CREATING A “SMART” SOLID WASTE RECYCLING SYSTEM: THE CASE OF A HIGH RISE RESIDENTIAL APARTMENT BLOCK

By

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DECLARATION

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ABSTRACT

South Africa has experienced rapid urbanisation, population growth, and economic growth since 1994 and as a result, solid waste is being produced on an ever-larger scale, despite significant environmental, social and economic consequences. The South African State, via the South African National Waste Management Strategy (NWMS) aims to divert 50 percent of all recyclables away from landfills. However, by 2015 only 7.2% of urban households reported regularly recycling their solid waste. For apartment complexes, some 14.2% reportedly separated their waste in 2015. However, in general, data on waste separation and recycling in South Africa is poor. Thus, this study represents a novel intervention, whereby QR codes were used to characterise the waste stream of an apartment block in Gauteng. The purpose was to firstly generate a base line dataset of waste generation rates, recycling participation rates, and attitudes towards recycling. Secondly, it hoped to increase the recycling rate, which it did, achieving a recycling rate of 35% for those residents who participated in the intervention. By the end of the intervention, participating units generated 4.95kg/household/week of solid waste compared to 5.81kg/household/week before it. Thus, the intervention helped participants reduce their total solid waste outputs by 14.8%. In terms of recycling behaviour, the study found that lack of knowledge, apathy, and a lack of facilities (recycling bins) on each floor were the main inhibitors of recycling. In a further intervention, whereby large, dedicated recycling bins were installed on each floor, a recycling rate of 19% was achieved. Finally, an awareness campaign using flyers, posters, notices, door-to-door conversations, weekly bin stickers with actual versus target rates, and a responsive website was implemented. This also had positive results, with a steady weekly increase in the recycling rate from 8.1% to 24%. Residents reported a strong influence of the interventions on their recycling behaviour. That said, the recycling rate is still far from the national target of 50%, although biodegradables were not measured in this study and they are likely to be a sizeable proportion of the solid waste stream. It is recommended that additional incentives such as free recycling bags, and in-unit separation receptacles be introduced to increase recycling and participation rates. But additional research is required to establish why some households persistently refuse to recycle their waste.

Keywords: solid waste management; recycling; apartment block; website; QR codes

LIST OF ABBREVIATIONS

AISWM	Advanced integrated solid waste management
App	Application
AWT	Advanced waste treatment
C&DW	Construction and demolition waste
CoCT	City of Cape Town Metropolitan Municipality
CoJ	City of Johannesburg
DST	Department of Science and Technology
EIs	Economic instruments
EMM	Ekurhuleni Metropolitan Municipality
EPR	Extended producer responsibility
HCD	Human capital development
HTML	HyperText Markup Language
ICT	Information and communication technologies
IWMPP	Integrated waste management policy and plan
MFD	Multi-family dwelling
MSW	Municipal solid waste
MySQL	My Structured Query Language
NEMWA	National Environmental Management: Waste Act
NPSWM	National Pricing Strategy for Waste Management
NWMS	National Waste Management Strategy
PAYT	Pay as you throw
PHP	Hypertext Preprocessor
PPP	Public-private partnerships

QR	Quick Response
R&D	Research and development
RDF	Refuse-derived fuel
RDI	Research, development, and innovation
RFID	Radio frequency identification
SAWIS	South African waste information service
SFD	Single-family dwelling
WtE	Waste-to-energy

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Waste management is an issue of primary importance on a global scale (Catania & Ventura, 2014; Xevgenos, Papadaskalopoulou, Panaretou, Moustakas, & Malamis, 2015). Africa is set to have an exponential rate of waste generation over the next century as urbanisation and population growth combine to alter consumer purchasing patterns, overshadowing global waste reductions (UNEP, 2018). The rise in urbanisation, economic development and patterns of resource consumption mean that the type and volume of waste generated by households has increased rapidly in South Africa (Simelane & Mohee, 2012; Samah et al., 2013; StatsSA, 2018). As a result, the largest city in South Africa, Johannesburg, declared itself to have a "waste management crisis" due to the vast illegal dumping problem (costing R170 per annum to clean-up), nearly diminished landfill space, and increasing yearly waste volumes (CoJ, 2017, para. 6).

South Africa lags Europe in terms of diverting waste from landfills into recycling and recovery streams (Godfrey & Oelofse, 2017). Locally, the recycling rates vary drastically, however. On the one hand, the plastics recycling rate in South Africa is 43.7% (significantly above the European rate of 31.1%) (Plastics SA, 2018). Unfortunately, most of this is recovered in a contaminated state, as it is collected by some 90,000 waste pickers scattered across the country (Godfrey, Muswema, Strydom, Mamafa, & Mapako, 2017; Plastics SA, 2018). Paper recycling is also high, as South Africa achieved a paper-recycling rate of 70% by 2017 (Paper Recycling Association of South Africa, 2017). On the other hand, only 5.2% of South African households regularly recycle their waste (StatsSA, 2018).

The lack of waste separation at source presents a significant problem. This is because the central prerequisite to building a recycling economy is access to high quality (source-separated) recyclables. It is estimated that R11.5 billion per year and 45,000 additional jobs could be generated if South Africa could divert its 20 million tonnes of solid waste away from landfills and into the recycling economy by the year 2023 (GreenCape, 2018). As a result, the country's recycling economic sub-sector, comprising several waste streams, technologies, and stakeholders, and contributing R24.3 billion to GDP in 2016, including 36,000 formal and 80,000 informal jobs, is smaller than it could be (GreenCape, 2018). Thus, source-separation also offers significant economic opportunities, especially for household solid waste (plastic, paper, glass, metals).

Separation at source is still a new concept in South Africa (CSIR, 2011; DEA, 2012). Despite some progress in the last decade, it is estimated that only 4.9 million tonnes (or 11%) of the 42 million tonnes of general waste produced is recycled in South Africa (DEA, 2018). In terms of policy, the requirements for the collection of recyclables separately only came into being with the promulgation of the Waste Act (No. 59 of 2008) (CSIR, 2011; Oelofse, 2012). Despite this, a lack of awareness of, and compliance with, legislation, together with municipalities facing financial and management difficulties and challenging labour conditions, significantly hinders recycling initiatives (CSIR, 2011; Sehlabi & McKay, 2016; UNEP, 2018). Various solutions have been proposed, such as, kerbside collection services, and the establishing of drop-off and buy-back centres in strategic locations to allow community members to deliver recyclables (CSIR, 2011; CoJ, 2017a). However, success rates are low. The City of Johannesburg's (CoJ) *Separation@Source* programme (reaching 490,000 households) fell short of its most recent diversion target by 38%, and has seen far lower recycling rates (4.5 vs 13kg/household/month) than projected in its pilot study, citing strikes and a delay in the partnership with the private sector for this deficit (Pikitup, 2016).

This study seeks to understand the dynamics of source-sorting of solid wastes at the household level within an urban setting, specifically a multi-storey apartment complex. It takes the form of a case study where various interventions were implemented in order to increase the volumes of recyclables collected at source. The innovative aspect of this study is the leverage of readily available technologies, namely a simple QR (quick response) code and smartphone application ("app"), to gather waste stream data, which together with a responsive website and awareness campaign was used to implement a 'reactive' recycling system in a residential apartment block. Waste stream data is used to incentivise, promote awareness, set targets, and promote sustainable recycling practises. It is posited that as the Internet of Things (IoTs) becomes established, so connected devices capable of acquiring environmental data, will allow for sophisticated applications to manage resources, meet quality of service demands, and ultimately improve citizens' quality of life (Catania & Ventura, 2014; Poncela et al., 2014). It is further argued here that this is also possible within the sphere of waste management. This extends to South Africa, where opportunities exist to encourage user participation and recycling rates using smartphone applications and other ICTs (Information and Communications

Technology). Sustainability goals including cost recovery and the design of recycling facilities to better meet user needs can be greatly enhanced by ICTs (Kipngetich, 2014).

1.2 Problem statement and rationale

As the vast majority (74%) of South African households do not recycle their waste or separate at source, the 2016 target of achieving 25% diversion from landfill of recyclables was not achieved (Strydom, 2018). Hence, there is a clear need to increase the level of participation in recycling at the household level. The problem is two-fold: (1) barriers to establishing recycling behaviours persist, and (2) a lack of accurate waste stream data. For example, behaviourally, local barriers to recycling fall in line with international findings. That is, South Africans cite insufficient time and space, untidiness/dirtiness of waste, a lack of knowledge, and inconvenient recycling facilities for low recycling rates (Strydom, 2018). Linked to this, is the lack of quantitative data to inform decision-making (a major problem in South Africa and further afield) (Twardowska & Allen, 2004; Pollard, Popp, Gbur & Cleaveland, 2007; Nwokedi, 2011). Without statistical data on waste streams, it is difficult to set targets for environmentally and economically feasible waste management strategies (Twardowska & Allen, 2004). Although much is understood in both international and local literature concerning barriers to, and facilitators of, recycling, little has been done in the apartment complex setting. More generally as regards the state of recycling in South Africa, there is only one recent, large-scale work which publicly illuminates the topic, namely the 2015 CSIR National Household Waste Recycling Behaviour Survey (Strydom & Godfrey, 2016).

Within this context, an apartment complex setting is an ideal opportunity for practical case study research on recycling issues. Firstly, it is relatively easy to measure the waste stream of multiple households. A basic quantification of types and amounts of recyclables and non-recyclables produced from a residential apartment block is required for the development of a successful waste diversion programme for such residences. Secondly, it is a suitable venue for the trialling and testing of methodological mechanisms/interventions. Importantly, once a methodology for characterising the waste stream is developed, a generation rate baseline can be established, and the recycling rate monitored before and after interventions. Understanding the challenges facing these households regarding participation in proposed recycling initiatives would also inform purposeful design and implementation of recycling systems that will increase the chances of continuous recycling. In addition, there were 717,000 people living in apartment complexes in 2016 in South Africa, representing an opportunity to generalise across this particular dwelling type, for which not much data is available (StatsSA, 2016a). The study design afforded the opportunity to test a novel QR code waste stream quantification methodology to reflect in real-time changes in the recycling rate before and after recycling interventions. A responsive website embedded into an awareness campaign was designed to offer continuous feedback to the community and sustain ongoing recycling.

1.3 Aims and objectives

This study sought to quantify the waste stream in one apartment block in Gauteng and describe the recycling behaviours and attitudes of the resident population. The study also sought to test various interventions designed to improve the recycling rate.

1.3.1 Aim

The overall aim of the study was to gather waste stream data and trial interventions to determine their ability to increase the recycling rate. It was conceived, therefore, that the study could provide information to facilitate the implementation of effective and sustainable recycling systems in this and other apartment complexes in South Africa.

The aim of this study was realised through the following objectives:

1.3.2 Objectives

1. To test a QR code methodology for characterising the waste stream.
2. To determine the quantities of general waste and recyclables produced in an apartment complex, before and after interventions, as part of implementing a recycling system.
3. To develop and test the efficacy of a responsive website (for mobile and desktop) together with a door-to-door campaign to promote it, to further the purposes of the recycling and general waste management awareness.
4. To measure the effect of the responsive website/door-to-door intervention on the recycling rate.
5. To investigate the possibility of incentivising positive recycling behaviour, using the responsive website.

The research questions, both quantitative and qualitative, which facilitated meeting the research objectives are listed below:

1.4 Research Questions

Research Question 1: Can a QR code methodology accurately describe the waste stream?

Research Question 2: How much solid waste does an apartment block produce on a daily/weekly basis (recyclables and non-recyclables) both before and after a QR code, recycling bin, and website / door-to-door intervention?

Research Question 3: How resource intensive is the QR barcode quantification system, continued monitoring and the interventions in terms of set up and running costs?

Research Question 4: Which interventions increase the recycling rates the most: QR codes, changing communal bin sizes, allocating dedicated recycling bins, a responsive website or door-to-door?

Research Question 5: What are the prevailing attitudes of residents towards recycling and how well can incentives-based interventions work?

Research Question 6: What recommendations can be made with regards to implementing recycling systems in similar settings?

1.5 Research Design and Methodology: An overview

In terms of design, the case study was chosen as not much is known about recycling interventions in apartment complexes in South Africa. This includes a lack of accurate waste stream data in these settings. The case study methodology is useful for investigating how a situation is naturally, and then again after a series of purposeful interventions. It allows for a more realistic description of a situation with all the complexities of the real world (Leedy & Ormrod, 2015). The research approach was primarily descriptive in terms of generating quantitative waste stream data before and after the interventions, and survey data relating to recycling behaviours and attitudes – a time-series design therefore (Creswell, 2013).

Sampling was 'purposeful' (Leedy & Ormrod, 2015): the apartment complex consists of 60 households and a 25-household subset was approached, of which 17 participated throughout the QR code waste characterisation phase. The first phase quantified the general waste stream for five weeks, followed by the QR code waste stream characterisation (doubling up as the first intervention), for a further five weeks. The second phase of the study was a lengthier whole-population general waste baseline to help minimise sources of variation. Two interventions followed: (1) the introduction of larger communal waste bins and the introduction of an extra (third) bin for recyclables per floor; (2) a door-to-door campaign and a responsive website to give feedback and engage with the population, of 10 and five-week duration respectively. The organic waste category was omitted to simplify. Also, the waste stream of the commercial units below the apartment complex was not considered in this study, primarily because of the practical difficulties associated with measuring these outputs.

1.6 Description of the Study Site

The apartment complex/flats, *Glendower Place*, is situated in Edenvale, Ekurhuleni, Gauteng, GPS coordinates -26.149873, 28.135390. The residential component comprises 60 units. Below the residential units are two floors of shops / commercial tenants, including restaurants, craft shops, a deli and a speciality chocolate wholesaler, comprising a further 29 units. The apartment complex with commercial units in the basement levels is shown in Figure 1.1. Edenvale is a middle-income suburb about 12km east of the Sandton CBD. The study area is closely nestled between the upper-middle –class areas of Dowerglen, Dunvegan, and Linksfield.

Figure 1.1 Glendower Place apartment complex and shopping centre, Edenvale, Ekurhuleni (Source: Author)

Residents of the apartment block were generally middle class. Whilst there were families in some units, it was uncommon to have more than three persons per unit, with the average estimated at two per unit (2.5-bedroom units of 108m^2). It is well managed by the body corporate and the residents themselves. Waste management services in the area were reliable, and streets were clean. Within the complex, a janitor emptied communal bins located on each floor into a waste skip on the basement level each day. At the start of the study, a private company had been collecting the skip once a week, but the municipality took over this function in the middle of 2018.

1.7 Overview of the Chapters

The remainder of the dissertation presents via the following chapters:

Chapter 2: Review of international literature: A thematic survey of the international literature was undertaken, including but not restricted to waste stream data collection methods, the composition of the solid waste stream in high rise residential sites, trends and attitudes around recycling, the use of ICT in recycling, and the viability of recycling systems in residential settings.

Chapter 3: Review of South African literature: The international review was extended to the local situation, including but not limited to a statistical background, currently available waste stream data, a legislative framework, factors influencing recycling behaviour, and literature specific to Ekurhuleni and the City of Johannesburg (CoJ).

Chapter 4: Research design and methodology: An account was given to the reader of the conceptual and procedural basis of the study, detailing how the study was conducted. The *case study* design was discussed, anchoring this largely quantitative study, followed by the various important peripheral ethical, scope, and data-related treatments.

Chapter 5: Results and analysis: Chapter 5 presents the results of the study, both of waste stream characterisation and survey component, including a discussion of these as linked to the study objectives. More specifically, it described the findings of the waste characterisation (baseline), how the various interventions including smartphone app and website affected waste output, and the prevailing attitudes towards recycling of the study community are presented.

Chapter 6: Discussion of the results: This chapter starts with a discussion of the QR code methodology. Centrally, waste generation and recycling rates are discussed. The prevailing attitudes of residents are also discussed, along with motivating and demotivating factors which interact with these attitudes. The chapter concludes with a consideration of furthering the relationship with waste pickers as well as possibly including biodegradables in future interventions.

Chapter 7: Conclusion and recommendations: Chapter 7 brings the study round full circle to the manner of resolution of each of the research questions. Important recommendations for further investigation and study are outlined in bringing the study to a close.

CHAPTER 2: REVIEW OF INTERNATIONAL LITERATURE

2.1 Introduction

Across all countries, a fundamental environmental issue is the need for sound management of waste streams (Twardowska, 2004; McKay, Mbanda, & Lawton, 2015). Globally, solid waste management is facing challenges associated with population growth, increased urbanisation and waste streams of ever greater quantity and complexity. In addition, solid waste needs to be managed within the context of changing regulatory regimes, climate change concerns, and a scarcity of raw resources (DST, 2014). There is a growing move away from landfilling, facilitated by new stringent management controls, increased costs, and a push for 'zero-waste' (DiGiacomo et al., 2017). Crucially, landfills emit methane (a potent greenhouse gas) and pollute groundwater and soil with heavy metal and synthetic compound leachates (Woodard, Bench, & Harder, 2005; WCG, 2015; Midhar Harijani, Mansour, Karimi & Lee, 2017). Thus, reducing reliance on them is important from an environmental management perspective.

In the context of resource scarcity, it is no longer economically or environmentally feasible to ignore waste as a resource. Thus, a fundamental driver towards recycling and materials recovery is the economic demand for such resources. Therefore, municipalities are moving away from landfilling in favour of alternative waste management options such as materials recovery and energy conversion (DST, 2014). Some have implemented capital intensive, advanced waste treatment facilities, while others have adopted low-tech, labour-intensive options. One aspect of materials recovery is recycling, which continues to gain attention as a means of mitigating environmental damage since it offers "one of the most sensible solutions both economically and ecologically for managing waste" (Omran, Mahmood, Abdul Aziz & Robinson, 2009:276). There are also important indirect benefits of recycling campaigns and recycling initiatives. By raising educational awareness of recycling, broader waste and environmental management issues are in turn highlighted and elevated (Palm, 2012).

In the European Union (EU), Waste-to-Energy (WtE) technologies (including incineration, pyrolysis, and anaerobic digestion) and recovery technologies (including recycling) are becoming common. Diversion strategies have resulted in ever-increasing diversion rates: Germany had a 62% municipal diversion rate in 2010. Italy and Belgium dispose of less than 20% of solid wastes in landfills (DST, 2014; Dai et al., 2015). While there are a large range of municipal recycling rates in the EU (64% in Germany to 1% in Serbia in 2014), the average municipal recycling rate for the region has increased from 30.6% in 2004 to 43.6% in 2014, underscoring the effectiveness of targets and strategies for waste diversion (EEA, 2017). In addition, revised recycling targets in the European Union (EU) are estimated to create 180,000 jobs, while diverting 70% of Municipal Solid Waste (MSW) by 2030 (WCG, 2015). However, it should be noted that these statistics are influenced by the practice of many EU markets, who, instead of building their own recycling industry, export waste (such as plastics and paper) to China (Xevgenos et al., 2015). In contrast, the United States of America (USA) has a modest 35% recycling rate (Saphores & Nixon, 2014). The USA still sends over half (52%) of all MSW to landfills – a trend largely unchanged for at least a decade (Sidique, Ludi & Joshi, 2010; EPA, 2017).

Saphores & Nixon (2014) outline a three-step evolution of a typical recycling system: the introduction of kerbside recycling, the promulgation of legislative and regulatory directives, and the launching of fee or remuneration-based systems where users pay for waste management services or are reimbursed for returning materials such as beverage bottles. In another example of a progressive recycling strategy, 40% of China's copper production is from secondary materials. These successes can only be achieved with a strong focus on recycling and energy recovery, in turn through the development of a circular economy promoted by reduced resource usage (DST, 2014). Some of the best practise methodologies for waste management and recycling system implementations will now be discussed.

2.2 Best practise methodology

Xevgenos et al. (2015) reviewed 19 cases of best practice recycling systems around the world. They found that the most critical element was access to combined collection systems, that is, kerbside pickups, recycling banks, and drop-off centres. Combined collection systems lead to higher recycling rates, regardless of the maturity of the system (Miliute-Plepiene, Hage, Plepys, and Reipas, 2016). Source separation also lowers per-capita waste generation. For example, Areeprasert at al. (2017) found a 39% lower per-capita waste generation (by mass) when comparing two communities in Bangkok, one which source-separated MSW (municipal solid waste), and one which did not. Source-separation also means less cross contamination, making the processing of waste easier and cheaper (Zheng, Zhang, Zhang, Wang, & Wang, 2015). In terms of organised collection of recyclables, worldwide, household waste collection systems vary from no organised collection to the doorstep collection of 10 separated recyclables using multi-compartment vehicles (Dahlén & Lagerkvist, 2010). Xevgenos et al. (2015) reported that the kerbside collection of at least three different types of recyclables was the best way to achieve high quantity and quality of source-separated materials. In addition, the quality of source-separated recyclables was maintained or improved where regular information updates and clearer labelling of containers was practised (Miliute-Plepiene et al., 2016). Bernstad (2014) found that providing food separation equipment in an appropriate location, i.e. in the kitchen cupboard of each apartment, contributed to increased diversion of food wastes. Such separation of organics can provide the materials for high quality products such as compost and biofuel (Xevgenos et al., 2015).

Banning materials such as plastic bags and light bulbs from entering landfills, are powerful measures but do not create a revenue stream. Landfill taxes were found to have a weak effect in encouraging sustainable practices whereas Pay-as-You-Throw (PAYT) systems were effective as they continuously exposed residents to the cost of the waste that they generated (Xevgenos et al., 2015). In Canada, Ferrara and Missios (2005) found that user fees on garbage collection significantly increased recycling rates for almost all materials. In another example, the Belgian region of Flanders, lauded as having the best recycling and prevention programme in Europe in 2012, centred its strategy around a PAYT implementation (Allen, 2012). This involved residual waste being heavily taxed, graduating down from organics, to plastic bottles and certain packaging types, while paper, card, glass, and textiles collection were free of charge. Mwanza and Mbohwa (2017) in their review of drivers of plastics recycling found that incentives directly influenced recycling rates at household and community level. Along similar lines of reasoning, deposit-refund systems can also increase recycling rates as they directly reward residents for depositing sorted materials at specific collection points. However, Miliute-Plepiene et al. (2016) found that financial incentives for sorting or collecting waste and depositing at drop-off points were not significant in a mature Swedish system, nor in an emerging Lithuanian system.

Thus, recycling systems are specific to each community and often require piloting and responses to empirical observations to be effective and sustainable. Several examples serve to illustrate that recycling initiatives may not perform as expected. In Malaysia, the questionable sustainability of recycling systems prompted studies to profile recyclers in an attempt to influence behaviours toward best practise (Zen, Noor, & Yusuf, 2014). In England and Wales, the many variations in the collection cycle have evolved to meet local preferences and conditions, with fortnightly (alternating weekly) collection emerging as the most common approach moulded by local authority resource constraints (which prevent more frequent collection) (Woodard et al., 2005). In respect of collection container systems, there is no consensus as this once again varies across communities. In England, for example, the predominant methods are separate containers for each waste stream (plastic, paper, metals, glass), twin-stream systems (paper, and metals/plastics/glass), or co-mingled collection (Waite, Cox, & Tudor, 2015). Thus, the message emerges that pre-analysis of the study site and community profiling is vital to the design of a sustainable recycling system.

2.3 Challenges and opportunities in recycling

At a fundamental level, recycling represents an opportunity to re-use materials for manufacturing or energy recovery, while simultaneously reducing disposal and environmental costs associated with landfilling. The increasing global demand for resources means that global markets are attracting recyclables in greater quantity and quality. Thus, recyclables (together with organics and industrial streams such as mining tailings) represent an 'opportunity waste stream' (DST, 2014). The untapped potential in developing countries is huge, with countries such as Algeria, Cambodia, and Morocco collecting up to 70% of their waste but only recycling 5% of this (Dai et al., 2015). Negative consequences are inevitable, as in the case of Cameroon, which faces significant waste management challenges due to increasing waste volumes, declining collection rates, and a constraining environment for development in the sector (McKay et al., 2015). In another example, Nigeria has 509 critically stressed landfills, leaving unprocessed wastes visible across most parts of the country (Abd'Razack, Medayese, Shaibu, & Adeleye, 2017). However, there is much opportunity for growth with the implementation of systems and processes, backed by enabling governmental policy and private sector involvement. In Maputo, in 2014, a public waste monitoring system was developed to address the capital city's continuous growth and demand for basic infrastructure and services. This technological system allowed for text message, telephone, mobile, or email reporting of waste-management-related issues. This in turn enhanced the quality of these services by raising awareness of citizens, allowing reaction to issues, allocation of resources, and monitoring of service levels (Barroca, 2014).

Challenges of a different type are present in developed countries, where opportunities exist to improve 'established' recycling rates. An example where improvements have been seen over a period of time is in Nagoya City, Japan, where recycling is now a social norm, and an increase in recyclables recovery of 250% (including per capita household waste reduction from 460kg to 275kg) was achieved between 1998 and 2013 (Zheng et al., 2015).

A significant challenge to the recycling industry lies in the efficiency of recovering and recycling materials (DST, 2014). In institutional settings, the cost saving opportunity for collection services may be significant. The University of Idaho waste stream characterisation study determined that reducing recyclables going to landfills would allow for a downscaling and optimisation of dumpster pick-up routes, with a projected cost saving of USD 70,000 annually (Nagawiecki, 2009). In terms of source-separation, labour-intensive separation of recyclables from the general waste stream is more effective for extracting high quality materials. Maintaining sufficient flow of quality recyclables for processing facilities and markets (feedstock management) precedes technological interventions. In addition, increasing product complexity at the design stage limits later dismantling and therefore recyclability (DST, 2014). Even in the developed economy and recycling culture of Japan, recycling systems cost the city of Nagoya JPY 36.9 billion. Surveillance cameras and other equipment, which add to nett complexity and cost, monitor the misuse of recycling facilities to avoid cross-contamination (Zheng et al., 2015). Thus, when implementing recycling systems, costs of various types need to be factored (Hage, Söderholm, and Berglund, 2009). However, Xevgenos et al. (2015) suggest that extra effort in source separating eventually offers waste management authorities cost savings. At the household level, the example of the receding recycling rates of Canada serve to frame the challenge of maintaining or improving recycling rates in countries where recycling is perceived as a social and environmental good. Municipalities are thus faced with the ongoing challenge of finding ways to recover more materials and increase participation (Lakhan, 2016).

2.4 Waste stream characterisation

Waste stream characterisation studies are undertaken to determine the relative proportions of component materials that make up the waste stream. This includes plastic, paper, glass, and organic materials (garden waste, food waste) (CSIR, 2017b). A quantitative knowledge of the waste stream in the respective setting is an essential part of appropriate decision-making when embarking on a waste management programme (Twardowska, 2004; Kamara, 2006; Pollard et al., 2007; Taiwo, 2009; Dahlén & Lagerkvist, 2010; Mbeng, Tudor, & Fairweather, 2011; Nwokedi, 2011; Late & Mule, 2012; Samah et al., 2013; Oelofse, Muswema, & Koen, 2016). Waste characterisations allow targets to be set for waste prevention and reduction and provide baseline data against which goals can be assessed (EPA, 1995). These data then form part of a larger suite of evidence-based investigations that are arguably the best means of effecting positive waste management change. In effect, the results of waste stream studies inform local government regarding the formulation of strategies for the more effective use of available waste resources (CSIR, 2017b). At the municipal level, differences in residential waste stream composition are influenced by factors such as: socio-economic status, types of industry, geographic location, climate, consumption levels, collection systems, population density, levels of recycling, legislative and regulatory structures, and attitudes towards waste management and recycling (Taiwo, 2009). Significant variation in the waste stream of Multi-Family Dwellings (MFDs) is associated with factors including seasonality (becoming lower in autumn and winter in general), economic influences, and the keeping of pets (for example, cat litter) (Pollard et al., 2007).

2.4.1 Quantitative waste stream indicators

Dahlén & Lagerkvist (2010) suggest the following important indicators. Firstly, the Specific Waste Generation Rate (kg/capita/year), notably the most fundamental waste stream descriptor. It expresses waste mass generated per person per year. It can be applied to component material streams or to the aggregated waste stream. A useful related quantitative indicator (reflecting recycling behaviour) is the recyclables output per household, which can be used to calculate the fees payable (in the case of private collection of recyclables), or for incentives schemes (Wang, Richardson, & Roddick, 1997). Secondly, the Source-Sorting Ratio (weight-%), which is the sum of sorted waste in relation to the sum of all waste. The term 'recycling rate' is also sometimes used, but with the assumption that sorted materials are used to produce new products, a significant caveat. Thirdly, the Ratios of Materials in the Residual Waste (weight-%), i.e., the fraction of a specific material (such as glass) over the residual waste portion. These indices are useful when planning a specific waste treatment intervention, or when planning campaigns to recover certain material types. Fourthly, the Ratio of Mis-sorted Materials (weight-%), which represent the proportion of sorted materials mis-sorted over the residual portion. These ratios are useful when considering component waste stream processing options or sorting interventions.

Quantitatively, participation in recycling programs (kerbside) is most often gauged using the 'set-out' rate (percentage of households which set out recyclables on collection days), the participation rate (set-out rate within a given period), and quantity of recycling materials per recycler. The participation rate enables collectors to calculate efficient collection routes, and to determine the feasibility of servicing an area (Wang et al., 1997). However, the participation rate does not necessarily predict total recycling yield. In some cases, higher participation rates have been associated with lower total output of recyclables.

2.5 Motivating and demotivating factors that influence recycling

2.5.1 Willingness to recycle versus action

Several studies focus on, or have integrated into their design, a consideration of the factors which facilitate or act as barriers to recycling practises (Pollard et al., 2007; Omran et al., 2009; Taiwo, 2009; Dahlén & Lagerkvist, 2010; Abdelnaser, Mahmood and Read, 2011; Samah et al., 2013). The key is to get people to start participating in source-separation, and then to continue participating. Czajkowski, Kądziela, & Hanley (2014) found strong empirical evidence that people are willing to sort waste themselves at the household level rather than discard unsorted waste even in the absence of taxes or fees. However, attitudes which influence participation are complex. Thus, deciphering which of these have a practical effect on expressed behaviours, and how these might be manipulated for best practice is not straight forward. Oftentimes, there is a distinction between expressed willingness to sort and recycle and actual recycling rates (Dahlén & Lagerkvist, 2010; Saphores & Nixon, 2014). In general, the correlation between positive attitudes toward the environment and demonstrated behaviour is weak. While recycling may be voluntary or required by legislation, an understanding of the factors which lead people to participate, which, in the case of recycling, does not necessarily lead to direct personal gain, is important. So, attempts to implement a sustainable formal recycling system in any study site, a consideration of facilitating and discouraging influences is therefore crucial.

