
# New Business Models for South African Waste Handling Equipment Manufacturers.

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

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**Plagiarism Declaration**

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

**Abstract**

This research explores the integration of sustainable business models in South African waste-handling equipment manufacturing, focusing on the adoption of Circular Economy (CE) principles and innovative technologies. Given the sector's challenges, including urban-rural infrastructure disparities and regulatory barriers, the study evaluates the potential benefits of circular and data-driven approaches. The research employs qualitative methods, including semi-structured interviews, to investigate business models, technological advancements, and regulatory influences. Findings reveal that South African manufacturers are beginning to adopt sustainable practices but face significant hurdles due to financial constraints, high technology costs, and a lack of skilled workers. Despite these challenges, embracing CE principles, automation, and AI-driven models could significantly enhance operational efficiency and sustainability. The study emphasises the need for supportive government policies and industry partnerships to overcome these barriers, fostering a more sustainable and resilient waste-handling industry in South Africa.

**Key words**: Circular Economy, sustainability, waste management, technological adoption, automation.

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# CHAPTER ONE: INTRODUCTION

## 1.1 Introduction

Global efforts to promote sustainable waste management have demonstrated the effectiveness of customised waste handling equipment manufacturing in enhancing efficiency and reducing the negative impact on the environment (Fatimah, Govindan, Murniningsih & Setiawan, 2020). Countries like Germany, Japan, and the US have effectively integrated this waste-handling equipment into their waste-management strategies (Ma, Shi, Zhang, Hao, Huang, & Lin, 2019). However, South Africa has its peculiar challenges because its infrastructure is formal and informal, and the differences between urban and rural regions are substantial.

The manufacturing sector evolves its business practices through new technological innovations in combination with sustainability standards. The principles of circular economy, together with sustainable business models, matter because they work toward waste reduction and material reuse to match global sustainability targets (Forti et al., 2020). These models force manufacturers to redesign products and their lifecycle management so they can enhance sustainability while decreasing operational costs (Santa Maria, Vermeulen, & Baumgartner, 2022). South African waste-handling equipment manufacturers could achieve better sustainability and profitability results from implementing these innovative approaches.

The research investigates distinctive business models for manufacturing waste-handling equipment in the South African market. It evaluates the present business model designs within this industry to identify the differences between current practices and potential emerging model formats. The research analyses possible new business models to provide South African Waste-handling equipment manufacturers with essential opportunities for modernisation and sustainable business growth.

## 1.2 Background

The manufacturing sector behind waste-handling equipment undergoes substantial changes because of rising environmental understanding, technological developments, and regulatory pressure. A "take-make-dispose" traditional model suffers from environmental damage to the extent that it faces mounting challenges (Murray et al., 2017). New business models across industries are transforming the market through their combination of Data-Driven Business Models along with Circular Economy, Sustainable Business Models and AI-enabled Business Models, Servitisation and Product-Service Systems (Bocken et al., 2014). The Circular Economy enables maximal resource performance by dedicating itself to product life

extension through recycling and refurbishing in addition to reuse practices (Geissdoerfer et al., 2017). The integration of environmental and social factors into business operations constitutes Sustainable Business Models that pursue combined economic, environmental, and social benefits (Stubbs & Cocklin, 2008). The waste handling equipment manufacturer must utilise these models because environmental influence stands as a primary operational concern.

Through examination of South African manufacturing companies, researchers explore alternative frameworks for waste handling equipment production. The study investigates current business models and explains the differences between established practices and current model types, including circular economy and sustainable business models. The implementation of these new models presents manufacturing companies with three significant barriers: high initial expenses, resistance to change, and insufficient supporting networks (Kirchherr et al., 2018). Businesses face substantial barriers in adopting Circular Economy principles because they need considerable investments to develop new technologies and processes (Wu et al., 2022). Organisations need to transform their conventional practices by making them support environmental and social objectives according to Sustainable Business Models (Rusch et al., 2023).

The analysis of successful cases delivers crucial information about handling such obstacles. Using Circular Economy principles, Siemens provides an extended product life design for more sustainable and operationally efficient solutions (Siemens, 2021). Through "Ecomagination," General Electric delivers both environmental benefits and financial advantages through sustainable innovations that increase resource efficiency (GE, 2020). Through its circular lighting model, Philips allows customers to lease products instead of buying them to improve resource recovery and decrease product waste (Philips, 2019). Waste-handling equipment manufacturers can find practical model transformations through these examples that demonstrate success in the adaptation of a business model.

Looking toward the future, the waste-handling equipment manufacturing sector will progressively implement a Circular Economy and Sustainable Business model. The industry needs to develop innovative business approaches since environmental restrictions grow and market preferences change for survival and durability (Murray et al., 2017). These model integration opportunities create new economic development paths, which technological progress combined with market evolution brings forth (Das et al., 2022). The research explores current industry trends that direct South African waste-handling equipment manufacturers toward sustainable business transformation. Through the adoption of these

management approaches, organisations will build sustainable operations that serve environmental needs as well as societal goals (Mamudu et al., 2024; Godfrey et al., 2022).

