Rolim et al. (2015) state that the ICT-enabled waste reclaimers system allows waste reclaimers to be socially included and empowered in smart city waste management initiatives.

## 6.7 Current status of the ICT-enabled waste reclaimers system in South Africa.

The above sections have discussed the extent of digital transformation of the informal recycling sector by applying the ICT-enabled waste reclaimers system in South Africa. The model is manifested through the application of ICTs, blockchain technology and smartphones, as illustrated in the BanQu, Kudoti and Regenize case studies. Although the applications, development and refinement of the ICT-enabled waste reclaimers' system are constantly being conducted, two implementation models have emerged. Figure 5.10 presents the two emerging models: the BanQu and Kudoti waste reclaimer system and the Regenize waste reclaimer system. These two models vary in their degree of ICT integration and implementation in the provision of recyclable collection services in smart cities.

### 6.7.1 BanQu and Kudoti waste reclaimer system – EPR Model

BanQu and Kudoti waste reclaimers model is a multi-technology-based model which aims to enable waste reclaimers to sell their materials at local registered buyback centres. The role of BanQu and Kudoti is to register waste reclaimers into the ICT-enabled recycling value chain. Kudoti and BanQu do not directly work with households and waste reclaimers to schedule household collection like the Relix model in Brazil (Coelho et al. 2019), which allows waste reclaimers to collect recyclable materials from scheduled household requests. Fig 5.10 below shows that the collection phase in this model is unsystematic and disorganised, with an uncertain number of trolleys and waste reclaimers travelling long distances, similar to the traditional informal recycling sector interaction with the technologies experienced at the registered buyback centres for payment transactions and recording of waste quantities. Similarly to RecycleGO and EmpowerAPP (Ahmad et al. 2021), the platform has connected waste reclaimers, buyback centres, collectors, recyclers, financial institutions, producers and other actors in the recycling supply chain to enhance better trading and creation of e-markets for recyclables materials. Implementing an ICT-enabled waste reclaimers system in South Africa has also improved data accuracy in waste inventories and supply to buyback centres. Thus, not only does the ICT-enabled waste reclaimers system serve as the platform for waste management trading, but it also creates decentralised public inventories facilitating information sharing through permanent transaction inscription and traceable data among various users within the waste recycling value chain ushering in a new transparent and integrated waste management business model (Esmaeilian et al. 2018).

Despite implementing the BanQu and Kudoti waste reclaimer system, this has not transformed the collection phase but only enhanced the trading and payment systems. What is clear is that the BanQu and Kudoti waste reclaimer system is used as a medium for data collection, mainly designed to serve the interests of the producers in compliance with the requirements of the EPR regulations. Although waste reclaimers are the intended beneficiaries empowered by the platform, implementing the BanQu and Kudoti waste reclaimer system demonstrates that it incorporates unequal and exploitative relations (Samers, 2005). Schmid (2021) asserts that the application of technology infrastructure neither effectively responds to socio-economic challenges experienced by waste reclaimers nor provides a context for waste reclaimer integration initiatives to thrive. Although waste reclaimer organisations and cooperatives were engaged in designing the ICT-enabled waste reclaimers system, they lacked the influence to effect a profound change in the trajectory of technological applications despite having a corrective role in the sector (Buch-Hansen, 2018).

### 6.7.2 The Regenize waste reclaimer system- Entrepreneurship Business Innovation Model

The Regenize waste reclaimer system is a product of an entrepreneurial business innovation model in a bottom-up smart city integrated waste management model in Cape Town. Even though the Regenize waste reclaimers system continuously improves, the implementation approach resonates highly with the developed systems in Canada, the USA, France, China and Brazil. The ICT-enable waste management systems in developed countries are highly organised and systematic from household collection stages, transportation and transaction at buyback centres or waste recycling depots (Steenmans et al. 2021). Similarly to the Relix model in Brazil (Coelho et al. 2019) and China's intelligent collection system (Xue et al. 2019), the application of ICT and involvement of the private sector in the informal recycling sector has provided accurate data on the number of waste reclaimers and reliable tracking of waste movement from household level. Unlike BanQu and Kudoti waste reclaimer system, which does not directly work with households and waste reclaimers, the Regenize waste reclaimer system provides an assurance that all the waste materials collected from households are accounted for and channelled to the registered local buyback centre and sorted on designated local hubs in an environmentally benign way thereby reducing illegal dumping.

Adopting the sophisticated Regenize waste reclaimer system provides several advantages, such as reduced distance travelled, specialised collection area, reduced time and enhanced efficiency over the traditional informal collection system and the EPR model. The Regenize waste reclaimer system can verify inaccuracies in waste quantities by comparing the total waste collected at each household and the received final sorted waste at the local hub. This verification feature is crucial for achieving the zero waste goal, as it determines lost and inaccurate waste quantities in the system, thereby increasing waste data reliability in smart cities (Recycling Today, 2017). The Regenize waste reclaimer system illustrates a highly integrative system which is built on "spatial technologies (e.g. GIS, GPS), identification technologies (e.g. RFID, barcodes), data acquisition technologies (imaging) and data communication technologies (e.g. GSM, Wi-Fi)" (Esmaeilian et al. 2018:181). Regarding ICTs, we can see that data acquisition, data communication and data processing technologies are present in BanQu, Kudoti and Regenize waste reclaimer collection systems. Thus, this research has demonstrated the application of IoT and blockchain technology in the informal recycling sector, which has improved the welfare of waste reclaimers and enhanced the quality of recycling data in the informal sector.

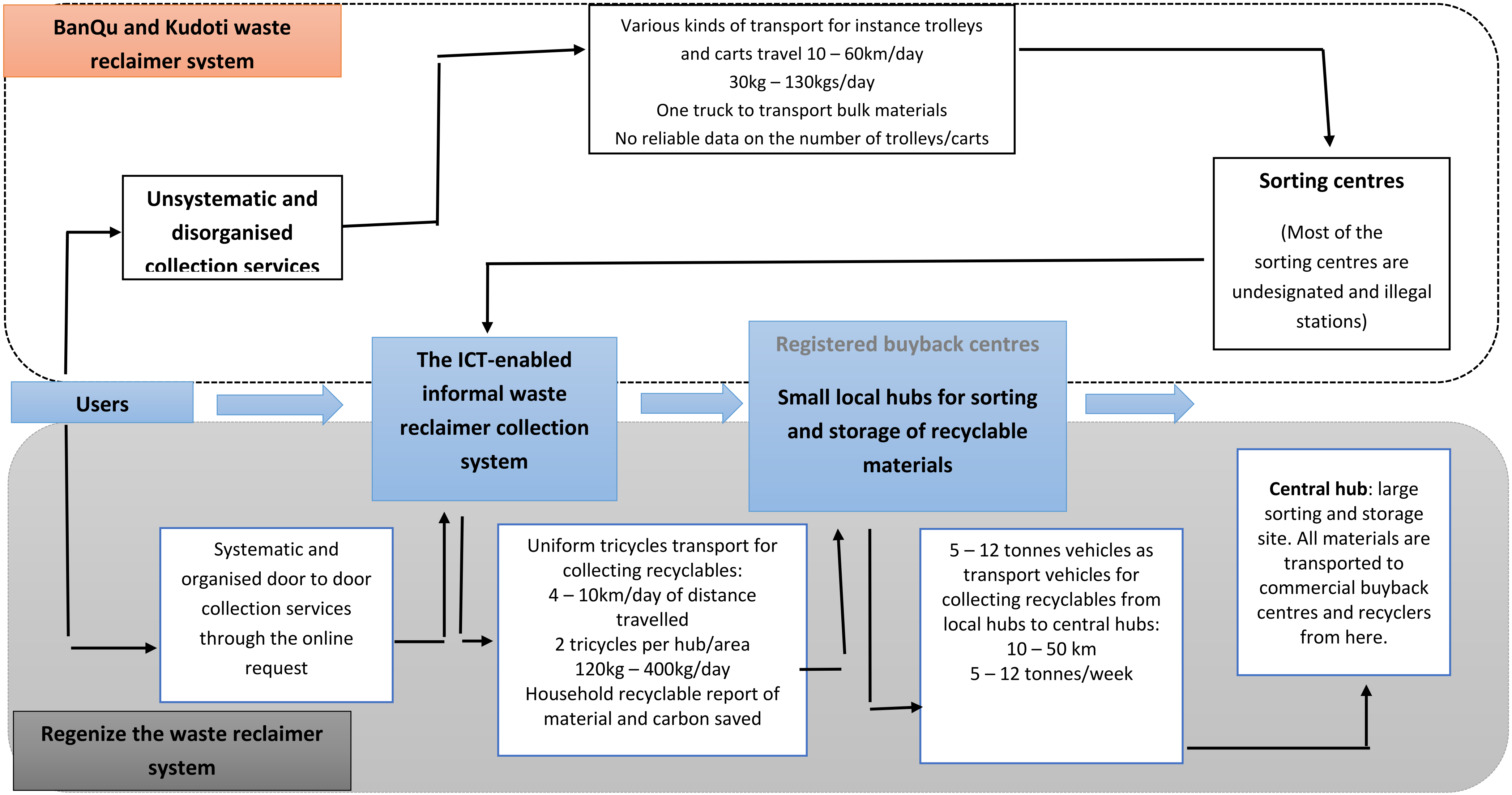


FIGURE 6 1. THE EMERGING ICT-ENABLED WASTE RECLAIMER SYSTEMS IN CAPE TOWN AND JOHANNESBURG.

## 6.8 Integration and co-existence with existing traditional informal recycling systems.

### 6.8.1 Co-existence with existing traditional informal recycling systems.

Waste management, especially in the informal collection and recycling industry, involves various stakeholders, technologies, policies and regulations, devices and organisations working closely in co-existence to manage waste collection in smart cities (Coelho et al. 2019). The use of IoTs and ICT-enabled waste reclaimer systems in South Africa must be interoperable and compatible with the existing traditional informal collection and recycling systems to effectively manage the activities of all the stakeholders involved in the recyclable supply chain in smart cities. The informal waste collection and recycling sector is a highly contested space between various stakeholders in waste management. During the data collection phases, the researcher observed that buyback centres, waste collectors, recyclers, producers and waste reclaimers have competing interests in using technology in smart waste management.

Although smaller buyback centres have adopted and embraced the ICT-enabled waste reclaimer system to aid them in their waste management activities, bigger commercial buyback centres like REMADE Recycling resisted adopting and integrating the ICT-enabled waste reclaimer system into their technologies and existing systems. The BanQu platform is seen as a foreign system adopted from Colombia which is being imposed on waste reclaimers in South Africa by multinational companies like Coca-Cola and Unilever hence the hesitancy to embrace it fully. Regenize started as a programming and IT tech company providing reward vouchers to households participating in recycling activities. However, existing waste collectors and recycling companies refused to adopt the Regenize platform because of the reward aspects which formed the core of the Regenize recycling initiative. As a result, Regenize designed the reward model after a successful pilot project in Bridgetown, transforming the programming and IT tech company into a waste recycling collector using their developed ICT-enabled waste management system to manage the entire waste management process. Only buyback centres, waste collectors and waste recyclers linked to specific platforms are permitted to transact and trade within the platform, thus limiting the performance of cross-chain transactions and data sharing between BanQu, Kudoti and Regenize systems.

### 6.8.2 The extent of waste reclaimers' integration.

The previous chapter has shown that the concept of waste reclaimer integration is not yet fully understood by the ICT companies and producers beyond the precepts of policies and regulations. Similarly to Colombia and China, the ICT-enabled waste reclaimers system in South Africa highlights two integration models: depth integration and collaborator integration of waste reclaimers (Xue, Wen and Bressers, 2018; Yang et al., 2009). The collaborator model of integration in South Africa is demonstrated in the BanQu and Kudoti systems, in which the technology is imposed on waste reclaimers to serve the interests of the manufacturers like Unilever, Coca-Cola and Distell. The waste reclaimers only use BanQu and Regenize platforms to generate waste-related data and transactions needed by the producers to report on their performances towards the EPR regulation waste recycling targets. Thus the ICT-enabled waste reclaimer systems track the target percentage of products that must be diverted from the landfill by the producers in collaboration with waste reclaimers.

The second model of integration manifesting in South Africa is the limited depth integration, where the ICT-enabled waste collector company engages with waste reclaimers and equips them with technology, trains them to use the technology and smartphones, and provides them with PPEs and resources for ICT-enabled waste reclaimer collection. Limited depth integration is almost similar to depth integration in China in terms of formalisation and empowerment through resource allocation and training (Xue and Bressers, 2020), with only one exception of that in South Africa, waste reclaimers are neither remunerated nor access welfare benefits provided by these ICT companies (Regenize) and manufacturers. Waste reclaimers neither enjoy benefits that accrue from formal work nor are covered by labour regulations (Holt and Littlewood, 2017; Schenck & Blaauw, 2011; Viljoen, 2014). Thus, the absence of remuneration and welfare benefits explains the private sector and government treatment of waste reclaimers within the recycling value chain.

The ICT-enabled waste reclaimers system in South Africa has integrated waste reclaimers through the 'regularisation' of illegal foreign immigrants without legal protection in South Africa. The integration of waste reclaimers faced challenges because the government perceived foreign waste reclaimers without identity documents or work permits as dangerous to society (Sentime, 2011). The ICT-enabled waste reclaimer model has provided avenues for the visibility of waste reclaimers (Coelho et al. 2019) and regularisation through work permits for waste reclaimers. As an informal waste reclaimer who is not bankable, it is difficult to provide proof of income, but the ICT-enabled waste reclaimer systems have provided transactional records which can be used as proof of income for them to access credit, cellphone contracts and open bank accounts. The ICT-enabled waste reclaimers' system has enabled waste reclaimers to legalise and regularise both their resident status and work permits by providing proof of income which is a key requirement in obtaining work permits, for instance, Zimbabwean Exemption Permit (ZEP) and Lesotho Special Permit (LSP). Through regularising and legalising their status in South Africa, foreign waste reclaimers can now access some benefits that are part of the formal sector, such as opening bank accounts and insurance. Regularization helps integrate waste reclaimers into the formal systems and removes the stigma associated with staying and working in South Africa illegally.

The digital transformation of the informal sector has shown that buyback centres are key institutions of integration which connect, train and register waste reclaimers into the ICT-enabled waste reclaimer system. For Barnes et al. (2021), buyback centres are points of convergence between the waste economy's formal and informal recycling sectors. In the traditional informal recycling sector, buyback centres "add value to recyclables by sorting, cleaning and baling the recyclable material before selling it at higher prices to larger buyback centres or directly to large recycling companies and are the connection between the informal reclaimers and the activities of the formal waste economy in the form of recycling companies, exporters and manufacturers" (Barnes et al. 2021:02). The ICT-enabled waste reclaimer system has shown that buyback centres are being used to disburse EPR funding to waste reclaimers and facilitate interactions between the waste reclaimers and producers in the recycling value chain. In addition, the new business innovation has resulted in the ICT-enabled waste collector companies replacing buyback centres in the integration initiatives in Cape Town. For instance, Regenize Company has integrated individual waste reclaimers in various suburbs and performed all the recycling activities of diverting waste from the landfill. The waste collector companies using the ICT-enabled platforms are now the emerging key institutions of waste reclaimers' integration and environmental sustainability (See Section 5.4.1). Thus in South Africa, both the buyback centres and ICT-enabled waste collector companies are key institutions in providing linkages and integration of waste reclaimers in smart city waste management.

## 6.9 Understanding the configurations, innovation and structure of the ICT-enabled waste reclaimers system in South Africa

From the discussions and analysis above, it can be observed that the ICT-enabled waste reclaimer systems in South Africa emerged within the entire configuration of technology, local innovative networks, cultural meaning and market, policy and regulations, alignment of structures and utopian vision for zero waste goal. In this section, the research will further discuss the ICT-enabled waste reclaimers system using some conceptual tools from the socio-technical transitions theory to sustainability. What is clear is that the ICT-enabled waste reclaimer systems in South Africa are a novel 'socio-technical configuration' which encompasses various stakeholders within the informal collection and recycling value chain. The current implementation of the ICT-enabled waste reclaimers system in South Africa, especially the BanQu and Kudoti platforms, is in the first phase, encompassing pilot projects in Brixton and Auckland Parks for BanQu and Khayelitsha for Kudoti. The pilot projects and South African cities provide the potential for niche innovation and create an enabling environment to determine the acceptance, feasibility and performance of the ICT-enabled waste reclaimers system in the informal collection and recycling sector. For Regenize, the project is in the second phase of implementation, where various stakeholders in waste management interact with the technology and transform them into artefacts entrenched in their daily practices and routines (Lie and Sørensen, 1996). Despite various implementation phases, some waste reclaimers resist using the ICT-enabled systems, especially on ownership, accessibility and presentation of data which impede further development resulting in conflicts and stalemates (Devine-Wright et al. 2017).

