The value of waste data within the City of Cape Town's waste management systems: an exploratory case study

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By

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ABSTRACT

Producers are increasingly compelled by legislation to understand the volume of their products recycled and a product's total impact on waste management systems (WMS). Improved data quality is essential to drive the adoption of a waste management system, and to guide policy strategy and planning decisions. This study focuses on the data from post-consumer waste in the City of Cape Town within the broad field of solid waste management (SWM).

This study explores the (primary) research questions*: "What is the value of waste data in the City of Cape Town waste management system ?"*

It answer the primary question through three secondary-questions

1. *How do stakeholders within the WMS perceive the availability of waste data?*
2. *What is the current volume and composition of waste data in CCT. WMS ?*
3. *Additionally, can data from the informal waste sector assist in improving existing waste data quality?*

A sequential mixed-methods exploratory case study approach and the solid waste information management model (SWIMM) are used. Through interviews with key industry players, a review of selected literature, and publicly available data on waste from the City of Cape Town, the study surfaces the misalignment between stakeholder expectations and currently collected data on waste within the waste management system.

This study finds that expectations from stakeholders across waste management are misaligned around the perception of essential waste data indicators.

The research presents a novel SWIMM model that collects a higher volume, frequency, quality, diversity, and composition of data across the waste stream, predicting future short-term waste scenarios, legislation compliance, and production planning.

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GLOSSARY

Acronym / Abbreviation / Terminology	**Meaning**
Buy Back Centres	Specialize in buying recycled material from informal waste pickers and then selling it into the formal waste industry
Formal Waste Management Systems	The formalised waste systems responsible for collecting waste from households and companies
Informal Waste Management Systems	Waste pickers and the systems that are outside the formal waste collection activities
Integrated Solid Waste Management	Solid waste management system that takes into account the prevention of waste, how to recycle composting, and a disposal program
IWP	Informal waste pickers
MRF	Material Recovery Facility
Municipal Solid Waste (MSW)	Waste entering the formal municipal solid waste stream
Solid Waste Management	The collection, treating, and disposing of solid material that is discarded after it has served its purpose
Waste leakage	Materials that enter oceans or are exported and lost from the waste stream accounting system
Waste Management Systems (WMS)	All the systems across a city or a defined entity are responsible for managing waste from collection to disposal. Including but not limited to the private entity responsible for waste recycling.
Waste minimization	To limit the amount of waste that reaches landfills.
Waste Processing companies	Companies specializing and processing recyclable waste
Waste Residue	Amount of waste remaining after separating and recycling process has finished
Waste Value Chain	All the steps needed for post-consumer waste travel from household to landfill, with all treatment and processing companies included.

CHAPTER 1: BACKGROUND OF THE STUDY

1.1 Introduction

Successful implementation of waste management systems (WMS) is essential for reducing the footprint of waste on the environment. WMS plays a critical role in creating a system through which waste is measured, decisions are supported, and resources are allocated within local governments. In developing countries, a consolidated view, availability, quality, and volume of the data to support these systems are lacking (Guerrero, Maas & Hogland, 2013; Marshall & Farahbakhsh, 2013; Stemmet & Uys, 2020) primarily due to the existence of two parallel systems, namely the formal and informal WMS.

It therefore becomes important to examine the co-existence of both the formal and informal WMS in developing countries, to create a consolidated view on the state of waste data. The proposed research should also explore the necessary data that would drive the successful adoption of the WMS. This study examines the need for a better quality, volume, and viscosity (more comprehensive range) of data within the City of Cape Town's (CCT's) formal and informal WMS. This study further examines how this data is collected, and how the information flow can be improved towards developing a model to assist in priority-based decision-making for waste management.

This chapter introduces the waste problem, then moves on to the statement of the problem, objects, and aim of the research, and concludes by providing a suggested research design and framing the limitations of the research.

1.2 Background of the problem

The world is generating 2.1 billion tons of Municipal Solid Waste a year (Worldbank, 2019). Although there are numerous definitions in the literature for this dissertation, the definition of MSW aligns with the generally accepted definition: "solid waste encompasses residential, commercial, and institutional waste" (Hoornweg & Bhada-Tata, 2012, p. 7). Waste management is a relevant and topical issue, and an extensive body of research on waste is available. The field, however, lacks consistent terminology, measurement, and data. Leading research reports usually have a cautionary section to highlight the use of extrapolated data due to limited data and no primary source data (Ratnasabapathy, Perera, & Alashwal 2019; Worldbank 2018).

A Municipal Solid Waste Management (MSWM) service-is one of the most critical and costly services a city provides and the single largest budget item employing the most people (Kaza, Yao, Bhada-Tata, and Van Woerden, 2018). MSWM ranges from 4% in high-Income countries to as high as 20% in low-income countries (Worldbank, 2018). Although MSWM are both critically costly to cities, lack of reliable waste data (Worldbank 2018) is hampering the successful implementation of WMS in developing countries (Guerrero et al. 2013; Marshall & Farahbakhsh 2013).

An estimated 29.3% of domestic waste in developing countries like South Africa never enters the formal MSW system (Rodseth et al., 2020; Worldbank, 2018), resulting in waste data being under-reported and therefore being extremely unreliable for managing the waste. The primary limitation in using data from the informal waste sector have been its "Informality." This scarcity of data within WMS has resulted in a lack of research around information systems that are able to support waste management (Gholami et al., 2013). In turn, according to these authors, this has led to a lack of actionable research driving, policy, and change. A higher quality, volume, and diversity of data could be generated by combining data from informal and formal WMS and reformulating waste management system requirements to understand the entire management stream.

In developing countries, waste data is underreported due to limited coverage of formal WMS (Barnes, Blaauw, Schenck, & Pretorius, 2021). A consolidated view, availability, quality, and volume of data is lacking in developing countries (Guerrero, Maas & Hogland, 2013; Marshall & Farahbakhsh, 2013; Stemmet & Uys, 2020) primarily due to two parallel systems existing, formal and informal WMS. Informal waste pickers (IWP) are the most significant contributors to recycling and diverting waste from landfill sites in developing countries (Ghisolfi et al., 2017; Godfrey, L. Strydom W., Phukubye, 2016; Miezah et al., 2015; Moore, 2012; Oteng-ababio et al., 2017; Rutkowski & Rutkowski, 2015; Wu et al., 2018). No research on waste would therefore be complete without incorporating waste pickers and their contribution. Socially, challenges and stigma exist between waste pickers, society, and the waste management industry (Wiego 2014; Peres,2016).

1.2 Statement of the problem

The original motivation of the study was to investigate whether data and a systems-driven approach could help waste pickers and clean up the environment. Numerous research studies acknowledge the role of waste pickers in developing countries as the largest contributors to

recycling and diverting waste from landfill sites (Moreno-Sanchez, Maldonado, & Sheldon 2004; Oteng-ababio, Owusu-Sekyere, & Amoah 2017; Peres 2016; Rutkowski & Rutkowski 2015; Viljoen J.M.M. 2014; Yu, Blaauw, & Schenck 2020).

However, during the research process, it became evident that very little formalised data is available to substantiate and quantify their contribution. The problem definition also had to be extended to understand waste pickers contribution. Waste pickers exist in a difficult quantifiable parallel informal waste management system next to the formalised waste management system (Godfrey, L. Strydom W., Phukubye 2016; Moreno-sanchez et al. 2004; Oteng-ababio et al. 2017; Stemmet, Uys 2020; Rogerson 2001; Wiego 2014). Numbers in research reports usually state the quantifiable formal waste management system (Hoornweg & Bhada-Tata 2012; Worldbank 2018), and they extrapolate the informal WMS contribution based on estimates.

With waste coverage services as low as 9% in rural areas and 43% on average in Sub-Sahara Africa (Worldbank, 2018), up to 91% of waste management in the informal waste management industry goes unreported. The lack of quality and volume of waste data in developing countries is affecting the successful deployment of waste management systems (Stemmet, Uys 2020).

1.3 Research Questions

This study explores the need for better quality, volume, and viscosity of waste data across the waste stream. The study seeks to identify and provide insights into how stakeholders across the waste management value stream's requirements for data are misaligned with the data collected across the waste management system (formally and informally). It seeks to show that a much richer data environment can be created by aligning stakeholder data requirement expectations from the private waste industry with government policy requirements.

In addition, data from the informal and formal waste management industries needs to be combined to fully understand the waste management system. This research explores the primary question of:

"**What is the value of waste data within Cape Town's waste management systems?**".

To understand the value of waste within the waste management system the research focuses on three secondary-questions:

1. *How do stakeholders within the WMS perceive the availability of waste data**?***
2. *What is the current volume and availability of waste data within the CCT WMS ?*
3. *Additionally, can data from the informal waste sector assist in improving existing waste data quality?*

These questions are explored through the lens of integrated sustainable development. The collected data is used to create a suitable model for evaluating waste data generated by the waste industry with a focus on incorporating informal waste-pickers. This research takes the form of an exploratory case study. Dimensional sampling and the SWIMM model are used to identify stakeholders in the waste management system within Cape Town. The research uses a sequential mixed-methods approach structured around interviews that surface the perceived value of data from stakeholders. The data is then interpreted, tested against available data in the industry, and compared to the proposed waste value SWIMM model.

The results of this study may contribute to literature about waste and the informal waste industry and waste pickers' data availability towards presenting a model to assist in priority decision making for waste. The next section elaborates on the aims and objectives for this study.

1.4 Aims and objectives of the study

The purpose of this study is to broaden the knowledge on the data availability and the quality of data in the formal and informal WMS and stakeholder expectations on data requirements. The aim of this research is to establish the value of the waste data within the informal waste industries (which include waste pickers) in developing countries. The objectives flowing from the aim of the study are to:

- Review and synthesis the literature on factors driving successful adoption of WMS in industrial countries,
- Create a framework (boundaries of the system) and contextualize a waste management system (informal and formal) with stakeholders across the waste stream,
- Ascertain what data stakeholders within the waste management system perceive as valuable,

- Analyse existing available data within the waste management system and waste stream to compare them to stakeholder expectations, and,
- Create a waste decision-making model based on stakeholder requirements.

1.5 Research design

Many studies examine the informal waste industry and waste pickers (Dias, 2016; Moreno-Sanchez et al., 2004; Peres, 2016; Rutkowski & Rutkowski, 2015; Viljoen J.M.M., 2014; Waste & Industry, 2007; Wiego, 2014). These studies are usually qualitative in nature with a focus, in general, on the socio-economic impact on waste pickers. From a formal waste management perspective, research tends to largely be quantitative in nature (Ferri, Diniz Chaves, & Ribeiro 2015; Hoornweg and Bhada-Tata 2012; McDougall 2001; Sukholthaman and Sharp 2016; Wilson et al. 2015; Worldbank 2018). The research design for this study was therefore chosen after carefully considering previous studies.

In line with studies by Barnes et al. (2021) and Viljoen (2014) which spanned both the formal and informal WMS, an exploratory sequential mixed-methods design was chosen for this study. Berman (2017) characterises the exploratory sequential mixed-methods as an initial qualitative phase of data collection and analysis (the words from stakeholders in the waste value chain), followed by a quantitive phase of data collection (what numbers are available in the WMS), and then a last phase linking the two outcomes.

It is important to note that this study does not follow the normal exploratory mixed-methods approach in that it follows the qualitative phase and theme with a follow-up questionnaire and survey. It uses primary quantitative data from the CCT's data portal to compare themes and data generated from the qualitative phase. The CCT was selected for the study, although it may represent a unique blend for developed and developing world formal and informal WMS, in consideration of the researcher's proximity to the area and knowledge of the industry to gain access to industry experts.

1.6 Research limitations

The unconventional nature of the informal waste industry makes the definitions of the boundary of the waste management system in CCT challenging. Combined with the fact that waste pickers migrate, through the sheer nature of their informality, it creates a challenge in depicting an accurate report on their nature. For this reason, the research report has shifted more to places

where the informal nature of this industry is "formalised," like buy-back centres (Barnes et al., 2021). The way data is measured across the waste stream, and the description of data is, as other reports have highlighted, not standardised. The timeframe of the research also narrowed down the time for responses from industry stakeholders. Due to the timeline of interviews, only a limited number of questions could be included.

In addition, the concept and language around data proved challenging and lacking from the industry. Challenges were experienced in mapping data between two different systems within inadequate naming conventions, update timing frequency, methodology, and compositional data available. This research did not distinguished between Critical Systems Heuristics (CSH) boundaries and resource theory. This would be an interesting extension of this research specifically to investigate the strength of the links between these two theories. This connection is added to future research in the conclusion.

1.7 Summary

By exploring waste data requirements for successful deployment of WMS from industrialised western countries, current data availability within a waste management system in developing countries, and the contribution of the informal waste management system, it may be possible to determine the requirements of waste data needed. A holistic approach is needed to obtain knowledge, through which both the informal and formal waste management system may be viewed within an aggregated environment. An exploratory sequential mixed-methods was selected based on previous similar studies to measure both the qualitative and quantitative nature of the WMS in the CCT.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter is a synthesised approach to reviewing the global state of waste data. It explores the accuracy and reliability of waste data before exploring waste data's relation to industrial and developing countries' demographical and socio-economic conditions. This chapter extends from the research gap identified by Stemmet and Uys (2020) around the lack of waste data within the waste management industry that impacts the successful implementation of WMS in developing countries. It is structured around the central research concern that improving waste data quality will stimulate the adoption of WMS. In turn, the successful adoption of WMS would lead to improvements in policy, strategy, and planning decisions.

This literature review starts by examining the various definitions of waste before exploring how the lack of reliable quality data across the industry hinders the implementation of WMS and going into more detail about how the under-reported data of informal waste systems impact waste data. Finally, waste indicators that could facilitate the successful implementation of WMS in the City of Cape Town are explored.

2.2 What is waste?

Central to the research is the question of a lack of data relating to waste management. The definition "waste" is complex, depending on perspective. Taking Žižek's (2009) 'parallax' view, the perspective through which waste is viewed shifts, to reveal that waste is not just the remainder of our everyday life, but an artifact and store of knowledge. Taking the position that waste is a store of knowledge, and not just the remainders of everyday life, the objects seen as waste could be reclassified.