### 1.3 Problem Statement

The waste-handling equipment manufacturing industry is undergoing swift transformation due to the implementation of both data enhancement approaches and circular economy methodologies, as well as AI-powered advancements. The traditional waste handling methods are undergoing significant changes because they now require businesses to implement sustainable and efficient operational practices. The majority of waste-handling equipment manufacturers within South Africa maintain traditional linear business models that fail to explore the advantages of sustainable business approaches and circular economy practices (Pieroni et al., 2021; Larkin, 2024). South African waste-handling equipment manufacturers encounter multiple obstacles moving to modern business strategies like servitisation and circular economy frameworks because these alternative methods provide superior environmental and economic benefits (Das et al., 2022; Santa-Maria et al., 2022). Research on integrating upcoming innovative business models into the South African context becomes necessary due to the significant difference between established and emerging business approaches. The research investigates sustainable and circular business models for waste-handling equipment production in South Africa through a specific analysis of implementation challenges and opportunities (Rusch et al., 2023; Badsa et al., 2024).

### 1.4 Purpose statement

This study aims to investigate the Circular Economy and Sustainable Business Models for waste-handling equipment manufacturing across South African industries. The research examines the application methods of new business models, including data-driven systems, AI-enabled technologies, and servitisation approaches in the waste-handling manufacturing sector, while comparing them to current operational standards. The research highlights difficulties South African waste-handling manufacturers' face in implementing advanced solutions by examining ways these companies can combine global sustainable practices with better waste management results.

### 1.5 Study Scope

The study explores business model development within waste handling equipment manufacturing while exploring new approaches such as Data-Driven Business Models, Circular Economy, Sustainable Business Models, and AI-Enabled Business Models together with Servitisation and Product-Service Systems. These forces for change direct corporations toward new sustainability methods and operational effectiveness models. The research

investigates Circular Economy and Sustainable Business Models specifically for their utilisation within South African waste-handling equipment manufacturing. An analysis of companies (anonymously identified as A through F) provides the research with practical examples that show effective sustainability strategies and successful sustainability implementation approaches within their sector.

The research investigates existing South African waste-handling equipment manufacturing business model operations, focusing on identifying the differences between traditional methods and current sustainable innovations. This study will the highlight hurdles manufacturers of waste handling equipment face when adopting new business frameworks in order to establish a complete picture of sustainable and circular methods transition barriers. The research findings present multiple perspectives about realistic implementation strategies and possible routes for industry adoption of contemporary business models.

### 1.6 Business need of the study

A major industrial revolution has been detected in the waste-handling equipment sector because of emerging business models that integrate data-driven approaches with circular economy fundamentals, AI-based solutions, and servitisation services. The new business models create possibilities to improve operational performance with more excellent sustainability outcomes (Accenture, 2021). Due to their efficiency in lifecycle management and resource optimisation, Waste-handling equipment manufacturing can enable radical change through sustainable business models and circular economy principles (Kanda et al., 2021; Bican & Bre, 2020; Ghadge et al., 2020).

The waste-handling equipment sector of South Africa requires an assessment of its business model performance to identify emerging model gaps. South African manufacturers experience obstacles during the adoption of circular economy practices as this research investigates present business models while focusing on the challenges this sector encounters with sustainable practices. By addressing these gaps, this research will deliver essential findings about combining new models to improve environmental results and operational effectiveness through its exploration of global sustainability patterns (Rusch et al., 2023; Epoh et al., 2024).

### 1.7Theoretical Need for the Study

The sustainability of waste-handling equipment in South Africa requires examination to validate sustainability and technology adoption principles. The research evaluates theoretical requirements for new business approaches in South African waste-handling equipment manufacturing within the framework of industrial transformation aspects such as data-driven

and artificial intelligence-powered and circular economy models. Data-driven models optimise production through big data analysis and analytics, while AI-enabled methods use advanced technologies to improve manufacturing processes (Frank, Dalenogare, & Ayala, 2019; Boström et al., 2021). The transition to a circular economy combined with sustainable business models is of great importance because they target waste reduction through effective material reuse (Forti et al., 2020).

South African companies, through their case studies, show that business success comes from sustainability integration into their operational models alongside effective best practice adoption. Examining these case studies makes it possible to understand both the current condition of business models and the differences between established methods and new business model approaches (Dube, 2020). The objective of this research centers on South African manufacturers' difficulties during the implementation of the new business model by analysing their possibility of building sustainable practices and managing changing waste requirements. The research combines practical insights with theoretical concepts by suggesting strategies to enhance sustainable practices among waste-handling manufacturers along with the South African waste management sector.

### 1.8 Research Objectives

1. To analyse the current business models and market operations of South African waste-handling equipment manufacturers.
2. To evaluate how technological advancements and trends impact the business models of waste-handling equipment manufacturers in South Africa.
3. To assess the influence of regulatory requirements and environmental policies on the business models of South African waste equipment manufacturers.
4. To investigate the adoption and impact of data-driven and AI-enabled models in South Africa's waste-handling sector.
5. To propose and evaluate innovative, sustainable business models for South Africa's waste-handling market, focusing on effectiveness and efficiency.