2.5.2 Predictors of recycling behaviour

Various theoretical frameworks exist which consider the predictors of recycling behaviour. Saphores & Nixon (2014) categorise predictors of recycling behaviour as either (1) external, that is, socioeconomic and demographic, or (2) internal, such as attitudes, norms and beliefs, as well as (3) policy-linked behaviours, namely cost and convenience of the system. Another theoretical grouping based on meta-analysis of 63 empirical studies categorises variables into four groups: socio-psychological, technical-organisational, socio-demographic, and study-specific (Miafodzyeva & Brandt, 2013). Most engagements with the literature confirmed that predictors of recycling behaviour fell into one of these groupings. For instance, Samah et al. (2013) found economic status strongly influence generation rates, with increased per-capita waste generation. Yau (2012) found income level the main statistically significant factor with respect to recycling behaviour in a study of high-rise residential settings in Hong Kong. Abd'Razack et al., (2017) describe another 'socio-economic' example in Nigeria, which is experiencing a meteoric increase of waste generation due to improved living standards. Dahlén

& Lagerkvist (2010) reflect too, that changes in recycling system outputs are ultimately economically driven, with recycling system outputs dependent on personal choice in private consumption, product design, and source-separating behaviour (Dahlén & Lagerkvist, 2010). Similarly, in Kuala Lumpur, non-recyclers were predominantly tenants of one-story houses, of lower income and educational level, with little knowledge of recycling and peripheral issues, whilst recyclers were largely individuals who owned houses, had higher educational levels, higher income, and more developed social norms around recycling (Zen et al., 2014). As such, programmes and strategies designed to influence recycling behaviours should be aligned to the socio-economic backgrounds of the associated communities.

Despite various approaches to the study of recycling behaviour, wide-scale meta-analysis identifies convenience (technical-organisational), moral norms (socio-psychological), information (socio-psychological), and environmental concern (socio-psychological), as being the strongest predictors of household recycling behaviour (Miafodzyeva & Brandt, 2013). The correlation between moral norms suggests that recycling should be projected as a socially important and positive activity. The relationship between behaviour and environmental concern advocate that recycling initiatives should be sufficiently promoted, residents' levels of education raised to enable their confident participation, and the message to recycle reinforced through repeated exposure. Dai et al. (2015) promote such a means of promoting recycling behaviour, through 'doorstepping': knocking on doors of apartment complex residents, delivering a short interaction, with the goal of providing recycling-related information. This increased the recycling rate by 12.5% in a complex in Shanghai, China. Results also showed that it was the delivery method, i.e. the interaction, and not a typical environmentally related message, which proved effective. This finding serves to emphasise the importance of face-to-face connections to encourage recycling behaviours. Thus, a combination of internal and external factors forms a strong basis for understanding recycling behaviours and requires careful consideration when designing recycling initiatives.

The factors around the recycling decision, that is, to collect, store, and dispose of recyclables, versus simply disposing, are complex (Omran et al., 2009). Many statistically important variables are reported in addition to the 'top four' categories mentioned above. For instance, more than forty factors are reported by Dahlén and Lagerkvist (2010) as influencing recycling behaviour. In many studies, stratification of variables is used as a means of investigation and comparison. For example, stratification using incentives, residential structure (multifamily vs single residence), and type of collection service, are frequently used to investigate recycling behaviour. However, care must be applied when interpreting and analysing the findings in the literature, both in large and small-scale studies. For example, Xevgenos et al. (2015) in their analysis indicate that Pay as You Throw (PAYT) schemes were common to most high-performing recycling systems worldwide. This is disputed by Miafodzyeva & Brandt (2013), who, while acknowledging that 'unit pricing' (volume or weight-based billing) is becoming popular, found the non-dependence of recycling behaviour on unit pricing in more than half of the studies they reviewed. Since environmental behaviour is also influenced by intrinsic factors, namely personal norms, such as personal satisfaction, feelings of competence, and participation, incentives-based systems which reward good (and punish poor) behaviour will likely be insufficient to induce pro-recycling behaviours (Lingard, Gilbert, & Graham, 2001).

Inconvenience is the most commonly cited factor for non-participation or low recycling rates (Ebreo & Vining, 2000; Abdelnaser, Mahmood & Read, 2011; Miliute-Plepiene et al., 2016). Non-recyclers frame inconvenience in several ways. Commonly, drop-off points, kerbside facilities or recycling bins are cited as lacking or being too far away (Abdelnaser, Mahmood & Read, 2011; Zen et al., 2014). Taking materials to collection points was also noted as being too time consuming or 'troublesome' (Ko & Poon, 2009; Zen et al., 2014; DiGiacomo et al., 2017). Thus, the role of convenience cannot be overemphasised. Stated in the positive sense, convenience is the strongest predictor of recycling behaviour (Miafodzyeva & Brandt, 2013; Saphores & Nixon, 2014). Thus, the most effective measure to promote recycling is increasing convenience, making drop-off and kerbside facilities close to households. Convenience relates to the design of the recycling system. For example, the container size must enable residents to store the appropriate amounts of waste until transfer to a bigger disposal bin for collection is possible (Land & Wagner, 2013). Interventions should also be convenience centred. In an apartment complex setting, DiGiacomo et al. (2017) measured a 70% increase by mass in the recycling of compostables simply by providing recycling infrastructure (containers) close to apartments instead of in the basement. An increase of 139% was measured when bins were placed only 1.5m away. Likewise, Bernstad (2014) found a 49% increase in food separation by mass after the introduction of food segregation containers on the inside of kitchen sink cupboards, stressing the significance of making simple infrastructure available close to where the waste is generated (Bernstad, 2014).

2.6 The apartment complex / multi family dwelling (MFD) setting

Some empirical evidence suggests that single-family dwellings (SFDs) recycle more than multi-family dwellings (MFDs) (Ando & Gosselin, 2005; Lakhan, 2016). SFD's in Ontario, Canada, for example, recycle 10 times as much as MFDs. This may be primarily because SFDs have more storage space and 'convenience' to store recyclables than MFDs (Ando & Gosselin, 2005; Ko & Poon, 2009; Zen et al., 2014). In contrast, Abdelnaser et al. (2011) found the highest recycling rates (up to 61%) in MFDs. It is possible that the aggregated living configuration of the MFD lends itself to recycling by virtue of residents' mutual proximity. However, in the case of the latter study, the resident community were largely students and educated workers with elevated levels of environmental awareness. Factors that decrease the time cost of recycling in MFDs have significant positive correlation with recycling rates (Ando & Gosselin, 2005). Distance to the communal bin, and sufficient internal space for processing recyclables, were found to be significant. The perception of interior space in MFDs may be linked to attitudes towards recycling, educational levels, and promotional activities to motivate residents to find the space that they previously thought was insufficient.

Because of limited storage space, the collection of a communal bin, and limited kerbside services, multifamily dwellings (MFDs) pose a unique challenge since larger, undesirable accumulations of recyclables can occur, hindering recycling efforts. In the USA, the average recycling rate for MFDs is as low as 15%, though in exceptional best-case practices 50% has been achieved (Lane & Wagner, 2013). Collection frequency in the MFD setting (for those sites which municipal service) also offers a challenge: a fortnightly frequency of collection of recyclables – the most common one in England and Wales, for example– would not work in a MFD setting because containers would quickly overflow. Appeals to private removal services (with increased cost) may also be necessary for MFDs where municipal recycling programmes are not in place nor designed for SFDs (Woodard et al., 2005; Lane & Wagner, 2013).

2.7 Conclusion

The move away from landfilling, whether through low-tech or more labour-intensive means, is a global phenomenon driven by the demand for resources or by regulatory legislation in a move towards achieving 'zero waste'. Best practise methodologies for waste stream characterisations and recycling systems are those which are tailored to the community, waste stream(s), and scale of the undertaking. Willingness to recycle versus actual recycling behaviours were seen to be weakly correlated, and convenience emerged as perhaps the primary motivator (or demotivator) behind waste separation behaviours. Recycling systems in turn need to be designed with the recyclers' needs and preferences in the foreground. Other significantly correlated variables in predicting recycling behaviours included moral norms, information, and environmental concern. With the international context highlighted, Chapter Three focuses on the South African context to finalise the literary standpoint anchoring the study.

CHAPTER 3: REVIEW OF SOUTH AFRICAN LITERATURE

3.1 Introduction

In the past, waste management was assignment a low priority status across governmental hierarchies. However, urbanisation and the resulting increases in consumption of products and services, together with socio-economic drivers such as unemployment and diminishing landfill space, have forced government to prioritise waste management issues (Oelofse & Godfrey, 2008b; WCG, 2015). Solid waste management issues are often linked with urban settings because their generation rates are so much higher than those in rural areas (DEA, 2018). Collection is also better in urban settings, with an increase from 56.7% in 2002 to 64.9% in 2016 of South African households enjoying waste removal services at least once a week (StatsSA, 2016b). Currently, municipalities and their service providers typically manage household waste, whereas private companies manage commercial/industrial waste (GreenCape, 2017). Illegal dumping is also a significant problem. For example, the City of Johannesburg (CoJ) spends around R170 million annually cleaning up illegal dumping sites (CoJ, 2017b; WCG, 2015).

It is estimated that, per annum, South Africa loses roughly R17 billion worth of materials to landfills (CSIR, 2017a; GreenCape, 2017). This lost revenue warrants a more aggressive approach to recycling and recovery (Burger, 2014). The implication is that, a transition away from landfilling, is only possible if supported by a suitable socio-economic and political environment. Tackling the problem of solid waste by considering technological interventions such as Materials Recovery Facilities (MRFs) is dependent on a reliable flow of source-separated materials and, in turn public involvement, to ensure their economic feasibility (DEA, 2014a). Problematically, separation at source is relatively new in South Africa and not widely practiced (CSIR, 2011; DEA, 2012). Thus, MRF may divert far less than theorised if public involvement does not materialise, as happened in the City of Cape Town's (CoCT) MRF and composting plant, for example (Nkala, 2012).

For municipalities to process municipal solid waste (MSW) effectively, governance challenges must be addressed. Oelofse and Godfrey (2008b) identified four challenges that municipalities face regarding effective disposal and collection of solid waste: (1) financial management, (2) equipment management, (3) personnel management, and (4) institutional planning and management. In this light, most municipalities face serious economic, social, and environmental challenges around the management of MSW (WCG, 2015). Spiralling transportation costs, for example, are making the traditional 'collect and dump' approach increasingly economically untenable. An increasing middle class and tendency towards urbanisation means that the volume of MSW is set to double. Thus, the country may soon face a waste crisis if waste management practises do not change (WCG, 2015). A fundamental shift is needed. That is, South Africa needs to view waste as a resource, a way of creating employment, alleviating poverty, and putting resources back into the economy. This includes WtE (waste to energy) facilities, which would convert resources otherwise destined for landfill into energy at a time where energy resources are not secure.

3.2 Legislation pertaining to waste in South Africa

Protection of the environment through proper enforcement of waste management legislation is a priority (Oelofse & Godfrey, 2008a). South Africa has followed a progressive path towards proactively managing waste aligned with international best practise. It graduated from the basic approach of highlighting the need for a clean and safe environment, to an integrated waste management protocol with supporting legislation (Oyekale, 2018). The following provides an overview of the development and current status of South Africa's legislative framework around environmental and waste management and how it supports recycling practices.

3.2.1 National Environmental Management Act No 107 of 1998 (NEMA)

The National Environmental Management Act (NEMA) of 1998 provides the legislative framework for environmental protection in South Africa at a national level, with municipalities playing a vital role locally (CoJ, 2011; Sentime, 2014). It replaced the Environmental Conservation Act 73 (ECA) of 1989 which was the only legislation for controlling waste facilities for more than a decade (DEA, 2016). Eventually the ECA was considered too basic a tool for protecting the environment and was replaced by NEMA.

NEMA transformed the legal landscape around waste management, creating an integrated framework including a life-cycle approach to address each step in the waste management hierarchy (DEA, 2011). In addition, NEMA is centred around *sustainable development*, so that meeting the needs of the present generation doesn't compromise these resources for future generations (Sentime, 2014). It does so through the following guiding principles in Chapter 5: *"Polluter pays"*: those inflicting environmental damage must pay for the costs to repair the damage to the environment and human health, thus placing a duty of care to minimise and rectify pollution or degradation where it cannot be avoided (DEA, 2011); *"Cradle-to-grave"*:

a policy, program, project, etc., has responsibility for environmental health and safety throughout its lifecycle, from conceptualisation, through to re-use, recycling and disposal; *"Precaution"*: government will take a cautionary stance where there is limited knowledge about the consequences to the environment over decisions or actions; and *"Waste avoidance and minimisation"*, that in the best case, waste management should strive to avoid and minimise creating waste at source, including recycling activities (CoJ, 2011; Sentime, 2014; DEA, 2011, 2018;). NEMA was meant to pave the way to a proactive waste management framework around which non-landfill technologies would develop and stipulates the legislative channels around activities which have environmental impacts (Sentime, 2014; DEA, 2018).

The provisions of NEMA lead to the current framework by which waste management is governed, the National Environmental Management Waste Act (NEM:WA), 2008 (Act No. 59 of 2008) (DEA, 2016; 2018). Historically, waste management was managed by fragmented pieces of legislation in different departments, resulting in inconsistency and poor waste management practises (DEA, 2015a). As such, the NEM:WA was a milestone. Consolidating legislation for common understandings and applications regarding waste management (DEA, 2015a). It is guided by the principles of the waste management hierarchy, offering a systematic approach to integrated waste management, addressing waste avoidance, reduction, re-use, recycling, recovery, treatment, and disposal (to landfill) as a very last resort (DEA, 2011). The NEM:WA states that all listed waste management activities must pass through an environmental impact assessment (EIA) process to obtain a license (DEA, 2018).

The NEM:WA (2008) spurred several improvements and additions to the legal framework, some of the important ones are: the South African Waste Information System (SAWIS), a reporting tool for generators, recyclers, disposers, and exporters, to inform waste management decisions. Long-term strategic planning issues gave rise to the Integrated Waste Management Plan (IWMP), developed as a waste management tool for government. These are five-year plans reviewed annually and submitted by municipalities for provincial approval. The National Waste Management Strategy (NWMS), in its third and most recent revision in 2018, has eight goals which seek to realise the NEM:WA (DEA, 2018). Updates to fiscal policy in terms of encouraging/discouraging recycling include the National Pricing Strategy for Waste Management (NPSWM), aiming to address the under-pricing of waste services. The resulting relative cheapness of landfilling perpetuates it, instead of encouraging integrated waste management principles (GreenCape, 2017). Levies were introduced to change consumer behaviour and encourage recycling, including, a plastic bag levy (increased in 2018 by 50% to

12 South African cents per bag), and a tyre levy in 2017 on manufacturers of R2.30/kg per tyre (DEA, 2018). In terms of economic instruments, the 'polluter pays principle' embedded within the National Environmental Management Act still guides strategy. An important legislative implementation of this came in the form of notice that was given to packaging, electrical, and electronic lighting industries, to prepare an Industry Waste Management Plan (IndWMP). In addition, the National Norms and Standards for the Disposal of Waste to Landfill in terms of the NEMWA of 2008 was effected in August 2016, the requirements for which concern, among other things: construction of landfill sites, waste acceptance criteria for landfill sites, and prohibited waste (GreenCape, 2017).

3.2.2 Definition of waste

Subsequent shortcomings and ambiguities around the NEM:WA developed, leading to the effecting of the National Environmental Management: Waste Amendment Act (NEM:WAA) of 2014, including the advancing of an explicit definition of waste (DEA, 2018). Defining waste is important because it allows for the regulation and management of waste, putting limits on the impacts on the environment and human health (Oelofse, 2009). In the past, South Africa had at least two legal definitions of waste, based on its unwanted or superfluous nature, and on its potential to pollute, respectively (Oelofse & Godfrey, 2008a). This created a very broad but restrictive policy environment which had the practical impact of stifling waste entrepreneurship. The NEM:WAA (2014) following from the NEMA contributed the following definition of waste as: "*any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, by the holder of the substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act*" (DEA, 2016). Additionally, waste was now split into two categories according to risk factor: (1) *general waste* is that which does not pose an immediate threat, and includes domestic waste, inert waste, business waste, or C&DW; and (2) *hazardous waste*, including any waste that "*contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment*" (DEA, 2016; DEA, 2018).

Internationally, the promotion of waste recycling and recovery has been via legislation targeting specific waste streams rather than through all-encompassing frameworks (Oelofse & Godfrey, 2008a). Models of waste management that start with the assumption of materials as a resource rather than waste have better potential to encourage recycling and re-use by promoting industrial activities which can focus more on sustainably channelling wastes for re-processing or energy production (Oelofse & Godfrey, 2008a; Oelofse, 2009).

3.3 Statistical overview

South Africa currently produces around 111 million tonnes of waste, 75% of which goes to landfills (DEA, 2017). General waste constituted 42 million tonnes, hazardous waste 38 million tonnes, and unclassified waste 31 million tonnes. In 2017, only 4.9 of 42 million tonnes (11%) of general waste was recycled (DEA, 2018). Figure 3.1 shows the breakdown of this general waste output, of which the mainstream recyclables (glass, paper, plastic, metals) recycling rate is estimated at 34%. The category "other" refers to biomass mostly from the paper and sugar industries (DEA, 2018).

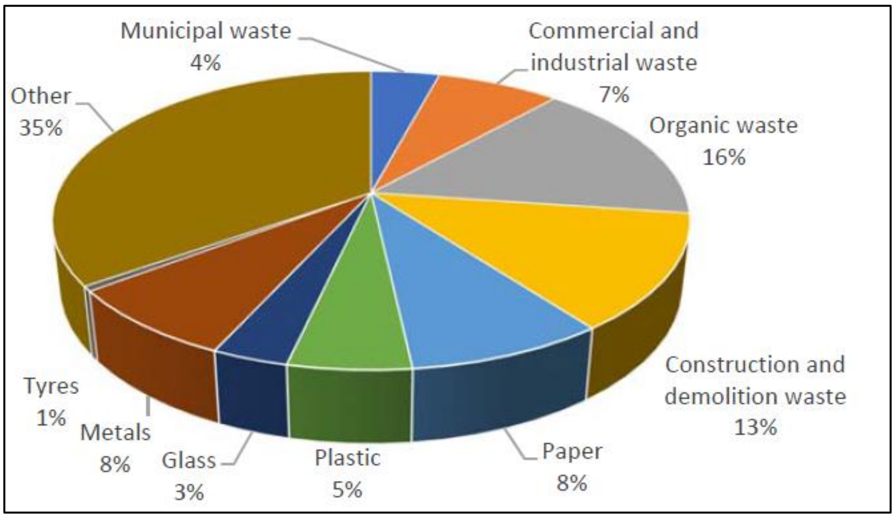
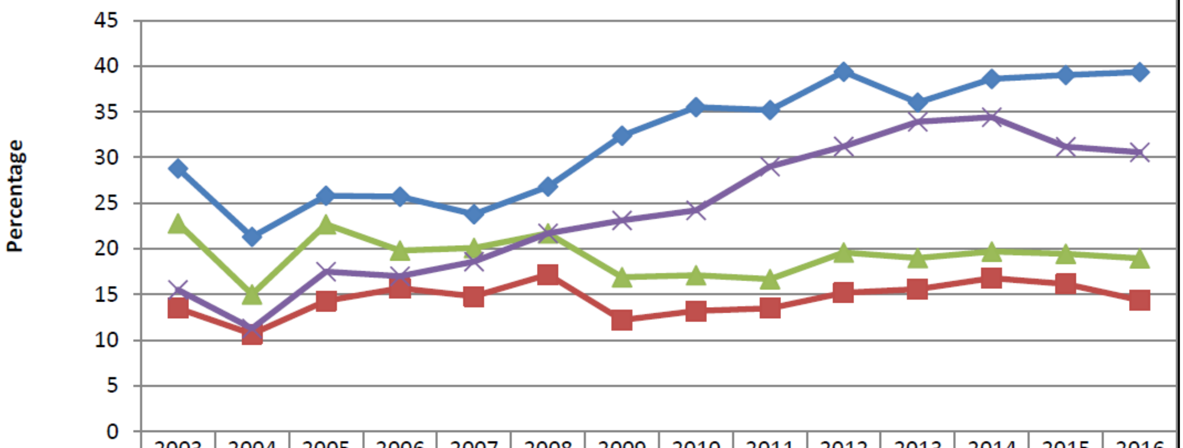


Figure 3.1 Breakdown of general waste in South Africa, 2017 (Source: DEA, 2018)

The concept of separation of recyclables is a concept still to take hold in most households: as recently as 2015, only 5.2% of the country's urban households regularly recycled their waste (StatsSA, 2018). Over the last decade, tangible targets to divert wastes have followed a progression of over-confident goals. In 2011, the Department of Environmental Affairs (DEA) set a target to divert 25% of recyclables from landfill by the end of 2015 (DEA, 2011). The target was revised down to 20% of recyclable waste from landfill by 2019 and then to 10% (DEA, 2014b). City of Cape Town (CoCT) is considered the most successful, having diverted 8.6% of its MSW in the 2010/11 financial year, a low figure despite investment by the CoCT in waste minimisation infrastructures and initiatives (Nkala, 2012). More recently, target reductions (by mass) of 20% of industrial waste and 60% of household waste have been set by the Waste Research, Development and Innovation (RDI) Roadmap by 2024 (Godfrey et al., 2014).



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Waste	28,8	21,3	25,8	25,7	23,8	26,8	32,4	35,5	35,2	39,4	36,0	38,6	39,0	39,3
Water	13,5	10,7	14,3	15,7	14,8	17,2	12,2	13,2	13,5	15,2	15,6	16,8	16,2	14,4
Air	22,8	15,0	22,7	19,8	20,1	21,7	16,9	17,1	16,7	19,6	19,0	19,7	19,5	19,0
Land	15,5	11,3	17,5	17,0	18,6	21,7	23,1	24,2	29,0	31,2	33,9	34,4	31,2	30,6

Figure 3.2 Percentage of households who experience specific kinds of environmental problems, 2003–2016 (Source: StatsSA, 2016b)

In terms of service delivery perceptions, Figure 3.2 highlights residents' concerns over environmental issues, of which waste concerns have increased in recent years and are in fact foremost among these (StatsSA, 2016b). In addition, the differences between the quality of service delivery in rural versus urban areas remains a concern. In Gauteng, for example, only 33% of rural versus 92% of urban residents enjoyed refuse collection at least once a week in 2016 (StatsSA, 2016b). This may encourage illegal dumping and inhibit recycling.

3.4 Infrastructure and alternative waste treatment strategy

To move away from a 'business as usual', landfilling approach, municipalities must consider alternative options and technologies, including advanced waste treatment (AWT) facilities (DEA, 2014a, DEA 2014b). However, the socio-economic, policy and institutional constraints particular to developing countries like South Africa, have caused several implementation failures of such technological solutions (CSIR, 2017a). In response, research to direct policy and decision-making based on the local and international knowledge base, will be indispensable for formulating successful solutions. AWTs are the next generation of waste treatment facilities, and refer to technologies that alter waste through thermal, physical, chemical, or biological treatment, prior to or in place of landfilling (DEA, 2014a). Introducing an AWT facility will usually incur an additional cost to the municipality, proportional to the complexity of the facility. The business case may only become compelling when social and economic factors are considered against (often marginal) profitability. In South Africa, labour intensity means that creating sustainable jobs is also an important consideration when choosing AWTs (Pienaar, Bhailall, Coetser, & Gcwensa, 2016). Possible solutions need to be relatively inexpensive, labour intensive, and have an established market demand for outputs.

In terms of solid waste recycling, the materials recycling facility (MRF) will be the most appropriate solution to meet South Africa's diverse waste management needs (DEA, 2014a). An MRF is a facility for sorting and recovering recyclable materials from the waste stream using a series of separation techniques, including hand-sorting, rotating drums, optical and air sorters, screens, and magnets (Rogoff, 2013). 'Clean' MRFs accept source-separated recyclables that then go on for further sorting and processing for the end-market buyer. The advantages are for higher recovery rates, less complex and costly sorting equipment, and lower need for hand-sorting. In contrast, 'dirty' or mixed waste MRFs accept unsorted waste. These may be appropriate for areas with service challenges or where source-sorting is not occurring for whatever reason, with the primary disadvantage being that practical recovery rates of 5-45% are achieved together with several operational and financial challenges (Rogoff, 2013). However, feasibility studies have suggested that, for South Africa, 'clean' MRFs would be most suitable since they require less capital expenditure and are simpler to operate than 'dirty' MRFs (Rogoff, 2013). In addition, given local parameters, MRFs would best be implemented with a manual sorting focus to create employment and training opportunities, together with some mechanical sorting (Sehlabi & McKay, 2016). The objective would be separation into waste streams for input into production processes, and fractional separation of fuel-components for refuse-derived fuel (RDF). In this way, valuable materials would be removed from landfill to enter the economy as energy or input materials (DEA, 2014a).

Practically, however, several capital-intensive MRFs have failed, including the Robinson Deep Waste Flow Plant in Johannesburg, the Resource Recycling Plant in Randburg, and a low-technology initiative in Durban by Tempo Recycling. The failures of these labour-intensive recovery facilities were not due to technical problems. Instead, overestimation of market value of the recyclables, economic downturn, and high demands on municipalities, were responsible (DEAT, 2008). That said, more recently, increased demands on landfill airspace and high operational costs of waste removal led to the renovation of the Robinson Deep MRF to resume processing 500 tonnes of recyclables per day (Chisadza, 2015). The importance of feed material from source-separation is once again highlighted, since through its introduction in several residential areas in Cape Town, it allowed the commissioning and successful implementation of South Africa's first MRF in Kraaifontein, with a 100 tonne/day sorting facility (Palm, 2012; SAICE, 2012). In monetary terms, source-separation is not always more beneficial than post-collection recycling. However, increases in public awareness levels around recycling and waste management is a significant benefit to be considered in such a decision. Ultimately, a one-size-fits-all approach will not work for each municipality or community, and a study of local conditions is necessary to provide a sustainable mechanism for separating valuable materials from the general waste stream (Palm, 2012; Lane & Wagner, 2013; Oelofse, 2018).

Considerably more expensive solutions than landfill such as WtE, may have a business case in the largest urban centres where landfill capacity is insufficient (DEA, 2014b). Despite the dominance of landfilling, surveys reveal a high level of innovation in the waste sector (Godfrey et al., 2014). Around 51% of private enterprises and 41% of municipalities indicated that they had introduced new product innovations within the last five years. Private enterprise was also more likely to import new technologies for the waste sector (Godfrey et al., 2014).

3.5 Socio-economic perspectives and contexts

Despite being a strong economy within the African continent, South Africa faces serious challenges to improve the waste management services and welfare of its population (Sentime, 2014). These include weak policy enforcement and monitoring, inaccurate and absent waste stream data, logistics deficiencies, and a shortage of experts to implement and manage solutions (Oyekale, 2018). Expansion of urban settlements, together with economic stagnation or decline, has resulted increasingly stretched and degraded services such as waste collection (Simatele, Dlamini & Kubanza, 2017). There is also the problem of motivation to recycle, where specific campaigns are needed to educate and enhance awareness, particularly amongst lower income groups (Oyekale, 2018). Despite this, the South African waste management sector is worth R15.3 billion in revenues per annum (CSIR, 2017a; GreenCape, 2017). It is a young sector. Per-annum revenues could double with strategic government and private sector investment (CSIR, 2017a). As with other developing countries, urban poverty together with high unemployment forces "waste pickers" into the informal market (in South Africa this is around 90,000 people) (Schenck, Blaauw, & Viljoen, 2016a; DEA, 2018). Waste pickers are individuals who collect, sort, and sell recyclable materials, mostly depending on this mode of existence for their survival (Schenck et al, 2016a; DEA, 2018). Recycling in South Africa is largely driven by these collectors, who are responsible for collecting roughly 80% of glass, 90% of PET plastic, and most paper for recycling in South Africa (DST, 2014). They are therefore deeply embedded within existing waste management systems (CSIR, 2017a; DEA, 2018) and contribute both economic and environmental wellbeing (Simatele, 2017). Paper recycling alone generates 37 000 formal and informal employment opportunities (RecyclePaperZA, 2017). Sixty-percent of waste pickers opportunistically target readily accessible materials on landfills, the remaining 40% use push trolleys to collect material, focusing on plastic (77%), followed by paper (69%), cans (65%), metal (58%), and glass and bottles (48%), with mean earnings of R1,430 per month nationally (DEA, 2015b).

Despite the vital role waste pickers play in reducing materials going to landfills, the unforeseen social problem which has emerged outweighs these benefits, as waste pickers lack personal protection equipment (PPE) (DEA, 2015b). The challenges faced by waste pickers include having to walk between sites and buyback centres, lack of infrastructural/municipal support, no formalised programmes to secure their income, health and safety risks associated with handling dangerous wastes (waste streams are largely mixed in South Africa), and several others (DEA, 2015b). In major cities such as Johannesburg, there is a continued lack of integration between the informal sector and formal systems (Simatele, 2017). Despite this, integration of technology and informal workers could have significant socio-economic benefits. For example, separating mixed solid recyclables on site (from source), or at a Materials Recovery Facility (MRF), represents an important opportunity to employ South Africans in a structured way at a time when unemployment is extremely high (DST, 2014; StatsSA, 2017).

The recycling industry in South Africa is has many well-developed sub-sectors, focusing mostly on packaging waste (Nwokedi, 2011; GreenCape, 2017). This is due to private-sector industry associations, and informal waste collection, creating demand and supply respectively. A prominent example is Collect-A-Can, started in 1993 by ArcelorMittal and Nampak. This organisation is responsible for improving the recovery rate for beverage tins from 18% to 72%, and for creating a culture of recycling to local and international fame, as well as making major contributions to job creation (GCIS, 2016). In South Africa, 80% of metals worth R12 billion a year are recycled (GreenCape, 2017). Considering the other major solid waste streams, paper, glass and plastics recycling can only be driven by mechanical processing technologies such as MRF’s, since their processing is only cost-effective in large quantities (DEA, 2014a; GreenCape, 2017). These facilities, however, require large capital investments and have to be driven by producers and material converters such as Mpact, Consol, SASOL, et al. Materials which cannot be recycled can be considered for other alternative treatment options, such as WtE (waste to energy) projects (DST, 2013).

Recycling as a feasible enterprise begins with offering cost savings on recycled input-materials for processes rather than the use of virgin materials, with or without the support of incentives. Hence recycling is only profitable within narrow parameters, and many municipalities who have attempted source separation have done so without adequate calculation of the costs involved or the assessment of local conditions and resources (Palm, 2012). Most municipalities have limited financial scope for considering AWT facilities. Public-Private Partnerships (PPP) are an attractive option however (DEA, 2014b). In addition, pricing distortions make the processing of waste for energy disproportionately expensive compared to coal power generation, discouraging shifts away from landfilling (Godfrey et al., 2014). Consensus is that introducing Economic Instruments (EIs) in South Africa will reduce waste generation and increase diversion from landfill (Nahman & Godfrey, 2010). However, several prerequisites need to be enabled for the successful implementation of these, including a legal framework, education and awareness, and infrastructure for extending basic waste services, to develop a culture of compliance (Nahman & Godfrey, 2010). There is also the problem of householders' motivations to recycle, where specific environmental campaigns are needed to educate and enhance awareness (Oyekale, 2018).