The government department, waste reclaimers, academia, NGOs and ICT companies were the key drivers behind the ICT-enabled waste reclaimers system in South Africa. The formation of this network of innovators was only accessible to individuals interested in the digital transformation of the informal collection and recycling sector. With the network of innovators, the ICT-enabled waste reclaims systems functioned as a facilitator, continuously facilitating innovative opportunities and waste management through digital transformation (Waste management platforms, data and internet, smartphones, cellphones) and end-users (humans and organisations). From the socio-technical perspective, the configuration occurs during the interaction of the end-users and technologies, resulting in innovation. As argued above, the ICT-enabled waste reclaimer systems aim to improve recycling activities and achieve the zero waste goal while integrating waste reclaimers in South Africa. The Multi-level Perspective (MLP) provides a conceptual tool to understand the configurations.

The "niche level, regime level, and landscape level" are three analytical levels provided by the Multi-level Perspective (MLP) in understanding the trajectory of the ICT-enabled waste reclaimer system in the waste management sector. As with new technologies, the ICT-enabled waste reclaimers system exists at a niche level where protection and support are provided to novelty innovation. However, above the niche level exists the regime, which is an existing stabilised waste management approach that can resist adopting this new technology in the informal collection and recycling sector. The regime can include existing laws and regulations, user preferences, uncertainty, politics and the market (Geels, 2002). During this phase, struggles between the innovators and the existing regime are prevalent in various dimensions. There may be economic competition between the existing technologies and new technology, business struggles between new ICT-enabled waste collectors against the old buyback centres, which might lead to the downfall of existing buyback centres, and political conflicts as a result of the power struggle between the informal waste reclaimers and private contracted waste collectors and industries over the "agenda-setting, problem framing, and adjustments in subsidies, taxes, and regulations" (Meadowcroft, 2009) for integrating waste reclaimers into the formal recycling value chain. These power struggles also involve municipalities, waste reclaimer organisations, and industries. Academia, NGOs, policymakers and other social groups are affected by the new technology. However, there remains uncertainty about whether the niche innovation will overcome these struggles as some technologies ultimately suffer setbacks.

## 6.10 Towards an integrative and efficient ICT-enabled informal waste reclaimers system in South Africa

The section above has presented the current status of the ICT-enabled waste reclaimers system and shown its potential and weaknesses in integrating waste reclaimers and enhancing efficient collection and recycling initiatives in South Africa. The newly proposed ICT-enabled waste reclaimers' model is built on the weaknesses of the current model and recommendations suggested by the respondents and end-users who desire an improved model. The proposed framework for an integrated ICT-enabled waste management system is suggested, with four interconnected elements: (1) ICT infrastructure for daily household scheduling and route optimisation, 2) Physical infrastructure for sorting and storage of materials, 3) Trading platforms for payment transactions and 4) Data Processing systems for generating statistical reports of transactions and quantity of waste recycled/collected. The efficacy of the proposed model for the ICT-enabled waste reclaimers system is anchored on the operational and social design, integration with existing systems, automated data input mechanism and product tracking throughout its life cycle in smart cities towards the zero waste goal.

### 6.10.1 Incorporating municipalities and government systems into the ICT-enabled recycling value chain.

The absence of municipalities and government in the value chain of the ICT-enabled waste reclaimers impedes the achievement of the zero waste goal in South Africa. Incorporating municipalities in the ICT-enabled waste reclaimer collection systems provide opportunities for accurate waste data reporting and efficient implementation of separation at source initiatives. The alignment of current EPR regulations to clearly define the responsibilities of municipalities and producers within the EPR framework would increase the cooperation between waste reclaimers, producers and EPROs or EPR Schemes using technology, thereby improving the recovery of recyclables from municipal waste and transforming the entire ICT-enabled recycling chain. Furthermore, the ICT-enabled waste collection system would provide information on the number of waste reclaimers operating in South Africa, leading to the development of the National Informal Reclaimer Registration System, a master list of waste reclaimers. The National Informal Reclaimer Registration System through BanQu, Kudoti and Regenize will be able to link municipalities, buyback centres, waste collectors, recyclers and producers into the South African Waste Information Centre (SAWIC) to allow for the potential transfer of data and flow of funding. This research concurs with Ahmad et al. (2021) that the ICT-enabled waste reclaimer system has provided an integrative approach to effectively store and share encrypted data on the number of waste reclaimers, quantities of waste collected and recycled, and a record of transactions transparently and securely.

### 6.10.2 The ICT-enabled waste reclaimers system – automated data input mechanism

The current ICT-enabled waste reclaimers system relies on manual data input into the system either at the household level or the buyback centres by waste reclaimers and owners of buyback centres, respectively. The manual input of data poses a considerable challenge in the waste management sector as waste data will constantly change up the value chain because recycle waste transfers from waste reclaimers to buyback centres to other and or recyclers. The ICT-enabled waste reclaimer system provides waste data security as data cannot be tampered with or modified once recorded. There is a need for automated data input to be done either remotely or through other mechanisms where there is no human interference. For advanced systems like Regenize, the hand scales should be linked with communication technologies to transmit household waste data quantities automatically into the system without human input. The current Regenize system has the required internet connectivity for the underlying technologies to be linked to the server or system for data transmission. Thus, pilot projects need to test the applicability of digital scales and sensors for automated waste data recording in the informal collection and recycling sector.

Waste management in smart cities involves large amounts of data generated in various formats, such as documents or images from waste collection to payment at the buyback centres. The imagery system currently used by Regenize can be added to BanQu and Kudoti as an add-on feature to improve recyclable sorting at buyback centres. This will ensure accurate data on waste streams and quantities being recorded in the informal recycling sector. The absence of accurate data will result in incorrect decisions regarding resource allocation and determining the annual recyclable waste data quantities. There is a need for strict control mechanisms to ensure that correct data is recorded in the system since data on blockchain technology cannot be changed. Thus municipalities, ICT-waste collector companies and producers must set responsibilities for managing and developing ICT-enabled waste reclaimers systems to curtail the recording of incorrect data in the system.

### 6.10.3 The ICT-enabled waste reclaimers system – automated recyclable pricing mechanism

Associated with the automated data input is that aspect of pricing of recyclables in South Africa. The fluctuating demand and supply of recyclable materials consequently force buyback centres to offer different price structures that permit waste reclaiming exploitation. Although the government or municipalities can intervene in the pricing of recyclables, the ICT-enabled waste reclaimer system has the potential to ensure fair pricing for waste reclaimers in South Africa through fixed pricing in the system. In Colombia and Brazil, where BanQu is used, the producers fix the prices because they want the waste reclaimers to be paid fairly. Similarly to Columbia and Brazil, the producers in South Africa must set the prices of recyclables in the system, which will be used at the buyback centres, rather than leaving the fixing of prices to the discretion of individual buyback centres. This has resulted in different pricing structures based on geographical locations. Thus, producers need to fix the prices of each recyclable material in the system for fair payment of waste reclaimers. The fixed pricing structure in the ICT-enabled waste reclaimers system will ensure that waste reclaimers are paid fairly and at similar prices in South Africa.

In addition, waste reclaimers generate income and make remittances back to their homes in rural South Africa and some to neighbouring countries like Lesotho, Zimbabwe and Mozambique. The challenge of BanQu, Kudoti and Regenize on remittances is that it only works with specific supermarkets and banks, which might not be available in neighbouring provinces and countries. Hence, the payment systems need to be linked to other money transfer facilities within South Africa and abroad. Aligning the ICT-enabled waste reclaimer system with money transfer facilities like Mukuru, Remit World, and MoneyGram would provide a secure mechanism for foreign immigrants to send their monies back home. Within South Africa, the ICT-enabled waste reclaimer system must be linked to other cash access facilities, either the Post Offices, SASSA pay points or retail shops like Shoprite and PnP. This will ensure easy transfer and access of monies to families of waste reclaimers.

### 6.10.4 The ICT-enabled waste reclaimers system – Social design and data management

The application and development of the ICT-enabled waste reclaimer system must be connected to the users' local dynamics or social context. The interaction of the market, culture, institutions and social groups influence the use of technology in the informal recycling sector. The needs, social and cultural norms of waste reclaimers and households have largely shaped how the ICT-enabled waste reclaimers system has been used, and their familiarity with the technology influences the resistance from other waste reclaimers. Thus, the ICT-enabled reclaimer system needs to have a multilingual system in its features and applications. The current system uses English, while most waste reclaimers suggested that the system must also use local languages such as Zulu and Sotho. This will motivate other waste reclaimers to embrace the new technology as it is customised to fit the local language barrier context. Thus, information on ICT-enabled waste reclaimers system and waste picker integration must be presented in local languages for better comprehension and accessibility.

Although the ICT-enabled waste reclaimer system permits for objective tracking of waste performance data by producers, there is contention over the ownership of this data. Currently, the ICT-enabled waste reclaimer system's objectives to collect, analyse and report recycled waste target performance data support the interest of the producers. Theoretically, the developers of BanQu assert that individual waste reclaimers own the data, but in reality, it is clear that the data is controlled by the producers who generate reports from it. Furthermore, the current ICT-enabled waste reclaimers system is unclear on how the transactional and waste-related data is presented to waste reclaimers who are not using smartphones. Moreover, uncertainty exists on how the producers will present this data to the government and municipalities. Thus, there is a need for a clear smart contract that will give control of waste management data in the system to waste reclaimers for them to access and report their contributions to the municipalities, government and other waste management organisations. Waste reclaimers will use this data to earn some profit by sharing this data with consultants, retailers and beverage producers.

The data is also essential to guide the policy compensation mechanism proposed in the EPR Regulation. Waste reclaimers anticipate being compensated for the services they provide in collecting and transporting recyclable materials from households and landfills to the buyback centres, which is the responsibility of the municipalities and producers. The ICT-enabled waste reclaimers can create an inventory of substantial recyclable databases detailed with quantities of recyclables and various waste streams. This substantial recyclable database is vital to the government designing a proper waste reclaimers' compensation strategy and management mechanism within the EPR Regulation. Sharing recyclable data with municipalities and government provides evidence of waste reclaimers' contribution to circular economy activities, especially recycling. For instance, in China, the municipality of Guangzhou produced a policy framework which guides the payment of informal waste reclaimers who uses the ICT-enabled collection system a "90 RMB subsidy for every tonne of low-value recyclable” (Xue et al. 2018:313). This will enable the waste reclaimers to receive subsidies and compensation fees, increasing the collection of recyclables and the recycling rate in South Africa.

### 6.10.5 Provision of designated spaces for waste pickers’ recycling initiatives.

The BanQu and Regenize model presented the weakness of the current model, especially the absence of municipally designated spaces for waste reclaimers to sort and store their recyclables. This has resulted in waste reclaimers using undesignated areas, parks and open spaces to sort and keep recyclable. The provincial government and municipalities must provide land that waste reclaimers can use to sort and store their products safely, controlled, and hygienically. The prices of recyclable materials are associated with the sorting and collection spaces. The recyclable waste collectors who travel to sorting areas and buy recyclables from reclaimers who are sorting and storing on land in informal areas usually pay lower than the buyback centres, which may be at a greater distance to access. Furthermore, the municipal planning and development departments must ensure that zoning regulations can enable the reclaimers and buyback centres more.

### 6.10.6 Workshops, training and awareness campaigns for separation at source (S@S)

The previously municipal-led separation at source (S@S) initiatives had limited success due to the absence of incentives mechanism, waste reclaimers, ICT-enabled waste management systems and producers. Training and campaigns by the municipalities in collaboration with waste reclaimers could help promote S@S to residents in formal and informal areas. Educating residents is central to the successful implementation of S@S. Households need to be educated and trained on how to use the ICT-enabled waste reclaimers systems to request collection services to improve how S@S works. Through incentives and rewards from the EPR fees, the municipality, in partnership with waste reclaimers, will be able to collect to separate waste regularly. Resident Associations are key stakeholders in implementing S@S by allowing waste reclaimers to collect recyclable materials in their suburbs or estates and ensure households reach the zero-waste goal. The residents association can bridge household behaviour change by interacting with waste reclaimers and treating them as key stakeholders in providing services that complement the municipal collection.

## 6.11 Conclusion

The chapter provided essential insights into the trajectory of digital integration and ICT-enabled waste reclaimers' system configurations that were unearthed in the BanQu, Kudoti and Regenize case studies. The ICT-enabled waste reclaimers' model was uniquely birthed out of the configuration of waste reclaimers, producers, policy, institutions and ICT-enabled waste collectors and software companies to integrate waste reclaimers and improve recycling activities. The configuration emerged due to the interactions of a network of innovators and actors who were responding to the digital transformation of the informal recycling sector and tracking the waste performance targets as required by the EPR regulation in South Africa. Implementing the ICT-enabled waste reclaimers' model was restrained by the municipally led and traditional informal waste reclaimers systems (regime). The waste management regulations and the absence of the national smart city guideline restricted municipalities' successful rollout of the ICT-enabled waste management system. Despite various stakeholders having to compete and varying reasons for the digital transformation of the informal recycling sector, the ICT-enabled waste reclaimers system has managed to integrate waste reclaimers and improve waste management towards the zero-waste goal. The chapter analysed the current ICT-enabled waste reclaimers system and identified the model's weakness. In response to the weaknesses of the current model, a new conceptual design was developed, which sought to develop a more effective and integrated ICT-enabled waste reclaimers system in South Africa.

# CHAPTER SEVEN: CONCLUSION

## 7.1 Introduction

The study presented detailed research on the emergence of a bottom-up smart city integrated waste management model through the implementation and diffusion of the ICT-enabled waste reclaimer system in South Africa. As a result of the fixed research timeframe, the research managed to capture the initial execution and pilot phases of this bottom-up integrated smart city innovation in BanQu, Kudoti and Regenize ICT-enabled waste reclaimer system. The thesis showed the unique and complementary socio-technological configurations in the three ICT-enabled waste reclaimers system case studies. Firstly, BanQu and Kudoti are being adopted to implement the EPR Regulation and are unsystematic and disorganised during the recycling value chain's collection, transporting, sorting and storage phases. Secondly, Regenize is highly systematic and organised from household collection to the trading phases of the recycling value chain. The research found that implementing the ICT-enabled reclaimers system is in the first trajectory phase, encompassing pilot projects and trial-and-error learning with the new technologies (Sengers et al., 2019; Schot and Geels, 2007).

The ICT-enabled waste reclaimers initiatives discussed in the context of South Africa's informal recycling sector exhibit elements of a "bottom-up" approach, although they are not without limitations. These initiatives can be seen as bottom-up due to the active involvement of waste reclaimers and local communities in shaping and participating in the design and implementation of the ICT-enabled waste reclaimer systems. Unlike traditional top-down approaches, waste reclaimers' input was sought in the development of these systems, signifying a departure from corporate-led initiatives and acknowledging their role in the process. The utilisation of technology to empower waste reclaimers through digital platforms such as Regenize, BanQu, and Kudoti aligns with the principles of bottom-up engagement. The deployment of ICT tools allows waste reclaimers to not only collect data but also co-create it, thereby increasing their agency in the waste management value chain. Moreover, the focus on providing waste reclaimers with tools such as tricycles, smartphones, and personal protective equipment (PPE) further empowers them to improve their working conditions, making their contributions more meaningful.

However, these bottom-up initiatives are not immune to limitations. The involvement of corporate entities like Distell and Coca-Cola, along with the potential influence of profit motives, raises questions about the extent to which these initiatives genuinely prioritise the well-being of waste reclaimers over corporate interests. Additionally, the uncertainty of sustained funding for privately driven models, despite elements of state regulation such as EPR, may jeopardize the longevity of these initiatives. Furthermore, the digital nature of these systems brings concerns about data accuracy, privacy, and the potential for technological solutions to be subject to "human interference" and biases.

Looking at the whole digital innovation process of the informal recycling sector, it is crystal clear that the bottom-up smart city integrated waste management was not only focused on the implementation of technology but a continuously evolving configuration of a local network of innovative actors with waste reclaimers, markets, social connect policies and regulations. The ICT-enabled waste reclaimers system has produced positive results and provided opportunities for waste reclaimers' integration, waste tracking and monitoring towards the zero-waste goal. This section also highlights the contribution of the research on the influence of a bottom-up smart city integrated waste management model on informal waste reclaimers' integration and municipal solid waste management in South Africa. The thesis concludes by suggesting potential areas for future research in ICT-enabled waste management in smart cities.

## 7.2 Addressing the research questions

The main research question asked in the first chapter of this research was an investigation into the role of the bottom-up smart city integrated waste management model in integrating waste reclaimers while enhancing municipal waste management performance towards the zero-waste goal. Collectors and producers used the ICT-enabled waste reclaimer system in collaboration with households and waste reclaimers to improve municipal solid waste management and recycling initiatives. The ICT-enabled waste reclaimer system has managed to improve waste reclaimers' well-being and recognition and visibility in communities where they are undertaking recycling initiatives. What is clear is that the Regenize ICT-enabled waste reclaimers have strengthened the relationship between households and waste pickers executing household collection request services. For BanQu, the involvement of Resident Associations partnering with waste reclaimers in S@S has increased households' awareness of the value of recyclable materials, increased residents' participation in S@S initiatives and established partnerships with producers and ICT-enabled waste collector companies.