### 1.9 Study Outline

The research problem background is presented in Chapter One before the study requires exploration of theoretical and business factors, which leads to the extensive literature review in Chapter 2. Chapter Three reveals the research questions to which the study responded. Chapter Four details the research methods that was used for the study. Research findings

appear in Chapter Five, while Chapter Six contains an analytical discussion of the research results. The research culminates in Chapter Seven, which incorporates conclusions, practical implications, suggested policies, and recommendations regarding practice and future research.

## CHAPTER TWO LITERATURE REVIEW

### 2.0 Introduction

The chapter examines all applicable theoretical models which shape sustainability programs of South African waste-handling equipment production companies. The research analyses the circular economy principles, sustainable theory and innovation diffusion theory to detail how local manufacturers use these models for environmental practice intensification and resource efficiency enhancement as well as advanced technology integration. The current scholarly works about related empirical literature topics will be examined to demonstrate effective strategies which address sustainability practices in the waste handling sector.

### 2.1 Theoretical Framework

Business models utilised by South African waste-handling equipment makers are changing sustainability initiatives, and CE practices and innovation distribution strategies are gaining momentum. These frameworks present methods that help businesses minimise environmental harm and enhance resource utilisation along with technological progress. This research will integrate relevant concepts to demonstrate methods by which local manufacturers can implement their strategies for sustainability improvement by resolving both domestic environmental issues and global market requirements.

#### 2.1.1 Circular Economy

The Circular Economy (CE) serves as a transformative business model that is widely adopted within various industries, with waste-handling equipment manufacturing among them. CE establishes its core principle by promoting a regenerative system that cancels traditional linear production methods, which generate waste through single-use resources and disposal. The CE model prompts businesses to transform their operational procedures to increase the persistence and reduce the ecological footprints of their products (Geissdoerfer et al., 2017). The situation in South Africa, which features serious environmental problems, including land degradation and waste accumulation, makes the design of CE principles a crucial fit for local waste-handling equipment manufacturers. These manufacturers need to adopt CE principles to minimise their resource usage while developing equipment that allows breakdown re-usage and recyclability when they reach the end of their operational lifespan. The CE model helps South African businesses pursue sustainable practices because it fosters ecological protection during economic development (Bocken et al., 2014). South African manufacturers who implement CE principles will be able

to satisfy their domestic environmental issues and establish themselves as market leaders in the expanding eco-conscious global market.

Business models that incorporate CE show indications of being vital for sustaining operations in the long run. Godfrey et al. (2021) explain how manufacturing industries in South Africa should implement CE techniques to manage waste because this will enhance operational efficiency and decrease environmental harm. Manufacturers are adopting modular designs in waste-handling equipment, according to Pieroni et al. (2021), so their equipment becomes more repairable and upgradeable and subject to recycling. The practice minimises waste costs and boosts economic strength because it extends product lifespans and cuts down raw material consumption. South Africa encounters significant obstacles to adopting a circular business model because the region lacks basic infrastructure and receives limited support from regulatory bodies. According to Mhatre et al. (2021), the necessary hurdles can be overcome through technological progress and a transition toward sustainable operations through consumer-service behavior. Understanding which factors affect the adoption of the circular economy principle in South African markets will help predict the fate of waste-handling equipment manufacturing.

### 2.1.2 Sustainable Theory

Sustainable theory serves as an organisational framework to direct business practices by promoting balanced relationships between environmental, social, and economic interests. The business needs to evaluate long-term environmental and social effects while focusing on future population health (Nocenzi and Sannella, 2020). The South African manufacturers who produce waste-handling equipment can implement sustainable theory as a means to link their production strategies to environmental objectives. Waste-handling equipment designers and producers need to use sustainable practices such as green materials and energy-saving technology per sustainability theory recommendations. Through this method, manufacturers lower environmental impact while simultaneously enhancing social aspects by improving waste management processes and backing local communities in their efforts to benefit. Hengst et al. (2020) emphasise the need for an adaptive management system with continuous improvement capabilities as well as active responsiveness to rising ecological product requirements and rising environmental regulatory needs for sustainability purposes.

The importance of sustainability for business models has led to substantial changes in waste-handling equipment manufacturer strategies. Businesses across the market have started implementing sustainable practices through green technologies and eco-design

principles (Agrawal et al., 2022). Customers, alongside governing bodies, are driving the need for businesses to conduct operations with social and environmental responsibility, which matches this market trend. The adoption of Industry 4.0 technologies brings several sustainability benefits to the manufacturing process since they improve resource management while decreasing emissions and enhancing operational efficiency (Bányai et al., 2019). South Africa's waste management sector has obstacles to sustainable practice adoption because of budget limitations and weak governance support (Munsamy, 2022). The existing barriers to sustainability in the waste-handling equipment industry demonstrate a clear need for more research that explains practical sustainable theory applications to remove these obstacles and develop sustainable business models in South Africa.