3.6 Waste stream data

Waste stream data is limited. As of 2012, only 23 waste stream characterisation studies have been undertaken, representing only 17 of 284 municipalities (6%) (DEA, 2012). Recent and current studies are underway in many cities to investigate diversion from landfill, including the CoJ, City of Tshwane, Ekurhuleni Metropolitan Municipality (EMM), and others. Insufficient information on waste volumes and types, and the incorrect choice of equipment and technology, has resulted in many failed interventions in South Africa. An example is a materials recovery facility (MRF) which was installed on a landfill site but which was not designed for the type of waste available to be processed, which resulted in crisis-management modifications to the international equipment at great cost (Oelofse et al., 2016; Sehlabi & McKay, 2016). 'Earthpower', a failed anaerobic food processing facility in Australia is similar. It was forced to close as its feedstock became contaminated (Oelofse et al., 2016). Thus, acquiring waste stream data does not necessarily lead to its effective use, due to the complex nature industrial processes, as well as political and bureaucratic interferences, inappropriate equipment and personnel constraints, all of which can jeopardise successful implementation (Godfrey & Scott, 2011).

3.7 Motivating and demotivating factors for recycling behaviour

The motivation for recycling falls into three categories: altruistic motivations (protection of the environment and related resources); economic factors (cost of waste disposal versus reuse of recyclable materials) and legal influences (legislative/regulatory) (Nxumalo, 1999; Saphores & Nixon, 2014). In the South African context, motivators and de-motivators to recycling behaviours largely follow international observations. Kamara (2006) found a link between socio-economic differences and participation rates in the City of Tshwane, where participation rates of 50%, 15-30%, and 0% were measured in the higher, middle, and lower income groups of Waterkloof, Sunnyside/Lynnwood, and Mamelodi respectively. Different modes and attitudes also matter. In the City of Cape Town (CoCT), lower income groups believed they needed compensation in return for participation in recycling (Nkala, 2012). Education levels have a direct correlation to environmental awareness and recycling rates. Kamara (2006) found in Tshwane, no link between disposal/recycling and the environment in an alarming 20% of sampled households, demonstrating a fundamental deficiency in education-led awareness. Thus, efforts to improve the availability and quality of waste services will not lead to increased participation where education is weak.

A lack of basic infrastructure to support recycling also presents a significant barrier. The City of Ekurhuleni (CoE) rolled out 77,000 240-litre bins in 2017/18 to replace plastic bags as part of an effort to improve waste management in critical areas. The rationale was to increase household waste storage capacity between collections to minimise illegal dumping. The CoE quotes an 18% recycling rate at present although this has not been independently verified (CoE, 2018). Behavioural factors extend to the municipalities, where a lack of consequence for non-compliance, and a low priority given to waste management within municipalities, have been noted as ongoing concerns (Godfrey & Scott, 2010).

Effecting improvement towards best practise, institutionally or otherwise, cannot be achieved by simply making more data available through analysis. This is because the relationship between data, knowledge, and behaviour is complex (Godfrey, Scott, Difford, & Trois, 2012). They found that perceived behavioural control (PBC) and not intention was the primary factor behind changing waste management behaviour. PBC refers to the ease with which an act can be performed, the perceived difficulty in performing the behaviour, or the extent/presence of facilitating/hindering factors to the behaviour (Godfrey et al., 2012). This explains why having a positive attitude and 'good intentions' towards recycling and waste management practises in general, does not always translate into action.

3.8 The City of Ekurhuleni (CoE) context

The study site is located within the City of Ekurhuleni (CoE) Metropolitan Municipality which has a population of roughly 3.1 million (Pienaar et al., 2016). The waste management mandate of the City includes street sweeping in central business and industrial areas, litter picking, kerbside and collection from informal settlements, as well as the operation of waste management facilities such as landfill sites and transfer stations (EMM, 2016). All formal and informal households and businesses in Ekurhuleni currently receive waste removal services at least once a week, totalling around 847,000 service points. However, it is recognised that while much progress has been made in the provision of basic waste management services, there is still significant inequality in the level of service delivery (DEA, 2018). Increased urbanisation and waste stream complexity have placed increasing pressure on waste management services. A primary infrastructural response has been the rolling out of 89,000 240-litre refuse bins (EMM, 2015). The model utilised by the CoE is to contract out 55% of waste management services to private contractors and cooperatives, with the aim of stimulating socio-economic opportunities (DEA, 2018). As many as 49,000 informal settlement households received waste collection services through cooperatives in 2016 (EMM, 2016). In addition, recycling received attention with the establishment of recycling banks in schools and recycling stations at customer care centres (EMM, 2015). Waste disposal rates for the City are calculated by using landfill sites' weighbridge data. The five major categories of waste are domestic waste (47%), industrial refuse, mixed rubble, clean building rubble, and clean compost (Pienaar et al., 2016). Despite enough landfill airspace, investigations suggested that four clean MRFs be constructed at landfill sites by 2020 to divert waste from these sites and extend their lifespan as part of medium- and long-term planning (Chisadza, 2015; Pienaar et al., 2016).

Opportunities exist for certain waste streams in the future, notably garden waste, which was revealed by waste characterisation to be a significant portion of the domestic waste stream (Pienaar et al., 2016). Another example of an opportunity waste stream being processed while creating jobs, is in South Africa's first refuse-derived fuel (RDF) plant, established in Germiston, Ekurhuleni, in February 2016. The facility accepts *non-recyclable* wastes (such as plastic) with high calorific value. An 80% saving in production is achieved due to source-sorting by 400 workers, both on site and at the customer's premises (Oliveira, 2016).

3.9 City of Johannesburg (CoJ) context

The CoJ context is outlined briefly in what follows because the study site borders this municipal zone, and because of similar waste management challenges which it faces. Landfill sites in the CoJ are under more pressure than those of the CoE, having less than nine years' capacity remaining, which could be described as a waste management crisis (CoJ, 2017a; DEA, 2018). Threats to the health of residents and visitors to the City through lack of service delivery and illegal dumping – the latter costing the City R170 million a year – are ongoing risks (CoJ, 2017a, 2017b). These issues manifest in the environmental degradation of open spaces and waterways, as well as the compromised cleanliness of the city (CoJ, 2017a).

Municipal Solid Waste (MSW) is the major component of the solid waste stream, accounting for more than half of all waste disposed of in the City of Johannesburg. In 2017, this translated to some 6,000 tonnes, collected from 831,000 households each day (CoJ, 2017a; CoJ 2017b). Residents enjoy a relatively high access to services: 95% of households have running water, flush toilets, and electricity (CoJ, 2017a). Though improving, there is still a backlog in services offered to the 180 informal communities, and in the worst cases there are unpleasant and unhygienic living conditions (DEA, 2011). Rural refuse collection services average 33% for Gauteng, despite the CoJ having the highest urban collection rate in South Africa of 96% (StatsSA, 2016b). However, there is room improvement with respect to the quality and consistent distribution of these services (CoJ, 2017a). Aside from refuse collection, the City's other priorities are the implementation of strategies and technologies to minimise illegal dumping and safely and sustainably manage waste sites (CoJ, 2017b). The City has voiced its forward strategy in transitioning away from waste management as generation, collection, and (landfill) disposal. It has backed this up by recently finalising two feasibility studies: a WtE solution for residual, non-recyclable, non-biodegradable MSW, as well as a 50-tonne bio-digester pilot study for biodegradable wastes of the City (CoJ, 2017b).

In moving away from landfilling, the CoJ, through its Integrated Waste Management Policy and Plan (IWMPP) has set targets for waste diversion from landfill at 30% by 2021 and 93% by 2040 (CoJ, 2017b), though poor implementation and widespread non-compliance with regulatory legislation has compromised its specification (CoJ, 2017a). Commercial response to recycling initiatives in a 2011 study was slow: nearly two-thirds (62%) of surveyed businesses were not recycling, despite a high proportion of recyclables reported in their waste outputs (Nwokedi, 2011). Additional targets by the CoJ include 100% reduction of illegal dumping target has been set by the city by 2040, together with 100% compliance with waste legislation (CoJ, 2017a).

In terms of solid waste separation at source, Pikitup, the CoJ's official waste services provider, has as one of its main projects the *Separate@source* programme. The project supports informal recyclers by setting up 'cooperatives': non-profit organisations which collect recyclables from the various areas which are part of the programme. It also sets up buy-back/sorting facilities and caged transportation vehicles managed by the cooperatives to coordinate the efforts of the informal traders (DEA, 2018). In an effort to encourage source separation, Pikitup initiated a pilot study in 2009, rolling out a three-receptable system to a number of households. One container was for general wastes, a reusable bag was provided for paper recyclables, and a clear plastic bag was issued for all other recyclables. Up to 500,000 households now participate, but no evidence was found for implementation in the apartment complex setting (Pikitup, 2017). Low participation levels in the Separate@source programme prompted a CSIR survey in 2018 which yielded insights into resident behaviour and perceptions, supporting findings which suggest that interventions which ultimately lead to increased source separation and participation must be structured around the specific needs of the community they serve (Oelofse, 2018).

One of the most recent waste stream characterisations has been of the Robinson Deep landfill in the CoJ to determine the proportion of organics being disposed of as a basis for evaluating a WtE proposition (Ayeleru, Ntuli, & Mbohwa, 2016). Compacted wastes contained 34% organics by mass (the largest waste portion), and non-compacted 'dailies' 14%. Similarly, the recent (as yet unpublished) EMM-commissioned characterisation found that as much as 60% of household waste was organic (garden and food wastes), despite efforts to divert these materials for composting, and providing evidence of energy profiles for possible WtE facilities for the City (CSIR, 2017b).

3.10 Conclusion

High-level governmental support has stimulated the waste recycling sector over the last 15 years (DST, 2013). Legislative support together with public-private partnerships has the potential to realise the R17 billion in materials currently being landfilled, while possibly creating several thousand jobs in the next five years (DST, 2014; GreenCape, 2017). Recycling, particularly through source-separation, will give increased access to materials that can stimulate South Africa’s emerging waste economy, allowing investment into more advanced technologies in transitioning away from landfill, including AWTs (Advanced Waste Treatment Facilities). Technological interventions such as AWTs are dependent on a supply of waste materials of sufficient quality. One readily available source of such materials exists in the case of the apartment complex, which offers a unique opportunity for source-separation of wastes, since there is a natural aggregation of materials, as well as the opportunity to influence behaviour through campaigns and interventions. While a few basic factors were found to be highly influential in significantly improving recycling participation and behaviour, the provision of conveniently accessible infrastructure was perhaps the most fundamental in terms of impact on recycling rates (Hage et al., 2009; DiGiacomo et al., 2017).

However, Lane & Wagner (2013) suggest first establishing a base of participants, and thereafter implementing interventions to improve the recycling rate. In conclusion, successful strategies and interventions in the recycling or greater waste management schema should at once take heed of the themes common to high-performing recycling systems, while simultaneously moulding around the unique parameters and context of the community and greater environment which they will ultimately serve. With the general theoretical groundwork laid, Chapter Four moves to add a research design and methodological framing in order to answer the research questions.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter outlines the planning and procedures followed in resolving the research problem. It explains why the case study research design was chosen as the overarching strategy of this study, as well as a critique of its limitations and how these were addressed. Methodological techniques for analysing the waste stream are considered using examples from the literature, familiarising the reader with both general and technical aspects of gathering these data. A brief theoretical description of the methodological setting and sampling strategy of the study is presented. Ethical issues are addressed in conforming to best practise, thereby maintaining the integrity and confidentiality of participants and any data generated. The methodological tools whereby the research questions would be addressed are specified, including a consistency matrix for this purpose and a data collection timeline to clarify the sequence in which the study was executed. The chapter also discusses the ways in which the validity and reliability of the data were maximised, given the central role of the waste stream and survey data in this study.

4.2 Research Design: A case study

The research design is the coherent strategy or 'blueprint' to ensure the study addresses the research problem (Mouton, 2006; Leedy & Ormrod, 2015). It ensures that appropriate planning is in place to direct all aspects of the project, so that the research problem will be resolved and fill an identified gap in current knowledge (Creswell, 2013). This study made use of a case study approach, which is the most widely used means of postgraduate research in South Africa (Rule & John, 2007). The case study was deemed suitable as not much is known about recycling interventions in apartment block settings in South Africa, neither is a wealth of literature available or further afield. The case study is also useful for investigating how a situation occurs, and how it may change after the introduction of interventions. Such studies may be precursors to additional, more generalizable ones (Leedy & Ormrod, 2015). Studying a system in-situ has the advantage, over a controlled laboratory setting, of observing complex phenomena and being able to more realistically describe the effects of interventions and provide commentary on possible extension of findings to other similar contexts. The case study allows for detailed insights and a more in-depth approach (Mouton, 2006; Rule & John, 2007; Breach, 2008). It is also a flexible approach since it can integrate elements of other design regimes. This 'mixed-methods' approach alluded to above and afforded within the case study architecture is now discussed as it was applied to the study.

4.3 Waste management data: Methodological considerations

Various techniques are used to collect waste management data. Modelling techniques based on generic waste generation rates are inexpensive but only provide a general idea of waste volume and type. Physical separation techniques such as quartering, block, and grid methods are accurate but time-consuming and suitable for smaller communities. Direct measurement techniques are capable of highly accurate data generation but are time consuming and costly (EPA, 1995). A balance therefore needs to be found between these factors considering the precision required and types of waste stream(s) being characterised. Detailed recording of the interventions enables future comparative studies, while primary variables including the number and type of waste streams, sampling size, and location, specify the framework of the waste stream quantification (Oelofse et al., 2016). The nature of the waste characterisation also needs to be tailored to meet the needs of different communities, evidence for which can be seen in the waste-stream studies below.

A typical example of a larger-scale waste stream characterisation (of six municipalities in Sweden over four years) is given in Dahlén & Lagerkvist (2010): five samples per municipality were taken along usual collection routes, during autumn and spring. Samples of between 200-500kg were extracted using quartering from a larger load, mixed using a front-end loader, raked into quarters, and mixed again. Eventual 200kg representative samples were then manually sorted into 21 categories, weighed, and recorded. Large-scale characterisation studies are often commissioned on behalf of city municipalities, such as for the City of Tacoma, Washington. The main objective of the City of Tacoma study was to identify further opportunities to divert waste from landfill by providing detailed statistical estimates of the primary waste categories. Samples were sorted into 79 material types, and quantitatively determined within a 90% confidence interval (Cascadia, 2010).

Stratification is often used to reduce the complexity of factors influencing the waste stream, depending on the aim of the study, by dividing the study into conceptual zones within which certain factors are constant (Dahlén & Lagerkvist, 2010). For example, Kamara (2006) stratified by income groups (higher, middle, lower), level of education (tertiary, high school, no formal education), and by suburb. In another example, Chicago performed randomised stratified sampling to develop composition profiles for the sectors "industrial, commercial, and residential", using specialised truck collection routes (CDOE, 2010). Wolf, Spitz, Olson, Závodská and Algharaibeh (2003) sampled on regular collection routes by suburb, and did not tell residents of the waste characterisation, to not influence regular disposal habits.

Traditional waste characterisation studies involve expensive and time-consuming hand sorting of wastes post-disposal. For example, the study by Dahlén & Lagerkvist (2010) drew on data generated by the hand-sorting of a total of 17,670kg of waste over four years during 28 sampling occasions, while the Chicago Department of the Environment study involved hand-sorting 500 samples between 90 and 136kg to formulate their residential composition profiles (CDOE, 2010). Another methodological route, for small and large-scale studies, is where wastes are sampled 'at source', that is, prior to being aggregated in a dumpster truck. The characterisations by Samah et al. (2013) and Mbeng et al. (2011) are examples, whose samples consisted of issued plastic bags for each household. These bags were weighed upon collection by electronic balance, the contents of which were transferred to a sorting area for sorting and re-weighing by category. These methods are still labour-intensive and time-consuming: Mbeng et al. (2011) weighed the plastic bags, then transported them to a site for sorting, which involved a 10mm screen for separating 'fines', manual sorting of the remaining waste categories, and re-weighing of separated wastes, all of which were repeated daily for 47 households over two weeks.

Some characterisations, such as that by Late & Mule (2012), also have a physico-chemical laboratory assay component to describe parameters including pH, organic matter, carbon, total nitrogen and phosphorus. Season variation in data can also be important, as shown by Aurangabad City, India, where the monsoon season affects disposal trends. Mbeng et al. (2011) also considered seasonal variation by sampling in two distinct periods to accommodate for the wet and dry seasons, as did Pollard et al. (2007) by sampling in spring and autumn. Mass of elementary waste streams is not always the primary consideration, however. Nagawiecki (2009) used a referenced mass-to-volume conversion factor to estimate the volume of waste stream components, since the ultimate objective was to reduce the number of dumpster removals needed, the latter constituting the most significant cost. Cardboard (35% by volume) and plastics were identified as by-volume priority streams, and prioritised for recycling and reduction, leading to action campaigns (and savings in collection costs).

Most studies are accompanied by surveys in major or in minor part, to fulfil other research objectives, or to support the waste stream quantification. In either case, survey data usually complements waste stream by providing information relevant to the study, allowing for data interpretation. Surveys typically extract demographic information, influences on recycling behaviours, and receptiveness to specific interventions.

In terms of dwelling type, few academic studies of apartment-complex / multi family dwelling (MFD) waste characterisations have been undertaken. In one such study, all 28-units of an apartment complex participated through lease-agreement. An estimate technique was employed by aggregating objects of similar volume (e.g. PET drinking bottles) and then using an average per item mass to quantify the waste stream of individual material types (Pollard et al., 2007). To illustrate the importance of site-specific considerations, cat litter was given its own category due to the significant mass of this stream.

4.4 Methodology

The research setting and research objectives called for data collection, analysis, and interpretation, using primarily quantitative methods (Leedy & Ormrod, 2015). Combining these interpretations coherently to address the research problem encapsulates the mixed-methods approach used in this study. The study was predominantly quantitative (measuring the waste stream, to baseline and assess the effect of several interventions). This was supported by several questionnaire surveys, and an interview. The survey component was both qualitative and quantitative (generating categorical and numerical data) and ran in parallel with the waste stream characterisation.

The study had elements of both descriptive and experimental research, as it was a type of action research study (Leedy & Ormrod, 2015). The study was predominantly *descriptive* (waste stream quantification, attitudes of residents towards recycling) but did have some action research elements (predicting and observing the effects of interventions on recycling rate). Surveys took the form of questionnaires, administered electronically as far as possible. The surveys sought to capture information about resident’s recycling-related attitudes and tendencies together with their demographic characteristics.

The causal aspect of the study was not rigorous as per an ‘pure experimental design’ which seeks to show variation in a dependent variable as caused by a change in an independent phenomenon. Such an experimental design was not efficacious because 100% sampling was not practically feasible (see *Section 4.5 Sampling*), meaning a statistical treatment was not appropriate given the small sample size. Quasi-experimental designs refer to those where random sampling is not possible, either logically or practically (Creswell, 2013; Leedy & Ormrod, 2015). Whilst the study was not an experimental one, it did have elements of the experimental design. One such design is called the one-group pretest-posttest design, in which a group is observed prior to and after the application of a treatment or intervention (Creswell, 2013; Leedy & Ormrod, 2015). Other explanations for the change in the dependent variable however cannot be ruled out entirely since not all independent variables were accounted for and controlled, and no randomly assigned control and treatment group design was used as per a true experimental design.

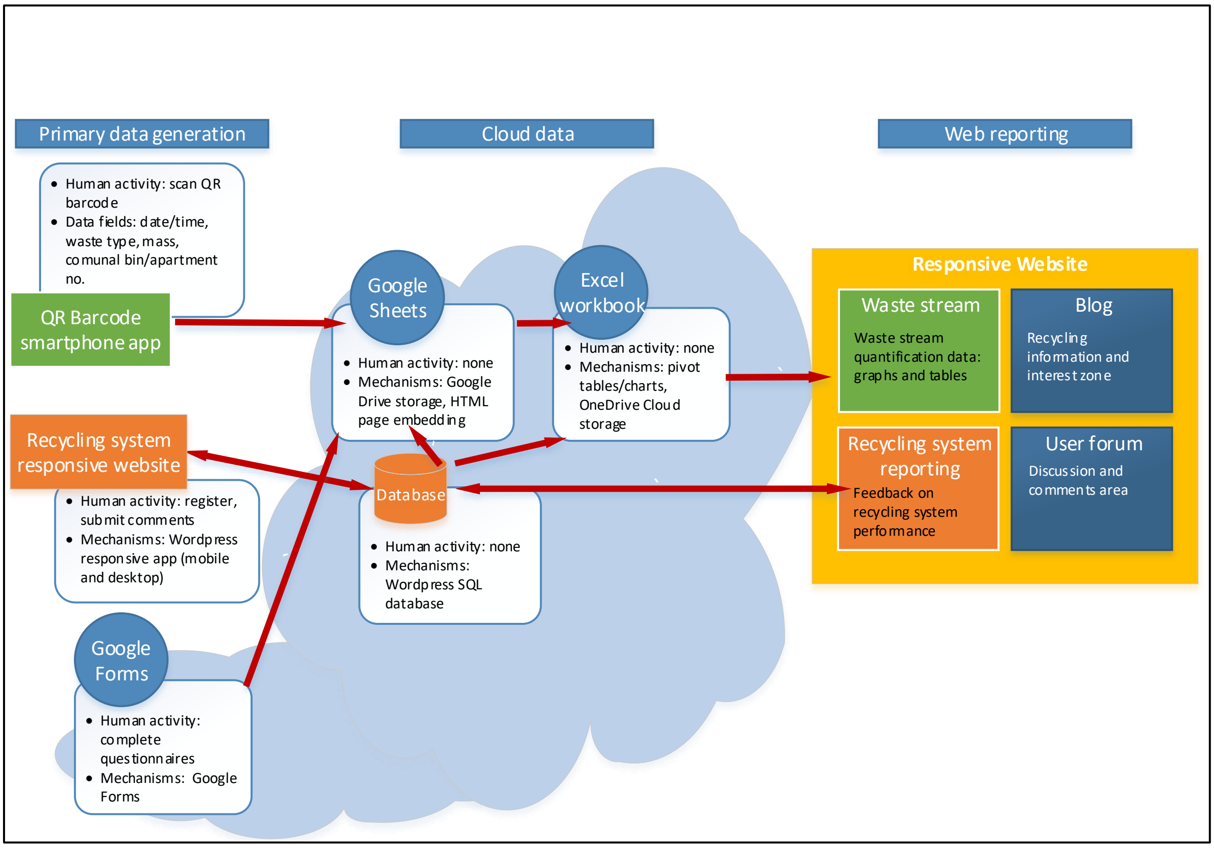


Figure 4.1 Data collection process

Figure 4.1 summarises the methodological components of the study, describing how the primary data were generated, stored, manipulated, and finally reported on. When there is only access to one group, but one can study them over time (using a number of interventions), the time-series design can be appropriate (Creswell, 2013). A simple time-series quasi-experimental design was used in the study, which is where a series of observations are made over a period of time, within which an intervention is introduced, and any change measured. The change could then be attributed to the introduced factor. The sequence of observations prior to the intervention are called the *baseline*, a mode of design that has been widely used in the physical and biological sciences (Leedy & Ormrod, 2015).

4.5. Sampling

Sampling is a subset of the total population, selected for quantitative measurement and analysis. If sampling is done carefully, it will be as closely reflective of the characteristics of the entire population as possible (Leedy & Ormrod, 2015). Non-probability sampling was used in this study for several reasons. It was difficult to recruit residents who would participate conscientiously throughout the initial 10-week waste characterisation (Phase I), and accompanying surveys. Hence, of the 60 units in total, 25 units were approached to participate in the study since they were thought to be 'ideal participants', 17 of which (28%) ultimately participated in the study. Pollard et al. (2007) managed to get high participation rates by having new tenants consenting to involvement in the recycling programme as part of their lease agreement. However, their study site facilitated this by having a high tenant turnover rate (averaging two years occupancy), compared with the study complex where tenancy turnover is low with a high rate of owner, not tenant, occupation.

During Phase Ia, general waste was measured daily for five weeks constituting the first 'general waste baseline', both of both participants and non-participants. In Phase Ib (five weeks), participants separated wastes in-situ, to measure the proportion of recyclables (glass, plastic, paper, metals). During Phase IIa, a second baseline was established over 20 weeks to 'normalise' after the preceding QR code intervention. Thereafter in Phase IIb, the second intervention was implemented, where the two old communal general waste bins were replaced by three larger bins, one designated for recyclable wastes only. The direct measurement data collection concluded with Phase III, comprising a door-to-door awareness campaign, a responsive website, flyers/posters at floor entrances, and bin-top label components.

4.6 Ethics and Ethical Issues

Ethical policies are in place to maintain the rights and integrity of research subjects involved in the study (University of South Africa [UNISA], 2016). A fundamental is that the research should cause no harm to person, animal or the environment (Breach, 2008). The four pillars of research ethics are autonomy (respect for the individual), beneficence (usefulness of the research), non-maleficence (absence of harm), and justice (spreading risks and benefits fairly) (Cleaton-Jones & Curzon, 2012), all of which were applied to the study to align it with the official UNISA Research Ethics Policy (UNISA, 2016). Ethics application number 2013/CAES/000 is available for reference in Appendix K.

All participants completed informed consent forms: survey participants, the caretaker, the informal waste collector, and the janitor (UNISA, 2016). Survey questionnaires were scrutinised to make sure that the questions asked therein were appropriate in wording and that information requested was relevant to the study. Survey responses were numbered to maintain anonymity when data was reported back to the population or public. The website forums and blogs only accepted user contributions from authorised persons (with a validated account) and could thereby be moderated.

Participants' confidentiality, a human right, was guaranteed. Their permission was sought before publishing any waste stream or intervention data to the study website. Survey data was stored in the cloud to be deleted at the end of the study. Participation in study or recycling activities was voluntary, and residents' ability to dispose of their waste was not affected in any way. The extra burden on the janitor was compensated and sanctioned by the Body Corporate. While there was engagement with residents to encourage participation and acquire survey data, any face-to-face activities were attempted at convenient and appropriate times.

4.7 Research Questions and the Consistency Matrix

The objectives were deliverables that broke the overall study aim into smaller problems. Key questions are specific questions that need answers in order to achieve the objectives (Breach, 2008). The tools used to investigate the specific research questions of this study are summarised below, including a Consistency Matrix (see Table 4.1) to link the research questions to the methodological tools used to collect and analyse respective data in a logical and transparent way.

Research Question 1

Can a QR code methodology accurately describe the waste stream?

Consistency matrix for Research Question 1

Research Question 1 was methodologically oriented and involved testing the novel procedure of QR codes stuck onto refuse bags, weighed, and published electronically. The goal was to characterise the wastes stream, that is, to accurately determine how much general waste and recyclables were generated by the residential population, and to answer questions of precision and resource-intensiveness of the method. This was achieved in Phase Ia and Ib, the piloting of the QR code method, involving direct measurement. Analysis was through basic statistical summarisation and comparison.

Research Question 2

How much solid waste does an apartment block produce on a daily/weekly basis (recyclables and non-recyclables) both before and after a QR code, recycling bin, and website / door-to-door intervention?

Consistency matrix for Research Question 2

Research Question 2 refers to the initial quantitative application of the QR code system to measure the proportion of recyclables being diverted from the general waste stream before and after interventions, namely the QR code method, changing the communal bins from two general waste bins to three larger bins with one dedicated to recyclables, and a combined responsive website / door-to-door campaign. These were in turn analysed by basic statistical summarisation.

Research Question 3

How resource intensive is the QR barcode quantification system, continued monitoring and the interventions in terms of set up and running costs?

Consistency matrix for Research Question 3

The cost of both materials and human input into the project were tabularised and can be found in *Section 4.10 Costs*. It included an ongoing attempt to quantify these costs as a basis for communicating these requirements to the reader, as well to determine the sustainability of continued waste stream monitoring beyond the project timeline.

Research Question 4

Which interventions increase the recycling rates the most: QR codes, changing communal bin sizes, allocating dedicated recycling bins, a responsive website or door-to-door?

Consistency matrix for Research Question 4

Research Question 4 was answered through the sequential measurement of the waste stream to find the in-situ responses to the interventions. These changes in the amount of recyclable and non-recyclable materials output by the population would be a simple and effective means to quantitatively describe these interventions. Analysis was through basic statistical description and comparison.

Research Question 5

What are the prevailing attitudes of residents towards recycling and how well can incentives-based interventions work?

Consistency matrix for Research Question 5

Research Question 5 sought to get a sense of residents' attitudes towards recycling at the onset and after interventions, to better understand the local 'condition' in terms of mindset and barriers to recycling. It was achieved via surveys at the end of Phases Ib, IIa and III as well through a structured interview with the janitor.

Research Question 6

What recommendations can be made with regards to implementing recycling systems in similar settings?

Consistency matrix for Research Question 6

A discussion of the Results (Chapter Six) in conjunction with the theoretical platform provided by the Literature Review (Chapters Two and Three) led to a number of recommendations which formed the basis by which Chapter Seven extended the study into new avenues of study in addressing anticipated issues and any opportunities created by these.

Table 4.1 Consistency Matrix

Research questions	Data collection tools	Data analysis
1. Can a QR code methodology accurately describe the waste stream?	Phase I QR code waste stream characterisation	Numerical description / descriptive statistics
2. How much solid waste does an apartment block produce on a daily/weekly basis (recyclables and non-recyclables) both before and after a QR code, recycling bin, and website / door-to-door intervention?	Phase I QR code waste stream characterisation Phase II Bin replace intervention Phase III Website / door-to-door campaign	Numerical description / descriptive statistics: comparison with Phase Ia and IIa baselines
3. How resource intensive is the QR barcode quantification system, continued monitoring and the interventions in terms of set up and running costs?	Phase I QR code waste stream characterisation Phase II Bin replace intervention Phase III Website / door-to-door campaign Janitor structured interview	Numerical description of human and material costs
4. Which interventions increase the recycling rates the most: QR codes, changing communal bin sizes, allocating dedicated recycling bins, a responsive website or door-to-door?	Phase I QR code waste stream characterisation Phase II Bin replace intervention Phase III Website / door-to-door campaign	Numerical description / comparison with Phase Ia and IIa baselines
5. What are the prevailing attitudes of residents towards recycling and how well can incentives-based interventions work?	Phase I questionnaire, Q's 2,3,4,13-17,21-23 Phase II questionnaire, Q 8 Phase III questionnaire, Q 5	Questionnaire response summarisation and description
6. What recommendations can be made with regards to implementing recycling systems in similar settings?	Phases I-III interventions	Interpretation of Chapter 5 Results

4.8 Data collection

While primary data collection is inherently time-consuming, costly, and risky when the methodology is untested (Breach, 2008), this was the challenge taken on by the study in generating primary waste stream data. A summary of data collection events is depicted in Figure 4.2 and is a useful methodological framework for understanding the study.

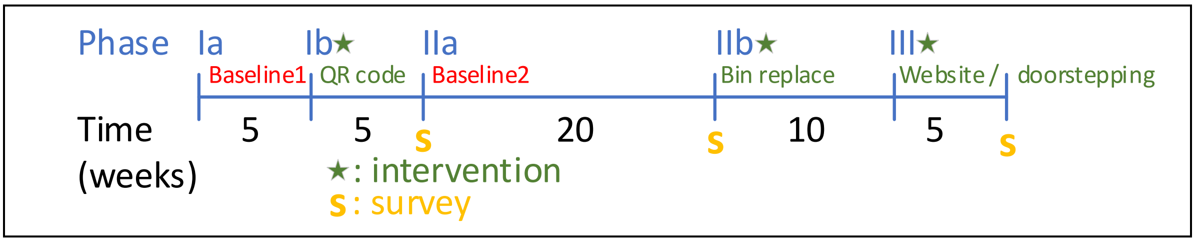


Figure 4.2 Data collection timeline (Source: Author)

4.8.1 Waste stream data collection: general procedure

A janitor was employed to quantify the solid waste stream daily as part of the routine emptying of the communal bins on each of the five floors of the apartment complex. He weighed each 85-litre communal bin together and removed any barcoded refuse bags for separate weighing.