The ICT-enabled waste reclaimer system in South Africa in the waste management sector is still in the early phases of development, with the influence of digital transformation constantly evolving and being shaped. The architecture of the South African ICT-enabled waste reclaimers system has managed to integrate IoT, blockchain technology, waste management digital platforms, monitors and mobile smartphones to allow arranged residential collection services. Technologies such as Global Positioning System (GPS), Radio-frequency identification (RFID), Image Processing, sensors, and Geographic Information Systems (GIS) have been applied in the informal collection and recycling sector. These technologies have been integrated into the current ICT-enabled waste reclaimer system to measure waste recycling rates and targets. The ICT-enabled waste reclaimers system is developed on blockchain technology and connected to the IoTs, allowing households to schedule waste collection services, optimise route planning and provide for digital transactions and trading. The development of incentives, for instance, the virtual currency *Remali,* profoundly influences the recycling rate at the household level and can be adapted to complement the formal municipal S@S projects. The South African ICT-enabled waste reclaimers mainly focused on the data collection process and transaction services (BanQu and Kudoti), while Regenize is focused on the whole recycling value chain.

This research has demonstrated the application of the ICT-enabled waste reclaimer system in the product's End of Life phase, which involves the collection, recycling and reuse. The ICT-enabled waste reclaimers system has ensured long-term business viability in the smart city for buyback centres and waste reclaimers in the recycling value chain. The integration and connection of various technologies in the ICT-enabled waste reclaimers system have provided opportunities for product life cycle data platforms which is key to the circular economy. The product life cycle data platforms in the ICT-enabled waste reclaimers system will integrate smart cities' business, environmental and social aspects. The research has shown that the ICT-enabled waste reclaimers system has advanced the concept of sharing and connected cities where households and waste reclaimers supply buyback centres, recyclers and waste collectors with recyclable products (raw materials) using the waste-based management and trading platforms providing transactional services. To the buyback centres, the ICT-enabled waste reclaimers system has created secure and immutable inventories for tracking recyclable stock quantities and a recyclable database which will provide accurate data on the contribution of waste reclaimers toward the zero-waste goal.

The EPR regulation requirements and the local context toward waste reclaimers' integration provided an opportunity to adopt and develop the ICT-enabled waste reclaimers system in South Africa. The expectations and visions of the producers, waste reclaimers and ICT-enabled waste collected provided pre-conditions for incubating the ICT-enabled waste reclaimers system through co-design and co-creation with other stakeholders. Despite the design and implementation, the trajectory of implementation was enabled and restricted by the structure embedded in current data sharing and waste management laws and regulations. Furthermore, the interests and goals of the manufacturers resisted the compensation and payment of transportation and collection services undertaken by reclaimers for free in the informal recycling sector. The ICT-enabled waste reclaimers system has provided a bottom-up smart city integrated waste management model, enabling various users to participate and not be passive beneficiaries of top-down government-driven projects.

Municipal and corporate-driven smart city initiatives tend to be technocentric and disruptive of existing efficient informal collection systems. The smart city and intelligent waste management systems in developing countries have failed due to the absence of waste reclaimers and producers in municipality-led smart city initiatives. The ICT-enabled waste reclaimers system in South Africa positioned waste reclaimers' participation and involvement as a key principle in designing and implementing digital transformational initiatives in the informal sector. The roles of the waste reclaimers in the ICT-enabled waste reclaimers system included system co-design, data co-creation and system application in the informal sector. The ICT-enabled waste reclaimers system has established that waste reclaimers are entrepreneurs and co-developers with some technological know-how in smart city waste management and circular economy initiatives. In general, the role played by waste reclaimers was limited to co-design and co-creation only, without providing them with the power to control and manage the waste data generated during the collection and transaction stages.

In contrast to the traditional informal recycling models, the current ICT-enabled waste reclaimers system adopted collaborative and limited depth integration. The limited depth integration has a comparative advantage over the collaborative integration in terms of being highly efficient and systematic, having rewards and incentives, scheduling collection and route optimisation, trading and logistics, data accumulation and processing, PPEs, sorting and storage designated hubs and multi-business making sources for waste reclaimers at household collection phases. These benefits render the ICT-enabled waste system the ability to integrate waste reclaimers and transform the traditional informal recycling and collection model.

The research has confirmed that the ICT-enabled waste reclaimers have the potential to record transactions of waste data and income, allow for payment waste reclaimers without bank accounts and regularise the residence status and work permit for foreign immigrants working in the informal recycling sector. Regularising the working permit and resident status enables the depth integration of informal waste reclaimers and provides them with the ability to access credit, open bank accounts and enter into contracts as cooperatives with the municipalities. The current ICT-enabled waste reclaimers' initiatives in South Africa run short of depth integration, which provides for the employment and compensation of waste reclaimers by the ICT-waste collector companies through EPR funding, a key demand by waste reclaimers enshrined in the South African EPR regulation.

Data on the contribution of waste reclaimers was previously absent, and the ICT-enabled waste reclaimers system has provided an opportunity to collect, store and analyse data on MSW activities. The ICT-enabled waste reclaimers' system has proven that the waste reclaimer can monitor the waste diverted from the landfill, and the data can be shared with all participating stakeholders in the recycling value chain. This system has provided the potential to determine the contribution of waste reclaimers using the data generated by the ICT-enabled waste management digital platforms to ascertain their expertise, economic contribution and role toward the zero-waste goal. The ICT-enabled waste reclaimers system provides permanent, accurate and traceable data regarding the contribution and role of waste reclaimers in MSW management and recycling activities. The research determined that waste reclaimers can meet the annual recycling target for the City of Johannesburg in three months. Waste reclaimers recycle more significant quantities than the total materials the municipality and privately contracted waste collectors recycled.

## 7.3 Contribution to knowledge

This thesis has made some important contributions to the informal collection and recycling sector practice in the bottom-up smart city integrated waste management model in South Africa's smart cities. The research has revealed the application of IoTs, ICTs and blockchain technology which has birthed an ICT-enabled waste reclaimers system as a new model of intelligent collection in the informal recycling sector in South Africa. Unlike in the European Union, China, Colombia and Brazil, countries where the ICT-enabled waste management system is funded through government funds, in South Africa, the producers and private companies, are key funders of the ICT-enabled waste reclaimers system. Incorporating the ICT-enabled waste collectors, ICT software developers, producers and industries in the integration provided the required technology, infrastructure and resources, which are key to the digital transformation of the informal recycling sector. The ICT-enabled waste reclaimers' model has enabled scheduled household daily collections, route planning and optimisation, resulting in a systematic and efficient informal and recycling system.

The ICT-enabled waste reclaimers system has the potential to integrate waste reclaimers and improve their well-being and working conditions. The finding of this research established that the ICT-enabled waste reclaimers system has transformed the traditional recycling sector and has been key to the integration and social inclusion process in South Africa. The ICT-enabled waste reclaimers have created employment opportunities in Bridgetown, Khayelitsha and some suburbs of Johannesburg and improved recognition and communication between waste reclaimers and various stakeholders in the recycling value chain. The provision of uniforms, PPE, gloves, tricycles, smartphones, and local hubs for sorting and storage have enabled waste reclaimers to collect more recycling by specialising in specific areas, increased the visibility of waste reclaimers and helped households to be aware and participate in recycling initiatives. The ICT-enabled waste reclaimer system contributed to the social acceptance of waste reclaimers in society and households, appreciating the role played by waste reclaimers in municipal solid waste management.

Privately funded waste management models raise valid concerns about their long-term viability, driven as they are by investor interests. The importance of state involvement in such initiatives becomes apparent, not only to ensure consistent funding but also to align objectives with broader societal and environmental goals. While specific funding sources for pilot programs like Unilever, Distell, and Coca-Cola's engagement in Extended Producer Responsibility (EPR) and Corporate Social Investment (CSI) initiatives in South Africa might lack complete clarity, the potential for discontinuation after initial private investment rounds underscores the need for regulated funding mechanisms. Integrating such mechanisms, tied to EPR and CSI obligations, would facilitate a sustainable approach, transcending short-term profitability and fostering a holistic response to waste management challenges. By mandating producers to contribute to waste management efforts, the state-regulated funding approach could provide stability, equity, and alignment with long-term environmental objectives.

The ICT-enabled waste reclaimers system in South Africa revealed new processes in the waste reclaimers' integration initiatives, namely the "onboarding" and "regularisation." Regenize implements the onboarding process of hiring and empowering experienced waste reclaimers using their platforms, thus creating innovative and equitable working environments. The second concept is connected to foreign immigrants: through the ICT-enabled waste reclaimers system, they can 'regularise' their working and residence status when they apply for work and residency permits. Regularisation of residence and work status is key to waste reclaimers' accessing municipal and government integration benefits. Through the ICT-enabled waste reclaimers system, waste reclaimers have collected more recyclables and earned more income.

The concept of regularisation and the broader themes of reclaimer inclusion, integration, and visibility within the context of ICT-led interventions prompts a critical exploration of both the potential benefits and the inherent risks associated with these approaches, especially when considering the situation of migrant waste reclaimers. It is instructive to draw from the extensive body of literature within critical development studies that addresses the phenomenon of "adverse incorporation." The concept of "adverse incorporation" underscores that integration efforts, while ostensibly promoting greater inclusion, can also give rise to unfavourable outcomes that affect marginalized groups in diverse ways. In the context of waste reclamation, migrant workers often occupy a vulnerable position due to factors such as legal status, limited access to resources, and socio-economic precarity. The introduction of ICT-driven solutions, such as the case of BanQu, Kudoti, and Regenize, may initially appear as progressive steps towards enhancing their working conditions and recognition. However, a closer examination reveals potential pitfalls that warrant consideration.

Waste reclaimer resistance, far from being mere obstructionism can be seen as a manifestation of concerns regarding the transformative potential of these technological interventions. For instance, the reliance on digital platforms for documenting reclaimer activities, while ostensibly increasing their visibility, may also subject them to heightened surveillance and scrutiny. This scenario risks exacerbating the vulnerability of migrant waste reclaimers, particularly if their legal status remains precarious. The very systems designed to uplift their status and integrate them into formalised waste management systems could inadvertently lead to their criminalisation, as observed in other contexts where vulnerable groups have been disproportionately affected by digital surveillance initiatives. The ICT-led integration has the potential to perpetuate unequal power dynamics, as the technologies may inadvertently reinforce existing hierarchies and contribute to the marginalisation of those they aim to empower.

The ICT-enabled waste recycling value chain was established with several tier levels in adopting the ICT-enabled waste reclaimers' system. The ICT-enabled waste recycling value chain introduces new key stakeholders in waste management who were previously excluded in the integration and waste management, for instance, the residents, ICT-enabled waste collectors, financial institutions, software developers, producers and manufacturers. In the ICT-enabled waste reclaimers system, the ICT-enabled waste collector substitute and executes the duties of middlemen and buyback centres, which are vital integration and trading institutions in the traditional informal recycling system. Introducing ICT-enabled waste collectors in the informal recycling sector creates avenues for an efficient and organised value chain, recyclable material flow and transactions.

The ICT-enabled waste reclaimers system has introduced the electronic and virtual currency trading of recyclable materials in South Africa. The transition from the cash-based recycling trading sector into electronic trading has provided various payment possibilities making the ICT-enabled waste reclaimers system more efficient, systematic and sustainable. Furthermore, the ICT-enabled waste reclaimers system has provided permanent, accurate and traceable data on the actual performance of waste reclaimers in the informal recycling sector. Thus, with the aid of ICT-enabled waste reclaimers collection systems, waste reclaimers in Johannesburg can now determine and evaluate their waste diversion rate from the data generated in the system.

The research is a departure from the municipality-driven techno-solutionist approach but embraces alternative bottom-up participatory approaches which have identified waste reclaimers as co-creators of data and co-designers of the ICT-enabled waste management system. Waste reclaimers are not only beneficiaries of the system but active participants in designing, monitoring and tracking waste-related data and transactions towards the zero waste goal. Co-creation of data is perceived as a systematic approach created by interacting waste reclaimers with households and buyback centres using the ICT-enabled waste reclaimers system. Thus, the research has contributed to the bottom-up smart city practice in creating new smart city waste management initiatives that seek to integrate waste reclaimers and improve the waste diversion rate from landfills in South Africa.

The research refines the socio-technological transition to a sustainability theoretical framework in the context of adopting technology in the informal recycling sector in South Africa. Based on the theoretical framework, the research has identified the transition level, configurations and barriers associated with the regime and structures. Furthermore, applying the theory has revealed how the regime and structures in the form of producers and manufacturers use regulations to delay and resist the depth integration of waste reclaimers. The current trajectory to zero waste and waste reclaimers' integration in South Africa is better explored in the socio-technological transition to a sustainability theoretical framework.

This study reflects a deep-seated conceptual alignment with the broader framework of environmental sustainability, particularly within the context of a circular economy paradigm. By engaging with the intricacies of the ICT-enabled waste reclaimers system and its integration into the smart city integrated waste management model, this research inherently resonates with the principles of the circular economy. This paradigm emphasises the regenerative and cyclical nature of resource consumption, where waste materials are not merely discarded but rather treated as valuable inputs that can be recaptured, refurbished, and reintegrated into the production cycle. The ICT-enabled waste reclaimers system, with its innovative fusion of technologies such as IoTs, ICTs, and blockchain, effectively embodies the spirit of the circular economy by creating a self-sustaining loop of resource utilisation and minimising waste through efficient recycling practices.

In the broader conceptual landscape of environmental sustainability, this study contributes to a burgeoning discourse surrounding urban resilience and the role of technology in advancing ecological harmony within urban centres. The ICT-enabled waste reclaimers system, as a pivotal component of the smart city integrated waste management model, showcases a holistic approach to waste reduction, which is intricately linked to the reduction of carbon footprints, conservation of natural resources, and mitigation of environmental degradation. By harnessing digital innovations and integrating waste reclaimers into the heart of this model, the study exemplifies a practical manifestation of sustainability principles within the dynamic urban context, ultimately positioning South African smart cities as laboratories for transformative environmental practices.

When considering the comparison of this study's observations with findings from similar endeavours across South Africa and the broader region, certain noteworthy theoretical insights emerge. One such insight pertains to the multifaceted nature of socio-technological transitions in waste management. While various studies might showcase parallels in terms of waste reclaimer integration and digital interventions, the unique interplay between local regulatory frameworks, socio-economic dynamics, and technological ecosystems inevitably yields divergent outcomes. This underscores the significance of context-specific analyses when evaluating the transferability of findings, as each locality's distinct factors play a critical role in shaping the success of waste management innovations.

## 7.4 Future Research Work

The ICT-enabled waste reclaimer system is seen as the solution toward depth integration of waste reclaimers and achieving the zero waste goals. It is envisaged that the ICT-enabled waste reclaimers system will likely replace the traditional informal recycling system due to the mandatory EPR regulation. The ICT-enabled waste reclaimer system must be compatible with the existing infrastructure and informal waste recycling system. There is a need to investigate the interoperability of the ICT-enabled waste reclaimers system in facilitating the integration of waste reclaimers within smart city waste management communities. Secondly, there is a need to explore the ability of the ICT-enabled waste management platforms to create secure and automatic product lifecycle information in smart city waste management.

Further research is needed to understand how the configurations can influence the transformation of several regimes. This will help shed more light on understanding the digital transformation trajectory in the informal recycling sector. Finally, research can be done to explore how the ICT-enabled waste reclaimer system facilitates governance of waste management with a focus on transparency, compliance, accountability and participation between various stakeholders.

# REFERENCES


Ahmad, R.W., Salah, K., Jayaraman, R., Yaqoob, I. and Omar, M., 2021. Blockchain for waste management in smart cities: A survey. *IEEE Access*, *9*, pp.131520-131541.

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A. and Owolabi, H.A., 2017. Critical management practices influencing on-site waste minimization in construction projects. *Waste management*, *59*, pp.330-339.

Akbarieh, A., Carbone, W., Schäfer, M., Waldmann, D. and Teferle, F.N., 2020. Extended producer responsibility in the construction sector through blockchain, BIM and smart contract technologies. *The World Congress on Sustainable Technologies* (WCST 2020), pp. 190–196

Akram, S.V., Singh, R., Gehlot, A., Rashid, M., AlGhamdi, A.S., Alshamrani, S.S. and Prashar, D., 2021. Role of Wireless Aided Technologies in the Solid Waste Management: A Comprehensive Review. *Sustainability*, *13*(23), p.13104.

Alawadhi, S., Aldama-Nalda, A., Chourabi, H., Gil-Garcia, J.R., Leung, S., Mellouli, S., Nam, T., Pardo, T.A., Scholl, H.J. and Walker, S., 2012, September. Building understanding of smart city initiatives. In *International conference on electronic government* (pp. 40-53). Springer, Berlin, Heidelberg.

Alberti, F.G. and Belfanti, F., 2019. Creating shared value and clusters: The case of an Italian cluster initiative in food waste prevention. *Competitiveness review: an international business journal*, 29(1), pp.39-60.

Albino, V., Berardi, U. and Dangelico, R.M., 2015. Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of urban technology*, *22*(1), pp.3-21.

Alverti, M., Hadjimitsis, D., Kyriakidis, P. and Serraos, K., 2016, August. Smart city planning from a bottom-up approach: local communities' intervention for a smarter urban environment. In *Fourth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2016)* (Vol. 9688, p. 968819). International Society for Optics and Photonics.