### 2.1.3 Innovation Diffusion Theory

According to Rogers (2003), innovation diffusion theory explains the process of technological and procedural spread across populations and creates a useful concept for understanding the adoption and scalability of waste-handling equipment in the manufacturing industry. IDT serves to determine which factors affect the adoption of artificial intelligence (AI) and data-driven waste management solutions specifically. Manufacturers who adopt new technologies first gain a competitive advantage through data-enabled products that satisfy the rising market need for advanced innovative waste management systems (Teece, 2010). The use of AI-enabled waste-handling equipment enables the optimisation of waste collection routes and predicts necessary equipment maintenance tasks while increasing complete system performance levels. The innovative technology fits sustainability objectives because it makes resources more efficient while producing less environmental impact. Rusch et al. (2023) have pointed out that implementing these technologies causes difficulties because of significant startup expenses, insufficient technical capabilities, privacy and security concerns in data management.

The study explains how communication systems, together with social networks, help speed up innovation diffusion between industries. The accomplishment of AI-enabled and servitisation business models in waste-handling equipment depends on both their technical advantages and effective promotional methods for prospective clients (Teece, 2010). Understanding the impact of pioneering customers on market expansion helps other manufacturers initiate similar business practices through market stimulation. South Africa needs specific collaborative efforts between waste-handling technology providers and manufacturers together with policymakers to advance innovation through barrier elimination

and broad implementation (Fatimah et al., 2020). Manufacturers will adopt new technologies when regulatory frameworks support positive policies because favorable regulations incentivise their adoption (Mhatre et al., 2021). IDT, together with sustainable and circular economy analysis, provides organisations with a complete understanding of how innovations transform the business models of South African waste-handling equipment manufacturers.

The reviewed literature demonstrates how circular economy theory, together with sustainable practices and innovation diffusion theory, will define the coming business strategies of South African waste-handling equipment producers. The rising demand for sustainable production practices, together with technological improvements, creates the necessity to change the plan for designing waste-handling equipment and its production and utilisation. Manufacturers benefit from circular economic models because these systems let them decrease waste generation and forge effective resource practices while improving environmental sustainability. Sustainability theory brings essential knowledge about making solutions between environmental, societal, and economic needs to build enduring business worth. Through the innovation diffusion theory, the industry understands how to integrate new technologies, including artificial intelligence and data-based solutions. These theories provide the foundation for this research that investigates the present and projected business models used by waste-handling equipment producers operating in South Africa.

### 2.2 Business Models of Waste Handling Equipment Manufacturers

The development of waste-handling equipment manufacturing models exists as a response to changing market needs and escalating global environmental standards. Dedicated to product sales in the past, the manufacturing sector followed a linear model by creating equipment from design through manufacturing to sell it for municipal, waste management and industrial use (Moalem & Kerndrup, 2023). A service-oriented model in business operations has seen significant progress in the previous few decades. Managers within the manufacturing industry create revenue stability by offering leasing and maintenance contracts that strengthen customer relationships while securing steady revenue streams (Agrawal et al., 2022). The waste management industry demands more uptime operations, so the new model suits the market and delivers efficient equipment while minimising operational stoppages. The service-based approach allows manufacturers to sustain income streams yet demands significant changes in their operational methods as well as their customer connection strategies and innovation strategies. Prior product-based approaches in waste management are being superseded by service-led models since waste

management businesses require new solutions along with heightened sustainability awareness.

The business model transformations within the South African waste-handling equipment manufacturing industry have developed due to domestic and international sustainability pressures. Waste management manufacturers now explore a circular economy approach to recover materials and components by implementing reuse and recycling with material repurposing (Pieroni et al., 2021). The circular economy business strategy focuses on wasting fewer resources while maximising efficiency in product cycles and enabling materials and products to re-enter the production cycle instead of ending in waste streams. Kanda et al. (2021) demonstrated that implementing circular economy approaches results in sustainable waste management since equipment components become eligible for reuse and recycling, minimising the manufacturing process's environmental footprint. The South African waste management landscape faces an urgent need for innovation because the country requires circular models, which are crucial in developing waste management practices. South African manufacturing firms now implement circular concepts through equipment design improvements for simple breakdown and part reuse elements and product component recycling initiatives that foster sustainable development throughout the African region.

Business models must overcome various obstacles when integrating circular economy principles because of their known advantages. The waste handling sector needs operational structure reforms and new technologies for recycled material handling (Fetanat et al., 2021). Integration of circularity within business models presents two main challenges to companies: operational hurdles and financial barriers. Developing countries like South Africa, along with small manufacturers, face high obstacles to adopting new recycling or remanufacturing equipment since the initial investment costs exceed reasonable capacity (Godina et al., 2020). Companies and consumers need to modify their thinking to emphasise durable equipment with recyclable qualities instead of new product acquisitions. The long-term advantages that include lower material expenses, better sustainability brand image convincing for industries to implement circular economic principles.