Figure 4.3 Sample barcode sticker attached to refuse bags and communal bins

Residents were provided with QR code stickers encoded with a resident number, floor number, and waste type, which were stuck onto refuse bags before being disposed of (see Figure 4.3). A simple android smartphone application ("app"), written by the author, allowed for 'refuse bag logging' (see Figure 4.4). For this, the QR code was scanned, prompting the user to input the mass of the refuse bag/bin.

Figure 4.4 Screen capture from the smartphone application

Once entered, this information, together with a timestamp of the event, was uploaded to a database in real time (see Table 4.2). Data visualisations (charts, tables), some of which interactive (with filters) were then automatically generated and posted to the study website for viewing by the resident population.

Table 4.2 Sample of raw data uploaded to Google Docs from the smartphone application

Application Time Stamp	Unit Number	Mass (kg)	Waste Type
Aug 26, 2015 5:38:41 PM	513	21.75	unsorted
Aug 26, 2015 5:39:52 PM	12	3.097	unsorted
Aug 26, 2015 5:41:58 PM	12	2.698	paper
Aug 26, 2015 5:43:01 PM	18	0.868	paper
Aug 26, 2015 5:43:49 PM	18	0.287	plastic
Aug 26, 2015 5:44:39 PM	20	0.414	plastic
Aug 26, 2015 5:45:30 PM	20	0.444	paper
Aug 26, 2015 5:46:21 PM	20	0.136	metal
Aug 26, 2015 5:47:09 PM	20	0.529	glass

4.6.2 Phase Ia: Pre-separation general waste baseline

This involved weighing the communal 85 litre bins, located centrally, two per floor, daily over five weeks (see Figure 4.5). Bins were placed on an electronic scale and the mass was recorded. A barcode placed on the lid of the bins was scanned using an android mobile phone to log the details per bin. No waste was separated by participants at this stage. The total waste was determined for each floor daily.

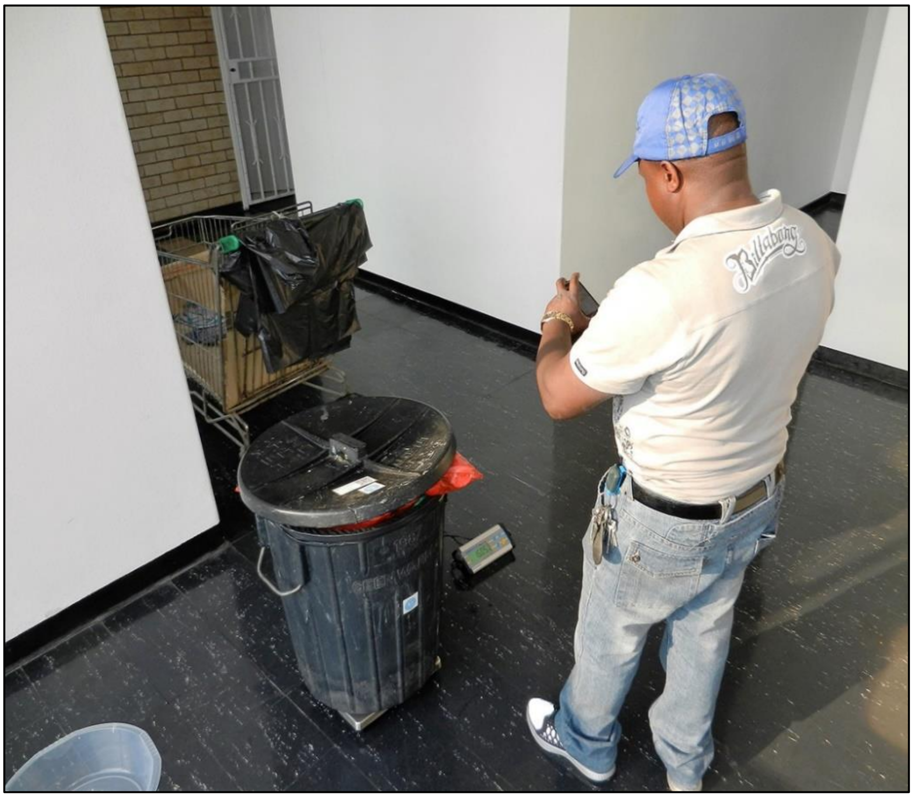


Figure 4.5 Daily weighing of a communal bin (Source: Author)

An Adam CPW Plus 150 electronic scale (150kg max ± 0.05kg) was used for the communal bins, whereas an electronic balance (5kg max ± 0.001kg) was used for the weighing of refuse bags. Participants altered nothing in their waste disposal methods during this phase, other than that they were provided with green, standard-sized refuse bags to replace the black ones in predominant usage, and that they placed a barcode sticker on the bag before disposal. The use of green bags was for the janitor to more readily identify bags containing recyclable wastes needing to be weighed and scanned.

4.8.2 Phase Ib: Source-separation phase

During the second five weeks, participants separated their waste. Two cylindrical, labelled bins (for plastic and paper) were provided to each participant to facilitate separation (see Figure 4.6). Red 600mm x 600mm refuse bags were provided to participants to line these cylindrical bins. Participants emptied plastic/paper bins (regardless of fullness) up to three times a week (Wednesday, Friday and Sunday, as far as possible, for regularity of measurement). Separation bins were not provided for metal and glass, as these waste types did to not accumulate as quickly, given the natural concern for the space available inside participants' units. Instead, residents placed glass and metal in purple bags (provided) (see Figure 4.7), which were to be disposed of once weekly at the weekend (Saturday/Sunday).

Figure 4.6 Temporary separation bins for the facilitation of in-unit paper and plastic separation (Source: Author)

Figure 4.7 Labelled photograph of the various waste types and bag colours used during the separation phase (Source: Author)

4.8.3 Phase IIa: General waste quantification baseline

This phase sought to determine a second and longer baseline of general waste generated by the residential population of the complex against which the remaining interventions could be compared. The two general waste bins on each floor were measured for 20 weeks to achieve this.

4.8.4 Phase IIb: Recycling bin intervention

The effect of adding an additional bin on each floor for recycling on the recycling rate and general waste output was measured in this phase, lasting ten weeks. The old general waste bins were also replaced with larger ones, barcoded, and labelled (see Figure 4.8). Recycling posters, reminding residents of what to recycle, were also placed at the entrance to each floor.

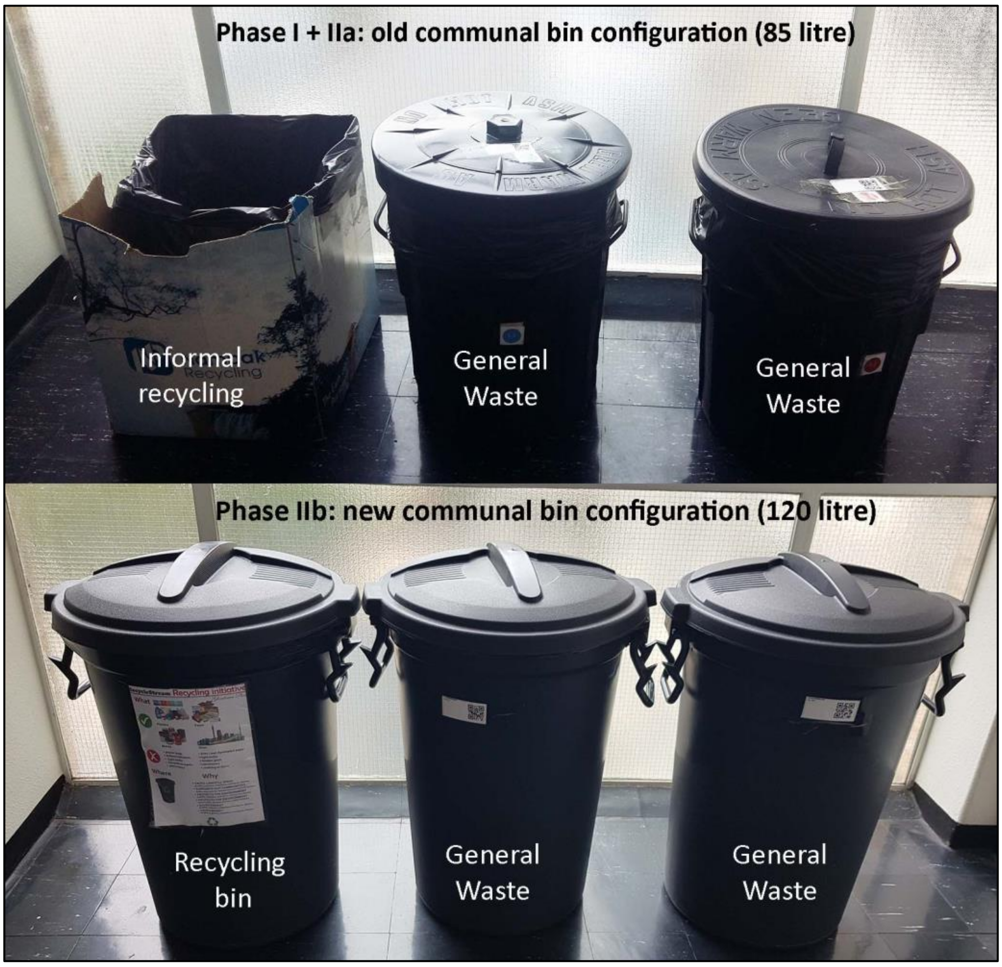


Figure 4.8 Communal bin replacement of Phase IIb including new recycling bin (Source: Author)

4.8.5 Phase III: Responsive website and door-to-door campaign

The final intervention was a combined awareness campaign consisting of a door-to-door visit/information drop (a), a responsive website (b), and recycling posters and flyers, and bin-top (lid) information update stickers (c), to see whether the recycling rate would increase in response.

Door-to-door campaigning is regarded as an effective means of changing recycling behaviours in various settings (DEFRA, 2007). Dai et al. (2015) reported a 12.5% increase in the recycling rate of food waste in an apartment block due to a door-to-door campaign. This intervention involves knocking at on each door with a form of identification and a clear and friendly message, with the intention of changing behaviours. An assistant was trained on how to conduct the door-to-door interactions, including a mention of the new responsive website which had just been launched. In addition, two flyers, one with general recycling information, and another relating specifically to the website, were left with each household (see Appendix I) as part of the interaction. The assistant was also shadowed by the caretaker (who knew most of the residents) to help legitimise the assistant and guide where necessary, as suggested by Dai et al. (2015).

The *responsive website* was designed to display seamlessly on devices of different sizes, for instance, on mobile or desktop devices, (hence the term 'responsive'). It was promoted via a door-to-door campaign as mentioned, through posters and flyers, and by word-of-mouth through the caretaker. One week was given for this exposure preceding the final measurement phase, Phase III. The website catered for 'casual users' as well as for those who wished to register and investigate features available to registered users. Users could browse pictures of the recycling activities, make suggestions on a forum post to a blog, read recycling-related information blogs, see the recycling rates through the study phases, and get a sense of how local waste pickers would benefit from the stream of clean recyclables directly resulting from their efforts. The website was https://www.glendowerplace.co.za.

4.8.6 Survey data collection

Surveys were conducted through electronic questionnaires and an interview with the janitor who was central to the data collection process. While questionnaires and interviews are an excellent means of collecting primary qualitative data, these need to be well thought out to make sure the data they produce is of good quality and aligns with the research objectives (Breach, 2008). The questionnaires were conducted in each of the three phases of the project to collect data before the study, from shop tenants, and after the study interventions respectively (Surveys I, II, and III).

The following were used to assess respondent's attitudes and awareness towards recycling in Survey I: Likert Scale of 1 (strongly disagree) to 5 (strongly agree) (10 questions), checkbox-type/dropdown-lists providing a selection of pre-defined answers (8 questions), yes/no –type (4 questions) as well as six questions which required short typed/written responses. Tabular and visual representation of survey results were adopted at the suggestion of Robbins and Heiberger (2011), who state that tables are excellent for providing exact values, but are less useful for representing the distribution of subsets of sampled respondents – in which case the diverging stacked bar chart is considered one of best practise. Questionnaires were administered electronically via Google Forms or completed in hardcopy where this was not possible. Questionnaires for Surveys I-III and Survey I responses are available in Appendices A-D for reference.

Interviews offer a more in-depth, qualitative dialogue on the problem area. Whilst 100% return rate is advantageous, preparation, time, experience, cost, and subjectivity and complexity of analysis are all considerations. Interviews that are structured (same questions asked in the same order) and focused ensure that the interviewee does not feel that the activity is a waste of time (Breach, 2008). A 15-minute interview with the janitor was conducted to obtain more detailed information about the data collection cycle and his experience as part of the project. The interview was recorded digitally and is included transcribed in Appendix J.

4.9 Permissible recyclables

The following waste stream components were recycled during the study:

- *Paper* included corrugated boxes, rigid board, newspaper, mixed paper (brochure, magazines, cartons, etc.). Excluded materials were those with laminates (wet-strength beverage cartons), which were dirty, or wet.
- *Plastics* included polyethylene terephthalate (PET) plastic containers, High Density Polyethylene (HDPE) which are rigid containers, bags (carrier bags, merchandise bags) excluding zip lock bags and paper-reinforced bags.
- *Metals* included steel cans and lids, and aluminium cans.
- *Glass* included brown-clear-green, which are ideally separated further by colour. Mixed-colour (broken) glass is virtually valueless. Window glass, vases, drinking glasses and ceramics were excluded (Pollard et al., 2007).

Participants were educated as to what and how to recycle via personal communications, flyer as part of the door-to-door campaign, posters at refuse bins, and guidance posted on study website with information on each materials type. A screen capture of the first study website is included in Figure 4.9.

Figure 4.9 Screen capture of the first study website home page

4.10 Costs

A summary of the costs incurred to run the study is included in Table 4.3. The three primary costs of the QR code method were: (1) remuneration of the person taking the measurement, if the researcher is not directly performing these and there is no option to obtain a volunteer to perform this central task; (2) precise measuring equipment, i.e. scales with small and large capacity to accommodate unsorted and sorted bags; and (3) the provision of refuse bags/bin liners, which are required in large volume and if not obtained directly from a manufacturer can turn out to be costly.

Table 4.3 Tabulation of costs of the project

Item	Item description	Cost/unit(R)	Qty	Total (R)
	Phase I			
Janitor wage	daily measurement of wastes (per week)	300	10	3,000.00
150kg scale	Adam CPW150 Plus	1710	1	1710.00
Mobile phone for janitor	HTC Desire S	1000	1	1,000.00
Corrugated cardboard roll	construction of separation bins	25	30	750.00
Bin liners	Green (refuse)	187	4	748.00
Bin liners	Red 600 x 600 (separated wastes) x 500	380	1	380.00
Labels	24 labels per page, pack of 20	85	4	340.00
Airtime for scanning of barcodes via smartphone	100mb data bundle	30	4	120.00
Coloured paper	bin labels, A4 sheets, 10s	12	4	48.00
Flyers	study participation flyers for each unit	0.5	60	30.00
	Phase II			
Janitor wage	daily measurement of wastes (per week)	300	34	10,200.00
Airtime for scanning of barcodes via smartphone	100mb data bundle	30	4	120.00
	Phase III			
Janitor wage	daily measurement of wastes (per week)	300	6	1,800.00
Airtime for scanning of barcodes via smartphone	100mb data bundle	30	2	60.00
Flyers print	printing flyers	4.58	60	275.00
	Annual costs			
Web hosting	Linux web hosting, basic package	12	39	468.00
TOTAL				**21,049.00**

Across all project phases, ongoing costs (janitor wages, web hosting fees), consumables costs (bin liners, airtime) used at varying rates, and set-up costs (scales, mobile phone, flyers et al.) are summarised in Figure 4.10.

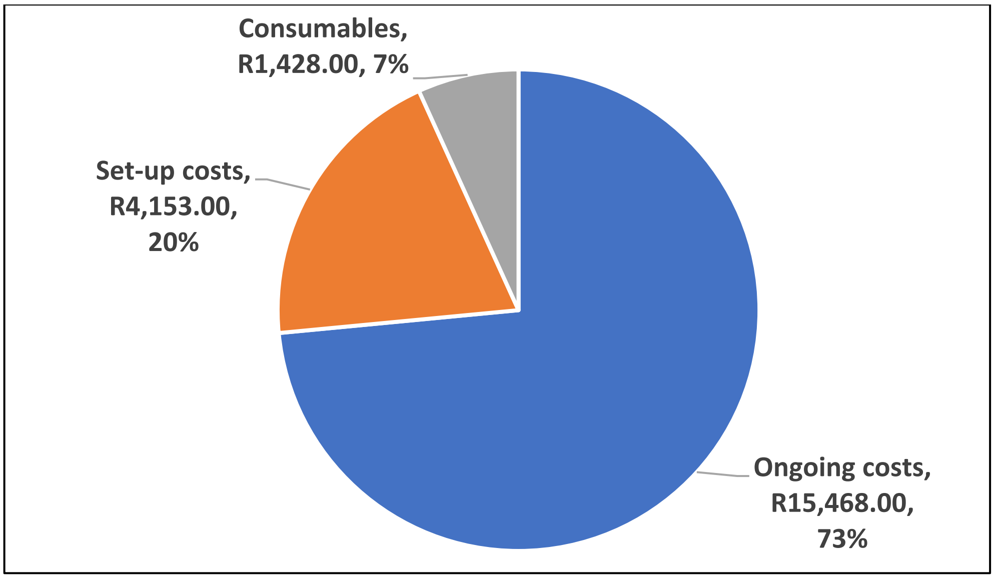


Figure 4.10 Categorisation of costs of the project

4.11 Data Analysis

Data analysis using statistics is important because measurements made have error. Analysis should lead to meaningful conclusions and may be in the form of hypothesis testing and lead to quantifying significance or may simply be in finding measures of uncertainty in the results (Breach, 2008). Before analysis, several essential questions need to be asked, and answered. The way in which data is organised, and the way in which results and interpretations will be presented, is a vital consideration behind the choice of analyses. Perhaps most significantly, the research questions in need of answers will play the largest role in determining the type of analysis to be conducted (Creswell, 2013).

Since the design was not experimental in the strict sense, statistical hypothesis testing was not conducted. Much of the data analysis was thus descriptive. A comparison of the mean using standard deviation was used to relate the unsorted daily waste measurements across all collection phases, providing additional description to contrast the variation between general waste output before and after the three interventions. The interview with the janitor around his role and activities was recorded electronically, the transcript of which is available in Appendix J.

4.12 Validity and reliability

The validity and reliability of method and acquired data determine the extent to which the researcher can legitimately learn about the phenomenon under scrutiny, draw statistical conclusions, or make truthful interpretations from results based on these data (Leedy & Ormrod, 2015). The mechanisms whereby validity and reliability were considered and maintained during the study are discussed below.

4.12.1 Validity

Validity, in its longstanding definition, is the extent to which all the evidence points to the intended interpretation of the results for their proposed purpose (Creswell, 2013). Phrased more practically, the validity of the research refers to the probability that it will yield meaningful, accurate, and credible results which can help to resolve the research problem (Leedy & Ormrod, 2015).

In terms of internal validity, *unobtrusive measurement* was used at the start of the study where measurements of general waste were made with little attention drawn to the process, to obtain a baseline for the whole apartment complex's general waste output. In Phase IIa, an updated baseline was obtained via 20 weeks' general waste measurement – enough sampling time to ensure reliable figures since the QR code intervention was trialled some months prior. This allowed for reliable comparison with data after the interventions of Phase IIb and Phase III which followed.

Validity of measurement refers to bias introduced by the measurement instrument itself (Leedy & Ormrod, 2015). In the context of the study, this refers to the precision of the measuring instruments used to obtain primary data during the study. These measurements took the form of measuring whole waste bins (containing recyclables or general waste) or individual waste bags (containing separated recyclables). An electronic measuring balance accurate to the nearest gram was used (5kg max ± 0.001kg). In the theoretical worst case scenario (largest error margin for each of 586 measurements), a 0.6kg (0.4%) total/cumulative error would have resulted. Similarly, the measurement of refuse bins, using an industrial scale, was subject to a 0.05kg error margin (150kg max ± 0.05kg). Likewise, this implies a maximum theoretical error (worst case) of 66kg over the 1310 individual readings for Phase I measurements (1.6%). The statistical chance of this worst-case scenario is negligible.

In terms of external validity, the case study research design allowed for increased validity as interventions and waste stream characterisations were performed in the 'real world', i.e. on site. A *triangulation* strategy (in terms of a mixed-methods) also allowed for the research problem to be investigated from various methodological angles. That is, the survey and interviews, quantitative waste stream characterisation, and pre/post-intervention measurement strategy, were all employed to illuminate the research problem. Additionally, the interventions selected were based on results obtained through the literature review.

4.12.2 Reliability

Reliability of data refers to the extent to which measurements yield a consistent, stable result (Creswell, 2013). As far as measurements, reliability includes the correct and consistent use of the instrument (Leedy & Ormrod, 2015). Reliability of data measurements was maintained by:

(1) Standardisation of the scales: The scales were placed on an even, flat surface as far as possible. The instrument was zeroed each time it was switched on and showed a symbol on its display to indicate this status. Black refuse bins were placed onto the middle of the scale for consistency. For measurements made with the small electronic balance, a basket was used to contain the separates-bags, the latter was not allowed to overhang the basket or contact the ground. Refuse bin lids were replaced onto the same bins (via numbered and colour-coded stickers) as they had variable masses in Phase I (before being replaced by standardised ones in Phase II). Refuse bins were always measured with the lids on.

(2) Ensuring that the staff (janitor and any assistants) tasked with the conducting measurements were adequately trained. The janitor (who took most of the measurements) was trained for a week to ensure that the procedure was done correctly, and obvious and more subtle errors mitigated. Subsequent supervision from time to time by the researcher also ensured that the basic procedures were still being followed. Measurements captured on the spreadsheet were also regularly checked for overt errors (e.g. negative bin masses). The janitor also had telephonic contact with the researcher and caretaker to raise any urgent issues which might have interfered with electronic data flow, especially due to technical issues.

4.13 Limitations of the study

Areas of challenge and potential weaknesses of the study are discussed below, with a view on how and to what extent these were addressed, and to what extent they remain as considerations for the attention of the reader.

Characterisation of the waste stream of the residents in the complex, in terms of general waste and recyclables, was challenging as recycling was a new practise in the apartment complex. Prior to the study, recycling was very rudimentary (boxes for paper waste were largely contaminated with other waste and seldom utilised). A limitation was that when source-separation was implemented, recycling bins were not checked rigorously for contamination:

instead, only informal checks and photographs showing what was in those bins was undertaken, which in very large part showed the correct use of the recycling bins by residents. A prominent behavioural challenge also emerged during the study, as might be expected: a portion of the resident population appeared to be indifferent, failing to see any reason to expend extra energy on a new task in the name of recycling.

Acquiring primary waste stream data at several points through the study timeline, based on a novel method, presented a challenge. This QR code methodology, which was trialled in the first phase of the study, needed to meet the expectations of capturing these data electronically. This trialling opened the opportunity for any methodological difficulties to be exposed so that the system would be less prone to these in its later re-use in Phases II and III where further interventions were introduced. During this QR code trialling, a sampling limitation was that the initial waste stream characterisation of the apartment complex was based on a sample size of only 18 households of the 60 in total (30%). The sampling method was convenience sampling, since only volunteers were recruited. Non-probabilistic sampling of the small population meant that study findings would also not be subject to more formal statistical descriptive treatment. Causal relationships would also therefore not be the focus of the study because of the potential for bias in the sample (favouring 'ideal recyclers' chosen for being thought to participate, firstly, thereafter with a minimum level of conscientiousness), and the small sample size

Time spent in the field is an unstated prerequisite for intensive work in a setting. The researcher lived on site for about half of the study, seeing through Phase I in-situ, and employing a coordinator who lived on the site to oversee the remainder of the project. Another limitation was that data collection periods had gaps in time between them. This together with the fact that waste generation rate comparisons were not done at the same time each year introduced more variation due to the possible impact of seasonal factors. To overcome this, a longer, 20-week baseline period was used to establish a credible index for comparison of the subsequent waste generation and recycling rates. Moving to Phase III, a limitation was that the exposure to awareness-campaign materials prior to intervention was relatively short for the website intervention of Phase III.

Waste generation rates of the commercial tenants' (shops) were not measured nor was recycling infrastructure for these shop units installed. This was both a limitation as well as a delimitation because the intention was to allow the study to not become too large and complex but did mean that a valuable source of recyclables was likely to continue going to landfill. There were 26 commercial units (shops) whose waste outputs were not measured during the study. Survey II did get some information from this sub-population, but more feedback is needed to initiate a relevant recycling response to bring these tenants onboard with the recycling programme of the residential tenants.

External validity was limited intrinsically because the study could not be replicated by virtue of it being a single case study design (Breach, 2008). This meant that the insights obtained would be intrinsically limited the sphere of the case concerned. However, there were design and methodological measures taken to extend the applicability of the results, which are discussed in *Section 4.12.1 Validity*.

The *organic waste* category was omitted from the waste stream characterisation and further objectives to simplify the study and because of the lack of space / suitable area in which to perform composting were organics collected. Whilst studies show that organics constitute a significant portion of general waste (54% of the solid waste stream for the City of Tshwane), the study focused on dry recyclables, their diversion from landfill, and the use of technological interventions to possibly enhance this process (UNEP, 2018). For purposes of illustration, assuming only a 50% biodegradables composition by mass for the study site, this implies that the 35% recycling rate achieved in Phase Ib (via the QR code methodology) was for only *half* the waste output. *Section 6.10 A consideration of biodegradables* discusses further the issues around biodegradables and their treatment in the context of a quantitative study in an apartment complex setting.

Another delimitation was that only the waste stream of the residential population of the apartment complex (there were two levels of commercial tenants) was directly measured during the waste characterisation. Many of the commercial tenants' outputs were found to be very specific to their mode of business, with outputs that also fluctuated greatly according to their business production cycles. Several commercial tenants were reluctant to participate, having trouble seeing the value in separating wastes, either in-situ or in separation containers near the communal general waste skips on the lower level. Had separation been implemented as part of the study, it would also have been difficult to quantify the wastes as separate from the resident population and would have required separate general and recycling waste containers in the basement area, together with training and monitoring to ensure correct utilisation.

For the ICT intervention, a responsive website was chosen over a hybrid or native application ("app"). *Native apps* are designed to be run on a particular operating system, e.g. iOS or Android. These apps are fast and can take advantage of all hardware features of supported devices. They are, however, expensive and development is time-consuming and requires by teams of professional developers. *Hybrid apps* are designed to work on multiple platforms (computers, mobiles, tablets, etc.) and operating systems (IDF, 2018). They are written using HTML (HyperText Markup Language) (version 5) predominantly, the language of webpages. These are more cost-effective but may not have full access to device hardware and may not be as quick. This option was explored via the Ionic development framework, and the Siberian CMS platform. The Ionic platform ("Ionicframework.com", 2018) had an app builder, but did require advanced coding skills, and had subscription fees for publishing apps. The Siberian CMS platform ("Siberiancms.com", 2018) was an open-source app builder and had a free edition for publishing a single app. The fact that it was free and feature-rich made it worthy of investigation: competitors invariably charged non-trivial per-month fees to publish their apps. Siberian was very technically challenging to set up. Once this was in place, there was programming required and the learning curve to develop apps was large, ruling it out for the study.

Ultimately, the WordPress.org blogging platform was chosen to develop the responsive website, one of the core interventions of Phase III. WordPress is used by 32% of all websites on the internet and so has support, is highly customisable with many plugins to achieve varied functionality, has integrated webpage and blogging features, and has responsive design themes (Wordpress, 2018). This means that the target device can be any size (mobile right up to desktop) and running any operating system. The MySQL database is queried to add all the content to pages, whilst PHP is the server-side language in which WordPress is written, allows for the development of dynamic web applications ("PHP.net", 2018). Since it is free (aside from purchasing a once-off responsive theme with templates to speed up the development process), met the basic functional requirements needed for the purposes of the study, was technically within reach to set up and didn't require advanced coding skills, and was cross-platform (can be rendered on any device provided it has an internet connection), it was a good choice to develop the responsive website intervention.

4.14 Conclusion

The research enterprise seeks to add to and strengthen the existing knowledge base, using a series of small steps and a planning framework to structure it. One such design, the case study, is as challenging as any other type, and if not well-planned can result in superficial, unremarkable research (Rule & John, 2011). Chapter Four was concerned with the specifics of this framework, the research design and methodology, describing to the reader the conceptual and procedural basis of the project. The case study was chosen for its potential to yield insight while allowing a hybridisation with other study approaches for an enriched 'multi-dimensionality' (Breach, 2008). With the scope of the study framed and data credibility discussed, Chapter Five will set out to describe the results borne of the above conceptualising.

CHAPTER 5: RESULTS

5.1 Introduction

This chapter presents the quantitative study data. Prior to the study, the apartment complex had a rudimentary recycling scheme. On each floor, open rectangular cardboard containers next to the two communal bins, were the primary recycling infrastructure. These containers were mostly used for paper waste but were often contaminated with general waste. Recyclables such as glass or plastic containers were simply placed on the ground next to the communal bins for transfer to the basement skip by the janitor, to be subsequently collected by waste pickers. Otherwise residents had to personally dispose of recyclables at drop-off points roughly one kilometre away, but only one resident said they regularly did this.

This quantitative study results flow from three main interventions. Foremost are the results of the QR code methodology, its development, testing and implementation (and resultant data generated). Phase I had two sub-stages: in Phase Ia (five weeks), general waste generation rates were measured using QR codes and a smartphone application, without waste separation. In Phase Ib (five weeks), participants separated their plastic, paper, glass, and metal waste. The generation rates for these materials, as well as the recycling rate (ratio of recyclable materials to all materials discarded), was established, again using the QR code methodology. Phase II followed: in Phase IIa (20-weeks), a waste generation rate baseline for general waste was established (for the whole apartment complex), with no source-separation of waste. In Phase IIb (10.6 weeks), general waste bins were replaced with larger ones, and recycling bins added on each floor. With this additional basic infrastructure, the recycling rate was measured again and the general waste generation rate compared. Lastly, the results of the Phase III intervention are presented. This final intervention was a combination of (a) a responsive website, and (b) an awareness campaign consisting of door-to-door interactions with flyers, posters, and bin-top labels on recycling bin lids informing residence of recycling statistics and targets. A summary of waste generation rates in all phases of the study is included for the purposes of comparison. The results of surveys conducted in each phase are also presented to highlight the collective attitudes and conceptions held by the study population. The chapter concludes with the inputs of the janitor and caretaker, who played key roles in the operation of the project.