Accordingly, defining which objects are classified as waste is more complicated, with ongoing debates on how and where this should be happen (Oelofse & Godfrey 2008). The legal definition of waste is an ongoing process; the European Union defined waste in a 2008 directive as *" any substance or object which the holder discards or intends or is required to discard."* (European Union, 2008).

In South Africa, the National Waste Bill from 1994 seeks to govern the definition, measurement and treatment of waste. In their 2008 work, Oelofse & Godfrey identify a need to define waste in a broader way than purely as household waste or discard.

2.3 The size of the waste problem

2.3.1 South Africa

South Africa is a mixed economy with a population of 59.6 million people in 2020 (Statistics South Africa, 2020). It is one of the significant generators of solid waste, contributing 108 million tons of waste in 2012, of which 59 million tons were classified as 'general waste' (GreenCape, 2020). The average solid waste generated per capita is 0.9 kg per day in South Africa and is expected to increase to 2 kg per capita per day by 2030. Most of the waste in South Africa (90.1%) is landfilled, with the remainder recycled (GreenCape 2020). This recycling rate is low compared to global standards, as developed countries such as Austria and Germany recycle a maximum of 63% of all waste generated (Greencape, 2017; ISWA, 2015; RDI Roadmap, 2015; Samson, 2004).

2.3.2 The City of Cape Town

The City of Cape Town (CCT) is a major economic hub of 4 million people. The city has seen significant growth in its population, 56.8% over the 20 years to 2016, according to City records. The CCT is responsible for 3.713 of the 7.7 Million tonnes of waste produced in the Western Cape, including 1.7 million tonnes of MSW and 0.6 million tonnes of commercial and industrial Waste (GreenCape, 2020). Recyclables collected from households only represent 0.5% (by mass) of total waste generated (Kaiser, 2017). The City Of Cape Town's household separation rate is 23% (GreenCape, 2020). However, 90% of this waste goes to landfills, so only 10% of solid waste is recycled (2011, NWIB). According to Rodseth et al. (2020), up to 29.3% of its waste never enters formal waste management.

2.4 Waste management

2.4.1 The cost of managing waste

Proper waste management is one of the most costly services to a city (Artuso, 2011). Waste management consumes 4% of high-income and between 19% - 50% of low-income city budgets (Kaza et al. 2018; World Bank, 2021b). Waste Management strives to balance environmental preservation, social acceptability, safeguarding of human health, economic affordability, and natural resource conservation (Markic et al. 2019; Marshall & Farahbakhsh 2013). With increasing populations and changing consumption patterns the management of solid waste poses a financial burden globally to local municipalities (Abarca et al., 2013; Marshall & Farahbakhsh, 2013).

The four defined verticals of waste management are (1) MSW, (2) Industrial Waste,(3) Agricultural waste, and (4) hazardous waste (GreenCape, 2019, 2020; Waste & Industry, 2007; Worldbank, 2018, 2019). This review focuses on MSW generated from households, offices, hotels, and schools. Significant components of MSW are food waste, paper, plastics, rags, metal, and glass (Worldbank, 2018).

2.4.2 Systems needed to manage waste

Managing and discarding waste for cities is one of the most expensive services, requiring resources and finance. Using a waste management system to assist and drive decisions on waste management reduces the cost of managing waste (Hua et al., 2016; Miezah et al., 2015; Nahman & Oelofse, 2018). However, studies by Guerrero et al., (2013) and Marshall and Farahbakhsh (2013) show that quality and reliable data is in short supply in developing countries These authors claim that the lack of practical, quality, and affordable data leads to limited information to implement WMS and over time hampers research in the field of waste management. To work towards an improved understanding of the current situation, the state of waste data in CCT will be explored in further detail.

2.5 Waste data

Having identified how the lack of valuable, quality and affordable data in developing countries limits the successful implementation of WMS and increases the cost of managing waste in developing countries, the question arises as to why there are differences between waste data from developed and developing markets and the availability of waste data.

2.5.1 Global state of waste data

The World Bank report titled "What a Waste 2.0: A global snapshot of solid waste management to 2050" is one of the most cited references (1337 since 2018) for research on the state of waste (Kaza, S., Yao, L., Bhada-Tata, P. and Van Woerden, F., 2018). The authors of the report, question the quality of the data that they relied on for the report stating that*:"In general, solid waste data should be considered with a degree of caution because of inconsistencies in definitions, data collection methodologies, and availability"* (Kaza et al. 2018, p. 9). The report uses outdated sources ranging from as late as 2001 and as recent as 2017 aggregated into one view. Undefined words or phrases, lack of dates, methodologies, and sources influenced the quality and reliability of data in the report (Kaza et al 2018). There was also very little agreement on standards per country and city, resulting in the omitting of units and assumptions on data.

The low global quality of waste data and lack of standards are contributing to a level of distrust in waste data. Lack of reliable data is one of the important factors contributing to WMS in developing countries not being successfully implemented. Improving the quality of waste data could contribute to improved waste management system implementations.

2.5.2 Data from industrial countries

Industrial countries have well-implemented WMS (Marshall and Farahbakhsh 2013), producing high-quality, reliable data. This level of reliable data allows for insights and research to be conducted on the data and waste systems (Haupt, Vadenbo, and Hellweg 2017; Ratnasabapathy, Perera, & Alashwal 2019; Song, Li, and Zeng 2015). Haupt et al. (2017) argue that where discrepancies do occur, it is down to the recycling companies and producers monitoring different indicators for recycling rate and collection rates. Reliable waste data is necessary to drive the successful implementation of WMS. Although the global state of waste data is unreliable, industrial countries exhibit a high quality of reliable waste data. The high level of quality data in industrial countries is fuelling research and the successful implementation of WMS. The next section explores how developing countries' data quality compare to global and industrial countries.

2.5.3 Data from developing countries

With formal waste coverage at an average of 29% - 44% in sub-Sahara Africa (Rodseth et al.,2020; World Bank, 2018), a large volume of waste never enters the waste stream and is under-reported. An estimated 71% of this under-reported domestic waste in under-serviced metro areas land on private landfill sites and is therefore never reported (Rodseth et al.,2020). This under-reporting leads to a lack of data in developing countries. Where they are available, the data are inconsistent, cannot be validated, rather based on experience than recorded numbers (Hua et al. 2016), and are sometimes based on assumptions (Miezah et al., 2015). Research around waste and recycling tends to focus on "virgin material used in the country" and self-reporting by recycling companies (GreenCape, 2020; Plastics, 2019).

Solution and research to solve this lack of data in developing countries are concentrated around formalising the waste indicators for the (1) volume of waste generated, (2) physical composition, and (3) sorting efficiency (Chitaka & von Blottnitz, 2019; City of Cape Town, 2018; Miezah et al., 2015; Oteng-ababio et al., 2017).

Some developing countries like South Africa established Waste Information Systems (SAWIS) in response to this lack of data and low recycling rates. The specification for the system was that it should not only store "simplistic waste data" (Godfrey & Scott, 2011) but rather more detailed data from the solid waste sector by including all relevant stakeholders. Data providers can access the system directly at “http://sawic.environment.gov.za”,while publicly available data can be accessed through the public waste information centre. SAWIS, however, acknowledges that the quality of data might not be reliable since validating the data is up to the individual entities responsible for self-reporting and that the standard to collect the data is not defined per entity.

Globally there is a level of unreliability in waste data. Reports caution on the primary data quality reports relied on (Kaza et al 2018; Worldbank 2018). Industrialised countries have a higher quality of data available to drive decisions and research while developing countries lack higher quality data (Miezah et al., 2015). This lack of reliable data influences decisions and leads to a lack of trust (Miezah et al., 2015). The (1) volume of waste (2) physical composition, and (3) sorting efficiency are some of the main indicators required to improve data standardisation in developing countries. Improving these indicators would lead to improved data to facilitate the implementation of WMS. This, in turn, would improve waste management and associated cost.

2.6 Connecting formal and informal waste systems

Insufficient waste data is available in developing markets to drive successful implementation of WMS. Developing countries have a large portion of the waste management system under-reported by not including informal waste systems (Rodseth et al., 2020). The next section explores the link between formal and informal WMS and the buyback centres that act as the link.

2.6.1 Informal waste pickers

IWP are the most significant contributors to recycling and diverting waste from landfill sites (Ghisolfi et al. 2017; Godfrey, L. Strydom W., Phukubye 2016; Miezah et al. 2015; Moore 2012; Oteng-ababio et al. 2017; Rutkowski and Rutkowski 2015; Wu et al. 2018).Thousands of individual waste pickers play a pivotal role in recycling waste, extracting recyclable waste from streets and landfills, diverting waste in the recycling value chain by recovering waste directly at the source and thus removing the need for separation of waste at a later stage (Rogerson, 2001; D. C. Wilson et al., 2013). 80% to 90% of waste recycled in South Africa is

collected by the IWP, with waste pickers organised as cooperatives in some instances and sustaining themselves by extracting recyclable waste from streets and landfills. Waste pickers' way of life is under threat due to the gradual formalisation of the industry and the exclusion of waste pickers (Schröder, 2019).

2.6.2 Buyback centres, the link between formal and informal

Waste from several recycling industries remains outside the waste system. Such waste, instead, is taken directly by informal entrepreneurs (Guerrero, et al., 2013; Marshall & Farahbakhsh,2013.; Rogerson, 2001. Barnes et al. (2021) report that in Cape Town, buyback Centres (BBC) act as a central waste collection point that pay cash to waste collectors of waste paper . Indirectly they operate within the municipality SWM space and by extension within the study's research framework, by directing waste away from landfill sites (Barnes et al., 2021).

The formal waste stream sees the informal waste stream as competition to their existing business models (Nahman et al. 2018). In research conducted into how material recovery facilities perceive the contribution of waste pickers, the MRF owners suggested that there was a 75%-30% decline in waste for recycling once waste pickers moved into an area (Barnes et al., 2021), IWP recover 80%-90% (by weight) of paper and packaging (Godfrey, Strydom & Phukubye, 2016). It is also difficult to distinguish between the formal and informal industries (Barnes et al., 2021).

Incorporating or linking the informal waste industry with formal WMS in developing countries can address some of the challenges around data scarcity. Buyback centres supported by IWP act as the link between the formal and informal waste industry and can provide valuable waste data through the existing value chain to support the WMS (Barnes et al., 2021).

2.7 Literature Review Summary

The research questions of this study seek to understand whether improved data quality from waste data in developing countries can improve the implementation and management of WMS. The literature review surfaced that WMS systems are critical to managing waste effectively, but that lack of data in developing countries is hampering the successful implementation of WMS. Insufficient importance is attributed to the informal waste management industry's data generated from waste and is largely excluded from any calculations. Buyback centres can act as the link between formal and informal waste industry data. There is a general lack of uncertainty in waste data, resulting in mistrust in WMS. Recycling rate, collection rates, the

volume of waste generated, its physical composition, and sorting efficiency are highlighted as some of the essential waste indicators to drive successful decisions for the adoption of WMS.

The literature review highlights a gap in the literature and research around what data is required by WMS to drive successful deployment and implementation There also needs to be an understanding of whether the informal waste industry, and specifically waste pickers, can contribute to the data and indicators needed for implementation.

The next chapter of the research focuses on the theories needed to quantify what data is valuable within in the CCT's WMS. In addition, it seeks to define what the boundaries of the waste management system are that form part of the research, by exploring waste theories and models.

CHAPTER 3: THEORETICAL PERSPECTIVE

3.1 Introduction

A review of the literature highlighted that implementing a waste management system successfully is dependent on accessing timely, applicable, high quality, and trusted data to drive decision support in the waste management system. With the above relationship between data and successful implementation of WMS in developing countries, it is essential to contextualise what constitutes "valuable" data and define the boundaries of WMS. This chapter aims to provide a theoretical overview of how to establish the value of data concerning WMS by exploring existing waste management models and theories that can establish the value of waste data.

This chapter first explores existing waste management models to establish which indicators need to be monitored and who the stakeholders are in a waste management system. Once the stakeholders and measurable indicators have been defined, it continues by investigating the theoretical aspect of waste management to establish exactly what waste management is. Next, Critical System Heuristics (CSH) is used as a theoretical framework to define the boundaries of a waste system in the real world, but more importantly to understand the interplay of stakeholders within the waste management system. To understand the value of waste within the waste management system, resource-based theory is used.

3.2 Theoretical framework

3.2.1 Waste management theory

Waste management theory (WMT) includes the conceptual analysis of what constitutes waste, activities performed around waste, and waste management goals (Pongrácz, Phillips, & Keiski, 2004). The theory propounds that waste management is to prevent waste that causes harm to the environment and human health. In a practical application, the theory aims to (1) Guide selecting a waste management option, (2) predict the outcome of a specific waste management action, and (3) inform legislators on how to prescribe activities on waste. WMT provides the direction on what waste data must provide the answers to. It must be able to provide enough data to select waste management options. In addition the generated data must provide enough insights to predict the outcome of waste management action. Lastly the data should be comprehensive enough to assist in aiding legislation. WMT defines the outcomes of what is needed from the research. Critical system heuristic (CSH) in the next section defined the boundaries of the waste management system being investigated.

3.2.1 Critical system heuristics (CSH)

Marshall and Farahbakhsh (2013) argue for a more systems-driven approach to defining a waste management system.. Critical Systems Heuristics (CSH) is a "framework for reflective practice, based on practical philosophy and systems thinking" (Ulrich & Reynolds, 2010) developed by Werner Ulrich and later elaborated on by Martin Reynolds. Ulrich based CSH on critical social theory and the fact that there is no single correct answer . Linden et al. (2007), argue that the Information System community (IS) should incorporate inquiry systems more into IS reach. CSH allows the researcher to reflect systematically on the proposed research plan's validity and surface boundary questions. An important contribution to the CSH framework is Churchman's (1957) work on purposeful and inquiring systems. Churchman's work separates those involved in the system into a client, decision-makers, and planner (Churchman, Ackhoff, & Arnoff, 1957; Reynolds, 2007). CSH conceptual framework consists of twelve boundary judgments (Ulrich 1996) to make sense and understand everyday situations. CSH allows the research to unfold and reveal contrasting judgment and offer tools to understand multiple perspectives. Critical system heuristic is used in the study to understand multiple stakeholders with the WMS perceived opinion on value of waste data. Importantly CSH allows stakeholders to unfold who they believe the decision makers, client and planner of waste data within a WMS should be, contributing to the level of trust.