Waste handling equipment manufacturing adopts service-based and circular business models that integrate with the rising significance of digital technologies in industrial processes. The business models of manufacturing firms transform, because digitalisation boosts operational efficiency and opens creative paths for business value creation(Agrawal

et al. 2022). The IoT, together with AI and analytics tools, helps manufacturers achieve maximum operational efficiency while maintaining predictive equipment maintenance and promoting equipment extension, which follows service-oriented and circular economy business models. Continuous services built using technological advancements enable equipment monitoring and maintenance services that lead to minimal downtime and better customer satisfaction rates. Manufacturers in the waste handling sector use digitalisation to establish circular and service-oriented business models through these technologies. Sustainable data collection from product lifecycles becomes possible through digital transformation because it optimises recycling and reuse procedures for manufacturers (Larkin, 2024).

Therefore, business model strategies for waste handling equipment manufacturers change because of service-based approaches and circular economy implementation principles. Service-based models have become more popular than traditional product-based sales because they provide manufacturers ongoing revenue generation together with better customer relationships. The implementation of circular economy principles brings specific difficulties to manufacturers operating in South African markets while also creating multiple opportunities for sustainable growth between local and global sustainability standards. Manufacturers benefit from digital technologies to optimise their operations through which they create enduring business value and enhance efficiency. More research needs to explore how the identified business models can operate successfully in South Africa's specific circumstances because the industry remains in constant development.

### 2.3 Technological Advancements and Their Impact on Business Models of waste handling equipment manufacturers

Advanced waste management equipment technologies have brought about a major business transformation for manufacturers. Waste sorting and recycling and disposal procedures became more efficient and precise because of the introduction of automation technology combined with robotics and sensors systems and Internet of Things (IoT). Nascimento et al. (2019) explains how technological adoption optimises waste management operations while changing manufacturers to focus on delivering integrated technology solutions instead of individual products. Predominantly through predictive maintenance combined with real-time monitoring and data analytics companies improve customer experience because the experience drives development of business models that focus on value-added services rather than traditional product sales. Manufacturers use current advancements to put forth

pay-per-use or subscription-based models that minimise customer spending at the beginning and sustain continuous revenue streams(Ferasso et al., 2020). As such, modern technological innovations have synchronised waste handling equipment production with circular economy frameworks to establish sustainable business operations that extend product lifecycles and recover raw materials.

The adoption of machine learning together with IoT technologies created new operational flexibility, which enables manufacturers to develop flexible business models. According to Ghadge et al. (2020), existing technologies allow ongoing performance tracking, which lets waste-handling companies provide bundled maintenance services as part of their "as-a-service" packages. The new business model diverges radically from previous product-based selling systems. Real-time data analysis technologies enable manufacturers to develop specific waste management solutions that cater to their clients' requirements (Ferasso et al., 2020). Through these adaptable customer-centered manufacturing approaches, manufacturers become part of circular economy initiatives by cutting waste and prolonging product use while optimising resource usage. The challenges to complete implementation identified by Guldmann and Huulgaard (2020) include expensive initiation costs alongside resistance to change that researchers must study for South African contexts.

The adoption of Industry 4.0 technologies used for waste management changes the manufacturing approach toward sustainability alongside innovation. The combination of digital technological changes with clean technology and Internet-of-Things systems, as explained by Mamudu et al. (2024), allows manufacturers to decrease waste while improving performance and creating sustainable new products. The adoption enables companies to move toward circular business systems by encouraging recycling and product reuse throughout their operations. Through real-time tracking and data consolidation, Rusch et al. (2023) demonstrate how waste management equipment producers maximise resource efficiency and decrease environmental effects by supporting circular economy principles. Managers in many manufacturing facilities work to achieve a transition to sustainability yet face the challenge of integrating new technology with financial restrictions, particularly in South African markets. The investigations show that organisations require effective business designs that tackle these specific obstacles, especially regarding the expense, efficiency and scalability of modern technology systems.

Business models based on circular economy develop through two important drivers: digitalisation and sustainability trends. The merging of digitalisation and sustainability

projects has led to an examination of traditional business models in manufacturing because companies have shifted toward circular practices (Centobelli et al., 2020). User involvement with machine learning, along with sensors, enables manufacturers to create products that can be recycled and reused at their end-of-life cycle. This develops the circular economy structure. The alignment with circular economy principles remains essential as according to Demestichas and Daskalakis (2020), for tackling the global goals of waste reduction and resource preservation. Bican and Brem (2020) demonstrate that manufacturers face substantial challenges when they try to incorporate new technological innovations into their established business structures. Research must focus on implementing technological changes in South African waste-handling equipment manufacturers' business models due to the current transformations in the business environment.

Waste-handling equipment manufacturers progressively recognise the value of circular economy approaches in their business operations. The study by Akilandasowmya et al. (2024) demonstrates why waste reduction needs clean technologies a lot more because IoT solutions can track waste streams while maximising resource retrieval. Businesses within waste handling equipment must prioritise the acquisition of these sustainable technologies because customer demands for productive low-carbon solutions continue to grow rapidly. Huynh (2022) additionally indicates that modern digital innovations in waste management can lead manufacturers toward circular business models by prompting them to design products that enable simple recycling and maintenance. Innovation shows excellent potential, but its large-scale utilisation faces various obstacles because people need awareness, and companies must tackle financial and regulatory hurdles. The South African manufacturing sector needs strategic leadership, policy support, and technological innovation to establish suitable environments for circular economy models, according to Litvinenko (2020).