5.2 Socio-economic and demographic profile of the participants

The participant group who agreed to separate their waste and trial the QR code methodology consisted of 18 households (30%), comprising 32 adults and 8 children. The average age of respondents was 52 years, and average occupancy duration was 18 years. This is in contrast with the study of Pollard et al. (2007) where the average turnover period of residents in apartment complexes was two years. A large portion (61%) of respondents were educated beyond high school level. Basic demographic information is in Table 5.1, while Appendix B discloses the full survey response.

Table 5.1 Demographic profile of survey respondents, n=18

Demographic	*Frequency*	*Percentage*
Race		
White	13	72.0
Coloured	1	5.6
Other	1	5.6
Undisclosed	3	16.7
Age		
< 26 years old	1	5.6
26-34 years	1	5.6
35-44 years	4	22.2
45-54 years	1	5.6
55-64 years	4	22.2
>=65 years	4	22.2
Undisclosed	3	16.7
Gender		
Male	9	50.0
Female	8	44.4
Undisclosed	1	5.6
Education level		
High School	5	27.8
College/diploma	5	27.8
Degree	4	22.2
Postgraduate	2	11.1
Unemployed/retired	2	11.1

5.3 Data collection sequence

An overview of the data collection sequence is found in Figure 5.1. Each of the three phases was defined by an intervention and preceded by baseline data for comparison. The two baselines established general waste generation rates for the whole complex. The interventions ran as follows:

- Phase I trialled the QR code waste stream methodology to establish recyclable generation rates in a sample of participants.

- Phase II added a dedicated recycling bin on each floor of the complex and increased the bin sizes from 85 litres to 120 litres.
- Phase III introduced a responsive website combined with a door-to-door and conventional awareness campaign.

The Appendices provide additional quantitative and methodological background, pointing to various data from which the summarised versions presented in this chapter were obtained.

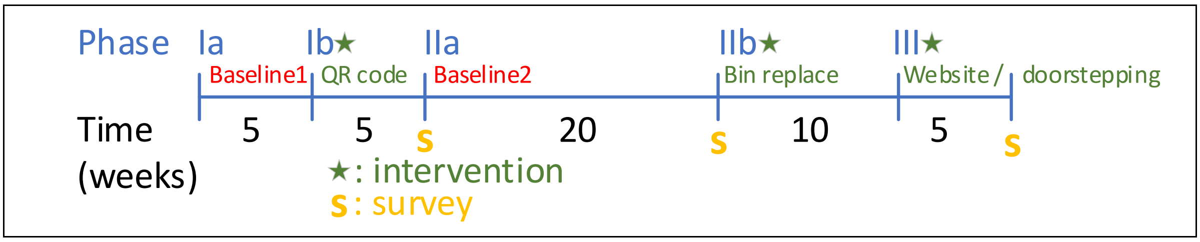


Figure 5.1 Data collection sequence

5.4 Phase I: QR code waste stream quantification

Quantitative data were gathered over a 10-week period from 30 June 2015 to 6 September 2015 (69 days) using the QR code methodology. During Phase Ia (five weeks), there was no separation of recyclables; during Phase Ib (five weeks) recyclable glass, plastic, paper, and metals were separated by participants. In total (Phase Ia and Ib), 3,171 kg of waste was measured via 586 refuse bag and 670 communal bin mass measurements. An average of 18 measurements per day were logged using a scale and smartphone application. Graphs and tables depicting these data were posted on the study website for the community to view[1]. Screen captures of the site are available in Figure 4.9. The website was www.glendowerplace.co.za and included real-time (daily), automatically updated recycling statistics. A screen capture of the study website is included in Appendix H.

The photograph in Figure 5.2 (taken on 31/08/2015) represents the separation activities of the participant group over a period of one month (28 days). The image represents 205 bags (125.5kg) of source-separated wastes, averaging about 4.5 kg/day.

[1] Note that the website used a web-builder called *Moonfruit.com* but this no longer hosts the website as it changed its pricing structure.

Figure 5.2 Recyclable materials recovered after one month of separating by participants (Source: Author)

5.4.1 Waste generation rates

At the whole-complex level, the generation rate was 5.29kg/household/week (2.30kg/person/week*) for Phase I (Ia + Ib) (see Table 5.2). Non-participants showed an increase in general waste output from Phase Ia to Ib. Since participants' general waste output was measured, as was whole-complex output, non-participants' output was calculated by subtracting the above. Possible explanations for the increase in non-participants' output are given in *Section 6.3 Waste generation rates*. Participants' unsorted wastes were 5.81 and 4.95 kg/household/week for Phase Ia and Ib respectively. Changes in waste generation rates are tabulated across the project for reference in Table 5.5. Generation rates for individual waste stream materials have been included in Appendix G.

Table 5.2 Generation rates for Phase Ia and Ib

Unsorted waste generation rates				
	Non-participants		Participants	
	Phase Ia	Phase Ib	Phase Ia	Phase Ib
Unsorted waste (kg/person/week)	2.19*	2.37*	2.53	2.16
Unsorted waste (kg/household/week)	5.04	5.45	5.81	4.95
Whole-complex generation rates (Phase Ia + Ib)				
Total mass (kg/person/week)	2.30*			
Total mass (kg/household/week)	5.29			

*actual household occupancy numbers were unknown for non-participants; an estimate was obtained (2.3 people/household) based on the data sample (see *Section 4.13 Limitations of the study*)

5.4.2 Phase Ia: General waste quantification (no source-sorting)

In Phase Ia (five weeks), no source-sorting of recyclables took place. The only difference in participants' usual routine was that they placed a QR code on their refuse bags before discarding them. This was to allow comparison between participants and non-participants. Participants and non-participants discarded general waste at rates of 5.04 and 5.81kg/household/week respectively. In total 1,578kg of general waste was generated by the apartment complex in this phase (see Table 5.3).

5.4.3 Phase Ib: Source-separating using the QR code methodology

In Phase Ib (five weeks) participants sorted their recyclables and placed them in colour-coded bags with QR codes for measurement and logging. Participants' general waste was also measured, along with whole-complex general waste. The quantities and types of materials generated are summarised in Table 5.3. Additional weekly data visualisations are included in Appendix F to highlight the relative proportions of wastes generated.

Table 5.3 Summary of waste types and quantities generated (kg) during Phase I

	Phase Ia 30/06 - 03/08	Phase Ib 04/08 - 06/09	Percent	Totals Phase Ia+b
PARTICIPANTS				
Recyclables				
glass	**-**	**40.89**	9.7%	40.89
metal	**-**	**8.04**	1.9%	8.04
paper	**-**	**68.75**	16.3%	68.75
plastic	**-**	**30.10**	7.2%	30.10
Unsorted	493.62	272.95	64.9%	766.57
Sub Total	493.62	420.73	100.0%	914.34
NON-PARTICIPANTS (unsorted)	1084.41	1172.40		2256.81
TOTAL COMPLEX	1578.03	1593.13		3171.16

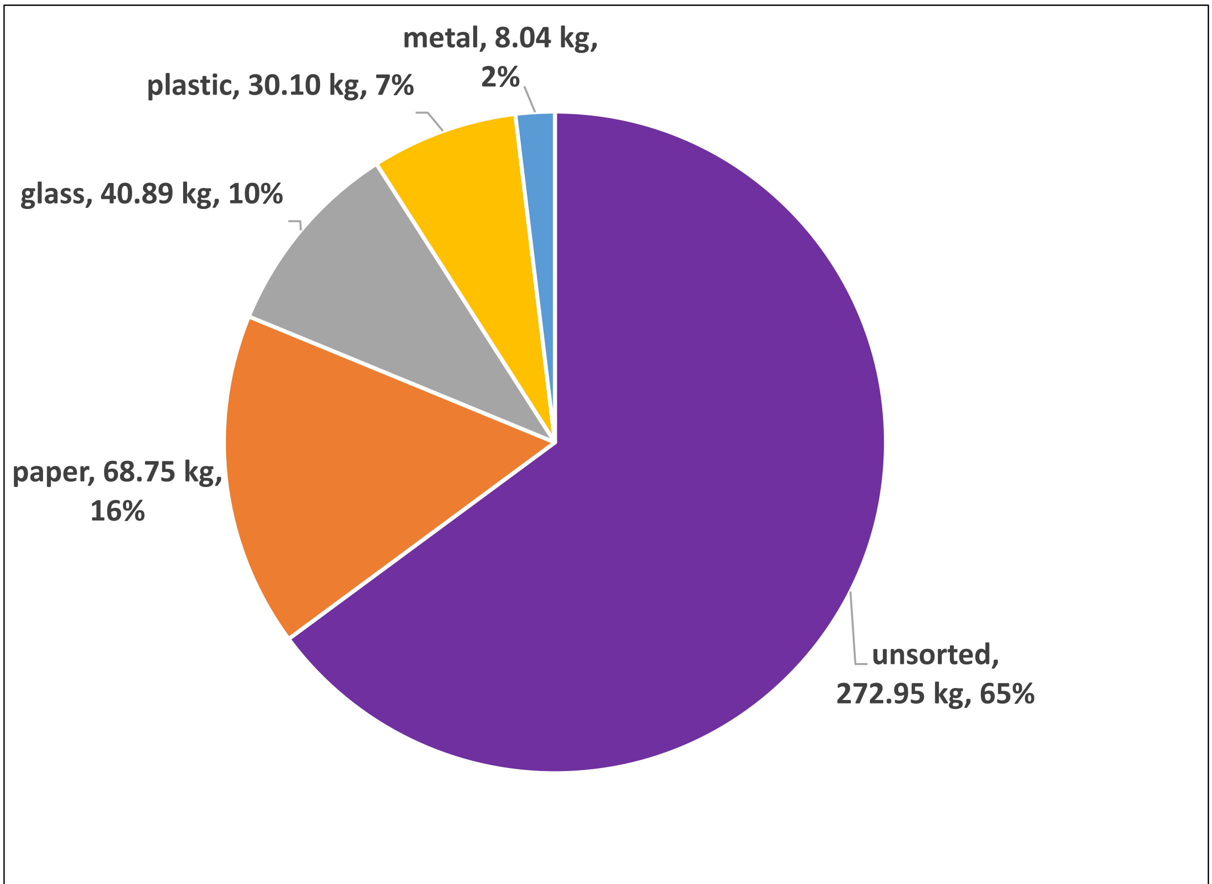


Figure 5.3 Relative proportion of recyclables to unsorted waste

5.4.4 Phase Ib: Recycling rate

A recycling rate of 35.1% was achieved in Phase Ib. The recycling or source-sorting rate is taken as the ratio of recyclables to total collected waste and is a fundamental indicator in evaluating the effectiveness of household recycling programmes (Dahlén & Lagerkvist, 2010).

It is an indicator of whether an increase in sorting is due to increased waste generation, or due to more aggressive sorting. Changes in the recycling rate formed the basis for quantitative evaluation of the interventions to promote recycling behaviours in this study.

5.4.5 Survey I: Participant's attitudes towards recycling

Survey I was undertaken with the participant group before the QR code intervention. At that stage, there was no formal recycling taking place in the apartment complex. Survey data indicated: that 66% of participants did some form of recycling. Respondents were of mixed views in terms of the effectiveness of the current recycling regime (Likert Scale avg 3.6). Regarding future formalised recycling systems, 61% said there was "*definitely a need*", and 33% said "*room for improvement*". Respondents also expressed a strong inclination to continue recycling beyond the study period (Likert Scale avg 4.6). Most respondents' motivations were around economic/poverty-alleviation (39%), followed by environmental benefits (33%), resource-reuse, increase in hygiene, and a structured recycling system (17% each) (see Figure 5.4).

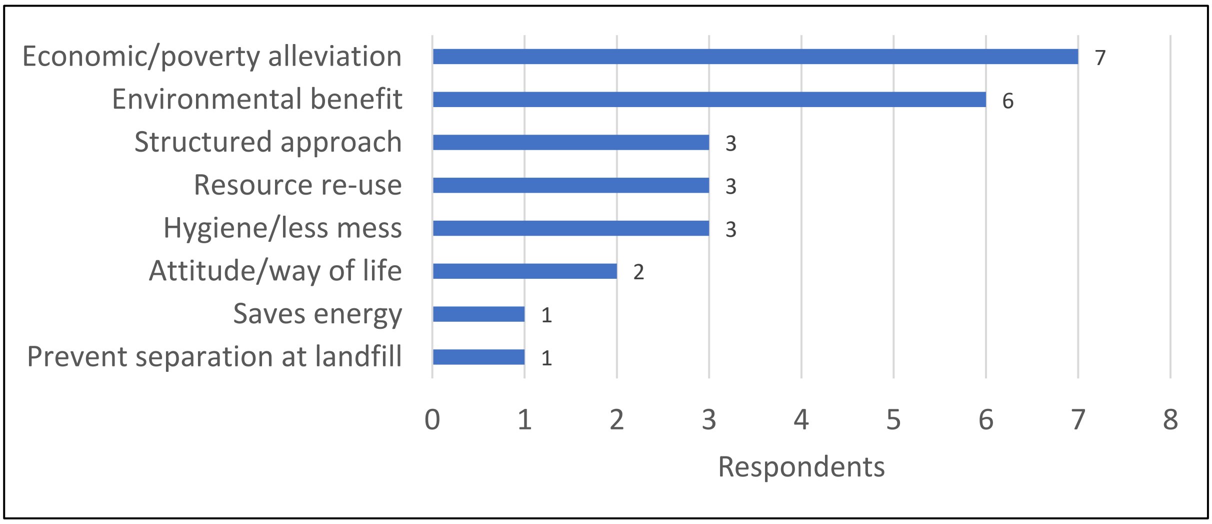


Figure 5.4 Survey I: Motivators for recycling

It is important to understand perceived barriers to recycling as a primary means of gaining site-specific information from the potential users of a proposed system. The top four factors inhibiting recycling participation by residents were listed as: lack of knowledge/awareness/education (66%), apathy/laziness (66%); a lack of facilities/system/bins on each floor (44%) and lack of time (33%) (see Figure 5.5).

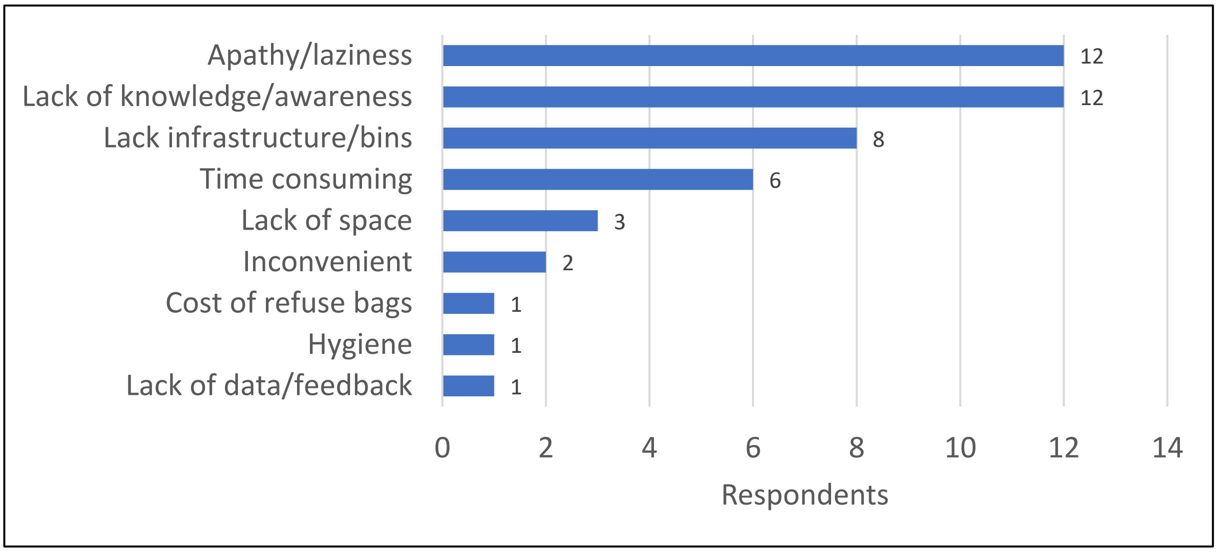


Figure 5.5 Survey I: Perceived barriers to recycling

5.5 Phase II: The 'Bin Replace' Intervention

A second baseline was necessary as some time had passed since the previous intervention and a 'normalised' generation rate was sought before the remaining interventions were trialled.

5.5.1 Phase IIa: Baseline

The second baseline for the study was performed over a period of 20 weeks from the 5th of August to the 20th of November 2016. The 10 communal bins for general waste (two per floor) were weighted daily and a total of 6,252kg of waste was generated. The 1,329 individual measurements averaged between 4.52 and 4.88kg (95% confidence) with a mean mass of 4.70kg. Thus, an average waste generation rate of 5.24kg/household/week. Using the 35% recycling rate established from Phase Ib, this gives an estimated 2,188kg of the 6,252kg as recyclable material.

5.5.2 Phase IIb: 'Bin replace' intervention

The *size* of a recycling bin is a much-studied parameter in the literature, with larger bins increasing recycling and participation rates (Lane & Wagner, 2013). Having a bin which can accommodate enough waste until the next drop is important, and if lacking, can contribute to users discarding their recyclables with general waste. Thus, a second fundamental intervention was to introduce a third (additional), recycling-only bin, in addition to up-sizing the communal bins from 85 litres to 120 litres (see Figure 4.8).

The recycling rate of 19% (508kg) was calculated over 10.6 weeks (74 days) from 17 June 2017 to 30 August 2017. The 15 communal bins (three per floor) were measured daily and in total 3,044kg of waste was measured. General waste averaged at 3.37kg (n=732), and recyclables averaged 1.59kg (n=366). The data is summarised in Table 5.4.

Table 5.4 General waste and recyclables descriptive statistics for Phase IIb 'bin replace'

	General waste	Recyclables
N	732	366
Sum (kg)	2 464	580
Mean (kg)	3.37	1.59
Std. Deviation	2.82	1.87
Range	12.05	14.7

5.5.3 Survey II: Shop owners' attitudes towards recycling

Commercial tenants were approached via survey to give their views and behaviours relating to recycling. Eleven respondents (55%) completed the online questionnaire. Their core businesses varied from food, fitness, and beauty, to IT services and car spares. No respondents were actively recycling. Paper (59%) and plastics (45%) were the main two waste streams with perceived recycling potential (see Figure 5.6). The main waste streams where no recycling was reported were glass (73%) and biodegradables (64%). The majority (73%) of businesses reported that clearly labelled separation bins in the communal waste collection area would help to encourage them to recycle in the future. Another management option was compartmentalised bins in-premises (18%). All businesses agreed (4 or 5 on the Likert Scale) that recycling is appealing for a variety of reasons: improving perceptions of their business; environmental reasons, and to support local livelihoods, namely the waste pickers active at the site. Discussions with one waste picker revealed the following: he sold plastic sheets for R1.30/kg, milk cartons for R3.00/kg, plastic water bottles for R3.20/kg, and cardboard for R1.50/kg. He would collect enough material to do about three visits to the buy-back centre per month. The waste pickers usually use large bags on trolleys to transport their haul.

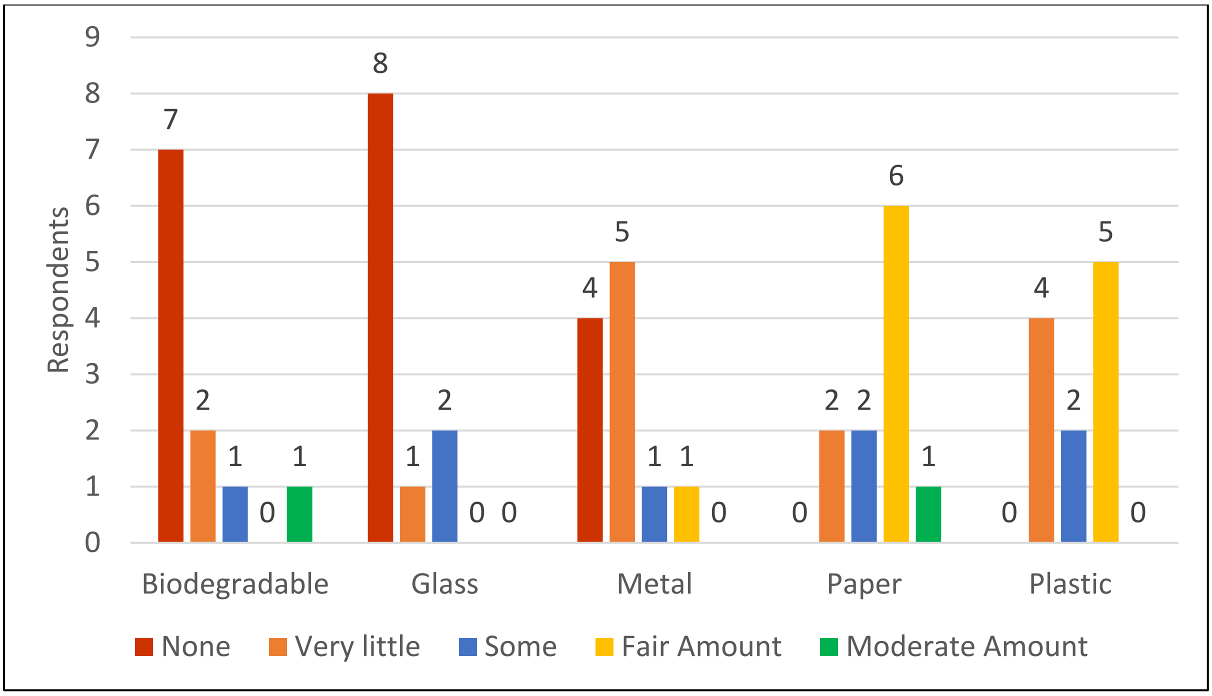


Figure 5.6 Survey II: Perceived recyclables output by shops

5.6 Phase III: The door-to-door and responsive website campaign

5.6.1 Phase III: Results of the intervention

The final intervention consisted of three interlinked components designed to have a positive effect on the recycling rate. It was hoped that Phase III would encourage a culture of sustained source-separation which would persist beyond the study. Data were collected over six weeks from the 4th of February 2019 to the 17th of March 2019 by measuring the 15 communal bins daily as before. In total 631 measurements were taken constituting 1,664 kg of waste. The average recycling rate was 20.8%. The recycling rate increased sharply in the first three weeks and then levelled out, reaching a weekly high of 23.8% after six weeks (see Figure 5.7). The general (sorted and unsorted) waste generation rate was 4.62 kg/household/week, compared with 5.24 kg/household/week for the 20-week Phase IIa baseline, representing an 11.8% decrease.

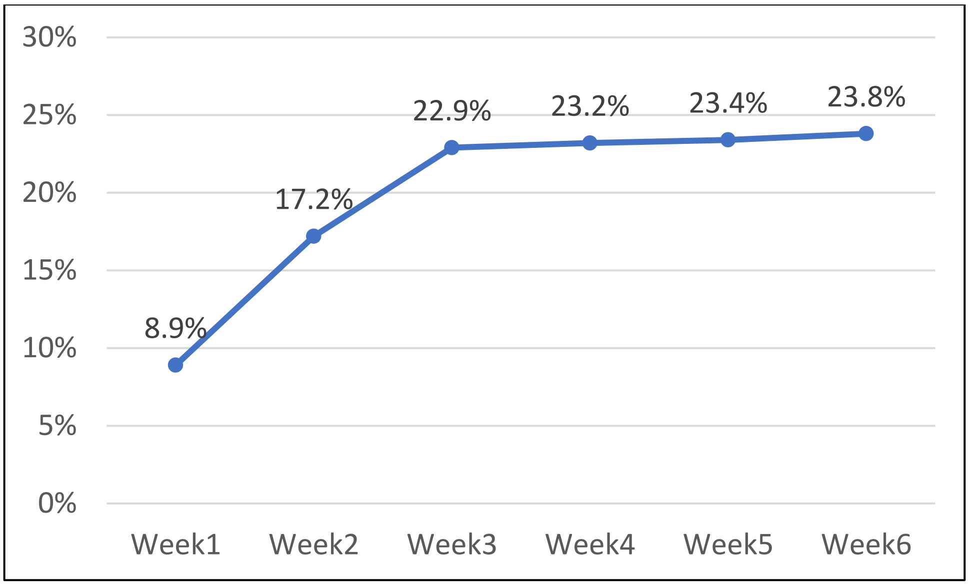


Figure 5.7 Weekly recycling rate

In terms of the study website, Google Analytics was used to get statistics on usage (page visits). In total, 64 users visited the site, with a high of around 50 visits per week on 27 February, coinciding with the second door-to-door campaign. Only four users registered and created user accounts. Thus, the website was accessed relatively infrequently despite 'referrals' on posters, bin-top stickers, flyers, and during the door-to-door campaign. The complementary survey results are now discussed.

5.6.2 Survey III

A final survey of households (n=21, 35%) was conducted at the end of Phase III to establish which interventions were the most effective, what the perceptions and attitudes towards recycling were, and what possibilities there were for improvement. In terms of encouraging recycling, 43% of respondents chose '*free recycling bags*', 38% chose '*more information as to how/what to recycle*', and 19% chose '*a recycling bin for use inside the flat*'. The overwhelming motivator was environmental - "*reduce pollution, greenhouse gas emissions*" (76%). Employment generation and poverty alleviation only appealed to 10% of respondents. Furthermore, respondents were asked "which initiative was most effective in promoting recycling habits". As Figure 5.8 shows, most said that *conventional* means of interaction were most effective, that is, informative posters (14 or 67% 'highly effective'), bin top labels/stickers with recycling statistics (12 or 57% 'highly effective'), and 10 respondents (48%) noted the door-to-door interaction to be 'highly effective'. This is in contrast with the response to the responsive website, where only one respondent (5%) found the website to be highly effective.

The frequency of recycling was high: 16 respondents (76%) reported to 'always' recycle, four (19%) 'most times', and one (5%) 'sometimes'.

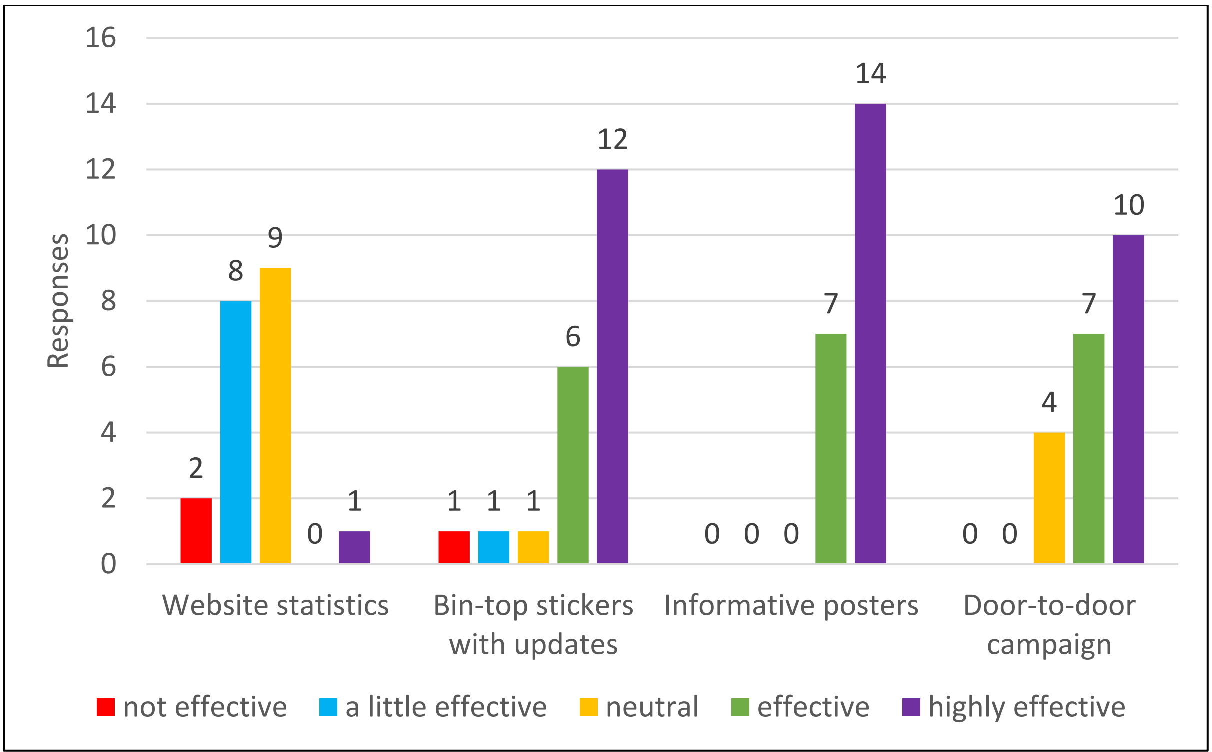


Figure 5.8 Survey III: Perceived effectiveness of Phase III interventions

In terms of deterrents, respondents said '*space constraints inside apartments*' (16 respondents, 76%), '*physically separating the materials'* (9, 43%), and the '*expense of recycling bags*' (7, 33%) (see Figure 5.9). These findings form the basis for further discussion and recommendations.

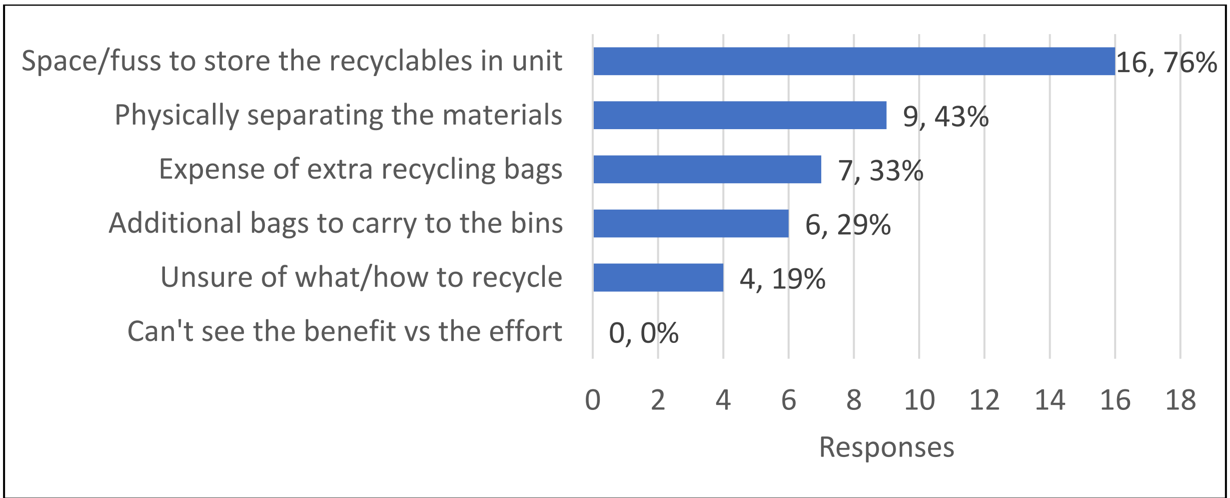


Figure 5.9 Survey III: Perceived demotivators to recycling

5.7 Changes in the waste generation rate over the project

A significant finding was that the total waste generation rate (recyclables and non-recyclables) decreased after each study intervention. Hence residents were throwing away less waste *in total*. The exception was the non-participants during the Phase Ib, who produced more waste in total (increase of 8.1%) (and caused a whole-complex increase because of their greater proportion versus participants). In Phase Ib, participants produced 14.8% less mass in total (recyclables and non-recyclables) after the QR code intervention. In Phase IIb when recycling bins were added, the whole-complex generation rate decreased by 8.8%. In Phase III when the website and door-to-door interventions were implemented, the whole-complex general waste generation rate decreased by 11.8% from the Phase IIa baseline. All changes were calculated by comparing the 'intervention rate' with the most recent baseline rate. These changes are outlined in Table 5.5.