3.2.3 Resource based theory

Resource-based theory is used to determine which assets provide a strategic advantage to a business in improving a firm's profit. In light of this theory, data can be classified as a physical capital resource within an organisation (Erevelles, Fukawa, &Swayne, 2016). Resource-based theory proposes that firms are heterogeneous and can have different strategies based on different resource availability. A firm's ability to harness and strategically apply its resources gives it a competitive advantage over competitors. Developed in 1991 by Barney the theory is used in managerial frameworks to determine the strategic resources a firm can exploit to achieve sustainable advantage. Barham (2017) proposes that big data from third-party companies can be seen as a strategic asset, supporting Erevalles et al.'s (2016) proposition that a more resource-based view across organisations can lead to an increase in the bottom line. In light of this theory, data from waste would be seen as a strategic asset to a company and cooperation. Waste data is therefore in this research is classified according to the five factors driving big data value, (1) Volume, (2) velocity, (3) variety, (4) the veracity of quality of data, and (5) the value of the data for a particular domain (Erevelles et al., 2016).

3.3 Waste management models

3.3.1 Existing waste management models

To establish what indicators will be measured and what constitutes the waste management system, existing waste management models were explored. Existing WMS models and indicators tend to focus on the implementation of WMS on national and city levels (Haupt, Vadenbo & Hellweg 2017; NALAS 2021; Roy et al. 2018). These models are usually concerned with measuring successful public policy and fund deployments.

The Integrated sustainable waste management model (ISWM) described by Guerrero et al., (2013) was originally developed in the 1980s by organisations in developing countries and extended by the collaborative working group on SWM in the 1990s (Anschütz et al., 2004). According to Guerrero et al., integrated WMS can be measured in three dimensions: (1) The stakeholders involved in the waste management system, (2) The elements and stages of the movement of waste, (3) the aspects and the lenses the system is analyzed through. Within these three dimensions, six factors influence the model : (1) waste generation, (2) separation, (3) collection, (4) transfer and transport, (5) treatment and recycling, and (6) final disposal.

The three dimensions identified in the model are used in this research to identify the stakeholders that need to be interviewed. The six factors from the ISWM model are used to classify stakeholder involvement within the waste management system and value chain.

3.3.2 Conceptual SWIMM model

Insufficient quality data about waste is hampering the implementation of WMS in developing countries. Existing waste management models do not take into account how waste data influences factors within the model and, more specifically, what data is perceived as valuable by different stakeholders in the WMS. This research proposes the conceptual SWIMM model that takes into account the value of waste data as a strategic asset as defined by resource-based theory. In addition, it uses CSH to surface the expectations of stakeholders on what they perceive the value of waste data to be.

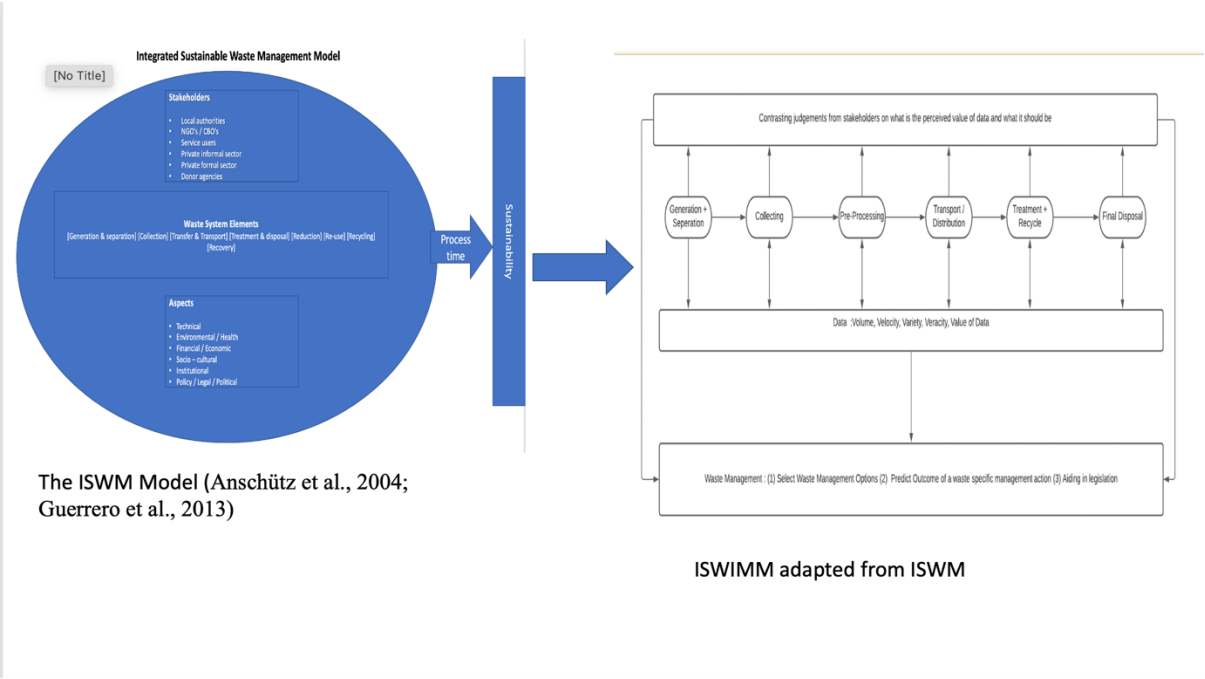

Figure 1: Conceptual SWIMM model adapted from ISWM (Anschütz et al., 2004; Guerrero et al., 2013)

SWIMM uses waste management theory (Pongrácz et al., 2004) to define the answers that the waste model should solve. These answers are: (1) Guide selecting a waste management option, (2) Predict the outcome of a specific waste management action, and (3) inform the legislation of the model. The model extends the ISWM model to define the stakeholders, indicators, and enabling environment (Anschütz et al., 2004; Guerrero et al., 2013) as hard system boundaries. The SWIMM then extends on the ISWM through a critical system approach (CSH) to include contrasting judgements from stakeholders. In addition, it uses resource based theory to classify the value of indicators.

3.3.3 Theoretical Summary

This study uses a combination of WMT , CSH and resource based theory to construct a new conceptual model SWIMM adapted from the ISWM that aims to measure the stakeholders, indicators and enabling environment with the hard system boundaries of a SWM. The next chapter in the research explores the research design used to apply the model in context of the CCT's waste management system and validate the proposed SWIMM.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

The research problem highlights that a lack of quality waste data in developing countries is hampering the successful implementation of WMS. In addition, there is a misalignment in perceived usefulness of waste data and indictors between the public and private sector. It proposes a new model called SWIMM, that incorporates waste data indicators from both public available waste data and perceived stakeholder opinion. To test and apply the model within the context of an existing waste management system (WMS) a single case study (The City of Cape Town's Waste Management System) and exploratory sequential mixed-methods design is used. The single case study allows for multiple perspectives and observations to be observed and combined into a single reference. The mixed-methods approach allows for stakeholder qualitative inputs to be combined with existing secondary quantitative data.

This chapter provides a detailed breakdown of the research methodology followed in this study.

4.2 Research questions

This research explores the question:

" **What is the value of waste data within Cape Town's waste management systems?**"

To understand what the value of waste is within the waste management system the research focuses on three sub questions

1. *How do stakeholders within the WMS perceive the availability of waste data?*
2. *What is the current volume and composition of waste data in CCT?*
3. *Additionally, can data from the informal waste sector assist in improving existing waste data quality?*

The first section looks at the aims and objectives identified in Chapter 1. The second section then explores the research design and methods adopted to address the primary research question: "What is the value of waste data within Cape Town's waste management system?".

This section also focuses on the research population, instruments used, sampling techniques, and how the data was collected and coded. Lastly, this chapter also highlights the ethical considerations in conducting the research.

4.2 Research aims, and objectives

The literature review surfaced that both the formal and informal WMS should be considered as one cohesive system. In addition, it emerged that high levels of mistrust exist within the waste management system due to the data and power relationships of stakeholders within WMS. Therefore as an adjunct to addressing the research gap, the research adopts a pragmatist philosophy in an exploratory case study that attempts to drive meaningful change. Thus it assumes Campbell's (2011) position that: "the meaning of a conception is to be found in the practical bearings of accepting it, and the function of though is to guide action, and the truth is pre-eminently tested by the practical consequences of believe" (pg.9). The research seeks to understand whether waste data from the informal waste sector can assist the formal waste industry. In addition, the research aims to understand if a higher quality of waste data can improve waste indicators and strengthen the reliability in waste data. Through this process, discarding impractical propositions and assumptions allows focus on what can be practically applied. It is hoped that collected data from this study may allow the construction of a suitable model to evaluate waste indicators and factors that influence WMS.

4.3 Research strategy

4.3.1 Case Study

Action research was strongly considered to drive a practical change, but the exact nature of the problem and its impact still had to be qualified through the research. The researcher is also an outsider to the industry and requires a more in-depth insight into the waste industry to consider action research. Therefore, a case study format is used in the research since it involves a single case (Rashid et al., 2019) The waste management system in the City of Cape Town. The case study approach allows for multiple sources of observations, interviews and analyses of documents based on an in-depth investigation into a single reference structured around the questions "How" and "Why?" (Yin, R.K., 2012). As part of the interview process, Critical Systems Heuristics (CSH) (is used to remove consciously, subconsciously, deliberately, or unintendedly implied judgments (Ulrich & Reynolds, 2010). This research focuses on the purposefulness of data within WMS needed to drive (1) waste management options (2) predict the outcome of waste specific management actions (3) drive legislation within a waste management system successfully. The case studies were designed of such a nature to construct both internal validity and external validity around the central research theme of the value of waste. To define and explore the waste management system (WMS) that is envisaged in the case study, the research uses Critical System Heuristic (CSH).

4.3.2 Critical system heuristics

Boundary critique is the methodological core of CSH and brings to the surface the unavoidable selectiveness of claims. According to Ulrich & Reynolds (2010), each boundary issue leads to three types of boundary problems (or categories):

1. Stakeholders – These are the people concerned by a situation
2. Concerns – The concerns associated with the individual stakeholders in questions
3. Difficulties – These arise from the problems in questions

The stakeholders, concerns, and issues result in 12 boundary questions. Boundary critiques face five tasks:

1. Identifying the sources of a selective claim by surfacing their underpinning boundary judgments
2. Examining these boundary judgments regarding the practical and ethical implications.
3. Finding options for determining the reference system conditioning claims, by giving alternative boundary questions
4. Seeking mutual understanding between all the stakeholders concerned regarding their different reference systems
5. Challenging the claims of those handling their boundary judgments uncritically.

By using Critical System Heuristics (CSH) approach to the research, stakeholders concerns and difficulties experienced with the City of Cape Town's Waste Management System can be incorporated into the conceptual SWIMM model.

4.4. Approach to theory development

This research attempts to determine if the quality, trustworthiness, and lack of data hamper WMS system adoption, rather than trying to understand what is happening around the informal waste management field. A deductive approach is used in the study to validate the conceptual SWIMM Model. The principle is to work top-down using new empirical data from field interviews to test and validate existing theoretical concepts and patterns (Bhattacherjee, 2012; Järvinen et al., 2008). Theories of waste management, CSH, and resource-based theory are used in the study to explain the problem around the SWIMM model and how data from the informal waste sector could potentially contribute to the model. Data was generated from the study using the SWIMM model and field of WMS, thereby applying it in context.

4.5 Research design and method

Based on previous studies that focused on the formal and informal waste industries (Barnes et al., 2021; Viljoen J.M.M., 2014) and to understand the scope of the problem, an exploratory sequential mixed-methods design (Fig 2.) was selected for this study. The mixed-methods approach allows for stakeholders' perceived value of waste data (what would emancipate them) to be collected through a qualitative approach. This, in turn, would guide the direction of the quantitative research that compares existing secondary data sources with the surface stakeholders expectations. Figure 2 illustrates that a mixed-methods design consists of at least one quantitative method (to collect numbers) and one qualitative method (to collect words) (Viljoen J.M.M., 2014).

Figure 2: Mixed-methods explanatory sequential design adapted from Viljoen J.M.M (2014)

The rationale in Figure 2 for using this specific sequential design is to gather qualitative data from stakeholders within the waste management system around the factors identified during the literature review that influence the successful adoption of WMS in developing countries.

These factors are: (1) general lack of trust and sharing of information, (2) the exclusion of the informal waste sector's data and (3) confirming and agreeing on waste indicators that are needed across the industry. While quantitative research uses secondary data reported by institutions responsible regionally and nationally for the management of waste, this data is used to link and substantiate the concerns from the qualitative survey. Where quantitative and qualitative approaches are mixed throughout the study, it is suitable for a single mixed-methods study Creswell, J. W. (2021) Guerrero, Maas, and Hogland's (2013) narrative is used as

classification guidelines in terms of waste generation and separation, collection, transfer and transport, treatment, recycling, and final disposal.

As was highlighted in the literature review (Chapter 2), waste itself can act as a store of knowledge (Žižek, 2009) and can therefore be used as the data construct (Hird, 2015) to classify where, what, and how data for the research has been collected. The study was conducted over two years' cross-sectional time horizon period (2020-2021). This period allowed for a stable two-year sample and the impact of COVID-19 to be taken into consideration. COVID-19's impact on waste management was considered since it was expected that waste generation patterns from post-consumer would change based on lockdown rules.

The next section explores the qualitative data collection process of the research design that was conducted through interviews.