Therefore, literature review shows that modern waste-handling equipment technologies are transforming manufacturing business models to achieve higher levels of operational efficiency, environmental sustainability, and resource management. The progress in waste handling equipment enables manufacturers to change their traditional product-based approach into service-focused circular economy systems with a focus on sustainability and resource recovery. However, business model integration challenges become evident through literature review since existing model owners face both resource limitations and stiff resistant to change. Additional investigation of South African waste handling equipment manufacturer' needs exists to understand specific challenges and prospects regarding their deployment of

advanced technologies alongside circular economy business planning. Technological advancements need critical analysis to show how waste-handling manufacturing evolves while manufacturers require groundbreaking solutions to transition toward sustainable and profit-generating business systems.

### 2.4 **Regulatory Requirements and Environmental Policies on Business Models of Waste Handling Equipment Manufacturers**

The business models of waste-handling equipment manufacturers are transformed because of environmental policies and regulatory requirements, which force them to develop new solutions for changes in legal compliance. Mouton (2020) explains that the National Environmental Management: Waste Act and Extended Producer Responsibility (EPR) regulations push waste handling equipment manufacturers to follow more stringent environmental standards. Through regulatory compliance, companies gain access to fresh market prospects while being forced to implement sustainable operational methods. According to Munsamy (2022), the rising demand for waste reduction, together with recycling, mandates manufacturers to adopt advanced technologies through ongoing innovation. These rules for environmental business practice create obstacles with financial costs, and technology adoption needs while simultaneously fostering sustainable model development. Regulatory compliance functions as a business opportunity, along with its implementation challenges because successful adaptation allows manufacturers to benefit from rising customer demand for sustainable options (Vilakazi, 2022). The regulatory pressures influence businesses to transform their conventional models and establish sustainable principles as part of their strategic platforms.

The implementation of environmental policies drives the shift toward circular economy frameworks that guide manufacturers of waste-handling equipment in their business model operations. The circular economy demonstrates a fresh model for producers by prompting them to build equipment and products that are repairable and recyclable to reduce waste and stretch product lifecycles (Godfrey et al., 2021). South African manufacturers are motivated to redesign production processes through environmental policy integration of circular economy principles so they can discover resource recovery and waste valorisation business possibilities (Godfrey et al., 2022). The transition to a circular economy faces obstacles because of insufficient infrastructure along with monetary restrictions present in local manufacturing (Maama et al., 2021). Implementing circular business models faces companies with two significant challenges, primarily due to the high costs associated with

green technology and process adoption. The future financial rewards from circular economy-based business models therefore motivate manufacturers to undertake investments even though they face challenges from short-term implementation expenses. Thus, manufacturers need to adapt to new technologies and business innovations after environmental policies create opportunities for circular economic models.

Manufacturers who produce waste-handling equipment pay attention to green supply chain management because of rising regulatory standards and environmental policies. According to Epoh et al. (2024), manufacturers must evolve their supply chains with these green practices, which focus on waste reduction and recycling as well as resource recovery strategies. Organisations are making their supply chains more environmentally sustainable because of increasing regulatory standards designed to decrease environmental effects and enhance sustainability targets. South African manufacturers who adopt green supply chain management techniques receive regulatory conformity compliance, market competitive advantages, local and international environmental standards(Badza et al. (2024). The successful execution of these practices faces obstacles because Munsamy (2022) identifies high initial expenditures combined with worker skill deficiencies and restricted availability of green technology platforms. The long-term sustainability features, along with the cost-saving potentials of green supply chain therefore keep attracting waste-handling equipment manufacturers despite existing obstacles. As such, the market position of manufacturers now depends heavily on their adoption of green supply chain management to fulfil environmental regulations.

Moreover, the waste reduction and recycling regulations offer manufacturers in the waste handling equipment business both advantages and obstacles to tackle. Moyo et al. (2022) explain that South African legislative requirements force manufacturers to create better waste segregation technology, collection systems and recycling solutions because the laws set higher recycling targets for waste reduction. Through these environmental policies, waste handling equipment manufacturers can generate specialised revenue streams by developing equipment and providing services that help achieve sustainability goals. Mouton (2020) reveals that rising demands for waste management technology create a manufacturing dilemma between pursuing environmentally friendly solutions and economic viability. The disagreement between environmental sustainability and economic viability results in business compromises regarding price levels and technological capabilities, as well as market opportunities. Manufacturing companies that implement successful innovations to fulfil regulatory requirements can therefore improve their market position while receiving

official support for green technology programs. In this sense regulatory requirements transform into an innovation driver for the waste-handling equipment manufacturing industry by making companies restructure their business operations to support environmental sustainability goals.