Table 5.5 Changes in waste generation rates

		Generation rate (kg/household/week)		
Phase	**Intervention**	**Whole-complex**	**Non-participants**	**Participants**
Ia (baseline)	-	5.26	5.04	5.81
Ib	QR code	5.31 (▲ 1.0%)	5.45 (▲8.1%)	4.95 (▼14.8%)
IIa (baseline)	-	5.24	-	-
IIb	Recycling Bin	4.78 (▼ 8.8%)	-	-
III	Website/ door-to-door	4.62 (▼11.8%)	-	-

5.8 The role of the janitor

The janitor had a central role in the data collection since he performed all the mass measurements of the communal bins, as well as of individual refuse bags during the QR code waste stream characterisation phases. He indicated that it took him around 15 minutes per day to complete the daily bin measurements[2]. He felt the intervention gave him an enjoyable sense of responsibility and was glad to be part of the improvement of waste management practises at the complex. He was remunerated weekly but felt that as the additional work was in line with his usual portfolio it was not burdensome. He was well known to the informal waste traders/pickers and liked the fact that he helped them in terms of their livelihood. The janitor measured and emptied the bins at around 10.30 am to prevent the bins from getting too full,

[2] The full interview transcript can be found in Appendix K.

which was the case if he measured them later in the day. The recycling bins were reported to overflow occasionally. The use of the scale was not difficult, according to the janitor, and bins were measured with their lids on. He felt the scale was reliable. Communal bin areas were reported to be kept quite clean because residents kept their wastes in refuse bags, which prevented the janitor from having to do excessive cleaning. The three-bin system was better for the janitor because prior to this any recyclables were left next to bins or mixed with general waste. The extra recycling bin kept all the recyclables neatly together in one place. The janitor also commented that without his *daily* attending to empty the communal bins and tidy up those areas, the building would quickly become messy.

5.9 The role of the caretaker

The caretaker lived on-site and hence was able to assist with the execution of the project. One important role was in the collection of survey data. As her portfolio included maintenance and cleaning, interacting with the janitor was a daily routine, which allowed her to monitor the measurement activities of the janitor and resolve any issues. She was central in executing the various interventions, including organising the printing, placement, and updating of awareness materials, gaining permission to start the website from the Body Corporate, paying the janitor, making sure there was data on the mobile phone used to scan the barcodes, and many other essential tasks.

5.10 Summary

Initially, only basic and informal recycling occurred at the apartment complex, with much cross contamination. Phase I saw the initial characterisation of the waste stream using the QR code method, a focal point for the study. A 28% cohort of participants sorted their recyclable wastes (glass, plastic, paper, and metals) for five weeks as part of the intervention, including a basic website for feedback. The whole-complex generation rate for Phase I was 5.29kg/household/week (2.30kg/person/week). Participants' total waste output decreased by 14.8% as a result of the intervention, whilst non-participants' total waste output increased 8.1% by mass. Paper (16%), glass (10%), plastic (7%), and metal (2%) were found to contribute to the recyclables separated at source (by mass). A recycling rate among participants of 35.1% was achieved as a result of the QR code intervention. Survey information showed that nearly two-thirds of respondents (61%) thought there was a definite need for a recycling system. The top two motivations to recycle were economic/poverty-alleviation and environmentally related

(39% and 33% respectively), and the top two barriers cited were apathy/laziness and a lack of knowledge/awareness (66% cited of respondents cited both categories).

In Phase II, a 20-week baseline established a general waste generation rate of 5.24kg/household/week. Adding recycling bins on each floor and upgrading the sizes of communal bins for residents was the intervention of Phase II. The generation rate decreased to 4.78kg/household/week (8.8% decrease), with a recycling rate of 19% over 10.6 weeks. A second survey for the basement shop tenants found that no respondents were recycling at that time, whereas all respondents agreed (point 4 or 5 on the Likert Scale) that recycling would be appealing for a variety of reasons. The top two recyclable waste streams reported were glass (73%) and biodegradables (64%). Most businesses (73%) reported that clearly labelled separation bins in the communal area would most suite their business in recycling their wastes, with around a fifth (18%) preferring in-premises recycling receptables.

In Phase III, an awareness campaign was launched including door-to-door interactions with 42 households (70%), bin-top stickers with recycling statistics and targets (on bin lids), posters on each floor and on recycling bins, and a responsive website with feedback on the progress of the project as well as for the general use of the community. The general waste generation rate decreased to 4.62kg/household/week as a result of the Phase III intervention, its lowest level through the study and a decrease of 11.8% from baseline. The recycling rate increased over the six week intervention from a low of 8.9% in week one, to a high of 23.8% in week six. The subsequent survey indicated that residents found the conventional awareness materials (bin-top stickers, posters, door-to-door interactions) to be highly effective, whereas the website was generally ineffective. This was confirmed by Google Analytics which showed a high of 50 visits/week around the time of the door-to-door campaign, with low usage thereafter. Deterrents were primarily lack of space/fuss for temporary storage of recyclables in-unit. The majority (76%) of respondents were motivated towards recycling by environmentally related factors. At the end of the study, perceptions of recycling frequency were high, with more three-quarters of respondents reporting that they ‘always’ recycled.

5.11 Conclusion

In laying out the study findings in the above, Chapter Six to follow will seek to guide the reader towards a critical interpretation of these findings.

CHAPTER 6: DISCUSSION OF THE RESULTS

6.1 Introduction

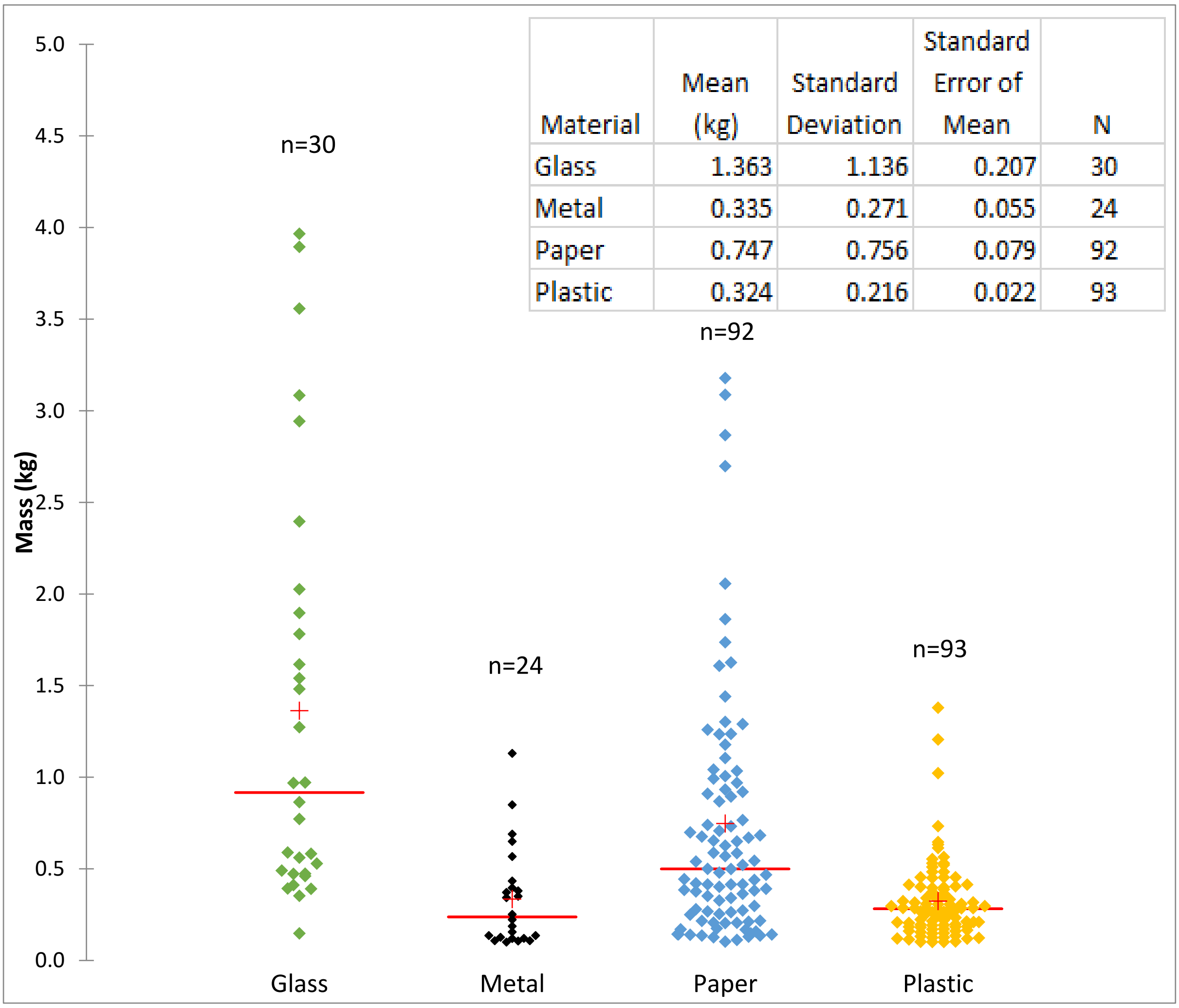
The application of the methodology described in Chapter Four produced primary data on the waste stream and measured the impact of interventions on the recycling rate. Survey data were also collected to provide a more complete quantitative landscaping structured around the proposed research questions and objectives. These data which were presented in Chapter Five are now explained in detail in synthesis with previous studies, to allow the reader a critical engagement with the resultant findings, challenges, and opportunities, now presented.

6.2 The QR code waste stream methodology

Waste stream data are fundamental on all scales of the waste management hierarchy. From national strategy to a single apartment complex setting, quantity and composition of waste stream outputs is necessary to make decisions concerning the implementation and management of recycling infrastructure (Pollard et al., 2007). To maximise correct sorting and recycling rates, user needs and what the recycling system offers must be synchronised (Ordoñez, Harder, Nikitas, & Rahe, 2015). Hence, waste stream characterisations involve determining the relative proportion of materials that make up the waste stream, and in this study included plastic, paper, glass, and metals. Food waste was omitted for the sake of limiting the complexity and scope of the study, but as it can make up a sizeable proportion of the waste stream, even in apartment complexes, it will be discussed in more detail in *Section 6.10 A consideration of biodegradables*. The QR code methodology, a simple procedure designed to electronically capture and report on waste stream, is critiqued below.

6.2.1 General experience

The QR barcode method enabled a detailed picture of the waste stream to be generated. The simplicity of the system allows a non-IT professional to set up the simple smartphone application, to efficiently and reliably scan QR codes, capture the relevant information to a cloud-based spreadsheet, generate visualisations of the data, and embed this information into websites or emails as needed. High precision in measurements coupled with electronic data processing allowed detailed data analyses (see Figure 6.1.). For example, 92 bags of plastics were thrown away with a mean mass per bag below 0.5kg, whereas for glass, with only 30 bags, the data were more spread with several outliers, elevating the mean to 1.4kg per bag. The figure also serves to illustrate the variability in the ranges of mass per waste type, as well compare the averages (mean, median) of each. Such detail was possible because each refuse bag or communal bin was weighed and scanned individually into the mobile application. Wastes did not have to be sorted from the general waste and their proportions estimated, as participants separated their wastes ‘at source’ using the provided resources (coloured recycling bags, QR code stickers, separation bins) to do this.



Material	Mean (kg)	Standard Deviation	Standard Error of Mean	N
Glass	1.363	1.136	0.207	30
Metal	0.335	0.271	0.055	24
Paper	0.747	0.756	0.079	92
Plastic	0.324	0.216	0.022	93

Figure 6.1 Recyclable materials scattergram from Phase Ib (n=number of bags weighed)

6.2.2 Optimal application

Once the QR barcode was scanned and the mass captured, the remainder of the data flow was largely automated. This resulted in attractive and interactive visualisations (tables and charts) which were updated daily on the webpage. Thus, with the ubiquity of smartphones and access to the internet, users can easily be given access to updated information relating to the ‘vital stats’ of the recycling system they use. The QR barcode method is feasible in situations where precise measurements are required over a relatively short period of time. It is also effective as a tool for measuring waste output in the longer term (for monitoring whole-complex outputs) and measuring entire waste bins as fewer discrete measurements need to be taken daily. Recommendations are made in *Section 7.4.1 Automated quantitative monitoring/characterisation of the waste stream* regarding further automation of the QR code method.

6.2.3 Challenges

A few challenges concerning the method emerged, some of which have been discussed in *Section 4.13 Limitations of the study*. Firstly, a basic smartphone application had to be written to enable the scanning of barcodes and capturing to a cloud-based data storage system. This required technical knowledge and testing. A larger challenge was visualising the data, publishing it online, and ensuring this was automated. A strong knowledge of Excel, Google Sheets, and some Visual Basic for Applications (VBA) programming was required. HTML snippets allowed for 'live charts' to be embedded into webpages for updated user feedback. Initial setup of data-flow mechanisms, such as data-storage containers, initial data-link of smartphone to cloud-storage spreadsheet, data-cleaning routines, automated pivot-table and pivot chart generation were time consuming and required subsequent testing before its use in the study. In terms of data capture, constant internet access was required when scanning QR codes on refuse bags.

The janitor had to be trained until familiar with the subtleties of using the smartphone and the application. For example, when scanning barcodes stuck to refuse bags, the light levels, angle at which the smartphone was held (especially if too far off a parallel plane from the barcode sticker), and ability to adjust distance of the camera from the barcode in such a way as to allow for focus and subsequent successful scan, all took practise. To help with this situation, the mobile phone was upgraded, which helped the situation. Leaking or wet refuse bags sometimes damaged the QR code stickers. Sometimes the QR code stickers needed to be 'straightened' to allow for successful scanning. Other issues included participants forgetting to stick QR code stickers onto refuse bags (although this was infrequent), which meant that these bags had to be 'tracked down' to their originator. In terms of consumables, it was difficult to find coloured bags in sufficient quantities at wholesale prices. Locating a manufacturer who would sell stock of the required bags in relatively small volumes was a challenge. That said, the use of coloured bags was effective, both for residents and the janitor.

6.2.4 Labour and resource requirements

The daily weighing of all the refuse bags took about 15 minutes in Phase Ia, and up to 25 minutes in Phase Ib (source-separation), as more bags needed to be weighed. Given the sample size was small (only 28%), more participants would have placed significant demands on the janitor, especially on prescribed set-out days for recyclables (Mondays, Wednesdays, Fridays, Saturdays/Sundays). As the janitor was paid for the additional work, the major cost of the project, more participants would result in greater labour costs. In terms of equipment, a suitably precise, industrial-use scale and electronic balance, and a means to place bins/bags on top/inside of effectively, was essential due to the number of discrete measurements required.

As was seen in *Section 4.10 Costs*, nearly three-quarters of the costs of the project was wages for the janitor for the additional work of scanning and weighing refuse bags and bins. To make ongoing efforts sustainable from a cost perspective, the job of the janitor could be replaced by electronic equipment for automating the weighing and logging of measurements, as suggested in *Section 7.4.1 Automated quantitative monitoring / Characterisation of the waste stream.* However, money would still have to be recuperated through other mechanisms to cover other costs. Since the monetary value of the recyclables is intended to go to the waste pickers to facilitate their survival, another feasible option would be to have less frequent waste collections from the Ekurhuleni Metropolitan Municipality (EMM). The number of bags of clean recyclables which were separated during Phase Ib represents a non-trivial *volume* which was being diverted, resulting in the real possibility of a dialogue with the EMM into rebates for less frequent collection of the communal skip. The possibility for incentives, linking with ICT solutions (smartphone applications, in particular), is another intriguing avenue towards sustainability, discussed in *Section 7.4.3 Incentives*.

6.3 Waste generation rates

The volume of waste generated by the apartment complex was a key quantitative unknown prior to the study. This formed the basis for testing interventions to increase the recycling rate and provided some data on the household waste stream albeit site- and dwelling-type –specific. At least 717,000 people lived in apartment complexes in South Africa in 2016 (StatsSA, 2016a). The generation rates obtained in the study might, thus, inform planning in apartment complexes with similar profile of resident and location. At the whole-building level, the generation rate for Phase I, for example, was 2.30kg/person/week, well below the middle-income average of 5.2 kg/person/week but in-line with the low-income average of 2.9 kg/person/week (DEA, 2015a).

The literature readily presents evidence that source-separating wastes causes a reduction in total waste output. For example, Areeprasert et al. (2017) found a 39% lower per-capita generation rate by mass when comparing two communities in Bangkok, where only one source-separated wastes. In this study, each intervention was associated with decrease in *total* waste generated (by mass). For example, in Phase Ib, a 14.8% decrease occurred. In Phase IIb there was an 8.8% decrease in the generation rate. In Phase III, saw a decrease of 11.8%. Though there may have been other causes of variation, decreases after every intervention occurred when compared to baseline generation rates. The baseline in Phase II was 20 weeks, for example, which was sufficient time to provide a reasonable index of comparison and affording a 'reasonable' (though informal) causal link between intervention and generation/recycling rate. An exception was seen, however, during the QR code intervention (Phase Ib), where an *increase* in overall waste generation rate (of 8.1%). It is difficult to explain this increase in the non-participant group other than through variation, predictable or random. The participating group (who separated their recyclables and were interacting with the recycling system) registered a significant decrease in total waste generation. It should be noted that Phase I was the only intervention where participants were selected to actively separate wastes as part of the QR code pilot; all other phases engaged with the whole community and then measured responses to interventions.

It is important to ascertain the volume of waste which may be diverted from landfills cumulatively over one year projecting the study data. For example, the 11.8% decrease in total waste output of Phase III (compared with the 20-week baseline prior to intervention), this represents a 1,700kg reduction in general waste entering landfill for the complex over one year, and 3,600kg of diverted recyclables (assuming the 23% diversion rate). Thus, the quantitative dual-benefit of source-separation was seen in the combination of waste reduction as well as waste diversion via the recyclables' separation. The above projection assumes a sustained generation rate reduction and recycling rate. Getting people to continue recycling beyond the project is a priority. One way is to provide recycling infrastructure (recycling bins). As a constant 19% recycling rate was achieved with recycling bins, this type of intervention is successful. This result hints that a 'tipping point' had been reached, due to a 'critical mass' of participation in the participant group, transferring recycling behaviour through to the whole resident population. Another way to maintain levels of recycling is to provide ongoing feedback to users and monitoring of the operation of the recycling infrastructure. The caretaker of the apartment complex played an important role in continuous monitoring, and although feedback via measurement of bins ceased after the study data was acquired, the Recommendations of Chapter Seven entertain options for ongoing quantitative feedback.

6.4 Recycling rates

A recycling rate of 35.1% during the QR code intervention (Phase I) diverted significant volumes of waste from landfill. By comparison, the 2014 European average municipal recycling rate was 43.6%, although this includes biodegradables (food and garden trimmings) which can be substantial depending on the population (EEA, 2017). The Phase I recycling rate of 35.1% was seen in the participant group of 18 highly monitored, convenience-sampled households, who may have been predisposed to be motivated recyclers. They were also interested in the study, regularly contacted the researcher, and participated in the surveys. Thus, the recycling rate achieved may represent a 'best case' scenario in terms of the potential to separate solid recyclables from the waste stream.

In Phase II, the 19% recycling rate (Phase IIb) achieved in response to the addition of recycling bins and increased communal bin sizes was a result of this intervention. The recycling rate of Phase III (website and door-to-door awareness interventions) surpassed that achieved in Phase IIb, at 23%. Achieving this rate took time (one week to raise pre-intervention awareness, and six weeks for the intervention itself). The fact that the recycling rate was initially very low during Phase III before eventually levelling off suggests that more time might have been needed to expose the population to the proposed interventions, especially the website and awareness posters. These and other possibilities are discussed in more detail in the Recommendations.

6.5 Making recycling convenient for residents: the addition of recycling bins (Phase II)

In Survey I, 44% of respondents cited a lack of facilities on each floor as a barrier to recycling (see *Figure 5.5 Survey I: perceived barriers to recycling*). This was one of the top-three factors identified through the survey (including apathy/laziness and awareness/education/knowledge) which could be targeted directly by intervention. The literature reflects this: by simply installing food waste bins in apartment units, DiGiacomo et al. (2017) found a recycling rate increase of 27kg/unit/year (70% increase). A similar finding applied for adding recycling stations on apartment complex floors instead of on the basement level. This underlines the large impact that a basic infrastructural component can have. Before 2015, there were no recycling bins on floors of the apartment complex, and prior to this there were only a cardboard box placed next to the two communal general waste bins, used only sporadically and often contaminated with general waste. The addition of recycling bins was the second intervention of this study, after the QR code waste stream quantification. Prior to this, residents would have to drive to a drop-off point because of a lack of kerbside recycling. The skip-area in the second basement was mostly locked, making it inaccessible, overall recycling was inconvenient. Thus, the addition of recycling bins on each floor represented a simple but significant upgrade to the recycling system.

A 19% recycling rate was established through adding recycling bins (and increasing the volume of the general waste bins), equivalent to 48kg/household/year diverted from landfill. Although DiGiacomo et al. (2017) found even greater recycling rates as recycling bins were moved closer to apartment suites, this was not an option at the study site since floors were too narrow to consider such optimisations. The *size* of recycling bin/receptable is the most studied parameter of recycling containers and the resulting recycling rate (Land & Wagner, 2013). Adding recycling bins of increased size (85 litres to 120 litres) was important to enable materials to accumulate sufficiently without overflowing. Since the introduction of the third (recycling) bin and the increase in size, the janitor only needed to empty the bins once a day versus twice a day previously. This represent a significant cumulative time saving. There was also less waste dropped next to the bins by residents, so the whole area was tidier. The option of in-unit recycling receptacles was explored, but resident feedback was lukewarm. Only four respondents (19%) chose in-unit recycling bins as an option (Survey III). In addition, the space/fuss to store recyclables in-unit was the highest barrier cited in Survey III (16 respondents, 76%). This is perhaps unsurprising given the space limitations inherent with smaller floor-spaces of apartments (108 m^2 in the case of the study site).

6.6 Engaging with residents: the door-to-door and awareness campaign (Phase III)

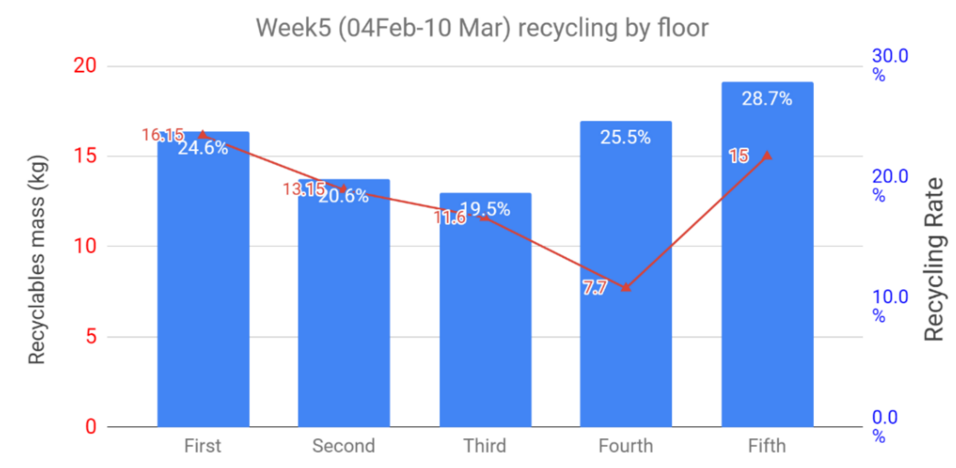
The challenge of achieving high rates of recycling is one largely of education, with people requiring extended guidance, monitoring and feedback (Fehr, Alves de Sousa, Queiroz Santos, & Maciel de Oliveira Domingues, 2009). The same authors claimed that the 62% diversion rate (of largely biodegradable waste) was a result of behavioural change which occurred due to frequent and ongoing communication of results of the recycling system to residents. In this sudy, feedback was provided via the responsive website and parallel conventional. The rate of recycling was linked, confirmed by the weekly increase from 8% in week one to a high of 23.8% in week six (See *Figure 5.7 Weekly recycling rate*). Residents did, however, favour the 'conventional' means of feedback over the website. That is, posters, bin-top stickers, and the door-to-door campaign received strong positive feedback (see *Figure 5.8 Survey III: Perceived effectiveness of Phase III interventions*). Daily life rhythms bring residents into contact with posters at lift entrances; updated recycling statistics and targets on bin top labels and the like. Over time, this exposure seemed to have more concord with residents than the website, despite the prevalent use of electronic devices in the community (see *Section 6.7*). Given the relatively minor effort required to access a webpage on a mobile or other electronic device, *motivation* was perhaps lacking (Oelofse, 2013).

6.6.1 Door-to-door information drop

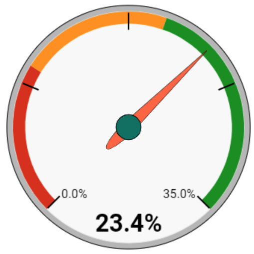
In achieving recycling rates as high as 67% (albeit with a large proportion of biodegradables), Fehr et al. (2009) spent four months on their door-to-door campaign, by a team of staff, allowing enough time for exposure ahead of interventions and initiatives to pass. Dai et al. (2015) reported a 12.5% increase in the recycling rate through a week-long door-to-door campaign [Phase III]. This was true for this study with the 42 households (70%) largely welcoming of the door-to-door interaction which included an informative flyer (Appendix I Figure I1). It is posited that as a familiar person (the caretaker) and an assistant performed the visits was invaluable to the campaign, as they already had a relationship with the residents and knew when to approach residents. The door-to-door intervention was repeated on a smaller scale (18 households) two weeks later.

6.6.2 Conventional information and feedback routes

As mentioned above, conventional feedback mechanisms (poster, bin-top sticker, flyer, door-to-door interaction) were strongly favoured by the resident population. Bin-top labels were updated weekly and included the target recycling rate, current rate, floor rate and absolute mass comparisons. This exposed participants to the statistics and targets and, hopefully, inspired them to continue recycling. Posters were also placed on each floor at the lift entrances, on the recycling bins themselves, and on a communal noticeboard. The material informed, thanked and reminded users of the benefits of their separation activities. Despite this, eight respondents (38%) wanted more information as to how/what to recycle to assist them to recycle more. This indicates that some lacked knowledge or confidence regarding waste separation, a factor deserving more attention (see 7.6 Recommendations).



Whole-building performance last week:



Target:

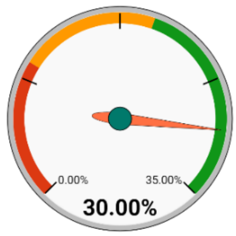


Figure 6.2 Sample bin-top label (Phase III, week 5) providing weekly feedback to participants

6.6.3 The 'caretaker role' in providing ongoing feedback

The role of the caretaker was central. The caretaker had held the position for more than three decades and was familiar with the residents and the subtleties of the apartment complex community. Moreover, she became a driving force or champion of the recycling initiatives. She checked for cross contamination, listened to residents' comments and directed maintenance staff who maintained the complex including the waste management-related activities. Without the researcher on site, it fell to the caretaker to direct the janitor, and monitor all aspects of the recycling system. Thus, an organised, influential, recycling champion, with professional (and possibly also personal) interests who lives on or near site and is in daily contact with the community, is highly desirable.

6.7 The responsive website as a mechanism for engagement and feedback (Phase III)

The pervasiveness of smartphones capable of an increasingly broad set of capabilities, cannot be underestimated. They are powerful enough to run complex applications ("apps"), which can share information and provide varying levels of interactivity. Electronic applications enable information sharing as access barriers are removed due to the 'always online' nature of modern mobile computing devices (Ertiö, 2013). As most smartphones ship come with powerful and cheap sensors (such as GPS, Bluetooth, and cameras), they can easily be used as a tool for environmental monitoring and awareness. However, smartphone apps are often platform and operating system specific (Android or iPhone) (Kipngetich, 2014). App making is usually complex involving teams of programmers and engineers with substantial budgets. For this study (see *Section 4.13 Limitations of the study*), several options were considered and even trialled as candidate platforms to host the electronic feedback mechanism. Native applications were ruled out because they would only work on a specific phone (iPhone / Android). Several excellent 'application builders', offering many out-the-box features and targeting the amateur coding / non-coding enthusiast, were considered, including GoodBarber, Appery.io, AppMakr, and Appy Pie. Each had different offerings, but most required non-trivial annual subscriptions for full-featured use, and/or substantial time to learn the interface. SiberianCMS ("Siberiancms.com", 2018) was also considered as it was open-source (no fees unless you require support and multiple applications) and had the capacity to build applications for multiple platforms ('hybrid'). However, to obtain a usable end-product, considerable time to learn it and having programming knowledge, was required.

Ultimately, WordPress was used with the addition of a paid-for 'builder' plugin to greatly enhance its power and usability. WordPress requires no programming skills for basic websites and has many themes which allow for 'responsive' design, meaning that website pages adapt and display correctly and scale to varying sizes depending on the end device (smartphone, tablet, desktop). This allows for a responsive website which could behave as an application in several ways, without the cost and development time[3]. Moreover, WordPress is user-friendly, able to easily update content and without recurring fees. Some technical knowledge is required to set up the database and web host to allow the platform to function, to learn the interface and find plugins to facilitate implementation of features necessary. Setting up the website with anti-spam (secure login), a security certificate (to increase the public-facing legitimacy of the site), a search engine optimiser (SEO) (to increase the chances of finding the page in a search-engine search, and linking the site with Google Analytics (for tracking of usage), was time-consuming and required technical knowledge. Importantly, the website (www.glendowerplace.co.za) allowed the potential for user interaction and feedback, including logging in and user accounts, feedback forms, multimedia content, blogs, and linking with the data and its visualisations contained in the cloud spreadsheets (captured by the janitor).

[3] HyperText Markup Language 5 (HTML5) was similarly used as the web interface for the citizen waste management reporting technological system in Maputo because it allowed for the information to be viewed as a webpage on any device type or size (Barroca, 2014).