4.5.1 Interviews

A single 30-minute semi-structured interviews was conducted with each of seventeen participants. The interview process made use of an interview guide (Appendix I) and a presentation of questions and topics. The interview guide for the in-depth interviews and questions was constructed around the SWIMM model. Due to COVID-19, most interviews were conducted via (Microsoft) Teams and transcribed. Once the interview responses had been recorded, the CSH framework was used to identify and surface different perspectives, categories, and stakeholders using the twelve boundaries questions that would define a waste management system (WMS) where the SWIMM was applied. An example of a transcribed anonymous interview can be found in appendix XI.

Qualitative comparative analysis (QCA) (Rihoux & Ragin, 2016) is an research methodology that allows for the analyses of a small number of cases (between 10 and 15). It allows us to take both qualitative (case-oriented) and quantitative (variable-oriented) phenomenon into account. In addition QCA allows the researcher to predict the casual structure of an outcome (more than one path to an answer). In QCA the choice of conditions of variables for analyses must be theoretical informed. For this research the SWIMM model supported by theories from waste management , CSH, and resourced-based-theory is used. The theories assist in the operationalisation of the model and with the selection of suitable case studies and variables. Based on the identified variables from the theories and SWIMM a crisp scoring matrix was developed (Appendix VI). Result from the QCA was then used to determine which waste

indicators were expected by stakeholders within the waste management system and which waste indicators would contribute to WMS adoption. Interviewees were only identified by the stakeholders' role within the CCT's Waste management system (Table 1) to ensure anonymity using SWIMM stakeholder classifications.

SWIMM Stakeholder	SWIMM Role
Municipal Authorities	Collection, transfer, transport: Treatment, final disposal
City Cooperatives	Generation, Separation
Non-Government Organisations	Generation, Separation
Households	Generation, Separation
Private Contractors	Recycling
Recycling Companies / Onsite waste management	Recycling, Transfer, Transport
Informal Waste Pickers	Separation
Material Recovery Facility (MRF)	Generation, Separation
Buyback Centres	Brokering

Table 1: SWIMM mapped to CCT sample

Table 1 shows the SWIMM classifications for stakeholders and their roles applied to the CCT's waste management system. This level of classification assisted with the interview process to determine which stakeholders within CCT WMS should form part of the dimensional sampling. Results from the interview process provided guidance on which factors stakeholders with the WMS perceived valuable from waste data. The research combined these findings to adjust the quantitative research process.

4.5.2 Quantitative analysis

The quantitative analysis aimed to gather readily available public information on the waste management system within the City of Cape Town (CCT). The research was structured around the waste indicators identified through the interview process from stakeholders during the qualitative interviews. Data from the CCT's integrated waste management plan (Kaiser, 2017) and a report conducted by the city on waste characteristics (City of Cape Town, 2018) were used as the guideline on data availability. This was combined with more up-to-date market analysis data reports (GreenCape, 2020). Once the data indicators from reports were identified, more real-time secondary data from the CCT open data portal was used (City Of Cape Town,

2021). Secondary waste data from the Department of Environment's national waste information source was used to compare and confirm the validity of the published data from the CCT. Data from these secondary sources were extracted, cleaned, and merged to form one data set using Excel (Appendix VII).

4.6 Data handling

Existing WMS are described in terms of waste generation and separation, collection, transfer and transport, treatment, recycling, and final disposal (Guerrero, et al., 2013). Waste management indictors were used as data construct to classify where, what, and how data had to be collected (Hird, 2015).

4.7 Sampling

It is not feasible to sample the entire waste management industry, and therefore a subsection was selected (Bhattacherjee, 2012). This research uses the SWIMM classification of stakeholders within the system but applies it within the context of the City of Cape Town (CCT). Dimensional sampling, as described by Arnold, (1970), was used to generate the research sample. Dimensional sampling is an approach that takes advantage of small numbers and the limited number of cases involved in the research. The samples and definitions from the research was structured in such a way that it could be generalised to WMS in developing countries. The criteria used for the selection of participants was provided by the dimensions from the SWIMM model of (1) Generation and separation, (2) Collecting and Pre-processing, (3) Transport and Distribution, (4) Treatment and Recycle and (5) Final Disposal as the typology framework to select a few number of data points from across the CCT's waste management system.

4.8 Research instruments

For the qualitative section of the research, an interview guide for semi-structured interviews is available in Appendix I. The questions were derived from the research question and the literature review. Interview themes relevant to the research report (O'Leary2019) was also used as basis for the questions. Questions were not pre-coded but instead framed as "open" questions to encourage stakeholders' participations.

For the quantitative section of the research an instrument was constructed to measure the impact of data availability within the SWIMM, using resource-based theory and the value of big data (Barney, 2007; Erevelles et al., 2016). This instrument is available in Appendix X.

Only publicly available data was used as part of the research. Since the research interest is in how stakeholders within the WMS would access data on a day-to-day basis and this level of accessibility is what contribute to its domain value. The availability and quality of two data sources are used: (1) City of Cape Town's Open Data Portal and (2) Waste Information Centre.

4.9 Data analysis

4.9.1 Analysis of qualitative data

The data analysis started with semi-structured interviews. Recorded interviews were transcribed through natural language processing (using Nvivo) and processed using qualitative speech analysis. Thematic analysis was then used to surface concepts and concerns that influences stakeholders based on the CSH framework and twelve boundary questions.

The interviews were rechecked to make sure data was captured correctly. Saldaña's (2016) suggested approach of handling and coding qualitative data was used as a guideline. Once the data was coded, it was prepared for analysis. First pass coding was performed by reading through the data to highlight general thoughts about the responses (Saldaña, 2016). Descriptive coding was initially considered, but the difference in language used by interviewers and specific nouns like "Bakkie" "bakkie mense" did not tell the full story, in the interviewer's opinion. Saldaña (2016) also cautions in limiting coding proliferation. Exploratory coding using the in-vivo coding method , that uses a particpants own words (and not the researchers own interpretation) was used to attain the participant's perspective and actions (Saldaña, 2016). This was followed by second cycle pattern coding to categorise coded data into an initial analytic strategy. Data were then coded according to topics, from which themes were generated.

A pilot study was conducted in December 2020 with the survey questionnaire adapted with feedback. A need to contextualise participants' understanding of "What do you understand data is ?" was specifically highlighted. It was observed from the analysis that there exist low levels of trust between participants in the system, who believe that sharing any information about data would provide a competitive advantage to other stakeholders.

4.9.2 Quantitative data analysis

The quantitative data collection and analysis used a similar population and sample as identified for the qualitative data section.

Data from the CCT's data portal and national government's Waste Information System (City Of Cape Town, 2021; Department of Environment, n.d.) were used to collect data about the waste management system in the CCT. The quality and ongoing maintenance of these sources are a legislative responsibility of the local and national government (Department of environmental and tourist affairs n.d.; Godfrey & Scott 2011; GreenCape 2020; Kohler et al. 2018; South Africa. Parliament (1994; National Assembly. n.d.)

Research data collected from these two sources focused on O'Leary's (2019) proposition that: "the waste data from the informal waste sector can assist the formal waste industry, improve waste indicators, and strengthen trust and reliability in waste data." The analysis also used feedback from the qualitative interview phase with indicators and factors that emerged to guide the direction in data that formed part of the qualitative section. All data that did not form part of the research question was excluded. All relevant data and appropriate variables were aggregated into one data source as per Appendix X. Time was then spent on understanding the variables, with a special focus on where primary data was captured on weigh-bridges.

The analysis also ensured that terminology and calculations for determining variables were the same across both systems. Descriptive analysis, followed by data exploration, was then performed across the data confirm its validity. Inferences were then identified that supported qualitative coding.

4.10 Research limitations

Seventeen (17) representatives from government, formal waste industry and waste collection, and informal waste industry were interviewed due to time and scope constraints and the impact of COVID-19 during this study. The interviews focused extensively on the recycling of plastic waste, but as the literature highlighted there are many waste streams just as important. It should be noted that seventeen respondents might not present a representative sample of the target population; however, these interviewees are key people with expert knowledge in the industry. Their experience, influence and insights into the CCT waste industry significantly increases the credibility of the research. As a last consideration, this is a mixed method study and limitations are mitigated by the robust treatment of data.

4.11 Ethical consideration

Researching a complex field like waste management with vulnerable and stigmatised social groups is complex (Town & Perez, 2019). It is important from an ethical justice perspective

that the research does not harm waste pickers' position in the existing system. The scope of this research paper was to understand the interplay between stakeholders in the waste management system and, therefore, was conducted through interviews in formalised structures for waste pickers and waste recycling companies. Due to the sensitivity of data, approval to conduct the interviews was sought from the relevant organisations and institutions.

Before commencing with data collection, ethics approval was sought from the University of Cape Town (Appendix II). Only relevant data was collected and stored during the data collection process, and in instances where information was collected by accident during the interview process, this was be removed. At the start of every interview process, a consent form was provided to interviewees (Appendix III) that explicitly stated the nature of the research and why interviews would be conducted A method was provided to interviewees opt-out of the interview process at any stage and remove their data from the research project.

All data was stored securely on the UCT one-drive system. To increase levels of participations in the interviews, full anonymity of participants had to be ensured. No covert research was conducted where interviewees were lured into answering questions under false pretences. Permission was asked to record interviewees digitally. All stakeholders were made aware of the research being conducted and the purpose of the research. No personally identifiable data was stored. All findings were reported back to stakeholders before publishing. Names of companies and institutions interviewed were removed from the final research to provide an additional layer of anonymity due to the limited number of players within the CCT's WMS.

4.12 Methodology Summary

This research used a mixed-methods-sequential design that starts with qualitative interviews conducted over a period of 2 years with identified stakeholders according to the criteria of the SWIMM model to understand the value of waste data within the CCT and the value of informal waste industries contribution. Responses from the interviews were coded and qualitative publicly available data was then used to confirm the validity of the research. As a last step , the new SWIMM model was validated against earlier interviewee participants and experts in the WMS.

CHAPTER 5: FINDINGS AND DISCUSSIONS

5.1 Introduction

This chapter represents the core findings and discussions of this study. In this section the main research questions are explored as well as the testing of the claim that waste data from the informal waste sector can assist the formal waste industry, improve waste indicators and strengthen trust and reliability in waste data. As a second objective this chapter aim to validate the conceptual SWIMM model. The findings below explore the research questions as set out in the methodology and research design in Chapter 4.

As per the SWIMM model, a qualitative perspective from which to understand existing stakeholder perception of waste data availability this chapter explores the first sub-question of "How do stakeholders within the WMS perceive the availability of waste data? To understand the extent of waste data availability within the sample population of the City of Cape Town, the study explores the second sub-question of "What is the current volume and composition of waste data in CCT?" And thirdly, as per the SWIMM model and literature review this chapter explores sub-question 3 "Can the informal waste industry play a role in providing a complete view of waste in developing countries?"

5.2 Waste data perception of stakeholders

As per the SWIMM model and as part of the research design, the study set out to understand the stakeholder perception of waste data and what they perceive as valuable. In addition, the research seeks to understand from stakeholders (based on low levels of trust found in the literature review) where legitimacy of waste data can be found in the waste management system.

Question 1: How do stakeholders within the WMS perceive the availability of waste data?

The data from the survey (Appendix VI) indicates that the stakeholder groups have conflicting views of the data within the CCT's waste management system. The outcomes are discussed in the next section in terms of the categories proposed by the theoretical perspective of CSH

5.2.1 The basis of motivation

The interview question identified differences of opinion amongst the government organisation (City of Cape Town), informal and formal stakeholders across the waste stream in what they perceive the purpose of a waste management system should be (Table 2).

	What ought to be the purpose of waste management data ?
Municipal Authority	Policy guidelines, Compliance, Monitoring
NGO	Improve recycle rate per residential household, Improve planning
Private Contractor	Improve efficiencies, where a recycling facility should be located. How transport should work
Buyback Centre	Waste composition, weight, waste pricing, resource deployment inside business. concern about propriety data shared with competitors.
Waste Pickers	Quantify waste pickers' contribution to waste. Assist in formalising waste pickers
MRF	Waste minimisation to landfill, internal waste quality control. Production efficiency, Transport
Recycle Company	Detailed data on suppliers, composition, quality and volumes available, transport

Table 2:What ought to be the purpose of waste management data ?

The participants from the CCT required WMS to support decisions on policy guidelines, compliancy and monitoring waste minimisation compliancy, whilst private stakeholders required waste data to optimise their production, planning, forecasting and transport. In addition, the research found that stakeholder participants seemed to perceive that waste data would provide other stakeholders with a competitive advantage. This was indicated by interviewee 6 who stated:

> "*…you see it's a competition in the waste recycling industries…if I'm going share with my opposition guy, then he might just take some of my suppliers*".

From the interviews it emerged that a wide range of planning activities were already being performed with currently available waste data ranging from production and capacity planning for recycling companies. Interviewee 14 confirmed that *"…we can gauge the market by the waste that comes in…what we would be able to supply in the future …"* .These findings confirm that waste can assist stakeholders in planning and deployment of more efficient infrastructure. More specifically the findings from the survey indicated the need to understand the physical composition of waste, recycle rate per area and the volume of waste generated per area (Table 3).

	What is (ought to be) the measurement of improvement ?
Municipal Authority	Waste diverted from landfill
NGO	Recycle rate per area, quality of waste captured at source
Private Contractor	Cost efficiency in planning logistics and operational resources. Quality waste
Buyback Centre	Waste Factors , ratio, composition of waste
Waste Pickers	Number of waste pickers formalised. Waste volumes reported to formal waste management. Improvement in waste price for waste pickers
MRF	Waste residue that goes to landfill.. Operational efficiency on resource. Quality of the recycled material provided manufactures
Recycle Company	Transport and logistics is a huge contributor to cost and data can improve this. Quality of the data received

Table 3: Measurement of improvement required

Transport logistics was highlighted as one of the costliest components across the waste value stream. Using data from waste would allow stakeholders within the waste value stream to understand demand and plan logistics needed for high demand periods. These findings are supported by the literature review and the waste indicators included in SWIMM waste indicators (Chitaka & von Blottnitz, 2019; City of Cape Town, 2018; Miezah et al., 2015; Oteng-ababio et al., 2017). These indicators are (1) Recycling Rate, (2) Collection Rates, (3) Volume of waste generated (4) Its physical composition and (5) sorting efficiency.