Finally, the business models of waste-handling equipment manufacturers receive significant influence from government incentives along with policies that help advance the adoption of green technologies. Godfrey et al. (2021) explain that financial aid through tax breaks and green technology subsidies combined with public-private collaborations provides businesses with resources to shift towards environmentally sustainable models. Local South African manufacturers require significant financial incentives because they struggle with the high initial expenses needed for sustainable practice implementation (Vilakazi,2022). The rising number of Extended Producer Responsibility (EPR) regulations that require manufacturers to handle their product lifecycles has motivated the development of waste-management technologies. The policies face limitations in delivering their intended outcomes because Epoh et al. (2024) note poor enforcement alongside irregular sector-specific implementation. Despite such challenges, government incentives function as a vital force behind enabling manufacturers to establish sustainable and profitable new business models. Therefore, the success of policy incentives to change business models relies on maintaining consistent implementation among all stakeholders who participate in the process.

In summary, regulatory requirements, along with environmental policies, have substantial effects on how waste-handling equipment manufacturers develop their business approaches. Manufacturers implement these policies to create innovative solutions while integrating sustainable practices at their operations and circular economy principles in production. Companies face multiple hurdles during their move toward sustainable business models because they must contend with high costs associated with innovations, as well as technological limitations and irregular enforcement of environmental policies. Manufacturers push forward with adaptation through both local and international standards and market differentiation and sustainable potential despite the existence of barriers. Waste-handling equipment manufacturers must do additional research to master regulatory challenges because green supply chain management and circular economy principles, along with government incentives, validate the necessity of innovative sustainable business models.

## 2.5 Data-Driven and AI-Enabled Business Models in Waste Handling Equipment Manufacturers

Industrial equipment manufacturers use data-driven and AI-powered business approaches to enhance their operations, thereby keeping up with market changes. Sikander (2024) highlights that AI, alongside big data analytics, stands as a fundamental tool when optimising waste management operations following the principles of the circular economy. Intellectual property in waste handling equipment gets superior performance along with operational effectiveness through predictive maintenance, enabling reduced costs and better customer satisfaction. AI implementations would allow manufacturers to foresee machine malfunctions in advance, which reduces system shutdown periods and enhances general system operation. These technologies offer numerous advantages, but manufacturers face substantial obstructions because initial costs are significant, while data analysis and AI application competence are challenging to find in the market (Farayola et al., 2023). The full advantages of AI innovation depend on resolving technical obstacles and staffing issues when implementing this technology.

Due to AI-driven models, businesses can customise waste-handling solutions specifically for customers operating in the waste management sector. Real-time data processing by AI allows manufacturers to customise their waste management solutions according to specific needs and improve their service efficiency (Danish & Senjyu , 2023). Through the implementation of machine learning algorithms, organisations can enhance their inventory management practice and supply chain logistics while ensuring timely parts and equipment availability. Installations of these systems face multiple hurdles throughout their implementation step. The implementation of robust data infrastructure needs significant investments from manufacturers because high costs and complex implementation are required to capture and analyse the extensive data volumes. Despite these hurdles , the integration of data-driven business models shows excellent potential to enhance manufacturing operations through more flexible and timely waste management by overcoming implementation obstacles.

AI plays a vital role for waste handling equipment manufacturers to improve sustainability factors in circular economy environments. Bashynska and Prokopenko (2024) identify data analytics and AI technologies to facilitate product lifecycle extension, waste minimisation and resource optimisation. AI tracking systems allow manufacturers to monitor product use while managing their lifecycle; thus, they can determine viable options such as product

repurposing, material recycling, and product refurbishment. The method supports sustainable practices and serves both the objectives of waste reduction and resource efficiency in circular economic models. The movement toward circular economy systems using artificial intelligence requires companies to overcome various implementation hurdles. The business sector needs to experience a substantial transformation of operational behavior and company thinking to achieve complete circularity adoption (Varghese 2022). Further research is required in order to bridge the gap between technological potential and practical application since manufacturers need to defeat resistance to change and adapt to the complexities of circular economy principles.

Implementing AI-enabled business models in waste-handling equipment faces significant obstacles due to concerns about both the privacy and security of operational data in regular usage. The acquisition of real-time waste-handling equipment data requires compliance with tight rules to protect sensitive information, as Sikander (2024) explains. The security risks regarding data breaches, together with cybersecurity challenges, function as significant limitations when taking complete advantage of operational process optimisation through AI. Manufacturers must spend money to create secure and regulatory-compliant data systems by building advanced cybersecurity frameworks for their data infrastructure. Compared to other concerns, strategies need to protect technological innovations and proprietary methods, which serve as critical concerns when organisations shift toward artificial intelligence. Robust governance frameworks must be established because they help organisations manage data-driven model benefits while protecting sensitive information effectively.

The implementation of AI in waste-handling equipment manufacturing demands businesses to change their traditional business approaches. Farayola et al. (2023) explain that waste-handling equipment manufacturers need flexible AI-driven business models that adapt to evolving market conditions and client requirements. To realise this transition, manufacturers require technical improvement as well as core organisational changes such as strategic developments, new business alliances, and revenue generation methods. Manufacturers utilise AI technology to provide supplementary services like predictive maintenance, remote monitoring, and real-time performance monitoring to generate additional income after their initial equipment transactions. Many organisations in the waste handling sector encounter major obstacles while working to integrate innovative models because they need to deal with internal employee pushback as well as operational changes that match the digital transformation plan.