Anagnostopoulos, T., Kolomvatsos, K., Anagnostopoulos, C., Zaslavsky, A. and Hadjiefthymiades, S., 2015a. Assessing dynamic models for high priority waste collection in smart cities. *Journal of Systems and Software*, *110*, pp.178-192.

Anagnostopoulos, T., Zaslavsky, A., Kolomvatsos, K., Medvedev, A., Amirian, P., Morley, J. and Hadjieftymiades, S., 2017. Challenges and opportunities of waste management in IoT-enabled smart cities: a survey. *IEEE Transactions on Sustainable Computing*, *2*(3), pp.275-289.

Anagnostopoulos, T., Zaslavsy, A., Medvedev, A. and Khoruzhnicov, S., 2015b, June. Top--k query based dynamic scheduling for IoT-enabled smart city waste collection. In *2015 16th IEEE International Conference on Mobile Data Management* (Vol. 2, pp. 50-55). IEEE.

Andrade, A.D. and Doolin, B., 2016. Information and communication technology and the social inclusion of refugees. *Mis Quarterly*, *40*(2), pp.405-416.

Anthopoulos, L. and Fitsilis, P., 2010, July. From digital to ubiquitous cities: Defining a common architecture for urban development. In *2010 Sixth International Conference on Intelligent Environments* (pp. 301-306). IEEE.

Aparcana, S., 2017. Approaches to formalization of the informal waste sector into municipal solid waste management systems in low-and middle-income countries: Review of barriers and success factors. *Waste management*, *61*, pp.593-607.

Archibald, M.M., Ambagtsheer, R.C., Casey, M.G. and Lawless, M., 2019. Using zoom videoconferencing for qualitative data collection: perceptions and experiences of researchers and participants. *International journal of qualitative methods*, *18*, p.1609406919874596.

Ardi, R. and Leisten, R., 2016. Assessing the role of informal sector in WEEE management systems: A System Dynamics approach. *Waste management*, *57*, pp.3-16.

Areff, M., 2019. *Opinion: SA needs smart cities, just not what you envisage, African News Agency (ANA) Archives*. [Online] Available at: https://www.iol.co.za/business-report/opinion/opinion-sa-needs-smart-cities-just-not-what-you-envisage-28716340. [Accessed 11 April 2020).

Arep., 2017. Data-Tritus–Comment la Blockchain Simplifie le tri des Déchets. Available online: www.digital.sncf.com/actualites/datatritus-comment-la-blockchain-simplifie-le-tri-des-dechets (accessed on 5 October 2020).

Asim, F. and Shree, V., 2018. A Century of Futurist Architecture: From Theory to Reality.

ASSAf (Academy of Science of South Africa). 2020. The Smart City Initiatives in South Africa and Paving a Way to Support Cities to Address Frontier Issues Using New and Emerging Technologies. Report of the Innovation for Inclusive Development seminar, Pretoria, South Africa, 3 September 2019.

Aswani, R., Kar, A.K., Ilavarasan, P.V. and Dwivedi, Y.K., 2018. Search engine marketing is not all gold: Insights from Twitter and SEOClerks. *International Journal of Information Management*, *38*(1), pp.107-116.

Ayeleru, O.O., Dlova, S., Akinribide, O.J., Ntuli, F., Kupolati, W.K., Marina, P.F., Blencowe, A. and Olubambi, P.A., 2020. Challenges of plastic waste generation and management in sub-Saharan Africa: A review. *Waste Management*, *110*, pp.24-42.

Babanyara, Y.Y., Ibrahim, D.B., Garba, T., Bogoro, A.G. and Abubakar, M.Y., 2013. Poor Medical Waste Management (MWM) practices and its risks to human health and the environment: a literature review. *Int J Environ Ealth Sci Eng*, *11*(7), pp.1-8.

Backhouse J, Karuri-Sebina G and Guya J. 2020. *A South African Approach to Smart, Sustainable South African Cities and Settlements: Towards a SACN response to the COGTA National Smart City Framework.* Johannesburg: SACN and SmartCity.ZA

Bai, X. and Imura, H., 2000. A comparative study of urban environment in East Asia: stage model of urban environmental evolution. *International Review for Environmental Strategies*, *1*(1), pp.135-158.

Bakıcı, T., Almirall, E. and Wareham, J., 2013. A smart city initiative: the case of Barcelona. *Journal of the knowledge economy*, *4*(2), pp.135-148.

Balkaran, S., 2019. Smart cities as misplaced priorities in South Africa: a complex balance of conflicting societal needs. *Journal of Management & Administration*, *2019*(2), pp.1-30.

Balkaran, S., 2019. Smart cities as misplaced priorities in South Africa: a complex balance of conflicting societal needs. *Journal of Management & Administration*, *2019*(2), pp.1-30.

Barnes, K., Blaauw, D., Schenck, R. and Pretorius, A., 2021. Buyback centres in Cape Town: The key integration point between formal and informal sectors in the waste economy of the Western Cape. *GeoJournal*, pp.1-15.

Barry, A., 2001. *Political machines: Governing a technological society*. A&C Black.

Bassi, S.A., Boldrin, A., Faraca, G. and Astrup, T.F., 2020. Extended producer responsibility: How to unlock the environmental and economic potential of plastic packaging waste?. *Resources, Conservation and Recycling*, *162*, p.105030.

Bastos, A., Casaca, S.F., Nunes, F. and Pereirinha, J., 2009. Women and poverty: A gender-sensitive approach. *The Journal of Socio-Economics*, *38*(5), pp.764-778.

Bayat, A. and Biekart, K., 2009. Cities of extremes. *Development and Change*, *40*(5), pp.815-825.

Begg, I. ed., 2002. *Urban competitiveness: policies for dynamic cities*. Bristol, Bristol University Press. .

Bibri, S.E. and Krogstie, J., 2017. ICT of the new wave of computing for sustainable urban forms: Their big data and context-aware augmented typologies and design concepts. *Sustainable cities and society*, *32*, pp.449-474.

Bibri, S.E. and Krogstie, J., 2017. Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable cities and society*, *31*, pp.183-212.

Bowen, G.A. 2009. *Document Analysis as a Qualitative Research Method*. Qualitative Research Journal, Vol. 9 (2).

Boyle, L. and Staines, I., 2019. Overview and Analysis of Cape Town's Digital City Strategy.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), pp.77-101.

Braun, V., Clarke, V. and Gray, D. eds., 2017. *Collecting qualitative data: A practical guide to textual, media and virtual techniques*. Cambridge University Press.

Brenner, N. and Theodore, N., 2002. Cities and the geographies of "actually existing neoliberalism". *Antipode*, *34*(3), pp.349-379.

Breuer, J., Walravens, N. and Ballon, P., 2014. Beyond defining the smart city. Meeting top-down and bottom-up approaches in the middle. *TeMA-Journal of Land Use, Mobility and Environment*.

Brown, B., Chui, M. and Manyika, J., 2011. Are you ready for the era of 'big data'. *McKinsey Quarterly*, *4*(1), pp.24-35.

Brown, D. and McGranahan, G., 2016. The urban informal economy, local inclusion and achieving a global green transformation. *Habitat international*, *53*, pp.97-105.

Bryman, A., 2012. Social Research Methods., 4th edn. (Oxford University Press: New York.

Buallay, A., El Khoury, R. and Hamdan, A., 2021. Sustainability reporting in smart cities: A multidimensional performance measures. *Cities*, *119*, p.103397.

Buch, R., Marseille, A., Williams, M., Aggarwal, R. and Sharma, A., 2021. From Waste Pickers to Producers: An Inclusive Circular Economy Solution through Development of Cooperatives in Waste Management. *Sustainability*, *13*(16), p.8925.

Buch-Hansen, H., 2018. The prerequisites for a degrowth paradigm shift: Insights from critical political economy. *Ecological Economics*, *146*, pp.157-163.

Bunnell, T., 2015. Smart city returns. *Dialogues in Human Geography*, *5*(1), pp.45-48.

Burgess, R. G. 1984. In the Field: An introduction to Field Research. London: Unwin Hyman

Byun, J., Kim, S., Sa, J., Kim, S., Shin, Y.T. and Kim, J.B., 2016. Smart city implementation models based on IoT technology. *Advanced Science and Technology Letters*, *129*(41), pp.209-212.

Calzada, I. and Cobo, C., 2015. Unplugging: Deconstructing the smart city. *Journal of Urban Technology*, *22*(1), pp.23-43.

Cao, S. and Li, C., 2011. The exploration of concepts and methods for low-carbon eco-city planning. *Procedia Environmental Sciences*, *5*, pp.199-207.

Caprotti, F., 2014. Critical research on eco-cities? A walk through the Sino-Singapore Tianjin Eco-City, China. *Cities*, *36*, pp.10-17.

Caprotti, F., Springer, C. and Harmer, N., 2015. 'Eco' For Whom? Envisioning Eco-urbanism in the Sino-Singapore Tianjin Eco-city, China. *International Journal of Urban and Regional Research*, *39*(3), pp.495-517.

Caragliu A, Del Bo C, Nijkamp P. Smart cities in Europe. Journal of urban technology. 2011 Apr 1;18(2):65-82.

Caragliu, A., Del Bo, C. and Nijkamp, P., 2011. Smart cities in Europe. *Journal of urban technology*, *18*(2), pp.65-82.

Carvalho, L., 2015. Smart cities from scratch? A socio-technical perspective. *Cambridge Journal of Regions, Economy and Society*, *8*(1), pp.43-60.

Castells, M., 1989. The informational city. *Information technology, economic restructuring, and the urban-regional process*, *535*.

Castells, M., 1996. The Rise of the Network Society. Vol. 1. 3 vols. The Information Age: Economy. *Society and Culture, ed. Cambridge, MA: Blackwell Publishers, Inc*.

Castro, A.F.N.M., Castro, R.V.O., Carneiro, A.D.C.O., Carvalho, A.M.M.L., da Silva, C.H.F., Cândido, W.L. and dos Santos, R.C., 2017. Quantification of forestry and carbonization waste. *Renewable energy*, *103*, pp.432-438.

Catania, V. and Ventura, D., 2014, April. An approch for monitoring and smart planning of urban solid waste management using smart-M3 platform. In *Proceedings of 15th conference of open innovations association FRUCT* (pp. 24-31). IEEE.

Chen, G., Xu, B., Lu, M. and Chen, N.S., 2018. Exploring blockchain technology and its potential applications for education. *Smart Learning Environments*, *5*(1), pp.1-10.

Cheng, H. and Hu, Y., 2010. Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. *Bioresource technology*, *101*(11), pp.3816-3824.

Chikarmane, P. and Narayan, L., 2009. *Rising from the Waste: Organising Wastepickers in India, Thailand and the Philippines*. Committee for Asian Women.

Chikarmane, P., 2012. Integrating waste pickers into municipal solid waste management in Pune, India. *WIEGO Policy Brief (Urban Policies)*, *8*, p.23.

Childe, V.G., 2015. The Urban Revolution. In *The City Reader* (pp. 54-62). Routledge.

Chowdhury, B. and Chowdhury, M.U., 2007, December. RFID-based real-time smart waste management system. In *2007 Australasian telecommunication networks and applications conference* (pp. 175-180). IEEE.

City of Cape Town, 2017. Five-year Integrated Development Plan July 2017 – June 2022. Available on: https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies%2C%20plans%20and%20frameworks/IDP%202017-2022.pdf. (Accessed on 15 October, 2019).

City of Johannesburg, 2013. The 2013/16 Integrated Development Plan (IDP). Available on: https://www.joburg.org.za/Campaigns/Documents/2013%20Documents/2013-16%20IDP.pdf. (Accessed on 20 October 2019).

City of Johannesburg, 2016. The Integrated Development Plan 2016/21. Available on: https://www.joburg.org.za/documents_/Documents/Intergrated%20Development%20Plan/idp%20documents/IDP%2020162021.pdf. (Accessed on 21 October 2019).

City of Johannesburg, 2018. Intelligence Operation Centre To Enhance Service Delivery. Available on: https://www.joburg.org.za/media_/Newsroom/Pages/2018%20News%20Articles/Intelligence-operation-centre-to-enhance-service-delivery.aspx#:~:text=%E2%80%8BThe%20City%20of%20Joburg,service%20delivery%20issues%2C%20using%20technology. (Accessed on 11 October, 2019).

City of Johannesburg, 2021. Joburg Smart City Strategy Revised 2019-2021. Available on: https://www.africanconstructionexpo.com/wp-content/uploads/2019/07/Monique.pdf. (Accessed on 10 October 2021).

City of Tshwane, 2013. Tshwane Vision 2055. Available on: https://www.tshwane.gov.za/Documents/Online%20version-%20CoT%202055%20vision%5bsmallpdf.com%5d.pdf. (Accessed on 05 May 2019).

City of Tshwane, 2021. Tshwane Metropolitan Spatial Development Framework, 2030. Available on: https://www.tshwane.gov.za/sites/Departments/Economic%20Development%20and%20Spatial%20Planning/MSDF%202012%20Approved%2028%20June%202012/1%20A.%20MSDF%20Cover%20page%20and%20contents%20Jul%202021.pdf. (Accessed on 18 October 2021).

Climate Legal., 2020. Policy effectiveness assessment of selected tools for addressing marine plastic pollution. Extended Producer Responsibility in South Africa. Bonn: IUCN Environmental Law Centre.

Coelho, T.R., Hino, M.R.M.C. and Vahldick, S.M.O., 2019. The use of ICT in the informal recycling sector: the Brazilian case of Relix. *The Electronic Journal of Information Systems in Developing Countries*, *85*(3), p.e12078.

Coelho, T.R., Hino, M.R.M.C. and Vahldick, S.M.O., 2019. The use of ICT in the informal recycling sector: the Brazilian case of Relix. *The Electronic Journal of Information Systems in Developing Countries*, *85*(3), p.e12078.

Coenen, L., Benneworth, P. and Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. *Research policy*, *41*(6), pp.968-979.

Coffey, A. and Atkinson, P., 1996. *Making sense of qualitative data: Complementary research strategies*. Sage Publications, Inc.

Coletto, D. and Bisschop, L., 2017. Waste pickers in the informal economy of the global South: Included or excluded?. *International Journal of Sociology and Social Policy*.

Corbin, J & Strauss, A. 2008. Basics of qualitative research: Techniques and procedures for developing grounded theory (3rd Ed.). Sage Publications

Creswell, J. 2007. *Qualitative inquiry and research design: Choosing among five approaches*. 2nd Edition. Thousand Oaks.

Creswell, J.W., 2013. Qualitative inquiry: Choosing among five approaches. *Los Angeles, CA*, *244*.

Cretu, L.G., 2012. Smart cities design using event-driven paradigm and semantic web. *Informatica Economica*, *16*(4), p.57.

Cretu, L.G., 2012. Smart cities design using event-driven paradigm and semantic web. *Informatica Economica*, *16*(4), p.57.

Crivellaro, C., Comber, R., Dade-Robertson, M., Bowen, S., Wright, P & Olivier, P. 2015. Contesting the City: Enacting the Political Through Digitally Supported Urban Walks. Newcastle University, UK

Crivello, S., 2015. Urban policy mobilities: the case of Turin as a smart city. *European Planning Studies*, *23*(5), pp.909-921.

Crompton, S.J., 2012. *The American mall* (Doctoral dissertation, The University of Iowa).

Crotty, M., 1998. The foundations of social research: meaning and perspective in the research process Sage. *Thousand Oaks, CA Google Scholar*.

Darnhofer, I., 2015. Socio-technical transitions in farming: key concepts. *Transition pathways towards sustainability in agriculture. Case studies from Europe*, pp.17-31.

Datta, A., 2015. A 100 smart cities, a 100 utopias. *Dialogues in Human Geography*, *5*(1), pp.49-53.

Datta, A., 2015. New urban utopias of postcolonial India: 'Entrepreneurial urbanization'in Dholera smart city, Gujarat. *Dialogues in Human Geography*, *5*(1), pp.3-22.

De Jong, M., Joss, S., Schraven, D., Zhan, C. and Weijnen, M., 2015. Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization. *Journal of Cleaner production*, *109*, pp.25-38.

de Vega, C.A., Benítez, S.O. and Barreto, M.E.R., 2008. Solid waste characterization and recycling potential for a university campus. *Waste management*, *28*, pp.S21-S26.

de Waal, M. and de Lange, M., 2019. Introduction—The Hacker, the City and Their Institutions: From Grassroots Urbanism to Systemic Change. In *The Hackable City* (pp. 1-22). Springer, Singapore.

DEA (Department of Environmental Affairs). 2011. National Waste Management Strategy, DEA: Pretoria, South Africa. Available online: https://www.environment.gov.za/documents/strategicdocuments/wastemanagement (accessed June 18, 2019).

Deakin, M., 2014. Smart cities: the state-of-the-art and governance challenge. *Triple Helix*, *1*(1), pp.1-16.

Deen-Swarray, M., Moyo, M. and Stork, C., 2013. ICT access and usage among informal businesses in Africa. *info*.

DEFF and DSI (Department of Environment, Fisheries and Forestry and Department of Science and Innovation). (2020). *Waste picker integration guideline for South Africa: Building the recycling economy and improving livelihoods through integration of the informal sector*. Department of Environmental Affairs, Pretoria.