5.1.2 The basis of power

Motivation for a waste management system and the resulting data and indicators are misaligned. The CCT requires indicators about waste minimisation and waste diverted from landfills, whilst the private sector requires data from the same indicators to improve production and planning. These findings highlight that the waste indicators are potentially controlled by the "wrong" stakeholder group. On closer exploration the findings show (Table 4), that this misalignment is due to the fact the CCT see themselves as the client of the waste management system. Whilst the private sector sees both the CCT and themselves as clients of the system.

	Who ought to be the client, and whose interest should it serve?
Municipal Authority	City of Cape Town. Researchers
NGO	Residential, but can sell it later to recycle companies, Recyclers
Private Contractor	Public and Private Sector, Recycle Companies
Buyback Centre	Manufactures and other recycling companies in waste stream. Have a concern in sharing propriety data
Waste Pickers	Industry PR Companies like Petco, to understand how much of their product lands on landfill. Government to understand the contribution of waste pickers
MRF	CCT to monitor the MRF's performance for compliance
Recycle Company	Converters (Manufacturers), Buyback centres, since they would know where waste is located. But we don't share data, since data is proprietary.

Table 4: Who ought to be the client of waste data?

These findings indicate that, as the perceived only client of the waste management system, CCT has set up the WMS in such a way as to address its own required measures of success. The CCT, as the waste reporting authority, sets the waste indicators required by suppliers and stakeholders within the waste management system. These waste indicators are aligned with CCT's waste minimisation compliancy strategy to national government rather than to support the requirements of the waste management industry. This is further substantiated when asked "who is the decision maker" (Table 5).

	Who is (ought to be) the decision maker . Who is (Should be) in the position to change measurement ?
Municipal Authority	CCT Waste Planning
NGO	individual households
Private Contractor	Procurement manager at private and municipal company
Buyback Centre	The operational manager on the floor
Waste Pickers	Waste Picking Associations, NGO's, Municipalities, Government
MRF	Quality controllers in MRF. Operational Manager at MRF
Recycle Company	Operations manager at recycling facility deciding on how many vehicles need to be dispatched

Table 5: Who is (ought to be) the decision maker?

The findings show that the CCT interviewees are of the opinion that the CCT waste planning division should be the main decision makers, while the private sector saw a diverse range of skills and people from across the waste management (including CCT) value chain contributing to how the waste management system would function.

5.1.3 The basis of knowledge

The question about expertise and who needs to be consulted highlights the short comings in the design of waste indicators across the waste management system. The CCT participants were of the opinion that knowledge for waste indicators comes from researchers and academics (Table 6).

	Who is (ought) to be considered a professional ?
Municipal Authority	Researchers, Universities
NGO	Informal Waste Pickers
Private Contractor	People within the waste management system that have experience
Buyback Centre	Waste Pickers
Waste Pickers	Waste Pickers, Buy Back Centres
MRF	Quality controllers in MRF. Operational Manager at MRF
Recycle Company	Internal ERP systems from recycle companies

Table 6: Who should be considered a professional

Public participants, on the other hand, indicated that they felt that knowledge resided in the field or with people that were practically involved with waste every day (buyback centres, waste pickers, recycling experts). These differences show a lack of design and development

efficiency in waste indicators. The findings highlight the need for stakeholders from across the waste management system to be included in the design of waste indicators for waste management in any future system. This would improve the alignment on which waste indicators are important across the waste industry.

5.1.4 The basis of legitimacy

Legitimacy inside a system can either be found in a guarantor or can be achieved by those involved in the system seeking a level of guarantee that some level of improvement would be achieved (Ulrich & Ulrich 2003).The quality of waste data is one of the major levels of measurements of improvement that interviewees highlighted and supports the findings from the literature review that quality of waste data is lacking (Kaza et al 2018). Interviewees agree that not enough primary data are available about waste and that researchers tend to aggregate the results of the data. There is a lack of standards in quantifying waste data and purity, with manual inspections still being used. One interviewee in the visual waste technology space highlighted the issue with visual inspection: "I mean it's still visual inspections with someone, kind of looking at a bale and saying, 'Yeah, that looks pretty pure,' and reporting" (Interviewee 2).

The view that waste data is of a low quality is supported by recycling companies in the findings that tend to rely rather on their own manual data collection. As observed by interviewee 14: "we found out that manual separation is the best separation; it's a slow process, but it guarantees 100% non-contamination of material.". Manual capturing of data influences the reliability and trust in the data that was collected since there are now standards driving the collection of data. This is illustrated by a response from interviewee 3 "*Waste pickers have no independent way of confirming the weight or price being paid for waste "they normally don't even get the receipts because it's happening in a very informal way*".

By improving the quality of waste data across the waste management system, legitimacy and trust in the system and resulting data would be improved. The study found that propriety waste data generated by stakeholders across the WMS is currently being used to drive internal planning and pricing decisions. A lack of (1) reliable, (2) up-to-date material, as well as (1) material composition, (2) recycle rate per neighbourhood, (3) sorting efficiency, and (4) waste generated is limiting the adoption of more waste data-driven decisions due to low levels of trust. In addition, limited data is shared between stakeholders since they believe their internal data would provide a competitive advantage to their competitors if made public. CCT as the

waste minimisation authority requires waste indicators and data to be collected around the diversion of waste from landfill sites, whilst the public waste management industry requires waste data indictors to drive optimisation decisions and to provide them with a competitive advantage. These factors therefore impact on how waste data is being collected.

5.2 Volume and composition of existing waste data

Question 2: What is the current volume and composition of waste data in CCT ?

This section uses a survey instrument (See Appendix X) to collect publicly available waste data within the City of Cape Town's Waste Management System. The survey instrument used the findings and responses from the qualitative interviews in the first section around waste data perception and waste measures to adjust the survey instrument.

5.2.1 Data availability

The system for capturing all waste moving into and out of waste management facilities for the CCT are weight bridges. Weighbridges only capture the tonnage of waste moving into and out of facilities as an aggregated number once a day. This data is also only published as an aggregated number once a month (Figure 3). This level of manual data collection is highly error prone and affects the reliability of the data. The focus of the data recorded is aligned with CCT's waste minimisation strategy, with a focus on landfill residue (the volume of waste is going to the landfill) and the volume of rubble and greens diverted , known as the active recycle rate. As per Table 7, the formula to determine total waste generated across the city that is used to report its total waste formula is:

$$
\begin{aligned}
&Total\ waste\ Generated \\
&= [Waste\ entering\ Facility\ over\ weightbridge] \\
&+ [Total\ waste\ diverted\ from\ the\ waste\ stream] \\
&- Smallest\ of\ [Builder\ Rubble] or\ [Builders\ Rubble\ reused] \\
&- Smallest\ of\ [Garden\ Greens\ entering\ landfill]\ OR\ [C\ Garden\ Greens\ Disposal\ Facility]
\end{aligned}
$$

Table 7: CCT Waste Formula (City of Cape Town 2021)

From the formula (Table 7) we can establish that waste from the informal sector is not taken into consideration by the CCT. This supports the findings from the literature review (Barnes et al., 2021; Rodseth et al., 2020) that waste from informal WMS is under-reported or not calculated into the formal waste management system formulas.

Interviewee 7 indicated that “There is massive gap between data from the private recyclers” (Interviewee 7). One of the reasons that private recyclers are not reporting in any data is that their sites might not be complying with CCT’s legislation, and they run the risk of being shut down (Interviewee 7).

The primary data collection process and data availability of waste data cross CCT is low. Data collection is affected by the CCT’s main aim to minimise landfill residue. The system is therefore designed to only report on the waste reaching the landfill sites and lack the accuracy, recency (only updated monthly) and material composition required by stakeholders.

5.2.2 Quantitative data analysis

It is important to determine the “value” of existing publicly available data. To determine the value, an instrument for quantitative analysis of the data (As described in Chapter 4) and document in Appendix X is used in Table 8. Table 8 indicates the data source which is either the CCT data portal or the Waste Information Centre (WIC). More information about these sources is available in Chapter 4. The survey instrument then describes these data sources based on the five variables from resource-based theory that quantify the value of data for an organisation to achieve a strategic advantage (Erevelles et al., 2016).

1. Volume of data – The volume of data available (Low, Medium, High)
2. Velocity – How quickly the data changes (Low, Medium, High)
3. Variety – The Variety of data available (Low, Medium, High)
4. Veracity – How well the data is validated (Low, Medium, High)
5. Value of data to Domain – How applicate the data is to a domain (Low, Medium, High)

The analysis in Table 8 indicates that domain value of data is of a high level (and used by the public sector, local and national government to shape policy and drive decision. However, veracity of the data is low with no independent verification of sources. In addition, updates are slow and typically only consolidated and provided monthly.

Data Source	City Of Cape Town Open Data Portal	WIC
Volume	Medium volume of data originating from weighbridges at owned facilities.	Medium volume of data provided by Municipalities and producers
Velocity	Low, Monthly Updates	Low, Monthly Updates
Variety	Low variety of data, only focus on waste minimisation	Medium, Variety of data, combined from municipalities and producers
Veracity	Low, No validations of data only rely on weight bridges and facility data reported	Low, No validation of data. Has no independent measurement systems; relies on self-reporting from municipalities and producers
Value of the Data to Domain	High, The CCT uses data for planning purposes (Infrastructure and operations). Also used by industry players to understand the market size and potential	High, The national government uses data to shape environmental policy and direction. Used by producers and recycling companies to estimate market size and compliance.

Table 8: Classification of waste data availability

This level of aggregation and low frequency of updates can be observed in Figure 3. As identified during the qualitative survey of respondents, the level of data collection is driven by legal compliancy on waste minimisation as a requirement by national government (Department of environmental and tourist affairs n.d.; Republic of South Africa, 2011), that requires reporting tonnage handled be facility per month and not the variety of waste composition.

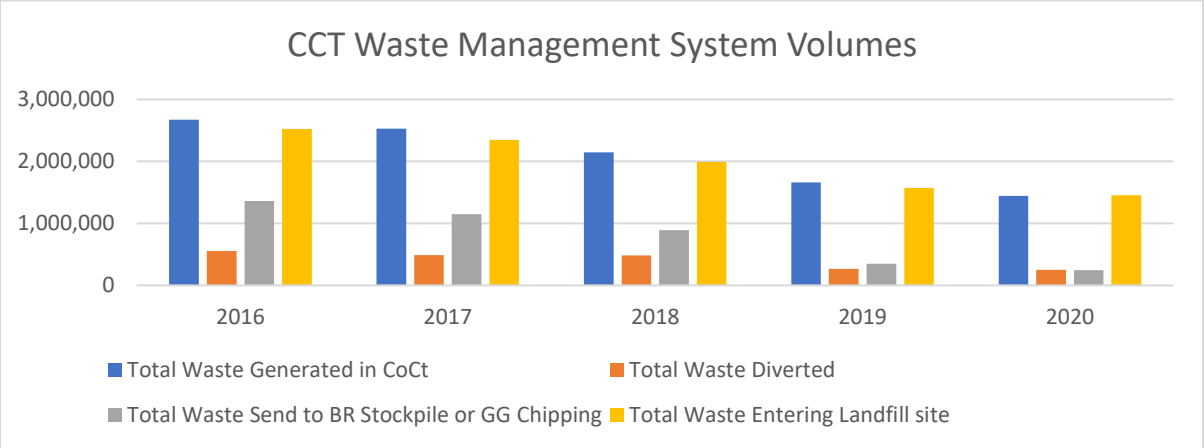

Figure 3: Aggregated waste data volumes (Source: Open Data Portal,2021)

Extending the search for more detailed and up-to-date waste data from the Waste Information Centre (WIC) reveals that there is higher level of classification in composition in the data available (Figure 4).

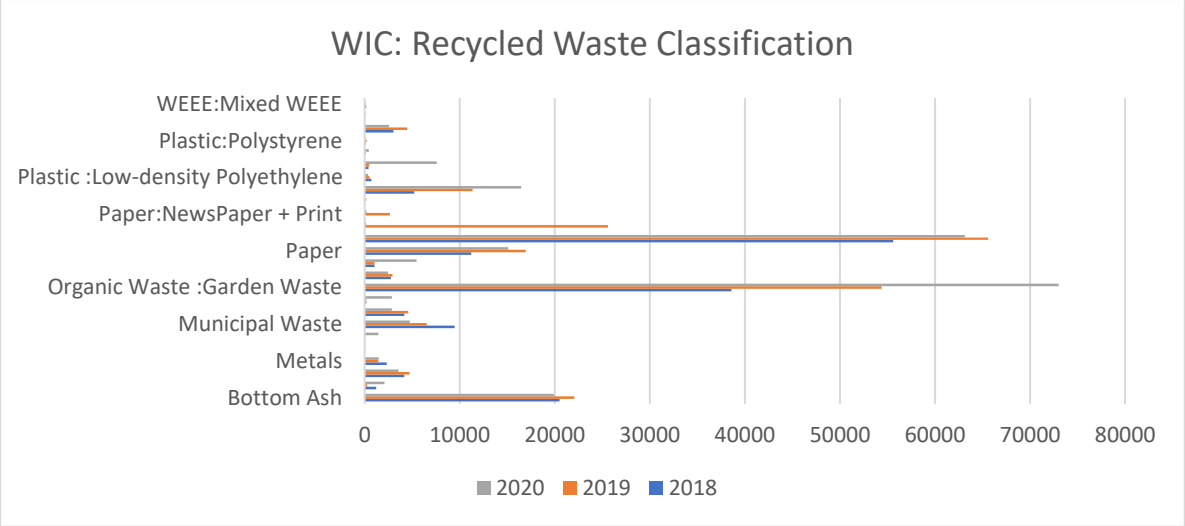

Figure 4: Waste composition classification (Source: WIC,2021)

However, the reported timeframe for the WIC's data is yearly, different from monthly frequency of the CCT's data. These findings are in line with the literature review that highlighted "Undefined words or phrases, lack of dates, methodologies, and sources influenced the quality and reliability of data " (Kasa et al , 2018).