The potential for intervention via smartphone application and / or website was not confirmed by this study. From Survey III, nine respondents (43%) said they had only visited once, while 10 respondents (48%) said they either did not visit the website or knew of it. Google Analytics usage statistics peaked during the door-to-door intervention, after which views subsided. This was despite most residents reporting they had access to the internet and used it regularly: 10 respondents (55%) reported that they used their mobiles to perform daily tasks ("often" or "part of daily life"), and 15 respondents (83%) had a computer/laptop device at home with internet access (Survey I). The low usage of the website (64 users and maximum of 50 visits per week over six weeks), solicited from Survey III results (only one respondent found the website to be "highly effective" or "effective") was unexpected, given its exposure during Phase III, both through the door-to-door engagements and continuous embedding in posters and bin-top stickers, as well as word-of-mouth. Writing/gathering updated material in terms of articles and relevant information to give residents a reason to want to access the website was challenging and time consuming. But, visually appealing and informative articles, useful information applicable to residents, and updated recycling-related information and statistics, did not increase page views. In a bid promote the utility of the app beyond the recycling-related material, and in collaboration with the managing agents and Body Corporate, important information and documentation was made available to residents on the website (such as house rules, dates of meetings, and emergency contacts). Thus, the website did not attract visitors, especially repeat visitors. This could be due to the website design itself together with a lack of content which appealed to the needs or interests of the population, or to shortcomings in the awareness campaign in terms of duration and appeal. Mobile users who typically have many "apps" on their phones would have a utilitarian disposition and would likely only use the app when and if necessary. As such, there is an argument to keep the app simple for this reason. On the other hand, the competition for gaining attention from the multitude of available apps also implies that apps need to be 'alternative', interactive, or interesting to the user, to ensure repeated use (UKISL, 2015). Some possibilities exist in terms of improvements, including incentives accessed through electronic registration, or to a more extensive exposure period prior to and after releasing the website. These are mentioned in *7.4.2 Providing ongoing feedback* (Recommendations).

6.8 Residents' prevailing attitudes to recycling

Changing expressed willingness to recycling into behaviour lies at the heart of the challenges around increasing household recycling rates. More specifically, understanding barriers to recycling, and how to encourage ongoing recycling was a key recommendation of the 2nd National Waste Recycling Behaviour Survey of 2015 (Strydom & Godfrey, 2016). But even strong willingness to recycle does not necessarily translate to actual recycling behaviour, the evidence for which is included in the discussion which follows.

6.8.1 Motivators

Recycling was voluntary at the apartment complex and will be for the foreseeable future. As such, understanding the motivators for recycling was key to implementing a recycling system in the complex. Before recycling activities were initiated, survey data indicated that there was 'definitely a need' for recycling (11 respondents, 61%). Generally, literature shows that environmental concerns tend to feature in the top thee motivators behind recycling activity (Abdelnaser, Mahmood and Read, 2011). This was reflected in the study which showed that residents' environmental concerns were the predominant reason for recycling (16 respondents, 76%, Survey III). Despite attention given to socio-economic aspects in the awareness campaign of Phase III, "employment opportunities and poverty alleviation" accounted for only 10% of respondent feedback (Survey III).

Respondents found the posters, bin-top stickers, and door-to-door interactions to be highly effective compared to the website. This polarised feedback was unexpected and highlights the challenges associated with the electronic feedback route. Simple bin-top stickers were popular, as they enabled residents' recycling efforts to be measured against a reasonable target. Residents showed a strong willingness to recycle from the early stages of the study (Survey I). However, the correlation between positive attitudes towards recycling and the environment and manifested behaviour is weak and does not necessarily translate into a high recycling rate (Dahlén & Lagerkvist, 2010; Saphores & Nixon, 2014; Strydom & Godfrey, 2016). This was seen in the study since 94% of respondents said they were willing to use a communal recycling bin and 89% "strongly agreed" to recycle beyond the study project (Survey I). The actual recycling behaviour of this phase (Phase IIb) reflected a 19% recycling rate which fell short of the 'ideal' rate of 35% achieved in Phase Ib (QR code method).

Another dimension to be considered for ensuring sustainable recycling practises may be in penalising residents who do not recycle, to complement an incentives-drive. This could be implemented through policy agreed upon by the Body Corporate, ultimately driven by local legislation. This fee for non-participation could also be implemented via the withdrawal of a rebate awarded due to savings on waste collection directly resulting from recycling activities from the community.

6.8.2 Barriers and their mitigation

6.8.2.1 Barriers: study findings against the national and international understanding

Since source separation requires effort, providing satisfactory conditions and infrastructure to enable it is fundamental and precedes recycling intervention rates (Stoeva & Alriksson, 2016). There are well understood disincentives to recycling applicable to this study. Inconvenience is perhaps the greatest barrier mentioned in the literature (Abdelnaser et al., 2011). Its components include lack of time, lack of space, messiness, and inconvenient locations. Local literature echoes this closely: a national survey of 2004 households in 2010 found insufficient space, time, dirtiness, and inconvenient recycling facilities were primary inconveniences reported by South Africans. The similarities extended to this study, where in Survey III respondents (n=21) were asked to list their top two barriers to recycling: 76% cited space/fuss to store the materials in-unit. Nineteen percent of respondents said that an in-unit recycling bin would greatly increase their future recycling efforts. A factor specific to apartment complex settings cited in the literature was a ‘lack of space’ as apartments have limited kitchen floor space for storing recyclables (Ko & Poon, 2009; Zen et al., 2014). Lack of space was also one of the top four reasons given in the 2004 national study (done across 11 major urban areas) which suggests that a perceived lack of space is not specific to any dwelling type.

The act of separating materials and carrying them to the recycling bins can be grouped under an ‘extra effort to recycle’ category. A significant proportion of the respondents (43%) found separating materials to be a barrier. While the time and effort involved in separating waste cannot be avoided, it’s ‘cost’ might be mitigated by the *7.4 Recommendations*. Another 29% of respondents mentioned that carrying additional bags to the communal recycling bins was a barrier. Thus, in some documented cases, recyclables can be left outside apartments and collected by a trolley or other device by a janitor (Fehr et al., 2009). This is not feasible for the apartment block understudy as the passages are narrow, and bags placed there would prevent the daily polishing of floors by maintenance staff, which if stopped may tarnish the highly maintained image of the apartment complex. In addition, it would add to the workload of the single janitor who emptied communal bins daily. For the same reason it was also not possible to move the bins closer to the apartment entrances.

One-third of the respondents mentioned recycling bag expense as a barrier. This is an area addressed in the Recommendations as an incentives strategy to mitigate this barrier and promote existing recyclers to continue to separate waste. Incentives can be highly effective in inducing beneficial behaviours. 'Pay as you throw' (PAYT) schemes implemented at the municipal level can be successful (Abdelnaser, Mahmood and Read, 2011). However, incentives programs are double-edged: they can also mask intrinsic and personal motivators, and even cause discourage waste reduction if effected without care (Lingard et al., 2001). Recycling rates have also been shown to return to previous levels once incentives are removed. Intrinsic factors such as personal norms, satisfaction, and feelings of competence, are not enhanced by incentives which punish poor behaviour and reward good behaviour, hence the contradictory nature of incentives and their application (Lingard et al, 2011).

A lack of knowledge of what to recycle is the other main barrier to recycling. It was shown to have the highest correlation with likelihood of recycling in a group of 67 studies (Abdelnaser, Mahmood and Read, 2011). A 'lack of knowledge' as barrier was once again reflected in the South African national survey of 2010 (Strydom, 2018). In this study, 19% of respondents said they were unsure of what/how to recycle, despite the multi-faceted awareness campaign. The implication is that still more needs to be done in terms of exposure to knowledge and raising of confidence in terms of recycling, *see Section 7.4.4 Ongoing education and awareness* (Recommendations).

6.8.2.2 The enablers of social behaviour change: barriers and opportunities

Social behaviour change requires three primary drivers: (1) willingness to change behaviour, (2) the skills and knowledge required to change, and (3) the opportunity/resources (Oelofse, 2013). Without all three acting simultaneously, behaviour change will be limited. In this study, all three factors had to be engaged with from the onset as recycling was adhoc and informal in the complex. In addition, survey feedback indicated areas of need directly from residents. These will now be discussed.

Firstly, *motivation* to recycle was provided by feedback, recognition, and awareness. Continued feedback is pivotal to encourage sustained recycling behaviours and has been demonstrated to be successful in apartment complex settings (Fehr et al., 2009; Oelofse, 2013). The Phase III interventions centred on this aspect, allowing residents to track the recycling rate and amount of waste diverted, with daily and weekly updates on the website and on refuse bin lids (via information stickers). Posters congratulating residents on their efforts with recycling metrics, and relating these to tangible benefits (environmental, socio-economic, in particular) were displayed. The door-to-door information campaign also served to increase awareness and motivation.

Secondly, *ability* to recycle through information of what, where, and how to recycle, was provided via the abovementioned mechanisms. Flyers were handed out during the door-to-door campaign and dedicated posters were fixed onto refuse bins and at lift entrances on each floor. The website had dedicated pages relating to what materials to recycle and how to go separating waste.

Thirdly, the *opportunity* to recycle was afforded in the study primarily by adding recycling bins on each floor, as well as by providing recycling bags and separation containers during the initial (Phase I) waste stream characterisation. Well-intentioned residents now had the means to drop their recyclables right next to their general waste, the latter which they had to do anyway. In theory recycling might represent only a small investment of extra time/effort.

6.9 The potential for collaboration with waste pickers

Waste pickers are informal traders who predominantly collect paper, cardboard boxes, plastic bottles, and scrap metal, as determined by what they can use personally or sell to buy-back centres. They are forced into informal trading due to South Africa's high level of unemployment and lack of economic opportunities. Their activity can be defined as survivalist (Schenck & Blaauw, 2011). Waste pickers are frequently active at the apartment complex, but there is no structured system in place. Different individuals come and go over time and there is no regularity of collection. A situation that is, therefore, an 'opportunistic' one. Operationally, transport is a primary issue as the waste pickers must push heavy trolleys over long distances to get their material to buy-back centres. These people are also exposed to the elements and hazardous substances or pathogens in the waste they collect. Viljoen, Blaauw, & Schenck (2018) found that the waste pickers themselves can do little to improve their income, other than using a trolley and collecting extremely early in the morning. Their integration into the waste management hierarchy needs to be delivered through government policy intervention and planning. The plight of waste pickers is an urgent public issue. There is an untapped opportunity to formalise their activities and facilitate their access to recyclables, their collection and buyback systems. Recommendations for this potential collaboration are made in *7.4.5 Assistance for the waste pickers.*

6.10 A consideration of biodegradables

Biodegradables or organic wastes including food wastes are estimated at around 46% of global municipal solid waste (MSW) (Boonrod, Towprayoon, Bonnet, & Tripetchkul, 2015). It is often the largest contributor to MSW, ranging from 28% in high-income countries to more than 64% in low-income states (Dai et al., 2015). For example, in two Bangkok districts, organics constituted the major portion of the waste stream (between 40% and 60% by mass) (Areeprasert et al., 2017). However, the literature shows fluctuations beyond this 'upper bound'. For example, in an apartment complex in Brazil, Fehr et al. (2009) found that more than 70% of the waste stream was 'humid' or biodegradable material by mass, and up to 77% by mass in Balakong, Malaysia (Samah et al., 2013). Locally, in the City of Tshwane, organic wastes were estimated at 54% (UNEP, 2018). For biodegradables recycling to be an option, a free collection service and a strategic move towards alternative treatment facilities is required (Ordoñez et al., 2015). Biogas, for example, is an area of opportunity in Africa, with a R100 million investment potential in South Africa, offering a solution to the landfilling of organic wastes and contribution to energy supply (GreenCape, 2018; UNEP, 2018). In this study, a scope delimitation excluded the consideration of organics, but organics separation is an area which should not be neglected due to its high proportion of the waste stream and opportunity to contribute to the economy. However, in the apartment complex setting, increasing source-separation would require the addition of specialised food collection infrastructure. For example, a metal hanger fixed on the inside of a kitchen sink cupboard, to house a paper bag for separation of food wastes, was highly effective in a Swedish study (Bernstad, 2014). The difficulty in estimating food waste also means that the first step would have to be a specific study to ascertain the proportion of organics being produced at this study site. The demand for organics and a means for its processing and transport requires further investigation before a serious consideration of the recycling of this waste stream component in the apartment complex setting.

6.11 Conclusion

The QR code methodology used in this study was effective for characterising the waste stream, including recyclables composition, without overbearing resource requirements. It also established a 35% recycling rate in its capacity to measure source-separation of a participant group and, thereby, set an 'ideal recycling target' calibrated uniquely for, and by, the resident population. This was a strength of performing the interventions and methodological piloting of the QR code methodology in a ‘realistic’ case-study setting. The system of scanning QR codes was simple, reliable, and allowed for automated reporting via charts and tables to the apartment community. It effectively quantified recycling rates as a means of establishing the effectiveness of the interventions. It did require an operator for daily mass measurements, a system which might be automated entirely with the right technology. The waste generation rate of the apartment complex was lower than expected (at 2.30kg/person/week for Phase I), more in-line with the South African low-income average of 2.90kg/person/week (DEA, 2015a). The fact that the whole-complex waste generation rate decreased after each intervention was evidence of an increased awareness by residents, separate from their recycling activities. This was encouraging and aligned with literature findings.

As far as recycling rates, the QR code methodology (Phase I) in the participant group achieved a 35% recycling rate, through constant monitoring and support of participants. In Phase II, a substantial 19% recycling rate was attained by providing the most basic unit of recycling infrastructure (Phase II), namely the addition of large (120 litre) recycling bins on each floor of the apartment complex. In the last phase (Phase III), it was found that the website was not as effective as a means of engaging with the resident group and providing feedback compared to engagement by the caretaker and door-to-door interactions. Additionally, more ‘conventional’ means of feedback and incentives, through posters, bin-top stickers on refuse bin lids, and door-to-door interactions, were found to be highly effective. This suggests that more work needs to be done to successfully integrate the potentially powerful electronic feedback component into a recycling system. Running in parallel to the interventions were surveys whose findings yielded important information about barriers and motivators to recycling, allowing for more effective design of the interventions themselves and how the results might be interpreted. The mitigation of these barriers as well as the opportunities for enhancing positive predictors of recycling behaviour direct the Conclusion and Recommendations which follow in Chapter Seven.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This study describes the household solid waste stream of a 60-unit apartment complex using a QR code methodology for measuring these wastes (plastics, paper, glass, and metals). After an initial 'ideal recycling rate' was obtained via the QR code methodology, the study moved to test two interventions to determine their effect on the recycling rate, and their effect on residents' attitudes towards recycling, whilst recording any actualised recycling behaviours. The lack of research on such interventions in the apartment complex setting in South Africa itself presented an opportunity to consider the use of IT-interventions such as QR codes and web applications as a means of measuring and encouraging recycling rates and behaviours, which rarely featured in the literature. These pursuits were set against the study aim of identifying which parameters are required to have a sustainable recycling system for an apartment complex in an urban area in South Africa.

7.2 Rationale

The majority (74%) of South Africans do not separate or recycle their waste (Strydom, 2018). As a result, many South African cities have a "waste management crisis" with illegal dumping, diminishing landfill space, and increasing yearly waste volumes (CoJ, 2017b). Why so few South Africans participate in recycling programmes is only partially understood in the local context. Furthermore, accurate waste stream data is limited in South Africa and is, therefore, a priority if recycling systems are to be conceptualised, implemented and improved (Nwokedi, 2011). This case study, set in an apartment block in a major South African city, therefore, provided an ideal opportunity to test a novel QR code methodology for obtaining waste stream data, as well as for gauging the effectiveness of interventions designed to promote recycling. Since some 717 000 South Africans lived in apartment complexes as of 2016, the study also represents an opportunity to understand recycling behaviours in these settings (StatsSA, 2016a). As the interventions in this apartment block generated readily available source-separated recyclables for locally operating waste pickers, the study highlights an opportunity to channel materials away from landfills and help waste pickers (who are a very poor subset of South African society) improve their livelihoods (Godfrey et al., 2017). As most municipalities do not have regular curb side recyclable collection systems in place, these waste pickers (of which there are roughly 90,000 across the country) play a vital role in collecting plastic, glass and tins (Godfrey & Strydom, 2016). The study also offered the opportunity to collect data on attitudes towards recycling and evaluating any changes in recycling behaviour as a result of interventions.

7.3 Resolution of the research questions

The formulation of this study was encapsulated in the research questions, the answers to which are summarised below.

Research Question 1: Can a QR code methodology accurately describe the waste stream?

General and recyclable waste output quantification was accurate as each refuse bag was weighed and electronically logged using precise measuring equipment, and sustained efforts to control systematic errors to increase reliability. It did require:

- A well-trained operator to do the daily measurements. Training included how to eliminate errors in measurement taking.
- Scanning of QR codes and entry into the smartphone app, which was simple and effective, albeit time consuming. During the separation phase, each type of material has its own bag and QR code stuck onto it (a total of 1256 measurements over 10 weeks).
- Some bags were missing QR code stickers, in which case the participant responsible had to be tracked down (where possible).

The logging of individual bags and waste types during separation resulted in a detailed quantification of the waste stream.

Research Question 2: How much solid waste does an apartment block produce on a daily/weekly basis (recyclables and non-recyclables) both before and after a QR code, recycling bin, and website / door-to-door intervention?

a. QR code methodology

Whole-complex (all residents) general waste generation rates were 5.26 kg/household/week and 5.31 kg/household/week (1.0% increase) before and after the QR code waste stream characterisation / intervention. Non-participants (72% of households) generated 5.04 kg/household/week and 5.45 kg/household/week (8.1% increase) before and after the intervention. In contrast, participants (28% of households) generated 5.81 kg/household/week and 4.95 kg/household/week before and after the intervention (a 14.8% decrease). During the separation phase (5 weeks), a total of 147.8kg of recyclables were generated vs 420.7kg of non-recyclable wastes. Recyclables compositions were 47% (68.8kg) paper, 28% (40.9kg) glass, 20% (30.1kg) plastics, and 5% (8.0kg) metals. Thus, the QR methodology for collecting waste stream data successfully generated reliable, detailed waste stream data.

b. The introduction of communal recycling bins

Before the intervention, there were two 85-litre general waste bins and a cardboard container for recyclables (mostly paper, but often contaminated with general waste) per floor. After the intervention, there were three 120-litre bins, two for general waste and one for recyclables, per floor. Before the intervention, a total of 6,252kg of waste was generated over 20 weeks, a generation rate of 5.24 kg/household/week. After the intervention, 3,044kg of waste (including recyclables) was measured over 10.6 weeks, a generation rate of 4.78 kg/household/week (an 8.8% decrease). The decrease in *general* waste output after a lengthy 20-week baseline suggests that the decrease in general waste output was due to the intervention. A recycling rate of 19% was achieved (580kg over 10.6 weeks) as a result of the intervention, which is significant considering its simplicity.

c. An awareness campaign including a responsive website, door-to-door interactions, bin-top stickers, flyers, and posters.

In total 1,664kg of solid waste (including recyclables) was measured over 10.6 weeks, a waste generation rate of 4.62 kg/household/week (11.8% decrease from the Phase IIa baseline of 5.24 kg/household/week). This was the highest reduction in general waste measured. A recycling rate high of 23.8% was achieved (average rate of 20.8%) during this six-week intervention, improving on the 19% achieved through adding recycling bins, but not approaching the ideal rate of 35.1% achieved through the QR code methodology.

Research Question 3: How resource intensive is the QR barcode quantification system, continued monitoring and the interventions in terms of set up and running costs?

Initial costs involved acquiring the measuring equipment and mobile phone to scan the QR codes. Initial time costs were due to having to learn how to write and test a very simple smartphone application with visual coding blocks. QR code stickers were prepared by encoding them through a webpage, printing them and allocating them to the study participants. Training the janitor to conduct accurate and reliable waste measurements took about a week. Choosing the correct technology platform for the project, learning how to create a secure, responsive Wordpress.org site including search engine optimisation, took around three weeks. Explaining to participants how to use these QR codes (which stickers to put on which bags, when, and how) during the separation phase was time consuming as it required finding a suitable time when residents were available during a typical working week. Recruiting participants also took a week. Operational costs were dominated by the janitor's weekly wages for measuring the wastes. Secondary costs included providing bin liners and recurring web hosting fees. Costs to run the study totalled R 21,049.

Research Question 4: Which interventions increase the recycling rates the most: QR codes, changing communal bin sizes, allocating dedicated recycling bins, a responsive website or door-to-door?

a. QR code methodology

This intervention resulted in the highest recycling rate (35.1%). Participants' individual recyclable and non-recyclables waste bags were weighed and tracked with QR codes during the five-week trialling of the QR code methodology. In this respect it was an 'ideal' recycling rate because of the close monitoring and feedback of the activity of participants. Support and guidance were given to participants through social interactions (face-to-face conversations), through electronic/statistical feedback on the website, together with 'corrective feedback' where separation or procedural mistakes had been made.

b. Changing communal bin size / allocating a dedicated recycling bin for residents

A recycling rate of 19% (580kg of recyclables) was achieved (whole complex, i.e. all households) when recycling bins were made available on each floor. Prior to the study there was virtually no separation at source recycling taking place in the complex. Thus, the intervention resulted in roughly a quarter of waste materials being diverted from the landfill. This may be greater if the recyclables that the waste pickers obtain from the site are added.

c. Combined responsive website and door-to-door intervention

The recycling rate increased from 9% in week one to a high of 23.8% in week six (final week). The recycling rate increased steeply over the first three weeks, and then levelled out, remaining between 22.9 and 23.8 percent over the final three weeks of the intervention. The combination of website, posters, door-to-door interactions, flyers, and bin-top stickers with recycling feedback, seemed to increase the recycling rate until it plateaued, not quite approaching the QR code methodology rate of 35.1%.

<u>Research Question 5</u>: What are the prevailing attitudes of residents towards recycling and how well can incentives-based interventions work?

a. Prevailing attitudes of residents towards recycling

Generally, residents supported recycling in theory and felt that not enough was being done to ensure recycling took place. Prior to the recycling initiatives of this study, 11 respondents (61%) indicated that there was “definitely a need” for recycling. Residents were willing to recycle: 16 respondents (89%) “strongly agreed” when asked whether they were willing to recycle beyond the study duration, 17 respondents (94%) were willing to use a recycling bin made available on each floor to separate wastes, and 13 respondents (72%) “strongly agreed” to separate wastes inside their households. Residents’ environmental concerns were the main reason for them recycling (16 respondents, 76%, Survey III). Barriers to recycling, were primarily ‘space/fuss to store recyclables’ (76%) and ‘effort to separate the recyclables’ (43%).

b. Are incentives-based interventions feasible in the complex?

Solid waste is currently collected by the Ekurhuleni Metropolitan Council, with no option to opt out. Nor can the frequency of collection be negotiated. Although the Waste Act No 59 of 2008 requires households to separate waste at source, there is presently limited support for the collection of sorted recyclables by this municipality. Thus, for all intents and purposes this section of the act is not enforced. Thus, source separation is not widespread and there are no financial incentives for people to recycle. Overall there are few incentives to support recycling in this metro. Pressuring apartment residents to recycle by introducing tariffs on unsorted wastes would most likely result in resistance, thus, positive incentives such as providing free recycling bags is a better option, as 42% of respondents supported the provision of recycling bags to facilitate source separation. However, this needs to be counter-balanced by measures enforced by the Ekurhuleni Metropolitan Municipality, such as by only collecting a certain amount of general waste, above which residents would be left to dispose of the balance themselves.

7.4 Recommendations

Recommendations to facilitate sustainable recycling systems and practises at the study site and similar settings, including suggestions for further study, are now outlined:

7.4.1 Automated quantitative monitoring/characterisation of the waste stream

QR codes can be effective in generating accurate waste stream data as each bag was weighed, both unsorted or sorted (mixed recyclable) waste. QR codes do, however require constant human intervention (on a daily basis in the case of this study) to perform these tasks (scanning of barcodes, weighing of bags). A cheaper, less labour-intensive option for continuous quantitative monitoring of the waste stream would be the use of a scale with a load sensor and an RFID (radio frequency identification) tag in the refuse bin. Complementing this, a mobile phone with NFC (near field communication) capability would be configured to send the bin information (date, mass, waste type) acquired through a 'tap' of the bin (tag). A wireless module would communicate the information from the load sensor to the mobile phone, and from there to a database (Chang & Pires, 2015). While there would be some human intervention (tapping the bin lid with the mobile phone), the time take would be greatly reduced.

Using this valuable data, multiple sites could be linked through a database, and web app, allowing for many management possibilities. These might include allowing waste pickers to be notified (via sms for example) when and where to collect recyclables, and for main waste skips to be collected only when full. The possibility for reduced frequency of skip collections, increased volume and quality of recyclable materials going into the hands of waste pickers in an organised way, and implied cost savings due to reduce collection overheads, needs to be investigated. This approach also aligns with the 'Internet of Things' (IoT) solution posited by Medvedev, Fedchenkov, Zaslavsky, Anagnostopoulos, & Khoruzhnikov (2015).

7.4.2 Providing ongoing feedback

Ongoing feedback is essential to sustain the recycling rate. Fehr et al. (2009) achieved a high recycling rate with four months of door-to-door interactions *before* the implementation of interventions, and recommend permanent, ongoing feedback after the interventions in order to keep recycling and participation rates high. In this study, the effects of feedback were clear, with recycling rates in Phase III increasing significantly in the first three weeks. Increased participation rates were reflected in survey results and through verbal feedback from residents who indicated their increased motivation to recycle and participate as a result of the positive feedback cycle. However, the lack of engagement with the responsive website and its limited appeal needs to investigated. Perhaps better a better designed web app to improve usage levels and to promote it as a multi-purpose waste-management tool is necessary. This might involve professional development and design. To increase the likelihood of it being used, the waste management functionality could be integrated within a broader app that includes the ability to check levy statements, electricity and water meter readings, paying levies, lodging reports/complaints to the body corporate, meeting reminders, planned maintenance status updates, and other useful features. This could increase user uptake of the app and, thereby increase engagement with the waste management component therein. It is also recommended that the pre-exposure awareness campaign before launching the website or equivalent electronic portal is longer in duration, more varied, and involves some hands-on demonstrations once it has been launched.

7.4.3 Incentives

User feedback showed that 43% of respondents said free recycling bags was their top motivator to recycle. Therefore, the use of an incentives scheme, whereby residents register for the responsive website/app get free clear recycling bags is proposed. Clear bags for recyclables are necessary, to ensure the bags are not used for general waste or other purposes. An additional layer of interaction could involve a facility whereby participants scan QR codes on full recycling bags, with electronic validation thereof enabling the resident to get more free recycling bags and other incentives.

7.4.4 Ongoing education and awareness

Residents need lots of ongoing guidance as to what/how to recycle. About one-fifths (19%) of respondents (Phase III) said that they needed more guidance in this respect, even after a detailed awareness campaign. The ongoing use of posters, flyers, and website resources (beyond the study duration) is suggested. A practical/physical door-to-door demonstration using an array of typical recyclables (and non-recyclables) could also increase confidence and reinforce the common permissible recyclable materials. Reinforcing the message over an extended period is necessary.

7.4.5 Assistance for the waste pickers

Enhancing access to greater volumes of higher-value waste is the primary means of enabling waste pickers to increase their income (Schenck, Blaauw, & Viljoen, 2016b; Viljoen et al., 2018). To facilitate this, a reconfiguration of the basement level where wastes aggregate, is suggested. This would involve the installation of clearly labelled, large bays or lockable cages for paper, plastics, and possibly electronics, textiles and other valuables. This would lessen the health risks to waste pickers who currently collect materials directly from the large waste skip. The local waste pickers can also engage the janitor (for example) to establish a schedule of ‘collection days’. Waste pickers could be provided with identification cards and protective clothing to afford them validity and recognition of their services (Schenck et al., 2016b). They could also be provided with a trolley or modified cart to assist them in transporting the waste (Viljoen et al., 2018). Any means of helping the approximately 90,000 waste pickers operating throughout South Africa should be taken seriously since at present they possess few means of escaping persistent poverty (Viljoen et al., 2018).

7.4.5 Biodegradable wastes

This important materials category needs to be studied, as it constitutes a significant portion of the waste stream. In particular, research is needed to determine: (1) how much the apartment complex generates in terms of biodegradables; (2) whether - and how - these might effectively be collected; and (3) if there is any scope for the broader processing of these, for example in combustion or decomposition waste-to-energy plants for generating electricity.

7.5 Conclusion

This case study succeeded in accurately describing the waste stream of an apartment complex in South Africa using a novel QR code methodology, helping to fill the very incomplete quantitative picture of household waste outputs in such settings. The study developed practical methods to initiate and sustain source-separation practises in an apartment complex where virtually no recycling took place before. This was done by leveraging readily available technology solutions such as responsive web pages, web apps, and QR codes. A good recycling rate was achieved, highlighting the potential for waste diversion away from landfills. The survey data which encapsulated residents' attitudes towards recycling, including indications of motivating and demotivating factors, would in turn influence the usage and performance of the recycling system. It was found that providing primary infrastructure (conveniently located, well-labelled recycling bins), ongoing feedback (through conventional and electronic means), as well as continuous confirmation of what and how to recycle, were crucial to fostering participation and attaining good recycling rates. The study makes suggestions as to how ICT solutions could be used to facilitate the monitoring and flow of recyclables. Increasing the recycling rate beyond that attained, however, will only occur if the identified barriers to recycling are reduced and the motivating factors for recycling enhanced. The recommendations have the potential to further the understanding and management of the solid waste stream in apartment complexes, in particular the implementation of sustainable recycling initiatives that are sensitive to the present socio-economic climate.

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APPENDICES

Appendix A Phase I electronic questionnaire

Waste Stream Characterisation Questionnaire

This questionnaire is anonymous and no respondent's name need be given. Please feel free to fill in this questionnaire with confidence therefore, and supply information which accurately reflects the situation.
Where applicable, please tick the box next to the option you prefer.

Introduction

This study was put together primarily to find out how much recyclable material people are throwing away in residential settings rather than diverting away from landfills. Currently, there is very little to no data from studies done on residential apartment blocks as regards the amount and types of recyclable materials generated.

Complementing the above, the level of awareness and attitudes towards recycling in the residential community constituting the study group needs to be understood. This is crucial for recycling projects to persist and be sustainable.

The questionnaire below has been carefully designed to gather data which will allow for more successful recycling practises in other apartment blocks, residential suburbs, municipalities and further afield.