Deloitte and Touche. 2015. Smart Cities, Big Data. Available online: https://www2.deloitte.com/za/en/pages/risk/articles/smart-cities-bigdata.html. (Accessed on 10 October 2019).

Denscombe, M. 2010. The Good Research Guide: for small-scale social research projects. 3rd edition. Maidenhead: Open University Press.

Department of Environment, Forestry and Fisheries and Department of Science and Innovation. (2020). Waste picker integration guideline for South Africa: Building the Recycling Economy and Improving. Pretoria: Department of Environment, Forestry and Fisheries.

Devine-Wright, P., Batel, S., Aas, O., Sovacool, B., Labelle, M.C. and Ruud, A., 2017. A conceptual framework for understanding the social acceptance of energy infrastructure: Insights from energy storage. *Energy Policy*, *107*, pp.27-31.

Devine-Wright, P., Batel, S., Aas, O., Sovacool, B., Labelle, M.C. and Ruud, A., 2017. A conceptual framework for understanding the social acceptance of energy infrastructure: Insights from energy storage. *Energy Policy*, *107*, pp.27-31.

Dias, K.T. and Braga Junior, S.S., 2016. The use of reverse logistics for waste management in a Brazilian grocery retailer. *Waste Management & Research*, *34*(1), pp.22-29.

Dias, S.M. and Alves, F.C.G., 2008. Integration of the informal recycling sector in solid waste management in Brazil. *Study prepared for GTZs sector project "Promotion of concepts for pro-poor and environmentally friendly closed-loop approaches in solid waste management*.

Dias, S.M. and Alves, F.C.G., 2011. The Waste Experts: Enabling Conditions for Informal Sector Integration in Solid Waste Management. Lessons learned from Brazil, Egypt and India. *GTZ: Federal Ministry for Economic Cooperation and Development. Viewed 30th November*.

Dias, S.M. and Samson, M., 2016. IEMS Informal Economy.

Dijk, A., Teuben, H., Duits, B., Hartveld, S., Ogura, A., Scharrenberg, A. and Tan, C., 2015. Smart Cities: How rapid advances in technology are reshaping our economy and society. *Deloitte*.

Dladla, N.E., 2018. *The construct of state practices: excavating Municipal relationships with waste pickers, the case of the City of Johannesburg* (Masters Dissertation).

Dlamini, S., Simatele, M.D. and Serge Kubanza, N., 2019. Municipal solid waste management in South Africa: from waste to energy recovery through waste-to-energy technologies in Johannesburg. *Local Environment*, *24*(3), pp.249-257.

Dlamini, S.Q. and Simatele, D., 2016. Unrecognized informal solid waste recycling in an emerging African megacity: A study of Johannesburg, South Africa. *WIT Transactions on Ecology and the Environment: Johannesburg, South Africa*, *202*, pp.13-25.

Dobraszczyk, P., 2019. *Future cities: Architecture and the imagination*. Reaktion books.

Donaldson, R. and Westhuizen, J.V.D., 2011. Built in a field of dreams? Spatial engineering and political symbolism of South Africa's rapid rail link development, Gautrain. In *Engineering earth* (pp. 683-695). Springer, Dordrecht.

Dornfeld, D.A. ed., 2012. *Green manufacturing: fundamentals and applications*. Springer Science & Business Media.

DTI (Department of Trade and Industry), 2012. Integrated strategy on the development and promotion of co-operatives: Promoting an integrated co-operative sector in South Africa 2012–2022.

Dutton, W.H., 1987. *Wired cities: Shaping the future of communications*. Macmillan Publishing Co., Inc..

Elia, V., Gnoni, M.G. and Tornese, F., 2015. Designing Pay-As-You-Throw schemes in municipal waste management services: A holistic approach. *Waste Management*, *44*, pp.188-195.

Elzen, B., Geels, F.W. and Green, K. eds., 2004. *System innovation and the transition to sustainability: theory, evidence and policy*. Edward Elgar Publishing.

Ertiö, T.P. and Bhagwatwar, A., 2017. Citizens as planners: Harnessing information and values from the bottom-up. *International Journal of Information Management*, *37*(3), pp.111-113.

Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C. and Behdad, S., 2018. The future of waste management in smart and sustainable cities: A review and concept paper. *Waste management*, *81*, pp.177-195.

Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C. and Behdad, S., 2018. The future of waste management in smart and sustainable cities: A review and concept paper. *Waste management*, *81*, pp.177-195.

Fainstein, S.S., 2014. The just city. *International journal of urban Sciences*, *18*(1), pp.1-18.

Fei, F., Qu, L., Wen, Z., Xue, Y. and Zhang, H., 2016. How to integrate the informal recycling system into municipal solid waste management in developing countries: Based on a China's case in Suzhou urban area. *Resources, conservation and recycling*, *110*, pp.74-86.

Forrester, J.W., 1970. Urban dynamics. *IMR; Industrial Management Review (pre-1986)*, *11*(3), p.67.

Foth, M., Brynskov, M. and Ojala, T., 2015. Citizen's right to the digital city. *Berlin: Springer. doi*, *10*, pp.978-981.

Furedy, C., 1997. Household-level and community actions for solid waste management and recycling in Asian cities: recent research and projects. *Recycling in Asia: Partnerships for Responsive Solid Waste Management. KOA Fernandez, D. Dungate, ed*, pp.13-25.

Gabrys, J., 2014. Programming environments: Environmentality and citizen sensing in the smart city. *Environment and planning D: Society and space*, *32*(1), pp.30-48.

Gall, M., Wiener, M., de Oliveira, C.C., Lang, R.W. and Hansen, E.G., 2020. Building a circular plastics economy with informal waste pickers: Recyclate quality, business model, and societal impacts. *Resources, Conservation and Recycling*, *156*, p.104685.

Garcia, A., Camacho, C., Bellenzier, M., Pasquali, M., Weber, T. and Silveira, M.S., 2016, July. Data visualization in mobile applications: Investigating a smart city app. In *International Conference on Human-Computer Interaction* (pp. 285-293). Springer, Cham.

Gautrain Management Agency (2010). Spatial development. Available on: http://www.gautrain.co.za/about/about-gautrain/studies-documents/spatial-development/ . (Accessed on 10 April 2019).

Geels, F. and Schot, J., 2010. The dynamics of socio-technical transitions: a socio-technical perspective, part I. *Transitions to sustainable development*.

Geels, F.W. and Schot, J., 2007. Typology of sociotechnical transition pathways. *Research policy*, *36*(3), pp.399-417.

Geels, F.W. and Verhees, B., 2011. Cultural legitimacy and framing struggles in innovation journeys: a cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). *Technological Forecasting and Social Change*, *78*(6), pp.910-930.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), pp.1257-1274.

Geels, F.W., 2005. Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological forecasting and social change*, *72*(6), pp.681-696.

Geels, F.W., 2005. The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology analysis & strategic management*, *17*(4), pp.445-476.

Geels, F.W., 2005. *Technological transitions and system innovations: a co-evolutionary and socio-technical analysis*. Edward Elgar Publishing.

Geels, F.W., 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research policy*, *39*(4), pp.495-510.

Geels, F.W., 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental innovation and societal transitions*, *1*(1), pp.24-40.

Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. *Current opinion in environmental sustainability*, *39*, pp.187-201.

Geels, F.W., 2020. Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. *Technological Forecasting and Social Change*, *152*, p.119894.

Gegenfurtner, A., Zitt, A. and Ebner, C., 2020. Evaluating webinar-based training: a mixed methods study of trainee reactions toward digital web conferencing. *International Journal of Training and Development*, *24*(1), pp.5-21.

Geisdoerfer, M., Savaget, P., Bocken, N.M. and Hultink, E.J., 2017. The Circular Economy–A new sustainability paradigm?. *Journal of cleaner production*, *143*, pp.757-768.

Genus, A. and Coles, A.M., 2008. Rethinking the multi-level perspective of technological transitions. *Research policy*, *37*(9), pp.1436-1445.

Ghose, M.K., Dikshit, A.K. and Sharma, S.K., 2006. A GIS based transportation model for solid waste disposal–A case study on Asansol municipality. *Waste management*, *26*(11), pp.1287-1293.

Gibbs, D., Krueger, R. and MacLeod, G., 2013. Planning 'Smart'city-regions in an age of market-driven urbanism. *Urban studies (Harlow)*, *50*(11), pp.2158-2387.

Gibson, J.J., 1996. The ecological approach to visual perception Boston: Houghton Mifling, c1996.

Giddens, A., Cabral, Á., & Morissawa, M. (1989). *A Constituição da Sociedade*. São Paulo: Martins Fontes.

Giffinger, R. and Pichler-Milanović, N., 2007. *Smart cities: Ranking of European medium-sized cities*. Centre of Regional Science, Vienna University of Technology.

Glasmeier, A. and Christopherson, S., 2015. Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society*, *8*(1), pp.3-12.

Glasmeier, A. and Christopherson, S., 2015. Thinking about smart cities. *Cambridge Journal of Regions, Economy and Society*, *8*(1), pp.3-12.

Glouche, Y. and Couderc, P., 2013, June. A smart waste management with self-describing objects. In *The Second International Conference on Smart Systems, Devices and Technologies (SMART'13)*.

Godfrey, L. and Oelofse, S., 2017. Historical review of waste management and recycling in South Africa. *Resources*, *6*(4), p.57.

Godfrey, L. and Oelofse, S., 2017. Historical review of waste management and recycling in South Africa. *Resources*, *6*(4), p.57.

Godfrey, L., 2021. Quantifying economic activity in the informal recycling sector in South Africa. *South African Journal of Science*, *117*(9-10), pp.138-144.

Godfrey, L., Muswema, A., Strydom, W., Mamafa, T. and Mapako, M., 2017. Co-operatives as a development mechanism to support job creation and sustainable waste management in South Africa. *Sustainability Science*, *12*(5), pp.799-812.

Godfrey, L., Muswema, A., Strydom, W., Mamafa, T. and Mapako, M., 2017. Co-operatives as a development mechanism to support job creation and sustainable waste management in South Africa. *Sustainability Science*, *12*(5), pp.799-812.

Godfrey, L., Strydom, W. and Phukubye, R., 2016. Integrating the informal sector into the South African waste and recycling economy in the context of extended producer responsibility. *CSIR Briefing Note: Pretoria, South Africa*.

Godfrey, L., Strydom, W. and Phukubye, R., 2016. Integrating the informal sector into the South African waste and recycling economy in the context of extended producer responsibility. *CSIR Briefing Note: Pretoria, South Africa*.

Godfrey, L., Strydom, W. and Phukubye, R., 2016. Integrating the informal sector into the South African waste and recycling economy in the context of extended producer responsibility. *CSIR Briefing Note: Pretoria, South Africa*.

Gomez, G., Meneses, M., Ballinas, L. and Castells, F., 2008. Characterization of urban solid waste in Chihuahua, Mexico. *Waste Management*, *28*(12), pp.2465-2471.

Graham, S. and Marvin, S., 1999. Planning cybercities? Integrating telecommunications into urban planning. *The Town Planning Review*, pp.89-114.

Graham, S. and Marvin, S., 2002. *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition*. Routledge.

Graham, S., 1997. Cities in the real-time age: the paradigm challenge of telecommunications to the conception and planning of urban space. *Environment and Planning A*, *29*(1), pp.105-127.

Greenfield, P.M., 2013. The changing psychology of culture from 1800 through 2000. *Psychological science*, *24*(9), pp.1722-1731.

Grin, J., Rotmans, J. and Schot, J., 2010. *Transitions to sustainable development: new directions in the study of long term transformative change*. Routledge.

Güneri, G.D., 2020. Reading Architectural Utopia (nism) s: A Proposal. *METU Journal of the Faculty of Architecture*, *36*(1).

Gutberlet, J. and Carenzo, S., 2020. Waste pickers at the heart of the circular economy: a perspective of inclusive recycling from the Global South. *Worldwide Waste: Journal of Interdisciplinary Studies*, *3*(1).

Gutierrez, J.M., Jensen, M., Henius, M. and Riaz, T., 2015. Smart waste collection system based on location intelligence. *Procedia Computer Science*, *61*, pp.120-127.

Habitat, U.N., 2009. Fact sheet. *Global report on human settlement*.

Hamdi, N., 2013. *Small change: About the art of practice and the limits of planning in cities*. Routledge.

Han, C., Jornet, J.M., Fadel, E. and Akyildiz, I.F., 2013. A cross-layer communication module for the Internet of Things. *Computer Networks*, *57*(3), pp.622-633.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J. and Williams, P., 2010. Foundations for smarter cities. *IBM Journal of research and development*, *54*(4), pp.1-16.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J. and Williams, P., 2010. Foundations for smarter cities. *IBM Journal of research and development*, *54*(4), pp.1-16.

Hendriksen, A., Tukahirwa, J., Oosterveer, P.J. and Mol, A.P., 2012. Participatory decision making for sanitation improvements in unplanned urban settlements in East Africa. *The Journal of Environment & Development*, *21*(1), pp.98-119.

Hennink, M., Hutter, I. and Bailey, A., 2020. *Qualitative research methods*. Sage.

Henreckson, J. 2018. Benefits of Smart Cities in Africa. Seattle, WA. Available: https://borgenproject.org/benefits-of-smart-cities-in-africa/ (Accessed on 03 February 2019).

Hogan, T., Bunnell, T., Pow, C.P., Permanasari, E. and Morshidi, S., 2012. Asian urbanisms and the privatization of cities. *Cities*, *29*(1), pp.59-63.

Hollands, R.G., 2008. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?. *City*, *12*(3), pp.303-320.

Holt, D. and Littlewood, D., 2017. Waste livelihoods amongst the poor–Through the lens of bricolage. *Business Strategy and the Environment*, *26*(2), pp.253-264.

Holt, D. and Littlewood, D., 2017. Waste livelihoods amongst the poor–Through the lens of bricolage. *Business Strategy and the Environment*, *26*(2), pp.253-264.

Hong, I., Park, S., Lee, B., Lee, J., Jeong, D. and Park, S., 2014. IoT-based smart garbage system for efficient food waste management. *The Scientific World Journal, 2014*.

Horber J. 'A new city is not a smart idea for South Africa', Daily Maverick, 29 July 2019. Available at: https://www.dailymaverick.co.za/article/2019-07-29-a-new-city-is-not-a-smart-idea-for-south-africa/ (Accessed on 13 May 2020).

Hubbard, J., Du Toit J., Goldstuck, A. & Nxumalo, R. 2017. Why SA is lagging behind global smart city developments. Johannesburg, South Africa: Finweek. Available at https://www.news24.com/Fin24/why-sa-is-lagging-behind-global-smart-city-developments-20170829. (Accessed on 03 May 2019).

IADB (Inter-American Development Bank). 2013. Preparing Informal Sector Inclusion Plans: An Operational Guide. Available online: https://publications.iadb.org/en/preparing-informal-recycler-inclusion-plans-operational-guide (accessed November 5, 2019)

Ishida, T. and Isbister, K. eds., 2000. *Digital cities: technologies, experiences, and future perspectives*. Springer Science & Business Media.

Karimi, H.A. ed., 2014. *Big Data: techniques and technologies in geoinformatics*. Crc Press.

Kashyap, P. and Visvanathan, C., 2014. Formalization of informal recycling in low-income countries. *Municipal Solid Waste Management in Asia and the Pacific Islands*, pp.41-60.

Kaza, S., Yao, L., Bhada-Tata, P. and Van Woerden, F., 2018. *What a waste 2.0: a global snapshot of solid waste management to 2050*. World Bank Publications.

Khaitan, S.K. and McCalley, J.D., 2014. Design techniques and applications of cyberphysical systems: A survey. *IEEE Systems Journal*, *9*(2), pp.350-365.

Kirchherr, J., Reike, D. and Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, pp.221-232.

Kitchin, R., 2013. Big data and human geography: Opportunities, challenges and risks. *Dialogues in human geography*, *3*(3), pp.262-267.

Kitchin, R., 2015. Making sense of smart cities: addressing present shortcomings. *Cambridge journal of regions, economy and society*, *8*(1), pp.131-136.

Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F. and Fünfschilling, L., 2019. An agenda for sustainability transitions research: State of the art and future directions. *Environmental innovation and societal transitions*, *31*, pp.1-32.

Komninos, N., 2013. What makes cities intelligent?. In *Smart Cities* (pp. 89-107). Routledge.

Komninos, N., 2013. *Intelligent cities: innovation, knowledge systems and digital spaces*. Routledge.

Konomi, S.I. and Roussos, G. eds., 2016. *Enriching urban spaces with ambient computing, the internet of things, and smart city design*. IGI Global.

Korhonen, J., Honkasalo, A. and Seppälä, J., 2018. Circular economy: the concept and its limitations. *Ecological economics*, *143*, pp.37-46.

Kosoe, E.A., Diawuo, F. and Osumanu, I.K., 2019. Looking into the past: rethinking traditional ways of solid waste management in the Jaman South Municipality, Ghana. *Ghana Journal of Geography*, *11*(1), pp.228-244.

Kosoe, E.A., Diawuo, F. and Osumanu, I.K., 2019. Looking into the past: rethinking traditional ways of solid waste management in the Jaman South Municipality, Ghana. *Ghana Journal of Geography*, *11*(1), pp.228-244.