In addition, this research found that the WIC's data are dependent on the local suppliers and reporting authorities' input. The quality of the data is based on self-reporting from data providers. Of concern is that the same unvalidated, largely manually captured data (from weighbridges) is reported upstream to the local province and national government to finally form part of the dataset in the national waste information centre (Figure 5).

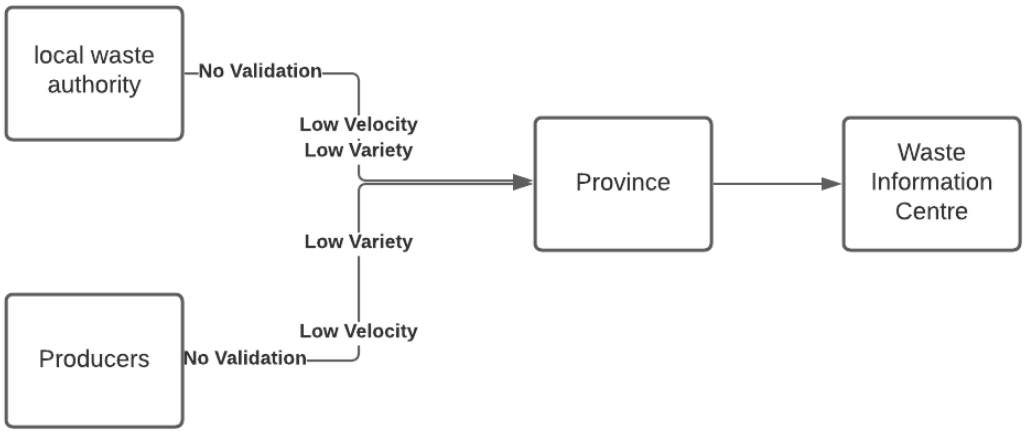

Figure 5 : Flow of waste data to WIC

A related finding from this research is that unvalidated and difficult to compare reported data from CCT, WIC is widely used and cited (City of Cape Town, 2018, 2019b, 2019a; GreenCape, 2019, 2020; Republic of South Africa, 2011; South Africa. Parliament (1994-). National Assembly., n.d.) and used for planning and policy documentation and therefore is of extremely high value to the waste management domain.

Question 2: *What is the current volume and composition of Waste within Cape Town's WMS, and how much data is available about the waste?*

Publicly available data on the composition and volume of waste data across the waste stream is limited with only two publicly accessible sources found for the research (1) City Of Cape Town's Data Portal and (2) WIC. The research further found that the update frequency of the data is slow with CCT's data updated and reported monthly and the WIC's data reported only on a yearly basis. In addition the data lacked veracity, since data reporting largely relies on out data manual data capturing at source, with self-reporting from data providers. There is also a lack standardised naming conventions and date keeping. The findings also highlight that waste composition details are lacking in the data. Waste composition and classification tends to be aggregated into a higher waste group classification level, making waste composition on a lower level difficult to identify. Lastly the findings revealed that, in line with the literature, the informal waste industry, and more specifically waste pickers contribution to waste management, is excluded from data reported by the industry.

5.3 Contribution of informal waste pickers

The literature highlighted the lack of waste data in developing countries because informal waste sectors' waste is under reported (Nahman & Oelofse, 2018; Rodseth et al., 2020). Findings from the research support the fact that waste pickers should be seen as both experts and professionals (Table 9) and that they have valuable information to contribute.

	Who is (ought) to be considered a professional in the WMS?
Municipal Authority	Researchers, Universities
NGO	Informal Waste Pickers
Private Contractor	People within the waste management system that has experience
Buyback Centre	Waste Pickers
Waste Pickers	Waste Pickers, Buy Back Centres
MRF	Quality controllers in MRF. Operational Manager at MRF
Recycle Company	Internal ERP systems from recycle companies

Table 9: Who should be considered as professional in WMS?

The findings indicate that quality and trust in waste data is lacking in the waste industry. Interviewees highlighted that waste pickers are in the unique position that "…they are close to the survey very close to the source." and that they are attuned to market conditions (Interviewee 3). In general, the data that waste pickers are privy to is extremely hard to come by. There is, however, an observed difference in opinion in waste pickers' roles within the waste management system (Table 9). Public companies within the waste management stream tended to acknowledge waste pickers as experts, whilst the CCT saw experts as researchers and more academical.

Q3: *Can the informal waste industry play a role in providing more complete view of waste in developing countries?*

The results demonstrate that the data from the informal sector can contribute significantly to a more complete view of waste data in developing countries. For example NGO's , private contractor and buyback centres believe that waste pickers are well positioned withing the waste management system at the point of separation. Data from waste pickers about physical waste composition at the source of separation can enhance existing waste reporting by providing data from the currently under reporting informal waste industry. Stakeholders within the WMS see waste pickers as professionals within the system.

5.4 The value of waste data in within Cape Town's waste management System

Primary research question "*What is the value of waste data within Cape Town's waste management systems"*

Stakeholders within the system indicated that they have different requirements from waste data within the system. The availability of this data and lack of (1) reliable, (2) up-to-date material, as well as (1) material composition, (2) recycle rate per neighbourhood, (3) sorting efficiency, and (4) waste generated is limiting the value of waste data in the WMS. The informal waste sector can contribute to this shortage of data, but additionally add legitimacy and thereby value to the data within the WMS.

5.5 Validating the SWIMM model

Jabareen (2009) states that, to validate a model, the framework should not only make sense to the researcher but also to scholars and practitioners. The Mixed-Methods Explanatory Sequential approach used in this research paper as a final stage uses feedback from practitioners to validate the conceptual SWIMM model as per figure 6.

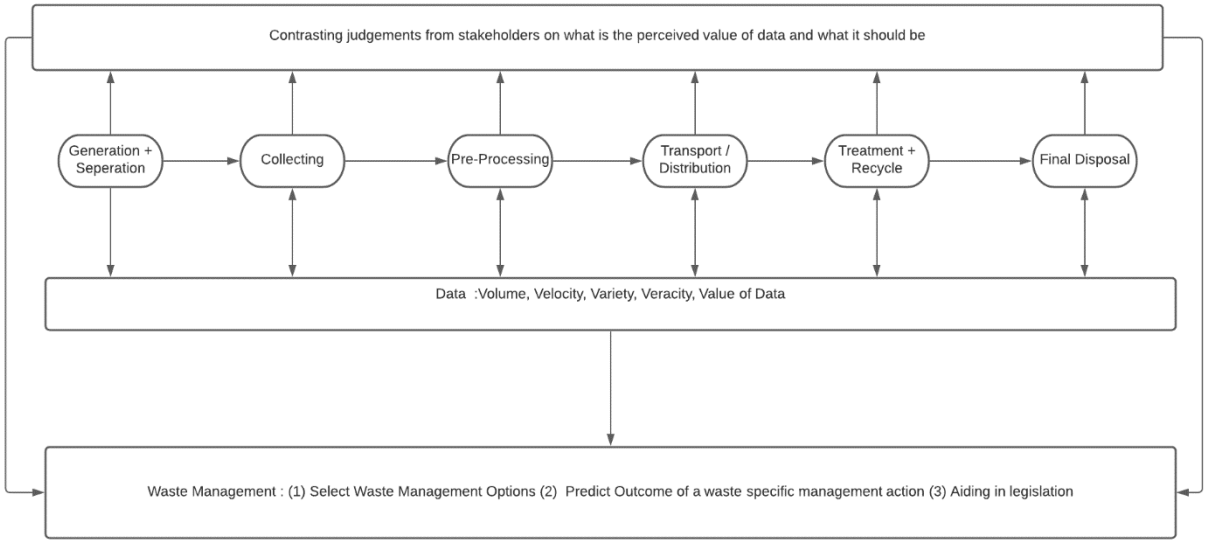

Figure 6: Conceptual SWIMM Model as proposed by the author

The findings indicate that the current paradigm of waste minimisation is contributing to incorrect data being collected to support the requirements of all stakeholders across the waste management system. The findings also validate the important contribution that the informal waste sector can make to providing a more comprehensive picture of the waste. The findings suggest that five waste indicators influence stakeholders' ability within the WMS to perform

planning decisions (1) Physical Material Composition, (2) Recycle Rate , (3) Collection Rates, (4) Volume of Waste and (5) Historical Waste Patterns.

Legitimacy or stakeholders' trust to use these indicators are, however, dependent on stakeholders' ability to trust the data behind these indicators, which, in turn, is influenced by quality and validation of data. In addition, stakeholders believe that these indicators provide a level of competitive advantage, which, in turn, creates lack of trust between participants and limits the level data sharing.

As a final validation step, the SWIMM model was presented to interviewees at the CCT. There was agreement on the waste indicators; however, they expressed caution on the usage of terminology such as "active recycle rate", since, within the CCT data, it is usually not associated with levels of household recycling. Rather, the CCT recycle rate is expressed as an overall recycle rate within the WMS. During the final validation of the model with the CCT, the researchers observed that the CCT did not agree with the strong level of mistrust expressed by interviewees from the private sector. These factors are relevant to developing countries, but further research needs to be done to investigate its relevance to developing countries.

5.6 Summary of Finds and Objectives

Literature was reviewed and existing studies indicating that a lack of waste data in developing countries is hampering the implementation of WMS. In addition, the role of waste pickers was identified to contribute to trust and improving quality of waste data availability. A new SWIMM model was developed that takes into account the context of waste management system within the broader context and as defined by stakeholders and literature. Literature on the successful implementation of WMS and interview data on perceived usefulness of data was combined to define the perceived value of waste data across the WMS.

This indicated that there is a misalignment between stakeholders expectations on data that's collected within the WMS. Government and the CCT main focus of the WMS and waste data is to drive waste minimisation, whilst the private sector requires more updated higher viscosity of data on material composition through the waste stream to drive decisions. Data from the CCT and the national Waste Information System was collected to measure what the availability of waste data is and to compare it against stakeholder expectations. This supported findings from objective 3, since existing data that is available is outdated, updated infrequently and focused on waste minimisation.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

This research provides empirical evidence of a misalignment of stakeholder data requirements due to the power dynamics within the waste management system (WMS). In addition, the current quality of waste data can be improved by including the informal waste sector and IWP in any conversation about waste data. The current WMS is set up in such a way as to drive the municipal authorities' (WMS) mandate to report on waste minimisation indicators. This misalignment in the expected outcome from the WMS is contributing to the lack of data required by the stakeholders across the WMS.

This research explores, and extends, the findings by Guerrero, Maas & Hogland (2013), Marshall & Farahbakhsh (2013) and Stemmet & Uys (2020) that there is a lack of quality and volume of waste data to support the implementation of waste management system in developing countries. This lack of data stems from the fact that there are two parallel waste systems in developing countries, namely the formal and informal WMS. This research proposes a novel solid waste information management model (SWIMM) to address this lack of data. The model proposes five waste indicators that takes contrasting judgments from stakeholders to generate important waste features into account. These indicators are (1) reliability of data, (2) update frequency, (3) detail on material composition, (4) recycle rate per neighbourhood, and (5) sorting efficiency. These features are able to assist in measuring, planning and legislation-related activities across the waste management system.

Findings from the study demonstrate that stakeholders across the WMS see the informal waste management system as a very important source of information and expertise. This conclusion is supported by Viljoen J.M.M, Blaauw, D., & Schenck, C (2019) & Godfrey (2021) research on the importance of informal waste pickers in the waste value chain. These findings also validate the proposed SWIMM model that proposes a more detailed approach to waste management that includes stakeholder input across the waste management system. The results suggest that different stakeholder perspectives should be considered on the intended outcome from a WMS.

Further research is required to confirm the value of the waste indicators identified by the SWIMM model. It is recommended that these waste indicators be tested in the form of a standardised questionnaire across the formal and informal waste sector.

In terms of waste management, it is recommends that municipalities such as CCT switch from an outcomes-based approach to waste minimisation towards a more detailed, up-to-date understanding of waste in the value chain aligned to all stakeholder expectations. In addition, the study recommends including the informal waste industry and specifically waste pickers, as part of the formal WMS system.

In conclusion, more reliable, easily accessible real-time waste data about the composition, recycle rate, and location of waste that is aligned to all stakeholder needs is required in developing countries. The informal waste industry has this data available based on its proximity to the source of separation and must be included for more reliable waste data and waste management.

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APPENDICES

Appendix I: Interview Questions

Question
What is your function in the waste Management system (Separation, Transport, Collection and Transfer, Treatment, Final Disposal, Recycling?
What do you understand data is? What is its definition?
Who is (ought to be) the client? That is, who is interest should waste data serve?
What is (ought) to be the purpose of waste management data? That is, what should be the consequences of Waste Management data?
What is (ought to be) the measure of improvement? That is, how can we determine that the consequences, taken together, constitute and improvement
Who is (ought to be) the decision-maker. Who is (should be) in a position to change the measure of improvement?
What resources are (ought) to be controlled by the decision-maker? That is, what conditions of success can (should) those involved control
Who is (ought to be) considered a professional. That is, who is (should be) involved as an expert?
What expertise is (ought to be) consulted?
Where should we search for consensus among these experts to guide us on a guarantee for improvement?
Who is (should) be a legitimate stakeholder, and who argues (should) the case of the stakeholder who cannot speak?
Where does the legitimacy in the system lie
What different versions of improvement are (ought to be) considered?
What do you perceive the value of waste data currently within your organisation? What ought it to be?
Does data generated from waste currently provide a strategic advantage to your organisation? Should it in the future?
Is the volume of waste data generate adequate currently for your domain? What should it?
Does the generated waste data change quickly currently enough to be of value to you? What is it look like in the future?
Is a variety of data generated from waste currently of value to you? What should it be in the future?
Is the quality of the data generated from the waste data currently good? What should it be?
Is the data of value to your particular domain currently? What should it be?
Do waste pickers contribute to your waste data?