* Required

Resident Information

Name

Age

Racial or ethnic group

Gender
(M/F)

Flat Number *

Number of adults in residence *

Number of children in residence *

How long have you lived in the apartment block? *

Please indicate your education *
check box(es) as appropriate

- [ ] High school
- [ ] College/diploma
- [ ] Degree
- [ ] Postgraduate
- [ ] Unemployed/retired

Current recycling practices in Glendower Place

Please describe any current recycling practises in place at present in Glendower Place *
(indicate none if there are none to your knowledge)

If you answered yes to the above, please indicate the effectiveness of the recycling

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

If there are recycling practices in place currently, please list three primary drawbacks which limit the potential of the recycling activity in your opinion

Would you like to see more recycling initiative in Glendower Place? *

- No
- There is room for improvement
- There is definitely a need for a recycling programme in the complex
- I am neutral in this regard

Janitor/groundsman involvement for long-term recycling in Glendower Place

Would you be willing to have any income generated from teh sale of recyclables go towards paying our groundsman for his extra work in processing recyclables? *

(Y/N)

Would you be willing to discuss at the next meeting the possible allocation of a small portion of the levy toward setting up a recycling infrastructure to make recycling a long-term practice at Glendower Place? *

(Y/N)

Are you aware that bins are emptied and cleaned daily? *

(Y/N)

Amount of waste generated per week

How many times do you empty your bin per week? *

Estimate how much waste you generate per week on average *

(0-5kg; 6-10kg; 11-15kg; >15kg)

Estimate how much glass you discard per week (jars, bottles) *

(1-5 items; 6-10 items; >10 items)

Estimate how much metal you discard per week (tins, cans) *

(1-5 items; 6-10 items; >10 items)

Describe the amount of recyclable paper waste you think you generate per week (magazines, newspapers, cereal boxes, dry consumables packaging) *

(very little; sometimes; moderate; appreciable)

Feasibility around recycling in apartment blocks

List the top three factors, in order of importance, which you think inhibit people from recycling their wastes daily *

What are the two main positives of recycling in your opinion? *

If recycling won't necessarily generate an appreciable amount of money, do you think setting up a permanent recycling system is worthwhile? *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Are you willing to separate recyclable wastes (plastic, paper, glass, metal) inside your unit? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

If you have reservations about separating wastes inside your unit, please state the main reason behind your viewpoint

Are you willing to place wastes such as glass and metal in special communal recycling bins on each floor as you generate them? *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Do you think that if there were recycling bins on each floor for each waste type, that people who currently don't recycle would start to use them? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Do you think the abuse of communal recycling bins on each floor would be a big problem? (carelessly throwing away any item into the bins, for example)

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Do you have any ideas as to how the possible abuse of such recycling bins, were they implemented, could be negated? *

Do you think that recycling containers should be made available downstairs at the shop level for those who want to recycle, and that those of us who don't want to should be left to continue doing as we please (eg. not recycling anything) ? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Would you be willing to continue your recycling practices beyond the duration of this study if you were not already doing so? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Would you be willing to continue your recycling practices beyond the duration of this study if you were not already doing so? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Would you like to see South Africa approach the high levels of source-separation -recycling which have been in place in certain other parts of the world for many years? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Use of the internet/smartphones

Are you a regular user of the internet? *

(never/hardly ever; few times a week; just about every day; several times a day)

Do you use your mobile phone to receive emails, go on the internet, etc. ? *

(never; infrequently; often; daily part of life)

Do you have a computer/laptop at home with internet access? *

○ No

○ Yes

Do you think that having a website for the environmental aspects of the building (renewable energy generation, recycling, energy budget) would go a long way toward increasing interest and awareness amongst residents in the complex? *

Do you think that having a smartphone app for Glendower Place, where residents could track the amount of wastes they discard/recycle, would be beneficial? *

	1	2	3	4	5	
strongly disagree	○	○	○	○	○	strongly agree

Submit

100%: You made it.

Never submit passwords through Google Forms.

Appendix B Phase I questionnaire responses

1. Timestamp	2. Name *	3. Age	4.Racial or ethnic group	5. Gender	6. Flat number	7. Number of adults in residence	8. Number of children in residence	9. How long have you lived in the apartment block?	10. Please indicate your education
8/10/2015 16:13:38		54		Male		2	1	6	College/diploma
8/31/2015 18:10:52						1	0	20	College/diploma
9/1/2015 15:35:52				Male		1	0	2	Postgraduate
9/3/2015 10:57:27		62	white	Female		2	0	37	College/diploma
9/5/2015 13:18:57		35	mixed	Male		3	1	5	College/diploma
9/5/2015 19:06:48		76	White	Male		3	0	33	Unemployed/retired
9/10/2015 21:02:50		59	White	Female		2	0	21	High school
9/18/2015 16:08:41		56	White	Female		2	0	29	Degree
		16	Coloured	Female		1	2	1	High school
		78	White	Female		1	0	31	Retired
		65	White	Female		2	0	18	High school
11/17/2015 18:55:16		37	White	Male		1	0	35	Degree
9/30/2015 9:45:55		44	White	Male		1	1	9	Degree
		30	White	Male		2	0	1	high school
			White	Male		2	0	20	college/diploma
		75	White	Male		1	0	29	degree
		64	White	Female		4	0	29	high school
		42	White	Female		1	3	0	postgraduate

11. Please describe any current recycling practises in place at present in Glendower Place	12. If you answered yes to the above, please indicate the effectiveness of the recycling	13. If there are recycling practices in place currently, please list three primary drawbacks which limit the potential of the recycling activity in your opinion	14. Would you like to see more recycling initiative in Glendower Place?	15. Would you be willing to have any income generated from the sale of recyclables go towards paying our groundsman for his extra work in processing recyclables?	16. Would you be willing to discuss at the next meeting the possible allocation of a small portion of the levy toward setting up a recycling infrastructure to make recycling a long-term practice at Glendower Place?	17. Are you aware that bins are emptied and cleaned daily?	18. How many times do you empty your bin per week?	19. Estimate how much waste you generate per week on average	20. Estimate how much glass you discard per week (jars, bottles)
None	5		There is definitely a need for a recycling programme in the complex	yes	no	Yes	4	11-15 kg	1-5 items
none			There is definitely a need for a recycling programme in the complex	yes	yes	Yes	5	6-10 kg	1-5 items
Paper recycling	5		There is definitely a need for a recycling programme in the complex	No	no	Yes	2	0-5 kg	None/very few items every month
none at the moment	5	Only the one you initiated-	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	3	6-10 kg	1-5 items

On going so far so good the little bins with markings help make it easier.	3	Lack of knowledge regarding recycling waste	There is room for improvement	yes	no	Yes	5	6-10 kg	None/very few items every month
Paper recycling box (previously on floor). Current research study	3	Poor response to the initiatives Lack of insight into the importance of recycling Not high on list of day to day concerns	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	4	0-5 kg	None/very few items every month
Yes	5		There is definitely a need for a recycling programme in the complex	yes	yes	Yes	4	6-10 kg	None/very few items every month
Glass and paper	1	Attitude of the residents Recycle bins need to present and made visible Recycling needs to be for job creation and not a community gain. We need to put something back into society.	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	2	6-10 kg	None/very few items every month
Paper	2	I feel people are placing wrong things in the indicated bins People are not fully aware of the positive impact of recycling has on the environment	there is room for improvement	yes	yes	yes	7	0-5 kg	1-5 items
Some	5		there is room for improvement		no	yes	7	0-5 kg	1-5 items
none	5	storage, hygiene, awareness	Definitely a need for recycling	yes	yes	yes	4	6-10 kg	1-5 items
basic separation of paper; contaminated	1	no instructions at informal recycling bin bin is open which lends to contamination (people throw anything in) no formal structure has been implemented	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	2	6-10 kg	1-5 items
Basic Recycling	1	Inhabitants abuse the paper recycling bins by placing other rubbish in the paper recycler.	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	1	0-5 kg	None/very few items every month
yes	4	lack of awareness/knowledge	there is room for improvement	yes	yes	Yes	2	11-15	1-5
-	2	people not used to it I will need a few rubbish bins in my flat and it takes up more room	I am neutral in this regard	yes	yes	Yes	2	6-10	1-5
recyclestream	5	no problems because I live alone, do not put out a recycling bag as frequently as all that	There is room for improvement	yes	yes	Yes	2	0-5	1-5
paper	5	there may be other recycling practices in place currently, but I'm not sure what they are The drawbacks are limited space perhaps, also that people do not wash out their bottles etc. and that they may smell. Also, many people will not participate in recycling	there is room for improvement	yes	yes	Yes	9	6-10	1-5
paper/plastic	4	no bin on our floor people throw household refuse into recycling bins	There is definitely a need for a recycling programme in the complex	yes	yes	Yes	5	6-10	0

21. Estimate how much glass you discard per week (tins, cans)	22. Describe the amount of recyclable paper waste you think you generate per week (magazines, newspapers, cereal boxes, dry consumables packaging)	23. List the top three factors, in order of importance, which you think inhibit people from recycling their wastes daily	24 What are the two main positives of recycling in your opinion?	25. If recycling won't necessarily generate an appreciable amount of money, do you think setting up a permanent recycling system is worthwhile?	26. Are you willing to separate recyclable wastes (plastic, paper, glass, metal) inside your unit?	27. If you have reservations about separating wastes inside your unit, please state the main reason behind your viewpoint	28. Are you willing to place wastes such as glass and metal in special communal recycling bins on each floor as you generate them?	29. Do you think that if there were recycling bins on each floor for each waste type, that people who currently don't recycle would start to use them?	30. Do you think the abuse of communal recycling bins on each floor would be a big problem? (carelessly throwing away any item into the bins, for example)
1-5 items	moderate	Not enough support structures Lack of knowledge Lack of interest	Environment will be improved Everyone will understand the importance of looking after our environment	5	5	27. I have no reservations	5	5	2
1-5 items	moderate	no proper system in place lack of understanding the importance of recycling laziness	environmental economical	5	5	n.a.	5	3	3
None/very few items every month	sometimes	Lack of education/ awareness No establishments	Better environment structured system	5	5		5	3	2
1-5 items	moderate	time consuming ignorance embarrassment	awareness toward environment hygiene	5	5	none	5	5	5
None/very few items every month	moderate	Time, no recycling bins to aid recycle and previously no data kept regarding waste	teaching my child how to recycle from a early age and showing the child how by just recycling the impact it has on the enviroment	3	4	Not a problem	3	3	3
None/very few items every month	moderate	Apathy Inconvenience Storage considerations	Environmentally 'green' action Economic efficiency	4	4	Identification of recyclables is sometime difficult or time-consuming	5	5	5
None/very few items every month	appreciable	They are lazy to separate items They don't have the means to do it	We are trying to make a difference Poor people make a living out of it	4	5		5	3	3
6-10 items	moderate	Lack of education Too lazy to separate waste Lack of visible recycling bins	Reduce landfill sites and the emission of methane gas Job creation	5	5		5	4	3
1-5 items	moderate	Recycling is inconvenient so many facets to recycling (too much effort) lack of space	saves energy preserves our resources and protects wildlife	4	4		4	4	5
1-5 items	moderate	Ignorance careless attitudes time	avoiding global mess cleaner space	3	5	carelessness	5	1	2
1-5 items	very little	awareness, storage space, hygiene	less refuse to separate from skip reuse of recyclable items	5	5	storage of items hygiene	5	5	2
1-5 items	moderate	Lack of recycling bins on each floor lack of awareness and education lack of feedback as to success of program	don't waste a resource saves huge volumes of potentially useful materials from going into the earth	5	3	space constraints looks ugly after a day or two	5	5	3

1-5 items	sometimes	Awareness ! People aren't aware of the benefits of recycling and don't care to participate. I think the only way forward would be to force it on the complex with a group initiative.	Saving the planet, saving money.	5	5		5	2	5
6-10	appreciable	Laziness lack of awareness	less waste cleaner bins	5	5	none	5	3	5
6-10	moderate	time cost of refuse bags waste of more rubbish plastic bags	not all the rubbish needs to go to the rubbish dump recycling is the way to go for the future	3	3	it will be my sole job/responsibility to do it time	4	4	5
1-5	sometimes	not interested time factro unaware of recycling plan	re-usable material not wasted a saving to the economy	1	5	n/a	5	5	3
1-5	moderate	don't have time don't care about it don't know about it	convervation of the planet generate money	5	5	don't know if I always have time, but will try and do have a domestic and don't know if she will do it properly will have to have extra bags	5	5	5
1-5	moderate	laziness don't care lack of education	becomes a way of life feel like you are making some small positive contribution to the landfill problem	5	5	not at all	5	4	4

31. Do you have any ideas as to how the possible abuse of such recycling bins, were they implemented, could be negated?	**Do you think that recycling containers should be made available downstairs at the shop level for those who want to recycle, and that those of us who don't want to should be left to continue doing as we please (eg. not recycling anything) ?**	**32. Would you be willing to continue your recycling practices beyond the duration of this study if you were not already doing so?**	**33. Are you a regular user of the internet?**	**34. Do you use your mobile phone to receive emails, go on the internet, etc. ?**	**35. Do you have a computer/laptop at home with internet access?**	**36. Do you think that having a website for the environmental aspects of the building (renewable energy generation, recycling, energy budget) would go a long way toward increasing interest and awareness amongst residents in the complex?**	**37. Do you think that having a smartphone app for Glendower Place, where residents could track the amount of wastes they discard/recycle, would be beneficial?**	**38. Would you like to see South Africa approach the high levels of source-separation -recycling which have been in place in certain other parts of the world for many years?**
Incentives can be put in place.	3	5	few times a week	Often	Yes	Yes	Yes	5
I don't really know. When we had the box for paper on our floor, some people used to place their general waste in that box although it was clearly marked for paper. I think there is a big problem with some residents' attitude towards the environment and also the cleanliness of our building.	5	5	several times a day	Infrequently	Yes	possibly with some residents	3	5
Simple explanation of the use of every recycling bin above the bin.	2	5	few times a week	Never	Yes	maybe	4	5

educating people and making them aware -	1	5	just about every day	Daily part of life	Yes	yes definitely	5	5
Place a list on or near the bin indicate what can be recycled	2	4	just about every day	Often	Yes	yes	4	5
Education	3	4	several times a day	Daily part of life	Yes	I doubt it	2	5
By using the wrong bins	4	5	several times a day	Daily part of life	Yes	Yes	4	5
Very clear instructions and labels must be on the bins. In the instructions it must be clear what the purpose of the recycling is.	2	5	just about every day	Never	Yes	Yes	3	5
	3	4	just about every day	Often	yes	yes	yes	5
Complicated at present	5	3	5	never	no	questionable	no	5
awareness make it easy for people to dispose of	5	5	never/hardly ever	never	no	yes definitely	3	5
having lids on recycling bins (dissuade casual throwing of anything inside) incentives per floor;	2	5	several times a day	Daily part of life	Yes	Yes	5	5
Cameras at the recycling points and fine people for abusing the system by dumping any rubbish wherever they please.	5	5	several times a day	Daily part of life	Yes	No	3	5
	n/a	5	several times a day	Daily part of life	yes	yes	no	5
clearly marked bins might help bins must have lids	4	3	few times a week	never	yes	maybe	yes, will take time	4
educating about re-cycling could help there always seem to be people who don't care	1	5	just about every day	Infrequently	no	it could help	yes	5
incorrect items will have to be re-sorted	5	5	several times a day	Never	Yes	yes	yes	5
fines	1	5	just about every day	Daily part of life	yes	no	yes	5

Appendix C: Phase II shop owner's electronic questionnaire

QUESTIONS RESPONSES 11

Glendower Place Shops - Recycling Survey

A pre-recycling system implementation short survey of the commercial units / shops and their current recycling tendencies

1. Name of business *

Short answer text

2. Name and surname

Short answer text

3. Title / position within organisation *

Short answer text

4.What is the company's core business activity? *

Short answer text

5. Please indicate the type and amount of recyclable waste your business produces *

Please choose an option per row

	None	Very little	Some	Fair amount	Moderate amount
Glass	○	○	○	○	○
Paper	○	○	○	○	○
Plastics	○	○	○	○	○
Tins / cans	○	○	○	○	○
Food or biodegra...	○	○	○	○	○
Hazardous waste...	○	○	○	○	○

6. Do you currently recycle in any way/to any extent? *

○ Yes

○ No

7. If you answered yes to the previous question, please indicate how often you recycle:

Please choose an option per row

	Never	Rarely	Sometimes	Often	Always
Glass	○	○	○	○	○
Paper	○	○	○	○	○
Plastics	○	○	○	○	○
Tins / cans	○	○	○	○	○
Food or biodegra...	○	○	○	○	○
Hazardous waste...	○	○	○	○	○

8. If you currently recycle, please indicate how you do so:

- ☐ Recycling/separation inside your premises
- ☐ Recyclables separation outside of your premises
- ☐ Manual dropoff at recycling facility
- ☐ Other

9. Which of the following means of recycling makes most sense for your business? *

- ○ Compartmentalised bins for recyclable wastes stored in-premises (which are then emptied into the communal wast...
- ○ Clearly labelled separation bins for paper and other recyclables in the communal waste collection area
- ○ Directly depositing recyclable wastes at collection centres/depots

10. Recycling would be appealing in the shops/apartment complex if it: *

Please choose an option per row

	Strongly disagree	Disagree	Neither agree or ...	Agree	Strongly agree
Contributed to the...	○	○	○	○	○
Could save on col...	○	○	○	○	○
Raised communit...	○	○	○	○	○
Was convenient	○	○	○	○	○
Was environment...	○	○	○	○	○

Business email address

You will be sent a copy of the completed survey results

Short answer text

Appendix D: Phase III resident's recycling questionnaire

Your location *

Choose

Which would cause the biggest increase in your future recycling? *

- ○ More information as to how / what to recycle
- ○ Free recycling bags
- ○ A recycling container / bin for use inside the flat
- ○ Other:

What is the biggest overall motivation for recycling? *

- ○ Environmental: reduce pollution, greenhouse gas emissions, landfill space, saves energy
- ○ Employment opportunities and poverty alleviation
- ○ Because it's 'the right thing to do'
- ○ Saves energy and resources (could power 1.4million homes/year)

In the last 5 weeks, which initiative was most effective in promoting recycling habits? *

	not effective	a little effective	neutral	effective	highly effective	I wasn't aware of this - n/a
website statistics	○	○	○	○	○	○
bin top stickers with updates	○	○	○	○	○	○
informative posters	○	○	○	○	○	○
door-to-door campaign and flyers	○	○	○	○	○	○

How often do you recycle? *

Choose

Which are your 'top 2' barriers to recycling? *

- ☐ physically separating the materials
- ☐ space/fuss to store the recyclables in my flat/premises
- ☐ additional bags to carry to the bins
- ☐ expense of extra recycling bags
- ☐ unsure of what / how to recycle
- ☐ can't see the benefit vs the effort

Do you think your recycling habits have increased since the recycling initiative in the building? *

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Increase in recycling habits since start of the project	○	○	○	○	○

Website www.glendowerplace.co.za

related to glendowerplace.co.za website

Do you think it's important to have a website and possibly facebook page for the building? *

- ○ strongly disagree
- ○ disagree
- ○ neither agree nor disagree
- ○ agree
- ○ strongly agree

Have you accessed the website of the complex? *

- ○ No
- ○ once
- ○ more than once

What type of content would you find useful for the website? *

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Documentation (house rules, dates of meetings, budget, emergency contacts)	○	○	○	○	○
Recycling and green-profile of the complex	○	○	○	○	○
Projects and maintenance plans and status	○	○	○	○	○
Shop tenants advertising	○	○	○	○	○

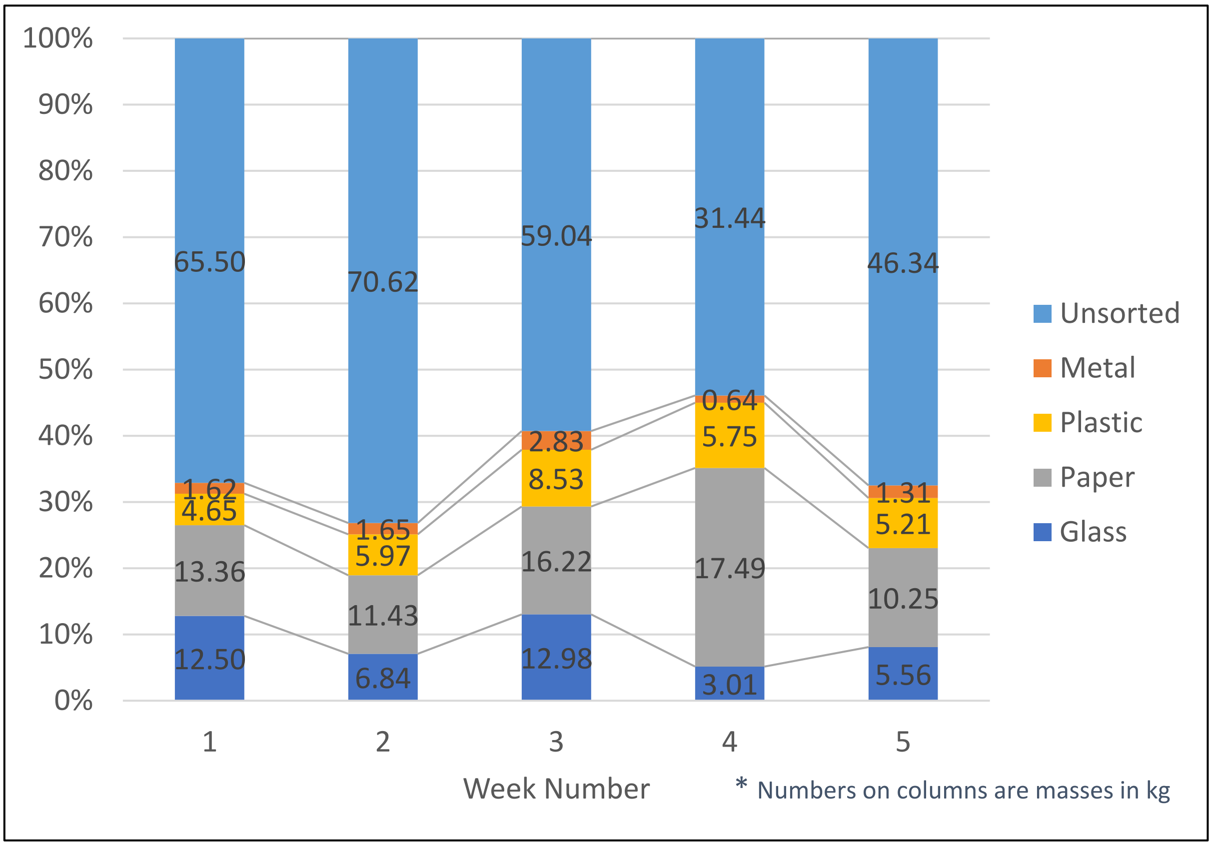
Appendix E Negative logged communal bin masses

* A sample of the dataset (week 10 of 10) is included below

Date *	Bin numbers									
	112	113	212	213	312	313	412	413	512	513
2015/08/31	3.50	2.75	5.15	3.20	2.75	-0.10	3.80	1.20	7.70	8.50
2015/09/01	4.45	5.25	5.90	5.65	1.80	5.15	5.05	4.10	6.75	8.10
2015/09/02	3.85	1.15	3.10	4.70	8.45	2.25	6.75	-0.20	7.65	11.65
2015/09/03	3.70	1.70	3.20	2.85	2.60	2.60	5.00	1.00	6.20	4.25
2015/09/04	10.20	2.80	1.85	1.05	0.25	4.05	4.25	10.10	-0.10	3.35
2015/09/05	2.15	2.50	4.20	2.15	3.30	6.95	10.35	9.75	8.45	12.70
2015/09/06	3.50	2.75	5.15	3.20	2.75	-0.10	3.80	1.20	7.70	8.50
Negative bin masses: whole-period summary										
	-0.10	-0.15		-0.40	-0.40	-0.10	-0.25	-0.20	-0.10	
						-0.10		-0.05	-0.20	
						-0.35		-0.25		
						-0.1				
						-0.05				
Sum (all):	-2.80 kg		Average:	-0.19 kg						
Count:	15		% Freq.:	2.2%						

Appendix F Proportions of unsorted to recyclable materials (Phase I)

Proportions of unsorted to recyclable materials for Phase II (source separation by participants)



Appendix G Generation rates for individual waste stream materials (Phase Ib)

Phase II waste stream generation rates for participants

Material	Waste gen. rate (kg/person/week)
Glass	0.210
Metal	0.041
Plastic	0.353
Paper	0.154
Unsorted	1.400

Appendix H Study website screen captures

https://glendowerplace.co.za/2019/01/12/recycling-news/ accessed 06.03.2019

Figure H1 Daily recycling targets and statistics

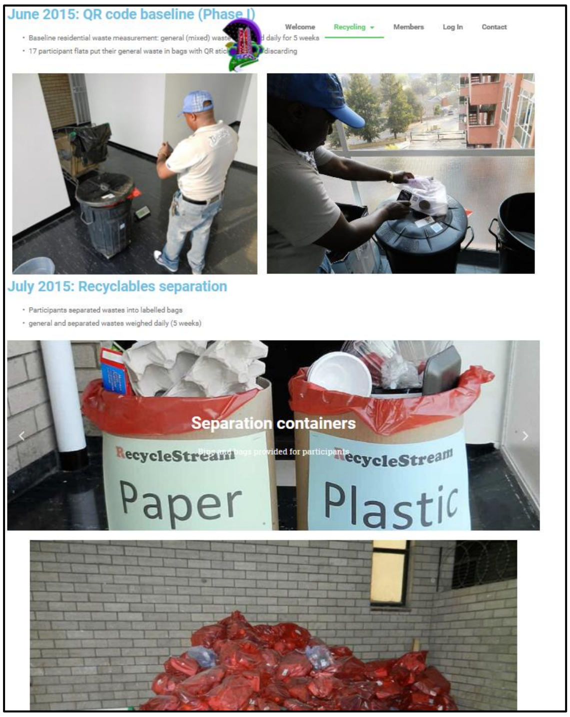


Figure H2 Project information and awareness

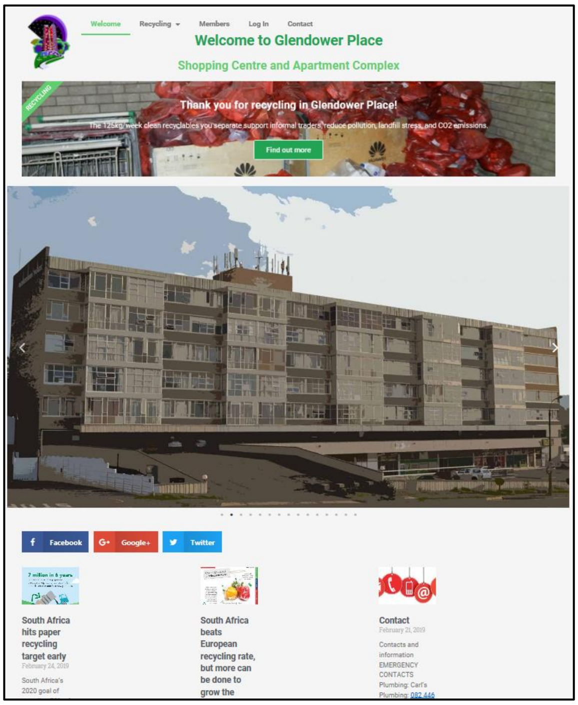


Figure H3 Website front page

Appendix I awareness campaign materials (Phase III)

Figure I1 Door-to-door campaign flyer

Figure I2 Awareness poster

Appendix J: Janitor interview transcript

Interview date: 12.09.2019

Place of interview: Glendower Place apartment complex, Edenvale, Gauteng

Interviewer: Caretaker, apartment complex [Caretaker]

Interviewee: Janitor [Janitor]

[Caretaker] *Janitor* has agreed to do this interview on the recycling project. He understands that the information will be kept private and not released to the public. He has been involved with the project for some time and the study would not have been possible without him. For which we are grateful and we thank him very much. Now we will go to the questions, and carry on with the interview.

[Caretaker] *Janitor,* describe how long it takes you to measure all the bins every day. How long does it take you to weigh the bins every day?

[Janitor] "It is taking me 15 minutes."

[Caretaker] 15 minutes, to do all of them?

[Janitor] "all of them, yes"

Thank you. Is it a lot of work for you to do that, and is it worth the money? Is it a lot of extra work for you?

[Janitor] "No, it's not a lot of extra work, because I try to help the people…make separate, because..he want to save, the what you call, the …"

[Caretaker] The recycling…

[Janitor] "the recycling, ya"

[Caretaker] Okay. Do you think the people buying the waste and selling it for a living are grateful for the material that the flats separate – do you think they are happy with collecting the waste separated by the building?

[Janitor] "Yes, he's very happy because he is selling and then he makes some money. "

[Caretaker] Making some money?

[Janitor] "yes"

[Caretaker] Okay. And what time of the day do you usually empty the bins and why?

[Janitor] "I'm starting between 10.40 or 10.30"

[Caretaker] Okay. And why do you do it at that time?

[Janitor] "because if I'm doing late, maybe by 12 or 1, it will be very full."

[Caretaker] Okay. And how many times do you empty the bins?

[Janitor] "Twice"

[Caretaker] Twice a day?

[Janitor] "Yes".

[Caretaker] Okay. Do the bins get very full that they're overflowing? Do they get very full at any stage, the dustbins?

[Janitor] "Oh yes"

[Caretaker] Which ones?

[Janitor] “very full, ya, because…especially the recycling.”

[Caretaker] Okay. Not the ones with the general waste?

[Janitor] “Ya, that one sometimes. Sometimes, yes. “

[Caretaker] Okay. And explain to us in detail how you measure each bin, step by step. How do you do it, when it’s time to measure the bin.

[Janitor] “okay, I’m start to weigh the bin, then I putting on the scale, and then I take the numbers and then I send to”

[Caretaker] Scan it

[Janitor] “ya scan it”

[Caretaker] When measuring the bin, do you keep the lid on? When you measure the bin?

[Janitor] “yes I keeping on.”

[Caretaker] Are people generally quite clean when they throw away their general waste, or do you often have to clean up afterwards?

[Janitor] “Oh, no, people, no it’s fine because is putting the rubbish inside to the rubbish bag, ya, I’m not cleaning the bin.”

[Caretaker] There’s no mess, you don’t have to clean?

[Janitor] “no, there’s no mess”

[Caretaker] Is the three bin system better than the two bin?

[Janitor] “oh yes, is better three”

[Caretaker] Why?

[Janitor] “Because the time I was using two, there was too much recycling, but now it’s easy for us, because now got the other one just for the recycling.”

[Caretaker] And is the scale easy to use?

[Janitor] “Is very easy”

[Caretaker] And does it every give you problems?

[Janitor] “No, since I’m starting to scan, it doesn’t give problem”

[Caretaker] Do you think you’re making a difference by helping in the project, even though you’re getting paid? Do you think that collecting, that you’re helping, making a difference, collecting all the recycling, maybe you’re helping because you know that we’re not throwing away all the rubbish, that it’s lying in the streets, that we’re collecting it and putting it downstairs – do you think we’re making a difference?

[Janitor] “is very different, because if I’m not doing the recycling, the building would be a mess”

[Caretaker] Okay. This project would not have been possible without all your daily hard work for many weeks, and the author of this study would like to thank you for accurate measurements and attention to detail. And of course your hard work. So *Janitor*, we thank you very much for allowing us to interview you in this project, and we thank you for all your hard work – thank you very much.

[Janitor] “Okay”.

Appendix K: Ethics Approval

UNISA university of south africa

CAES RESEARCH ETHICS REVIEW COMMITTEE

National Health Research Ethics Council Registration no: REC-170616-051

Date: 25/11/2016

Ref #: **2016/CAES/130**
Name of applicant: **Mr A Vlastos**
Student #: **42063159**

Dear Mr Vlastos,

Decision: Ethics Approval

Proposal: Creating a "smart" solid waste recycling system: The case of a high rise residential apartment block

Supervisor: Mrs T McKay

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Approval is granted for the project, *subject to submission of the relevant permission letter.*

Please note that the approval is valid for a one year period only. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 30 November 2017

Please note points 4 to 6 below for further action.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 24 November 2016.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and*

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principles expressed in the UNISA Policy on Research Ethics.

2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*
4) *The permission letter from the body corporate of the apartment block is outstanding, and must be obtained and submitted to the Committee before data collection may commence.*
5) *The use of photographs must be included in the consent form, and the standard consent form must be used.*
6) *The researcher must ensure that people are not identifiable in the photographs.*

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

NB: No's 4 -6

Approval template 2014

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