Kourtit, K. and Nijkamp, P., 2012. Smart cities in the innovation age. *Innovation: The European Journal of Social Science Research*, *25*(2), pp.93-95.

Kourtit, K., Nijkamp, P. and Arribas, D., 2012. Smart cities in perspective–a comparative European study by means of self-organizing maps. *Innovation: The European journal of social science research*, *25*(2), pp.229-246.

Kubanza, N.S., Das, D.K. and Simatele, D., 2017. Some happy, others sad: exploring environmental justice in solid waste management in Kinshasa, The Democratic Republic of Congo. *Local Environment*, *22*(5), pp.595-620.

Kummitha, R.K.R. and Crutzen, N., 2017. How do we understand smart cities? An evolutionary perspective. *Cities*, *67*, pp.43-52.

Kunzmann, K.R., 2014. Smart cities: A new paradigm of urban development. *Crios*, *4*(1), pp.9-20.

Lata, K. and Singh, S.S., 2016. IOT based smart waste management system using Wireless Sensor Network and Embedded Linux Board. *Int. J. Curr. Trends Eng. Res*, *2*(7), pp.210-214.

Lau, B.P.L., Marakkalage, S.H., Zhou, Y., Hassan, N.U., Yuen, C., Zhang, M. and Tan, U.X., 2019. A survey of data fusion in smart city applications. *Information Fusion*, *52*, pp.357-374.

Lawhon, M. and Murphy, J.T., 2012. Socio-technical regimes and sustainability transitions: Insights from political ecology. *Progress in human geography*, 36(3), pp.354-378.

Lazaroiu, G.C. and Roscia, M., 2012. Definition methodology for the smart cities model. *Energy*, *47*(1), pp.326-332.

Le Courtois, A., 2012. Municipal Solid Waste: turning a problem into resource. *Private Sector & Development*, *15*, pp.1-28.

Letaifa, S.B., 2015. How to strategize smart cities: Revealing the SMART model. *Journal of business research*, *68*(7), pp.1414-1419.

Liboiron, M., 2014. Against awareness, for scale: garbage is infrastructure, not behaviour. Discard Stud. *Social Stud. Waste Pollution. External*.

Lie, M. and Sørensen, K.H. eds., 1996. *Making technology our own?: domesticating technology into everyday life*. Scandinavian University Press.

Lie, M. and Sørensen, K.H. eds., 1996. *Making technology our own?: domesticating technology into everyday life*. Scandinavian University Press.

Lincoln, Y.S., Lynham, S.A. and Guba, E.G., 2011. Paradigmatic controversies, contradictions, and emerging confluences, revisited. *The Sage handbook of qualitative research*, *4*(2), pp.97-128.

Linzner, R. and Salhofer, S., 2014. Municipal solid waste recycling and the significance of informal sector in urban China. *Waste management & research*, *32*(9), pp.896-907.

Liu, P. and Peng, Z., 2013. Smart cities in China. *IEEE Computer Society*, *16*(7).

Lofthouse, V.A. and Prendeville, S., 2017. Considering the user in the circular economy. In *PLATE: Product Lifetimes And The Environment* (pp. 213-216). IOS Press.

Longhi, S., Marzioni, D., Alidori, E., Di Buo, G., Prist, M., Grisostomi, M. and Pirro, M., 2012, May. Solid waste management architecture using wireless sensor network technology. In *2012 5th international conference on new technologies, mobility and security (NTMS)* (pp. 1-5). IEEE.

Loorbach, D. and Rotmans, J., 2010. The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), pp.237-246.

Lowe, R., Chiu, L.F. and Oreszczyn, T., 2018. Socio-technical case study method in building performance evaluation. *Building Research & Information*, *46*(5), pp.469-484.

Mackenzie, D., & Wajcman, J. (1985). *The social shaping of technology: How the refrigerator got its hum*. Milton Keynes: Open University Press.

Marello, M. and Helwege, A., 2014. Solid waste management and social inclusion of reclaimers: opportunities and challenges. *Social-Inclusion-Working-Paper. Global Economic Governance Initiative, Paper*, *7*.

Markard, J., Raven, R. and Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. *Research policy*, *41*(6), pp.955-967.

Marrian N. 'News Analysis: Smart Cities forgotten as Ramaphosa focuses on "stark realities" in 2020 SONA', Business Live. Available at: https://www.businesslive.co.za/fm/features/2020-02-14-news-analysis-smart-cities-forgotten-as-ramaphosa-focuses-on-stark-realities-in-2020-sona/. (Accessed: 10 May 2020).

Marsal-Llacuna, M.L., Colomer-Llinàs, J. and Meléndez-Frigola, J., 2015. Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change*, *90*, pp.611-622.

Martins, F., Patrão, C., Moura, P. and de Almeida, A.T., 2021. A Review of Energy Modeling Tools for Energy Efficiency in Smart Cities. *Smart Cities*, *4*(4), pp.1420-1436.

Mata, A.M., 2018. Is smart city an utopia? Lessons learned and final reflections. *Smart and Sustainable Cities for Innovative Urban Planning in Mexico; Editorial Academica Espanola: Beau Bassin, Mauritius*, pp.198-207.

Matter, A., Dietschi, M. and Zurbrügg, C., 2013. Improving the informal recycling sector through segregation of waste in the household–The case of Dhaka Bangladesh. *Habitat International*, *38*, pp.150-156.

McManus, P., 2016. Eco-City Development and Urban Health Reform: The Sino-Singapore Tianjin Eco-City as a Model for Chinese and other Cities. In *Urbanization and in Public Health China* (pp. 317-336).

Meadowcroft, J., 2011. Engaging with the politics of sustainability transitions. *Environmental Innovation and Societal Transitions*, *1*(1), pp.70-75.

Medina, M., 2000. Scavenger cooperatives in Asia and Latin America. *Resources, conservation and recycling*, *31*(1), pp.51-69.

Medvedev, A., Fedchenkov, P., Zaslavsky, A., Anagnostopoulos, T. and Khoruzhnikov, S., 2015. Waste management as an IoT-enabled service in smart cities. In *Internet of Things, Smart Spaces, and Next Generation Networks and Systems* (pp. 104-115). Springer, Cham.

Memon, S.K., Shaikh, F.K., Mahoto, N.A. and Memon, A.A., 2019, January. IoT based smart garbage monitoring & collection system using WeMos & Ultrasonic sensors. In *2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)* (pp. 1-6). IEEE.

Mertens, D.M., 2015. *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage publications.

Mertens, D.M., 2019. *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage publications.

Misra, D., Das, G., Chakrabortty, T. and Das, D., 2018. An IoT-based waste management system monitored by cloud. *Journal of Material Cycles and Waste Management*, *20*(3), pp.1574-1582.

Mitchell, C.L., 2008. Altered landscapes, altered livelihoods: The shifting experience of informal waste collecting during Hanoi's urban transition. *Geoforum*, *39*(6), pp.2019-2029.

Moir, E., Moonen, T. and Clark, G., 2014. What are future cities? Origins, meanings and uses. *Government Office for Science*. [Online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/33 [Accessed 27 October 2020].

Mosco, V., 2019. *The smart city in a digital world*. Emerald Group Publishing.

Muchiri, N. and Wabwoba, F., 2015. The Role of ICT in Social Inclusion: A Review of Literature.

Nahavandi, S., 2019. Industry 5.0—A human-centric solution. *Sustainability*, *11*(16), p.4371.

Nahman, A. and Godfrey, L., 2010. Economic instruments for solid waste management in South Africa: Opportunities and constraints. *Resources, conservation and recycling*, *54*(8), pp.521-531.

Nam, T. and Pardo, T.A., 2011, June. Conceptualizing smart city with dimensions of technology, people, and institutions. In *Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times* (pp. 282-291).

Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G. and Scorrano, F., 2014. Current trends in Smart City initiatives: Some stylised facts. *Cities*, *38*, pp.25-36.

Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G. and Scorrano, F., 2014. Current trends in Smart City initiatives: Some stylised facts. *Cities*, *38*, pp.25-36.

Newton, P.W., 2018. Transitioning the greyfields. In *Urban Sustainability Transitions* (pp. 149-171). Springer, Singapore.

Nowakowski, P., 2017. A proposal to improve e-waste collection efficiency in urban mining: Container loading and vehicle routing problems–A case study of Poland. *Waste Management*, *60*, pp.494-504.

Nzeadibe, T.C., Anyadike, R.N. and Njoku-Tony, R.F., 2012. A mixed methods approach to vulnerability and quality of life assessment of waste picking in urban Nigeria. *Applied Research in Quality of Life*, *7*(4), pp.351-370.

OECD. 2016. Extended Producer Responsibility—Updated Guidance; ENV/EPOC/WPRPW(2015)16/FINAL. OECD: Paris, France. Available online: https://read.oecd-ilibrary.org/environment/extended-producer-responsibility_9789264256385-en#page5 (accessed February 25, 2020).

OECD. 2016. Extended Producer Responsibility—Updated Guidance; ENV/EPOC/WPRPW (2015)16/ FINAL. OECD: Paris, France. Available at: https://read.oecd-ilibrary.org/environment/extended-producer-responsibility_9789264256385-en#page5. (Accessed 23 October, 2020).

O'grady, M. and O'hare, G., 2012. How smart is your city?. *Science*, *335*(6076), pp.1581-1582.

Oosterveer, P. and Spaargaren, G., 2010. Meeting social challenges in developing sustainable environmental infrastructures in East African cities. In *Social perspectives on the sanitation challenge* (pp. 11-30). Springer, Dordrecht.

Orlikowski, W. J. (2000). Using technology and constituting structures: A practise lens for studying technology in organizations. *Organization Science*, 11(4), 404–428.

Pan, C., Bolingbroke, D., Ng, K.T.W., Richter, A. and Vu, H.L., 2019. The use of waste diversion indices on the analysis of Canadian waste management models. *Journal of Material Cycles and Waste Management*, *21*(3), pp.478-487.

Pan, G., Qi, G., Zhang, W., Li, S., Wu, Z. and Yang, L.T., 2013. Trace analysis and mining for smart cities: issues, methods, and applications. *IEEE Communications Magazine*, *51*(6), pp.120-126.

Pan, G., Qi, G., Zhang, W., Li, S., Wu, Z. and Yang, L.T., 2013. Trace analysis and mining for smart cities: issues, methods, and applications. *IEEE Communications Magazine*, *51*(6), pp.120-126.

Pansera, M. and Sarkar, S., 2016. Crafting sustainable development solutions: Frugal innovations of grassroots entrepreneurs. *Sustainability*, *8*(1), p.51.

Pardini, K., Rodrigues, J.J., Kozlov, S.A., Kumar, N. and Furtado, V., 2019. IoT-based solid waste management solutions: a survey. *Journal of Sensor and Actuator Networks*, *8*(1), p.5.

Patil, S., Zavare, S., Parashare, R., Rathod, P. and Babanne, V., 2017. Smart city waste management. *Int. J. Eng. Sci*, *3990*.

Petty, N.J., Thomson, O.P. and Stew, G., 2012. Ready for a paradigm shift? Part 2: Introducing qualitative research methodologies and methods. *Manual therapy*, *17*(5), pp.378-384.

Pholoto, L., 2018. *Theorizing the relations between space and waste: residents' Insights on recycling practices and waste pickers in Vaalpark, Sasolburg* (Masters Dissertation).

Plastic Bank., 2018. Join the movement. Available online: www.plasticbank.org (accessed on 18 October 2021).

Pollio, A., 2020. Making the silicon cape of Africa: Tales, theories and the narration of start-up urbanism. *Urban Studies*, *57*(13), pp.2715-2732.


Pollio, A., 2020. Making the silicon cape of Africa: Tales, theories and the narration of start-up urbanism. *Urban Studies*, *57*(13), pp.2715-2732.


Punch, K.F. 2009. *Introduction to research methods in education*. Sage.

Rada, E.C., Ragazzi, M. and Fedrizzi, P., 2013. Web-GIS oriented systems viability for municipal solid waste selective collection optimization in developed and transient economies. *Waste management*, *33*(4), pp.785-792.


Rada, E.C., Ragazzi, M. and Fedrizzi, P., 2013. Web-GIS oriented systems viability for municipal solid waste selective collection optimization in developed and transient economies. *Waste management*, *33*(4), pp.785-792.


Ramaphosa, C. *2019. State of the Nation Address.* Pretoria, South Africa

Ramaprasad, A., Sánchez-Ortiz, A. and Syn, T., 2017, September. A unified definition of a smart city. In *International Conference on Electronic Government* (pp. 13-24). Springer, Cham.

Ramparsad, S., 2020. Smart Governance in South African Cities. *SMART CITIES PAPER SERIES*.

Raven, R., Schot, J. and Berkhout, F., 2012. Space and scale in socio-technical transitions. *Environmental innovation and societal transitions*, 4, pp.63-78.

Recycling Today. 2017. UK Recycling Software Adds Blockchain Capabilities. Available online: www.recyclingtoday.com/article/recycling-software-blockchain-shipping-mti-fred-uk (accessed on 15 October 2021)

Rehman, M.H., Chang, V., Batool, A. and Wah, T.Y., 2016. Big data reduction framework for value creation in sustainable enterprises. *International Journal of Information Management*, *36*(6), pp.917-928.

Reis, P., Caetano, F., Pitarma, R. and Gonçalves, C., 2015. iEcoSys–an intelligent waste management system. In *New Contributions in Information Systems and Technologies* (pp. 843-853). Springer, Cham.

Reverter, F., Gasulla, M. and Pallas-Areny, R., 2003, October. Capacitive level sensing for solid-waste collection. In *SENSORS, 2003 IEEE* (Vol. 1, pp. 7-11). IEEE.

Rip, A. and Kemp, R., 1998. Technological change. *Human choice and climate change*, *2*(2), pp.327-399.

Rolim, R.S., Teixeira, K.M.D. and Fernandes, R.A.U., 2015. One value, other discriminate: family and society in the perception of recyclable material collectors. *Revista Brasileira de Economia Doméstica*, *26*(1), pp.205-224.

Rybnytska, O., Burstein, F., Rybin, A.V. and Zaslavsky, A., 2018. Decision support for optimizing waste management. *Journal of Decision Systems*, *27*(sup1), pp.68-78.

Rybova, K. and Slavik, J., 2016, May. Smart cities and ageing population-Implications for waste management in the Czech Republic. In *2016 Smart Cities Symposium Prague (SCSP)* (pp. 1-6). IEEE.

SACN. 2016. *The State of South African Cities Report 2016*. Johannesburg, South Africa: South African Cities Network

Sage Creswell, J. W. 2013. Qualitative inquiry and research design: Choosing among five approaches (3rd Ed.). Los Angeles: Sage

SALGA, 2020. SALGA on Smart Cities. Available on: https://salgadigital.org.za/pubs/cluster/press/_4.pdf. (Accessed on 03 March 2021).

Samers, M., 2005. The myopia of “diverse economies”, or a critique of the “informal economy”. *Antipode*, *37*(5), pp.875-886.

Samson, M., 2010. Reclaiming Reusable and Recyclable Materials in Africa a Critical Review of English Language Literature.

Samson, M., 2017. Not Just Recycling the Crisis: Producing Value at a Soweto Garbage Dump. *Historical Materialism*, *25*(1), pp.36-62.

Samson, M., 2020. Technical report: Integrating reclaimers into our understanding of the recycling economy.

Samson, M., 2020. The political work of waste picker integration. In *The Informal Economy Revisited* (pp. 195-200). Routledge.

Samson, M., 2020. Whose frontier is it anyway? Reclaimer “Integration” and the battle over Johannesburg’s waste-based commodity frontier. *Capitalism Nature Socialism*, *31*(4), pp.60-75.

Samson, M., Kadyamadare, G., Ndlovu, L. and Kalina, M., 2022. 'Wasters, agnostics, enforcers, competitors, and community integrators': Reclaimers, S@ S, and the five types of residents in Johannesburg, South Africa. *World Development*, *150*, p.105733.

Samson, M., Waste, R.D.I., Timm, S., Chidzungu, T., Dladla, N., Kadyamadare, G., Maeka, K., Mahlase, M., Mokobane, A., Molefe, K. and Ndlovu, L., 2020. Lessons from Waste Picker Integration Initiatives: Development of Evidence Based Guidelines to Integrate Waste Pickers into South African Municipal Waste Management Systems.

Sant’Elia, A., 2009. Manifesto of Futurist Architecture (11 July 1914). *Futurist manifestos, London, Thames and Hudson*.

Satgar, V., 2007. The state of the South African cooperative sector. *South Africa: COPAC (co-operative and policy alternative centre)*.

Saunders, T. and Baeck, P., 2015. Rethinking smart cities from the ground up. *London: Nesta*.

Scheinberg, A. and Anschtz, J., 2006. Slim pickin's: Supporting waste pickers in the ecological modernization of urban waste management systems. *International journal of technology management & sustainable development*, *5*(3), pp.257-270.

Scheinberg, A., 2011. Value added: Modes of sustainable recycling in the modernisation of waste management systems.