Appendix II: Ethics approval

Faculty of Commerce
Private Bag X3, Rondebosch, 7701
2.26 Leslie Commerce Building, Upper Campus
Tel: +27 (0) 21 650 4375/ 5748 Fax: +27 (0) 21 650 4369
E-mail: jacques.rousseau@uct.ac.za
Internet: www.uct.ac.za
@Commerce UCT UCT Commerce Faculty Office

12/11/2020

Paul Stemmet

Department of Information Systems

University of Cape Town

REF: REC 2020/11/007

The value of waste data in Cape Town's informal waste management systems:

an exploratory case study

We are pleased to inform you that your ethics application has been approved. Unless otherwise specified this ethical clearance is valid until 30-Nov-2021 .

Your clearance may be renewed upon application.

Please be aware that you need to notify the Ethics Committee immediately should any aspect of your study regarding the engagement with participants as approved in this application, change. This may include aspects such as changes to the research design, questionnaires, or choice of participants.

The ongoing ethical conduct throughout the duration of the study remains the responsibility of the principal investigator.

We wish you well for your research.

2020.11.12
17:20:34 +02'00'

Jacques Rousseau
Commerce Research Ethics Chair
University of Cape Town
Commerce Faculty Office
Room 2.26 | Leslie Commerce Building

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Website: https://www.commerce.uct.ac.za/Pages/Ethics-in-Research

Appendix III: Consent Sample

Consent Form

Project Title: The Value of Waste Data in The City Of Cape Town's informal waste management systems: an exploratory case study

Researcher: Paul Stemmet

I volunteer to participate in a research project conducted by Paul Stemmet from the University of Cape Town. I understand that this research project is designed to study the value of waste data in the City of Cape Town

As a Consultant at Plastix 911, I understand that I am being invited to take part in a survey and/or interview. I understand that in agreeing to participate:

- My participation is voluntary. I understand that I will not be paid for my participation.
- The survey will take approximately 30 minutes to complete.
- The interview will last approximately 30 minutes. Notes will be written during the interview and/or an audio taped. I can decline to be recorded.
- I understand that if I feel uncomfortable in any way during the interview I have the right to decline to answer any question or to leave the interview session.
- I understand that the researcher will not identify me by name in any reports using the information obtained from the survey or interview. My confidentiality as a participant will remain secure. Subsequent uses of recordings and data will be subject to standard data use policies which protect anonymity of individuals and institutions.
- Administrative and other teaching staff at from the University of Cape Town will neither be present during the interview not have access to raw notes or transcripts of either the survey or the interview. This precaution will prevent any of the findings having personal negative repercussions for me.
- If I choose to be interviewed, I have the right to view and comment on the transcribed interview data before the findings are analyzed.
- I have read and understand the participant information sheet provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.
- I have been given a copy of this consent form.

I hereby agree / ~~disagree~~ (circle the applicable option) to participate in the **survey** for this study.

I hereby agree / ~~disagree~~ (circle the applicable option) to participate in the **interview** for this study.

I hereby agree / ~~disagree~~ (circle the applicable option) to the **audio recording of my interview** for this study.

Name _____

Signed _____

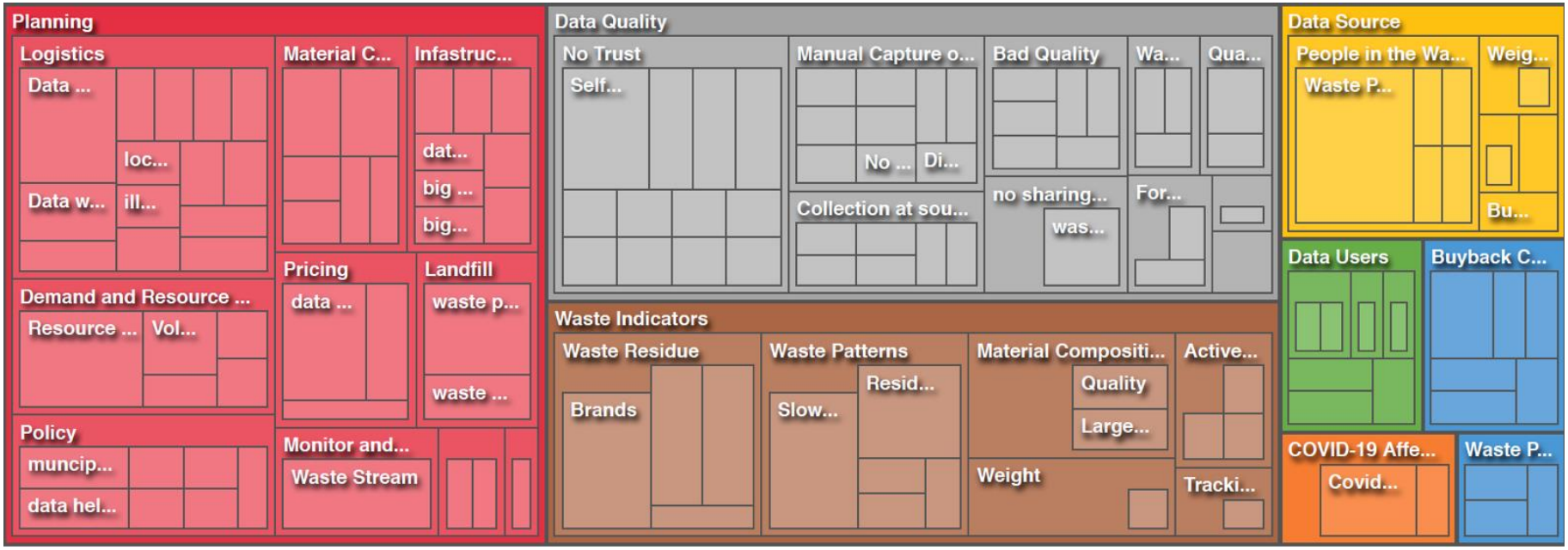
Date 2 February 2021

Appendix IV: Coding - Early Observations

Nvivo coded early observations from interviewees, highlighted concerns from respondents.

Appendix V: Final Coding

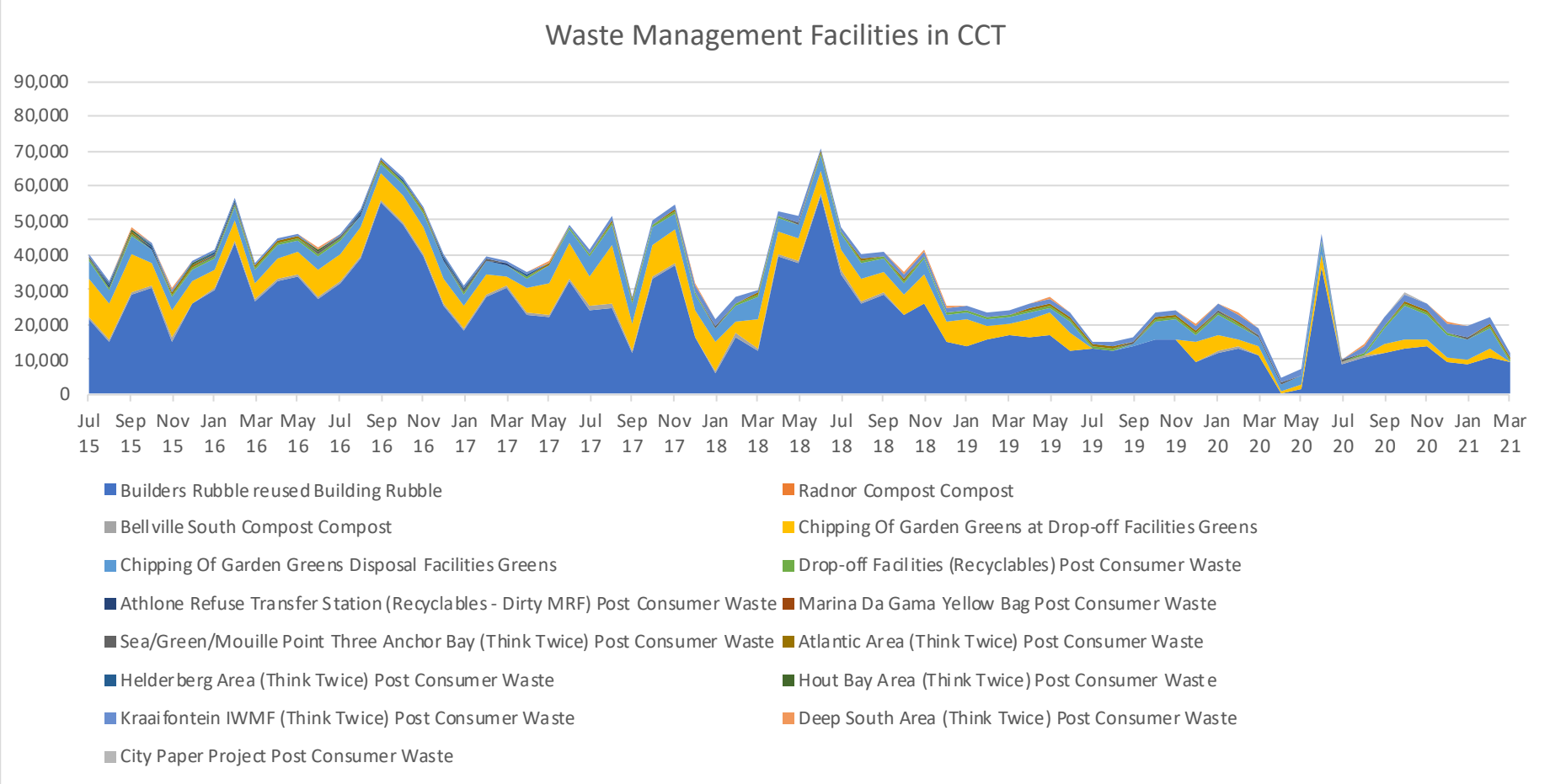
Final coded data in Nvivo from interviews.



Appendix VI: Qualitative Comparative Analysis

	What is your function in the waste management system	Who ougt to be the client, who's interest should it serve?	What ought to be the purpose of waste management data ?	What is (ought to be) the measurement of improvement ?	Who is (ought to be) the decision maker . Who is (Should be) in the position to change measurement ?	What resouces are (ought to be) controlled by the decision maker ?	Who is (ought) to be considered a professional ?	What expertise is (ought) to be consulted ?	Where should we search for concensus among experts	Where does legitimacy in the system lie ?	Does data generated from waste currently provide strategic advantage ? Should it in the future ?	Is the volume of waste data generated adequate for your domain ?	Does the generated waste data change quickly enough ?	Is the variety of data generated from waste data currently good quality ?	Is data in your domain current ?
Municipal Authority	Waste Minimization and final waste disposal	City of Cape Town. Researchers	Policy guideliness, Compliance, Monitoring	Waste Diverted from Landfiil	CCT Waste Planning	Ability to drive decisions	Researchers , Universities	Researchers and Industy PR		Quality and consistency of data	Yes , it assist with planning and budgetting decisions	Yes	Yes	Yes	Yes
NGO	Residential Recycling Services, Waste Research	Residential, but can sell it later to recycle companies, Recyclers	Improve recycle rate per residential household,Improve planning	recycle rate per area, Quality of waste captured at source	individual households	Real-time access to recycle rate per residentail area	Informal Waste Pickers	Informal Waste Pickers	Households and Waste Pickers	Waste Pickers	Yes, but it will guide us on more accurately assigning resources	Yes, but it will guide us on more accurately assigning resources	Yes, the recycle data compiostion changes fast enough	Waste Pickers collect and confirm waste identification at source , which increase waste data quality	Yes
Private Contra	Recycling	Public and Private Sector, Recycle Companies	Improve effeciencies , where a recycle facility should be located. How transport should work	Cost effeciency in planning logistics and operational resources. Quality waste	Procurement manager at private and muncipal company	Financial	People within the waste management system that has experience	CCT Waste Minimization	Recycling stakeholders	Quality , Sharing and trust between recycle stakeholders	Yes, but only for tender purposes	No, not enough real-time and compostion data available	The composition and volumes changes quickly enough , but waste patterns are predicable	No not enough data on waste composition	No
Buyback Centr	Buy waste from the public , process the waste and sell to manufactures	Manufactures and other recycling companies in waste stream. Have a concern in sharing propertiety data	Waste Compostion , Weight, Waste pricing, Resource deployment deployment inside business. concern that about propriaty data shared with competitors .	Waste Factors , Ratio, Composition of waste	The operational manager on the floor	Production Schedules	Waste Pickers	University , Industry PR , Research	Sharing of data is hampered by a lack of trust	Consistent data quality at a reliable updated frequency	Yes. Not available. Inferior quality waste, leads to as high as 40% loss	No, not enough data on composition . Also low quality.	Data from City isn't uipdated readily enough	No, need to increase waste composition data	No,delayed
Waste Pickers	Community based , waste picking and seperation at source (Household and landfills)	Industry PR Companies like Petco, to understand how much of their product lands on landfill. Government to understand the contribution of waste pickers	Quantify waste pickers contribution to waste minization. Assist in formalizing Waste Pickers	Number of waste pickers formalized. Waste volumes reported to formal waste management. Improvement in waste price for waste pickers	Waste Picking Association, NGO's , Municipalities, Government	Centralized Waste Pricing	Waste Pickers,Buy Back Centres	Waste Pickers, Buy Back centres	Improve trust across the waste stream by making waste pricing, volume and composition public	Publically available pricing data on waste	No, but in future it could assist with formalizing waste picker contribution and fair pricing				
MRF	Material recycle facility that takes presorted waste from commercial and private residence	CCT to monitor the MRF's performance for compliance	Waste Minimization to landfil, Internal Waste Quality control. Production Effiecency, Transport	Wast residue that goes to landfill.. Operational effeciency om resource. Quality of the recycled materrial provided manufactures	Quality controlers in MRF. Operational Manager at MRF	Sorting infrastructure of the MRF	Quality controlers in MRF. Operational Manager at MRF		Agreement from producers on the quality of the recycled material provided. Less waste residue going to landfill	Agreement from manufactures on quality	No	Yes	Yes	Yes	Yes
Recycle Compa	Recycle plastic. Sorting recycling and processing	Converters (Manufactures), Buyback centres, since they would know where waste is located.but we don't share data,since data is propriety.	Detailed data on Suppliers, composition , quality and volumes available, Transport	transport and logistics is a huge contributor to cost and data can improve this.Quality of the data received	Operations manager at recycle facility deciding on how many vehicles need to be dispatches	Allocation of resources	Internal ERP systems from recycle companies	Waste consultant	Buyback Centres	If the published data would allow stakeholders across the valuechain to determine waste localtion, pricing , quality and composition	Yes internal optimization	Yes	Yes	Yes	No not updated enough

Appendix VII: Quantitative Data Analysis



Appendix VIII: Data Sample

Transformed consolidated data from the City of Cape Town's waste data portal.