Scheinberg, A., 2012. Informal sector integration and high performance recycling: Evidence from 20 cities. *Women in Informal Employment Globalizing and Organizing (WIEGO), Manchester*, *23*.

Scheinberg, A., Nešić, J. and Bogdanović, M.M. 2018. Inclusion of Informal Collectors into the Evolving Waste Management System in Serbia, a Roadmap for Integration. Paper presented at Eurasia 2018 Waste Management Symposium.

Schenck, C.J., Blaauw, P.F. and Viljoen, J.M., 2016. The socio-economic differences between landfill and street waste pickers in the Free State province of South Africa. *Development Southern Africa*, *33*(4), pp.532-547.

Schenck, C.R. and Blaauw, P.D., 2011. Living on what others throw away: an exploration of a socio-economic circumstances of people collecting and selling recyclable waste.

Schenck, R. and Blaauw, P.F., 2011, December. The work and lives of street waste pickers in Pretoria—a case study of recycling in South Africa’s urban informal economy. In *Urban Forum* (Vol. 22, No. 4, pp. 411-430). Springer Netherlands.

Schleicher, J.M., Vögler, M., Inzinger, C., Fritz, S., Ziegler, M., Kaufmann, T., Bothe, D., Forster, J. and Dustdar, S., 2016, June. A holistic, interdisciplinary decision support system for sustainable smart city design. In *International Conference on Smart Cities* (pp. 1-10). Springer, Cham.

Schmid, B., 2021. Hybrid infrastructures: The role of strategy and compromise in grassroot governance. *Environmental Policy and Governance*, *31*(3), pp.199-210.

Schot, J. and Geels, F.W., 2007. Niches in evolutionary theories of technical change. *Journal of Evolutionary Economics*, *17*(5), pp.605-622.

Schot, J., 1998. The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the nineteenth century. *History and Technology, an International Journal*, *14*(3), pp.173-200.

Seetharaman, P., Cunha, M.A. and Effah, J., 2019. IT for the informal sector in developing countries: A broader perspective. *The Electronic Journal of Information Systems in Developing Countries*, *85*(3).

Seitz, S., 2016. Pixilated partnerships, overcoming obstacles in qualitative interviews via Skype: A research note. *Qualitative research*, *16*(2), pp.229-235.

Sekhwela, M.M. and Samson, M., 2020, March. Contested understandings of reclaimer integration—Insights from a failed Johannesburg pilot project. In *Urban Forum* (Vol. 31, No. 1, pp. 21-39). Springer Netherlands.

Sekhwela, M.M., 2017. *The policy and practice of reclaimer integration in the city of Johannesburg* (Masters dissertation, University of the Witwatersrand, Faculty of Science, School of Geography, Archaeology & Environmental Studies).

Şener, Ş., Şener, E., Nas, B. and Karagüzel, R., 2010. Combining AHP with GIS for landfill site selection: a case study in the Lake Beyşehir catchment area (Konya, Turkey). *Waste management*, *30*(11), pp.2037-2046.

Sengers, F., Wieczorek, A.J. and Raven, R., 2019. Experimenting for sustainability transitions: A systematic literature review. *Technological Forecasting and Social Change*, *145*, pp.153-164.

Sengers, F., Wieczorek, A.J. and Raven, R., 2019. Experimenting for sustainability transitions: A systematic literature review. *Technological Forecasting and Social Change*, *145*, pp.153-164.

Sentime, K., 2011. Profiling solid waste pickers: a case study of Braamfontein-Greater Johannesburg. *Africanus*, *41*(2), pp.96-111.

Sentime, K., 2011. Profiling solid waste pickers: a case study of Braamfontein-Greater Johannesburg. *Africanus*, *41*(2), pp.96-111.

Shelton, T., Zook, M. and Wiig, A., 2015. The 'actually existing smart city'. *Cambridge journal of regions, economy and society*, *8*(1), pp.13-25.

Shelzer, R., 2017. What Is Industry 5.0—and How Will It Affect Manufacturers.

Shin, H.B., 2016. Envisioned by the state: Entrepreneurial urbanism and the making of Songdo City, South Korea. In *Mega-Urbanization in the Global South* (pp. 95-112). Routledge.

Shirdastian, H., Laroche, M. and Richard, M.O., 2019. Using big data analytics to study brand authenticity sentiments: The case of Starbucks on Twitter. *International Journal of Information Management*, *48*, pp.291-307.

Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H. and Wang, J., 2021. Enabling a circular economy in the built environment sector through blockchain technology. *Journal of Cleaner Production*, *294*, p.126352.

Sholanke, D. and Gutberlet, J., 2020. Informal Recycling in Vancouver: Binners 'challenges And Opportunities. *Detritus, I-IV*.

Sholanke, D. and Gutberlet, J., 2021. Call for participatory waste governance: waste management with informal recyclers in Vancouver. *Journal of Environmental Policy & Planning*, pp.1-15.

Shove, E. and Walker, G., 2007. CAUTION! Transitions ahead: politics, practice, and sustainable transition management. *Environment and planning A*, *39*(4), pp.763-770.

Shove, E., 2002, October. Rushing around: coordination, mobility and inequality. In *ESRC Mobile Network Meeting, Department for Transport, London, October*.

Shwayri, S.T., 2013. A model Korean ubiquitous eco-city? The politics of making Songdo. *Journal of Urban Technology*, *20*(1), pp.39-55.

Shyam, G.K., Manvi, S.S. and Bharti, P., 2017, February. Smart waste management using Internet-of-Things (IoT). In *2017 2nd international conference on computing and communications technologies (ICCCT)* (pp. 199-203). IEEE.

Singh, S.K. and El-Kassar, A.N., 2019. Role of big data analytics in developing sustainable capabilities. *Journal of cleaner production*, *213*, pp.1264-1273.

Smit, S. and Musango, J.K., 2015. Towards connecting green economy with informal economy in South Africa: A review and way forward. *Ecological Economics*, *116*, pp.154-159.

Smit, S. and Musango, J.K., 2015. Towards connecting green economy with informal economy in South Africa: A review and way forward. *Ecological Economics*, *116*, pp.154-159.

Smith, A., Voß, J.P. and Grin, J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), pp.435-448.

Song, Q., Zhang, Y. and Miao, Y., 2016. Internet+ resource recycling" mode promotes the resource recycling revolution in China. *Environmental Pollution & Control*, *38*, pp.105-109.

Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P., 2015. Urban solid waste management in the developing world with emphasis on India: challenges and opportunities. *Reviews in Environmental Science and Bio/Technology*, *14*(2), pp.317-337.

Steenmans, K. and Taylor, P., 2018. A rubbish idea: how blockchains could tackle the world's waste problem. *The Conversation. Available online at: https://theconversation. Com/a-rubbish-idea-how-blockchains-could-tacklethe-worlds-waste-problem-94457 (accessed May 11, 2020)*.

Steenmans, K., Taylor, P. and Steenmans, I., 2021. Blockchain Technology for Governance of Plastic Waste Management: Where Are We?. *Social Sciences*, *10*(11), p.434.

Strickland, E., 2011. Cisco bets on South Korean smart city. *IEEE Spectrum*, *48*(8), pp.11-12.

Stübinger, J. and Schneider, L., 2020. Understanding smart city—A data-driven literature review. *Sustainability*, *12*(20), p.8460.

Sukholthaman, P. and Sharp, A., 2016. A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. *Waste Management*, *52*, pp.50-61.

Taiwo, O., Otieno, F. and Venter, C., 2008. Towards attaining the Polokwane waste reduction goals-where are we?. *Stads-en Streeksbeplanning= Town and Regional Planning*, *2008*(53), pp.25-31.

Tao, C. and Xiang, L., 2010, November. Municipal solid waste recycle management information platform based on internet of things technology. In *2010 International Conference on Multimedia Information Networking and Security* (pp. 729-732). IEEE.

Thakuriah, P.V., Tilahun, N.Y. and Zellner, M., 2017. Introduction to seeing cities through big data: Research, methods and applications in urban informatics. In *Seeing Cities Through Big Data* (pp. 1-9). Springer, Cham.

The Binners' Project, 2020. Annual Report 2019-2020. Retrieved from: https://www.binnersproject.org/uploads/3/8/7/1/38714015/bpannualreport2019_web.pdf. (Accessed on 22 March 2022).

Theron, J., 2010. Options for organising waste pickers in South Africa. *WIEGO Organizing Briefs*.

Thürer, M., Pan, Y.H., Qu, T., Luo, H., Li, C.D. and Huang, G.Q., 2019. Internet of Things (IoT) driven kanban system for reverse logistics: solid waste collection. *Journal of Intelligent Manufacturing*, *30*(7), pp.2621-2630.

Thuzar, M., 2011. Urbanization in Southeast Asia: developing smart cities for the future?. In *Regional Outlook* (pp. 96-100). ISEAS Publishing.

Tiong, W.N. and Sim, A.F.S.F., 2020. Web-based seminar-new source of qualitative study: Data collection during the pandemic of COVID-19. *SEISENSE Journal of Management*, *3*(6), pp.50-64.

Toppeta, D., 2010. The smart city vision: how innovation and ICT can build smart, "liveable", sustainable cities. *The innovation knowledge foundation*, *5*, pp.1-9.

Townsend, A.M., 2013. *Smart cities: Big data, civic hackers, and the quest for a new utopia*. WW Norton & Company.

Turnheim, B., Wesseling, J., Truffer, B., Rohracher, H., Carvalho, L. and Binder, C., 2018. Challenges ahead: Understanding, assessing, anticipating and governing foreseeable societal tensions to support accelerated low-carbon transitions in Europe. In *Advancing energy policy* (pp. 145-161). Palgrave Pivot, Cham.

Twomey, P. and Gaziulusoy, A.I., 2016. Review of System Innovation and Transition Theories.

UCLG Smart Cities Study., 2019. International study on the situation and future trends in Smart Governance. Retrieved from https://www.uclg.org/sites/default/files/uclg_smartcitiesstudy 2019_digital_en_0.pdf. (Accessed on 18 October 2021).

UNCTAD. (2016). Smart cities and infrastructure Report of the Secretary-General Economic and Social Council. [Online] https://unctad.org/system/files/official-document/ecn162016d2_en.pdf (accessed 20 July 2019).

Un-Habitat, 2010. *Solid waste management in the world's cities*. UN-HABITAT.

URERU, 2020. URERU Smart City Series Part 1: Overview And Analysis of Cape Town's Digital City Strategy. Available on: http://www.ureru.uct.ac.za/sites/default/files/imagetool/images/383/Final%E2%80%93%20Overview%20and%20Analysis%20of%20Cape%20Town%27s%20Digital%20City%20Strategy.pdf. (Accessed on 10 February 2021).

Ustundag, A.L.P. and Cevikcan, E., 2008. Vehicle route optimization for RFID integrated waste collection system. *International Journal of Information Technology & Decision Making*, *7*(04), pp.611-625.

Van Berkel, R., Fujita, T., Hashimoto, S. and Geng, Y., 2009. Industrial and urban symbiosis in Japan: Analysis of the Eco-Town program 1997–2006. *Journal of Environmental Management*, *90*(3), pp.1544-1556.

Vanolo, A., 2014. Smartmentality: The smart city as disciplinary strategy. *Urban studies*, *51*(5), pp.883-898.

Vanolo, A., 2016. Is there anybody out there? The place and role of citizens in tomorrow's smart cities. *Futures*, *82*, pp.26-36.

Vasileiadou, E. and Safarzyńska, K., 2010. Transitions: Taking complexity seriously. *Futures*, *42*(10), pp.1176-1186.

Velis, C.A., Wilson, D.C., Rocca, O., Smith, S.R., Mavropoulos, A. and Cheeseman, C.R., 2012. An analytical framework and tool ('InteRa') for integrating the informal recycling sector in waste and resource management systems in developing countries. *Waste Management & Research*, *30*(9_suppl), pp.43-66.

Verbong, G., Geels, F.W. and Raven, R., 2008. Multi-niche analysis of dynamics and policies in Dutch renewable energy innovation journeys (1970–2006): hype-cycles, closed networks and technology-focused learning. *Technology Analysis & Strategic Management*, *20*(5), pp.555-573.

Vestergaard, L.S., Fernandes, J. and Presser, M.A., 2015. Towards smart city democracy. *Geoforum Perspektiv*, *14*(25).

Vicentini, F., Giusti, A., Rovetta, A., Fan, X., He, Q., Zhu, M. and Liu, B., 2009. Sensorized waste collection container for content estimation and collection optimization. *Waste management*, *29*(5), pp.1467-1472.

Viljoen, J.M.M., 2014. *Economic and social aspects of street waste pickers in South Africa*. University of Johannesburg (South Africa).

Virgolin, IWC, Silva, EMTD and Santos, RAD, 2016. Experience report about the collector profession project: Garbage as labor supply and citizenship.

Vliet, B., van Buuren, J. and Oosterveer, P., 2013. Network governance and waste and sanitation service provision: An introduction to the modernised mixtures approach. In *Urban waste and sanitation services for sustainable development* (pp. 23-40). Routledge.

Wäger, P.A., Hischier, R. and Eugster, M., 2011. Environmental impacts of the Swiss collection and recovery systems for Waste Electrical and Electronic Equipment (WEEE): A follow-up. *Science of the Total Environment*, *409*(10), pp.1746-1756.

Wang, H., Han, H., Liu, T., Tian, X., Xu, M., Wu, Y., Gu, Y., Liu, Y. and Zuo, T., 2018. "Internet+" recyclable resources: a new recycling mode in China. *Resources, Conservation and Recycling*, *134*, pp.44-47.

Warschauer, M., 2004. *Technology and social inclusion: Rethinking the digital divide*. MIT press.

Waste, R.D.I., Samson, M., Timm, S., Chidzungu, T., Dladla, N., Kadyamadare, G., Maeka, K., Mahlase, M., Mokobane, A., Molefe, K. and Ndlovu, L., 2020. Lessons from Waste Picker Integration Initiatives: Development of Evidence Based Guidelines to Integrate Waste Pickers into South African Municipal Waste Management Systems.

Watson, V., 2015. The allure of 'smart city' rhetoric: India and Africa. *Dialogues in Human Geography*, *5*(1), pp.36-39.

Wei, Y., 2016. A study on "internet+ recycling" mode of WEEE. J. Hangzhou Dianzi Univ. *Soc. Sci*, *12*(2), pp.18-23.

Weiser, M., Gold, R. and Brown, J.S., 1999. The origins of ubiquitous computing research at PARC in the late 1980s. *IBM systems journal*, *38*(4), pp.693-696.

Wen, Z., Hu, S., De Clercq, D., Beck, M.B., Zhang, H., Zhang, H., Fei, F. and Liu, J., 2018. Design, implementation, and evaluation of an Internet of Things (IoT) network system for restaurant food waste management. *Waste management*, *73*, pp.26-38.

Wilding, R., 2009. Refugee youth, social inclusion, and ICTs: can good intentions go bad?. *Journal of Information, Communication and Ethics in Society*.

Wilson, D.C., Araba, A.O., Chinwah, K. and Cheeseman, C.R., 2009. Building recycling rates through the informal sector. *Waste management*, *29*(2), pp.629-635.

Wilson, D.C., Velis, C. and Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. *Habitat international*, *30*(4), pp.797-808.

Winters, J.V., 2011. Why are smart cities growing? Who moves and who stays. *Journal of regional science*, *51*(2), pp.253-270.

World Bank, 2016. *Doing business 2017: Equal opportunity for all*. The World Bank.

WRAPP, 2007. WRAPP Waste is a mobile app that makes waste removal simple, transparent, and dependable. Available on: https://www.wrapp.co.za/about. (Accessed on: 12 February 2021).

Xu, H. and Geng, X., 2019. People-centric service intelligence for smart cities. *Smart Cities*, *2*(2), pp.135-152.

Xue, Y., Wen, Z., Bressers, H. and Ai, N., 2019. Can intelligent collection integrate informal sector for urban resource recycling in China?. *Journal of cleaner production*, *208*, pp.307-315.

Yang, X., Moore, P. and Chong, S.K., 2009. Intelligent products: From lifecycle data acquisition to enabling product-related services. *Computers in Industry*, *60*(3), pp.184-194.

Yaqoob, I., Hashem, I.A.T., Gani, A., Mokhtar, S., Ahmed, E., Anuar, N.B. and Vasilakos, A.V., 2016. Big data: From beginning to future. *International Journal of Information Management*, *36*(6), pp.1231-1247.

Yigit, I.H., 2015. Survival tactics of waste paper pickers in Istanbul. *Journal of Ethnic and Cultural Studies*, *2*(1), pp.1-14.

Yigitcanlar, T., 2017. Smart cities in the making. *International Journal of Knowledge-Based Development*, *8*(3), pp.201-205.

Yigitcanlar, T., Wilson, M. and Kamruzzaman, M., 2019. Disruptive impacts of automated driving systems on the built environment and land use: An urban planner's perspective. *Journal of Open Innovation: Technology, Market, and Complexity*, *5*(2), p.24.

Yin, C., Xiong, Z., Chen, H., Wang, J., Cooper, D. and David, B., 2015. A literature survey on smart cities. *Science China Information Sciences*, *58*(10), pp.1-18.

Yu, L., 2014. Low carbon eco-city: New approach for Chinese urbanisation. *Habitat International*, *44*, pp.102-110.

Yu, Z. and Gibbs, D., 2020. Unravelling the role of green entrepreneurs in urban sustainability transitions: A case study of China's Solar City. *Urban Studies*, *57*(14), pp.2901-2917.

Zaman, A.U. and Lehmann, S., 2013. The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city'. *Journal of cleaner production*, *50*, pp.123-132.

Zaman, A.U., 2014. Measuring waste management performance using the 'Zero Waste Index': the case of Adelaide, Australia. *Journal of Cleaner Production*, *66*, pp.407-419.

Zamani, E.D., 2017. Social inclusion and ICTs: A literature review through the lens of the capability approach. *Social Inclusion and Usability of ICT-Enabled Services*, pp.11-30.

Zanella, A., Bui, N., Castellani, A., Vangelista, L. and Zorzi, M., 2014. Internet of things for smart cities. *IEEE Internet of Things journal*, *1*(1), pp.22-32.

Zhang, S., Zhang, M., Yu, X. and Ren, H., 2016. What keeps Chinese from recycling: Accessibility of recycling facilities and the behaviour? *Resources, Conservation and Recycling*, *109*, pp.176-186.

Zheng, Y. and Walsham, G., 2008. Inequality of what? Social exclusion in the e-society as capability deprivation. *Information Technology & People*.

Zheng, Y., 2009. Different spaces for e-development: What can we learn from the capability approach?. *Information technology for development*, *15*(2), pp.66-82.

Zhou, H., 2015. "Internet+" greenization: promote the developing way transition. *Pol. Outlook*, *9*, pp.46-48.

Zhu, S., Li, D., Feng, H., Gu, T., Hewage, K. and Sadiq, R., 2020. Smart city and resilient city: Differences and connections. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *10*(6), p.e1388.

Zia, H., Devadas, V. and Shukla, S., 2008. Assessing informal waste recycling in Kanpur City, India. *Management of Environmental Quality: An International Journal*.

# Appendix A: Ethics Clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

**HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)**

Registration number: REC-101114-044

**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING ETHICS COMMITTEE**

Ethics clearance number: CEECW 869691 2020

09/09/2020

Re: Vincent Siwawa (869691)

To whom it may concern,

Vincent Siwawa (869691) is currently registered as a PhD student at the School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg. This letter is to confirm that, at the time of writing, Vincent does not need ethical clearance for his study entitled **Influence of a Bottom-Up Smart City Integrated Waste Management Model on Informal Waste Reclaimers' Welfare and Municipal Solid Waste Management: The Case of Johannesburg, South Africa**. This decision has been reached based upon a description of the project supplied by Vincent to the School of Civil and Environmental Engineering Ethics Committee, constituted as a subcommittee of the University Human Research Ethics Committee (Non-Medical), which has been evaluated by the subcommittee chair. This decision has then been ratified by the University Human Research Ethics Committee (Non-Medical). If, however, Vincent changes the methods of data collection and analysis for this project, this decision may no longer be valid. If such changes take place, this should be communicated to the School of Civil and Environmental Engineering Ethics Committee.

Please feel free to contact me should you require any further information.

Thank you.

Yours sincerely,

Prof John Ndiritu, School Ethics Chair

**Shaun Schoeman** (Senior Administrative Officer)
Solomon Mahlangu House, 10th Floor, Room 10004, Jorissen Street, Braamfontein, Johannesburg
Private Bag 3, Wits 2050
**T** + 27(0)11 717 1408 | **E** Shaun.Schoeman@wits.ac.za | hrec-medical.researchoffice@wits.ac.za
**www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/**

# Appendix B: Certificate of Competence in Research Ethics

## CERTIFICATE OF COMPETENCE IN RESEARCH ETHICS

**Full Name:** Vincent Siwawa

**Student No:** 869691

**Date of Certification:** 15 April 2019 - 14 April 2022

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

***TRAINED BY:***

*Professor Jasper Knight (Research Ethics)*

*Signed:*

***ACKNOWLEDGED BY:***

*Dr Robin Drennan (Director: Research Office)*

*Signed:*

This certificate is confirmation of successful completion of a training course in Research Ethics for Non-Medical Human Research, based upon achieving a minimum level of competence in different assessment tasks. This certificate is valid for a period of three years from the date given above.

# Appendix C: Letter of Permission from Regenize

REG NIZE

**Regenize (Pty) Ltd**
**Web.**: www.regenize.co.za
**Email**: admin@regenize.co.za
**Contact**: 081 534 3586
**Address**: Unit 106, The Meat Factory
368 Voortrekker Road,
Maitland, Cape Town,
Western Cape, 7405

**School of Civil and Environmental Engineering**
Private Bag 3 Wits, 2050
**Tel:** 011 717 7121
**Fax:** 011 717 7045
**Email:** 869691@students.wits.ac.za
**Cell:** +27764858671

Dear Vincent Siwawa

**REF: REQUEST FOR PERMISSION TO CONDUCT RESEARCH: VINCENT SIWAWA**

The above subject matter refers.

I acknowledge receipt of your letter requesting permission to undertake research and conduct some field study in connection with your proposed research: ***"Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa."*** With the aim of assessing the role of ICT-enabled waste management digital platforms towards the digital transformation of the informal waste recycling sector towards the Zero Waste concept with the objective to introduce a data-driven "smart city" model for the informal waste recycling sector in South Africa.

The purpose of this letter is to grant **Vincent Siwawa** at the University of Witwatersrand in the School of Civil and Environmental Engineering, permission to conduct research at Regenize (Pty) Ltd. The project titled, ***"Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa."*** Entails interviewing staff, make observations, send out a questionnaire and access to Regenize (Pty) Ltd documents, study sites and contact details of organization members.

**Regenize (Pty) Ltd**
***Reg.**: 2015/1999/07*

After review of the study protocol, Nkazimlo Miti (Operations) I do hereby grant permission for Vincent Siwawa to conduct the research title ***"Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa."*** at **Regenize (Pty) Ltd.**

Miti

______________________________

Sincerely,


**Nkazimlo Miti**

Operations

Regenize

0737542890 | 0815343586

nkazi@regenize.co.za

www.regenize.co.za

368 Voortrekker Road, Maitland, Cape Town


REGENIZE

# Appendix D: Letter of Permission from BanQu

56 Grosvenor Lane
Bryanston, Sandton, 2191
Office: +2766 2388 529

Dignity Through Identity

BanQuApp (Pty) Ltd.

From: Ewald Meyer
Email: ewald.meyer@banquapp.com
Date: 10 March 2022

School of Civil and Environmental Engineering
Private Bag 3 Wits, 2050
Tel: 011 717 7121
Fax: 011 717 7045
Email: 869691@students.wits.ac.za
Cell: +27764858671

Dear Vincent Siwawa

REF: REQUEST FOR PERMISSION TO CONDUCT RESEARCH: VINCENT SIWAWA

The above subject matter refers.

I acknowledge receipt of your letter requesting permission to undertake research and conduct some field study in connection with your proposed research: "Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa." With the aim of assessing the role of ICT-enabled waste management digital platforms towards the digital transformation of the informal waste recycling sector towards the Zero Waste concept with the objective to introduce a data driven "smart city" model for the informal waste recycling sector in South Africa.

The purpose of this letter is to grant Vincent Siwawa at the University of Witwatersrand in the School of Civil and Environmental Engineering, permission to conduct research at BanQuApp (Pty) Ltd. The project titled, "Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa." Entails interviewing Ewald Meyer, observing a demonstration and accessing publicly available BanQuApp (Pty) Ltd information.

After review of the study protocol, I, Ewald Meyer do hereby grant permission for Vincent Siwawa to conduct the research title "Influence of a bottom-up smart city intergraded waste management model on informal waste reclaimers' welfare and municipal solid waste management in South Africa." at BanQuApp (Pty) Ltd.

Upon completion, we need to please get the research for our input or further comments in draft state before it is published.

Sincerely,

Ewald Meyer
Director, Business Development

Company registration: 2019/630626/07

# Appendix E: Letter of Permission from the City of Johannesburg

Joburg

City of Johannesburg
Environment & Infrastructure Services Department

118 Jorissen Street
Traduna House
Braamfontein

PO Box 1049
Johannesburg
South Africa
2000

Tel +27(0) 11 587 4210
Fax +27(0) 11 727 0311

www.joburg.org.za

**MEMORANDUM**

| | | |
|---|---|---|
| **TO** | **:** | **Mr. Vincent Siwawa**<br>**PHD Student: Wits University** |
| **FROM** | **:** | **Suleman Shuaib**<br>**Acting Executive Director: EISD** |
| **DATE** | **:** | **19 March 2019** |
| **Re** | **:** | **Permission to conduct Research** |

I acknowledge receipt of your letter dated 09th of March 2019.

The City of Joburg, Environment and Infrastructure Services Department hereby grant you permission to conduct research on your topic "Implementing smart city solutions for sustainable service delivery in Johannesburg, South Africa". The permission include interviewing staff, make observations, send out a questionnaire, access contact details of organization members. I have therefore requested the following officials from the City of Johannesburg within the Environment & Infrastructure Services Department to be the contact person on behalf of the City: Ms Makhosazana Baker, and Mr Mvuselelo Mathebula.

Upon completion of the study, you are required to provide the City with your bound copy of thesis.

Thank you,

**Suleman Shuaib**
**Acting Executive Director:**
**Environment and Infrastructure Services**
**Date:** 20/03/2019

**Cc: Makhosazana Baker:**
**Director: Waste Management & Regulations**
**(makhosazanab@joburg.org.za)**

**Mvuselelo Mathebula**
**Deputy Director: Waste Management & Regulations**
**(mvuselelom@joburg.org.za)**

# Appendix F: Letter of Permission from PikitUp

Joburg

PIKI TUP
JOHANNESBURG
SOC Limited

**City of Johannesburg**
Pikitup

Pikitup Head Office
Jorissen Place
66 Jorissen Street
Braamfontein
2001

Private Bag X74
Braamfontein
Johannesburg
2017

Tel +27(0) 11 712 5200
Fax +27(0) 11 712 5322
www.pikitup.co.za
www.joburg.org.za

Date: 13 March 2019

Prof Anne Fitchett
School of Civil and Environmental Engineering
Private Bag 3 Wits, 2050
Tel: 011 717 7121
Fax: 011 717 7045
Email: Anne.Fitchett@wits.ac.za
Cell: +27117177107

Dear Professor Anne Fitchett

**REF: REQUEST FOR PERMISSION TO CONDUCT RESEARCH: VINCENT SIWAWA**

The above subject matter refers.

I acknowledge receipt of your letter requesting permission to undertake research and conduct some field study in Johannesburg under your proposed research; ***"Implementing smart city solutions for sustainable service delivery in Johannesburg, South Africa."*** With the aim of assessing the level of achievement towards the Zero Waste concept through the implementation of the 'smart city' solutions with the objective to introduce a data driven "smart city" model for Municipal Solid Waste in Johannesburg.

The purpose of this letter is to grant **Vincent Siwawa** at the University of Witwatersrand in the School of Civil and Environmental Engineering, permission to conduct research at **PikitUp.** The project titled ***"Implementing smart city solutions for sustainable service delivery in Johannesburg, South Africa"*** entails interviewing staff, make observations, send out a questionnaire and access to PikitUP documents, study sites and contact details of organization members.

After review of the study protocol, Peter Hlubi, General Manager: Operations I do hereby grant permission for Vincent Siwawa to conduct the research title ***"Implementing smart city solutions for sustainable service delivery in Johannesburg, South Africa"*** at **PikitUp.**

Please note that upon completion of your research you must submit a copy of your research to Pikitup Johannesburg SOC.

# Appendix G: Interview Guide

## a) General Questions for Key Experts

1. Can you kindly provide me with a little background on yourself, what you do with regards to waste management and ICT-enabled waste reclaimers system?
2. Please kindly tell me about the digital transformation projects you are currently involved in and their intended purposes?
3. When, why and how are you getting various stakeholders/people to participate in the ICT-enabled waste reclaimers system initiatives?
4. What is the purpose for adopting the ICT-enabled waste reclaimers system in the informal recycling sector and what rationale suggested the fit of such system?
5. Can you describe how the ICT-enabled waste reclaimers system applied in the informal recycling system in South Africa?
6. What kind of technology is the ICT-enabled waste reclaimers system developed on?
7. For what purpose is blockchain technology being used in the ICT-enabled waste reclaimers system?
8. How are waste reclaimers involved in the ICT-enabled waste reclaimers' initiative and what are the benefits they get by using the system?
9. Can you explain the users' involvement in various stages of the waste material and cash flow in the ICT-enabled waste reclaimers system?
10. Are you able to clarify the data privacy concerns in the ICT-enabled waste reclaimers system?
11. How has the ICT-enabled waste reclaimers system managed to integrate waste reclaimers who are illegal immigrants to South Africa?
12. What is the size of your user base and how much is the much is the total investment to this project?
13. What were the incentives of developing the ICT-enabled waste reclaimers system on blockchain technology?
14. How have you incentivised or rewarded recycling initiatives by residents or waste reclaimers using the ICT-enabled waste reclaimers system?
15. Have you developed your own virtual currency/cryptocurrency as a form of an incentive or payment in the ICT-enabled waste reclaimers system?
16. What were your main challenges or difficulties for the ICT-enabled waste reclaimers system for the purpose of waste management in the informal sector?
17. How were these barriers and challenges overcome?
18. Are you aware of the ICT-enabled waste reclaimers system supporting waste laws and policies?
19. What implementation and practical design issues are you currently encountering with the system?

20. What recommendation can you give to municipalities/government to support the ICT-enabled waste reclaimers system in South Africa?

## b) General Questions for Waste Reclaimers

21. Can you kindly provide me with a little background on yourself, what you do with regards to waste management and ICT-enabled waste reclaimers system?

22. What is the number of waste reclaimers participating and what did they do before joining your project?

23. When did you start participating in the ICT-enabled waste reclaimers' project?

24. Which city is the ICT-enabled waste reclaimers system mainly used?

25. What clients does the ICT-enabled waste reclaimers system target?

26. What IoTs tools have been adopted and how are they applied in the system?

27. Please can you describe the recyclable material flow, information flow and cash flow in the ICT-enabled waste reclaimers system?

28. Can you list the various waste streams you collect as recyclable materials?

29. Does the project have registered buyback centres where you sell your materials and how what's difference with previous buyback centres?

30. How has the ICT-enabled waste reclaimers system transformed the waste reclaimer integration processes and improved your working conditions?

31. How many buyback centres are you working with?

32. What are the barriers and problems you have experienced using the ICT-enabled waste reclaimers system?

33. What's suggestion can you make to the ICT-enabled waste companies and producers to improve the system?

34. What advice can you give to government to support the ICT-enabled waste reclaimers system in South Africa

# Appendix I: Participant Information Sheet

Dear Sir/Madam

My name is Vincent Siwawa and I am a PhD student in Civil Engineering at Wits University in Johannesburg. As part of my studies I have to undertake a research project, and I am investigating, "**A bottom-up smart city approach to solid waste management: the case of ICT-enabled waste reclaimers system in two South African cities."** The research aims to determine the efficacy of the ICT-enabled waste reclaimer system as an alternative bottom-up smart city integrated approach in mediating environmental challenges and waste reclaimer integration.

As part of this project I would like to invite you to take part in an interview and answering a questionnaire. This activity will involve you responding to the questions and will take around 30 minutes. With your permission, I would also like to record the interview using a digital device (optional).

You will not receive any direct benefits from participating in this study, and there are no disadvantages or penalties for not participating. You may withdraw at any time or not answer any question if you do not want to. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information, and the information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym (false name) to represent your participation, in my final research report. If you experience any distress or discomfort, we will stop the interview or resume another time.

If you have any questions afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you upon request (optional). If you have any queries, concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (non-medical), telephone + 27(0)11 717 1408, email Shaun.Schoeman@wits.ac.za

Yours sincerely,

Vincent Siwawa
Wits University, Johannesburg: 869691@students.wits.ac.za, Cell: 0764858761
Supervisor: Prof Annie Fitchett, Wits University: Anne.Fitchett@wits.ac.za, Tel: +27117177107

# Appendix J: Participant Consent Form

**A bottom-up smart city approach to solid waste management: the case of ICT-enabled waste reclaimers system in two South African cities**

*Consent of Participant*

I ...................................................... agree to participate in and be interviewed for Vincent Siwawa's research project on a bottom-up smart city approach to solid waste management: the case of ICT-enabled waste reclaimers system in two South African cities for his doctoral degree at the University of Witwatersrand. The research has been explained to me and I understand what my participation will involve. I understand that despite anonymity, I understand I may still be identifiable in the resulting thesis write-up

Please circle yes or no for the following statements:

| | |
|---|---|
| I agree that my identity will be kept anonymous | YES/ NO |
| Do you allow me to use anonymous quotes from this interview in the thesis? | YES/ NO |
| Do you allow me to use identifiable quotes from this interview (referring to your name) in the thesis? | YES/ NO |
| I agree that the interview may be audio recorded | YES/ NO |

.......................................... (Signature)

.......................................... (Name of participant)

.......................................... (Date)