Date	General Waste	Hazardous Waste	Builders Rubble (BR) entering Landfill	Garden Greens (GG) entering Landfill	Total Incoming Waste
Jul 15	100,183	1,512	103,779	631	206,105
Aug 15	93,292	2,028	81,368	1102	177,790
Sep 15	98,981	1,862	87,740	843	189,426
Oct 15	104,708	1,961	86,022	1023	193,714
Nov 15	96,373	1,409	79,311	1040	178,133
Dec 15	103,617	1,132	59,625	1028	165,402
Jan 16	89,219	1,631	60,696	615	152,161
Feb 16	85,578	1,420	96,863	987	184,848
Mar 16	91,852	2,419	100,331	825	195,427
Apr 16	91,253	2,298	98,645	933	193,129
May 16	100,847	2,341	122,437	810	226,435
Jun 16	101,726	2,760	114,173	872	219,531
Jul 16	96,210	3,083	94,024	639	193,956
Aug 16	103,947	2,570	137,303	667	244,487
Sep 16	101,286	2,198	155,468	759	259,711
Oct 16	88,298	1,728	151,497	1315	242,838
Nov 16	93,561	2,103	138,475	1103	235,242
Dec 16	92,707	2,204	78,334	1875	175,120
Jan 17	94,778	2,589	66,623	808	164,798
Feb 17	87,130	1,833	72,412	735	162,110
Mar 17	87,506	2,714	106,615	955	197,790
Apr 17	80,982	2,725	94,766	583	179,056
May 17	97,446	1,870	98,937	731	198,984
Jun 17	92,310	1,706	99,788	969	194,773
Jul 17	106,829	597	96,380	753	204,559
Aug 17	135,640	645	96,261	515	233,061
Sep 17	112,644	521	86,560	704	200,429
Oct 17	96,352	1,053	122,285	770	220,460
Nov 17	104,541	1,295	114,536	737	221,109
Dec 17	87,494	851	83,032	711	172,088
Jan 18	92,881	886	19,723	579	114,069

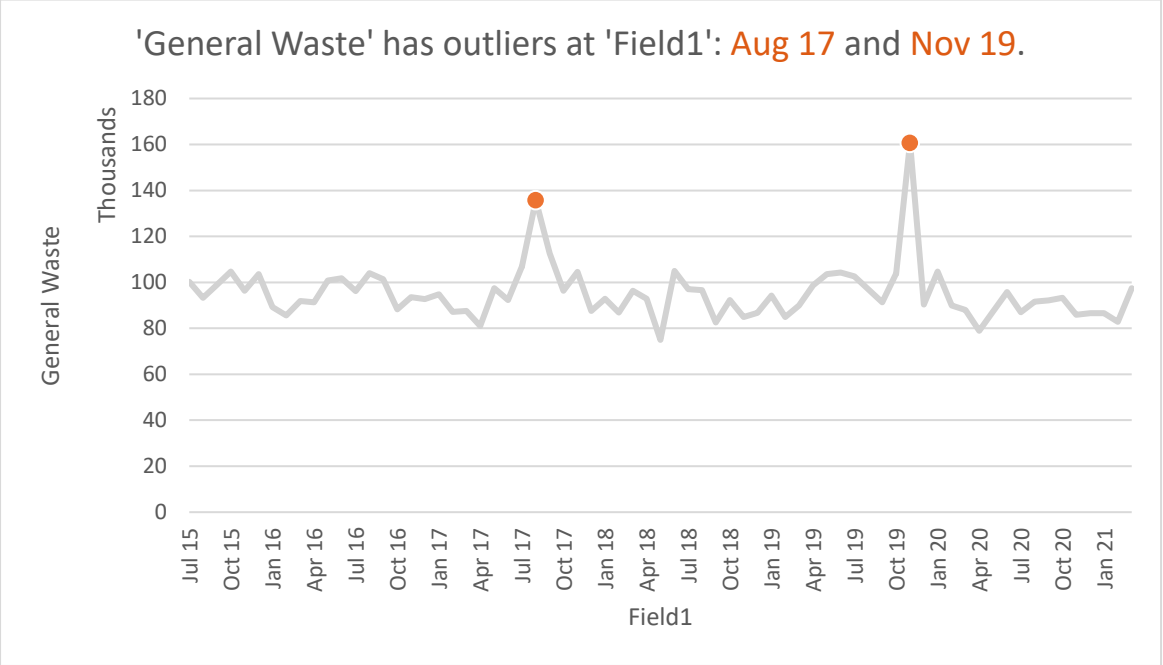
Date	General Waste	Hazardous Waste	Builders Rubble (BR) entering Landfill	Garden Greens (GG) entering Landfill	Total Incoming Waste
Feb 18	86,872	852	96,331	751	184,806
Mar 18	96,326	898	138,578	683	236,485
Apr 18	92,913	960	134,110	615	228,598
May 18	74,967	684	129,853	576	206,080
Jun 18	105,006	1,005	125,376	769	232,156
Jul 18	97,038	1,026	55,388	404	153,856
Aug 18	96,607	716	39,770	449	137,542
Sep 18	82,567	782	40,799	288	124,436
Oct 18	92,314	355	43,410	209	136,288
Nov 18	84,958	717	40,009	208	125,892
Dec 18	86,784	464	24,227	88	111,563
Jan 19	94,213	649	25,156	173	120,191
Feb 19	84,901	295	33,278	352	118,826
Mar 19	89,991	393	32,317	984	123,685
Apr 19	98,679	623	28,622	1046	128,970
May 19	103,597	687	26,379	1197	131,860
Jun 19	104,314	880	25,052	396	130,642
Jul 19	102,596	589	31,631	1989	136,805
Aug 19	96,871	701	26,584	2113	126,269
Sep 19	91,365	217	26,290	2361	120,233

Number of waste facilities reporting data to Waste Information System per year

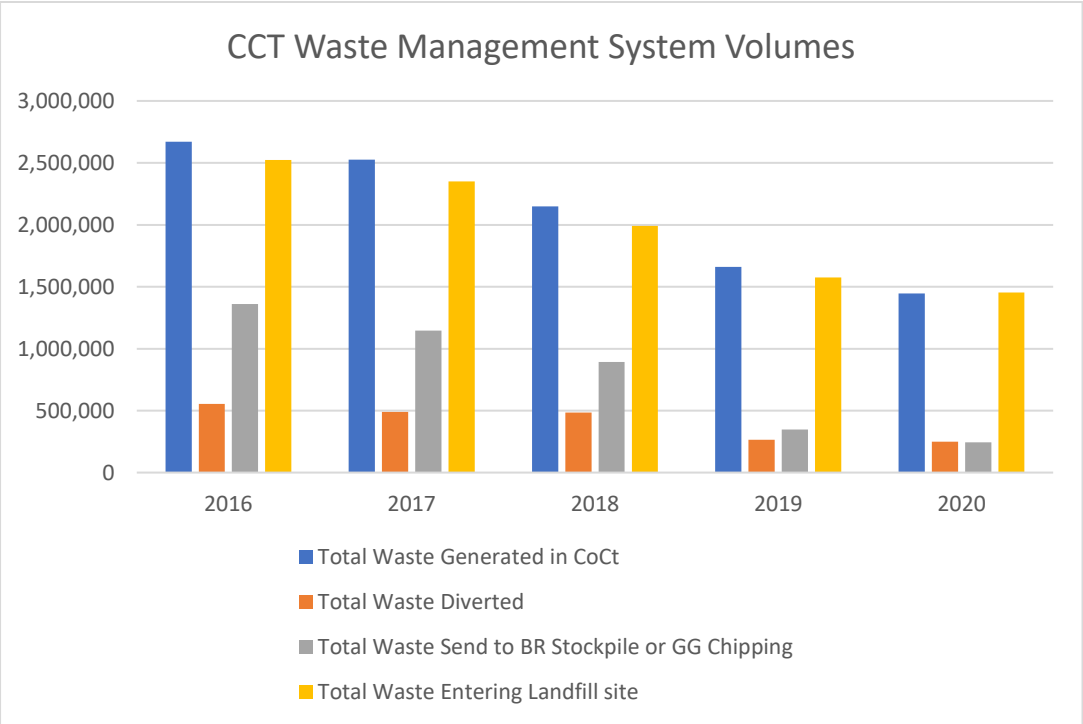
Facilities **Reporting**	2017	2018	2019	2020
Bottom Ash	1	1	1	2
Commercial and industrial waste	6	4	3	2
Construction and Demolition Waste	3	3	4	4
Glass	4	3	5	4
Metals	4	4		3
Metals:Ferrous Metal	1	1	1	5
Metals:Non-Ferrous Metal	0	1	2	5
Municipal Waste	6	5	6	4
Organic Waste	6	3	3	4
Organic Waste:food waste	1	1	1	1
Organic Waste :Garden Waste	5	5	6	7
Organic Waste :Wood Waste	5	3	2	1
Other	6	3	4	6
Paper	4	3	4	3
Paper:Brown grades	3	3	4	4
Paper:Mixed Grades	1	1	3	4
Paper:NewsPaper + Print	0	1	2	3
Paper:white grades	0	1	0	3
plastic	1	7	7	9
Plastic :Low-density Polyethylene	2	1	2	2
Plastic: Polyethylene terephthalate	1	2	2	4
Plastic:Polypropylene	1	1	2	3
Plastic:Polystyrene	2	1	4	4
Plastic:Polyvinylchloride	3	2	3	3
Electric equipment	2	0	2	2
WEEE:Mixed WEEE	1	1	1	1
Number of Entities Reporting	69	61	74	93

Source: Waste Information System

Anomaly detection on waste data



City of Cape Town's Waste Management System Volumes



Appendix IX: Research Diary

Date	Interviewee	Sector	Company	Comments
03.03.21	1	Recycling	pelmanco	Qualitative Interview
23.03.21	2	Waste Pickers	sawpa	Qualitative Interview
02.04.21	3	Waste Pickers	Regenize	Qualitative Interview
29.04.21	4	Waste Pickers	Groundwork	Qualitative Interview
18.03.21	5	Recycling	Wyckogroup	Qualitative Interview
18.03.21	6	Recycles	vdschyfplastics	Qualitative Interview
03.02.21	8	Buyback Centre	Top Plastic	Qualitative Interview
03.10.21	9	recycling	PlasticsSA	Qualitative Interview
16.04.21	10	recycling	Kraaifontein MRF	Qualitative Interview
18.03.21	12	Technology	Grey Parrot	Qualitative Interview
24.12.20	13	Expert	Interviewee 1	Qualitative Interview
18.03.21	13	Recycling	Atlantic Plastics	Qualitative Interview
03.03.21	14	Recycling	Myplas	Qualitative Interview
23.03.21	16	recycling	Polyco	Qualitative Interview
03.07.21	17	Plastics body	Petco	Qualitative Interview
18.03.21	18	Expert	plastics911	Qualitative Interview
03.07.21	19	Expert	Interviewee 2	Qualitative Interview
29.04.21	21	Expert	Interviewee 3	Qualitative Interview
01.05.21				Code data from interviews in Nvivo
01.06.21				Download and Access City of Cape Town Data Portal base of Waste Data Factors identified from interviews
20.06.21				Transform and check downloaded data for consistency
21.06.21				Create SWIMM Model
19.10.21	7	City of Cape Town	Interviewee 4	Qualitative Interview confirming quantitative findings and model
01.11.21				Final write up of finds based on interviews and quantitative findings

Appendix X: Survey Instrument for required waste

Waste Indicator	Available	Observations
Quality	No	No measurement for quality improvement, or validation
Physical Waste Composition	Limited	Limited, only at city facilities and monthly. Yearly available from WIC but different reporting Methodology
Recycling Rate per Area	Limited	Limited to only cities Think Twice Project
Collection Rate Per Area	Limited	Only areas and frequency of collection
Volume of Waste Generated	limited	Only waste that reaches waste management facilities are measured
Sorting Efficiency	No	Only used internally

Appendix XI: Example of anonymous transcribed interview

[PS] What is your function in the waste management System

[R] We are right at the end the guy that converts it into something, Recycling

[PS] What ought to be the purpose of waste data

[R] I have a concern that by highlighting our waste data, our business could be copied. You know the waste factors and ratios inside your own business. It can allow competition, and it can allow overseas companies, large then us to come into the market.

[PS] What ought the data be used for?

[R] To see what your buying is the correct value and if there is a pricing problem

[PS] How big is your company and are there other companies that could use the data?

[R] We're a 100 people and there's companies like Wingspan and Alanti, our focus is on quality that's why we need a lot of staff.

[PS] Is there any waste data currently available that you can use?

[R] There's currently no dependable waste data and we suffer up to a 40% loss due to no dependable data.

[PS] Does the generated waste change quickly enough to be of value.

[R] The price on recycled plastic is stable and provides quite a long-term picture for us

[PS] Where do you get your waste from?

[R] Generally from overseas (Italy), but local things we buy extremely expensive to transport. 15.50 Euro seems to be the break-even point

[PS] Where do you buy locally from?

[R] Must have quality, usually the "bakkie manne". Not usually directly from the waste pickers. Also buy from wasteplan, CR waste and alvera

[PS] Last thought?

[R] Waste for recycling is very predictable, there’s usually 10%-20% fluctuation. Could see competitors in Covid-19