Therefore waste-handling equipment manufacturing sector can benefit significantly from AI-enabled and data-driven business models, yet their implementation demands the resolution of multiple challenges. Multiple authors underline the necessity of studying technological organisational and regulatory obstacles when businesses transition toward circular economy principles, deploy artificial intelligence, and optimise their operations. Additional research should explore the effective implementation of AI models by manufacturers because AI offers excellent operational benefits, better predictive capabilities, and environmentally friendly solutions. This research investigates the real-world applications of AI-driven models to improve the understanding of how they will transform the waste-handling equipment manufacturing industry in South Africa.

### 2.6 Innovative and Sustainable Business Models for the Waste Handling Market

The global manufacturing sector, including the waste handling market, now emphasises sustainable business practices as its central theme over the past few years. Sustainability demands have gained strong relevance alongside the circular economy because it promotes waste reduction by promoting continuous resource use. Pieroni et al. (2021) explain that the circular economy business model stimulates companies to develop transformative strategies that lower environmental impact along with securing permanent economic benefits. The movement toward circular models remains a critical part of these changes since products need to be designed for their end-of-life stages. The waste handling equipment industry implements product-as-a-service (PaaS) models, which grant manufacturers equipment possession rights and allow customers to lease equipment, as well as manage repairs and redistribute resources for recycling purposes. The waste handling sector would benefit from implementing this model because it lowers resource consumption while lengthening equipment life spans, thereby advancing sustainability goals. This business approach has already proven effective across different industry segments. Widespread deployment of this model needs further work through customer acceptability and the development of the necessary infrastructure to reach its full potential( Awan and Sroufe ,2022).

Developing "take-back" schemes represents a sustainable business model in waste handling markets along with a Platform as a Service (PaaS) solution. Nascimento et al. (2019) explain that manufacturers must manage end-of-life disposal of products through these schemes. Product retrieval from inactive use lets manufacturers redirect their components through repair or reutilisation and waste recycling to avoid landfill accumulation while promoting the repeated circulation of material resources. The model follows the core principles of circular

economy because it maximises material recycling while simultaneously reducing waste streams. For the successful implementation of take-back schemes, the industry must have advanced reverse logistics systems together with government support that monitor waste disposal during the entire return process. The success of take-back schemes depends on comprehensive education efforts that direct end-users about their return responsibilities (Awan and Sroufe, 2022). Therefore, the literature shows that take-back schemes has gained growing authorisation as a practical solution that demands substantial infrastructure development and wide-ranging stakeholder involvement to succeed.

An innovative business model requires waste-handling equipment manufacturers to integrate renewable power sources alongside sustainable framing ingredients into their production systems. According to Awan and Sroufe (2022), sustainable circular economy operations can be improved through renewable energy use regardless of how it reduces carbon emissions while enhancing production facility environmental output. Waste-handling equipment manufacturers should implement renewable energy systems to operate their production lines since this action would substantially reduce both energy utilisation and manufacturing-related ecological damage. Machine production through the utilisation of ecologically sound materials enables additional cuts to the environmental impact of such equipment. Manufacturable items with recycled metal and biodegradable components support the objectives of the circular economy because they reduce the impact on the environment. The literature indicates that waste-handling equipment manufacturers need to address cost barriers associated with renewable technologies and sustainable materials when adopting these sustainable practices. These innovations provide manufacturing businesses with market advantages in an industry that prioritises environmental sustainability.

There exists substantial academic discussion about how digital technologies support circular business model implementation. The improvement of circular economy practice effectiveness through manufacturing becomes possible through the application of Industry 4.0 technologies, including the Internet of Things (IoT) and big data analytics along with artificial intelligence (AI) (Mamudu et al., 2024). Waste handling operations use these technologies to enhance equipment lifecycle management, track product performance, and maintain equipment foreseeably. The Internet of Things enables waste handling equipment to provide continuous monitoring data about its condition, which allows manufacturers to conduct proactive maintenance tactics, replacement planning, and waste recycling programs. The management of take-back programs, together with waste material recycling,

becomes possible through digital technologies that track products from beginning to end. The adoption of these technologies demands increased investment in digital infrastructure and skilled personnel for business model integration. Research must continue to determine the cost-to-benefit ratios of implementing these technologies in the waste-handling market sector.

Waste management issues in South Africa create an opportunity for sustainable business models in the waste-handling equipment sector to drive positive transformations. Local waste management problems in different regions require sustainable business solutions that fit within their specific condition (Langseth, 2023). The South African market faces obstacles to circular economy adoption because of inadequate infrastructure and regulatory issues, as well as low awareness about sustainable practices. The combination of PaaS, take-back initiatives, and renewable power usage as business models enables manufacturers to resolve their market challenges while strengthening their international marketplace position. Therefore, the literature review shows that these successful models work well in developed nations. However, developing countries including SA need specialised approaches to accommodate local circumstances.

Numerous studies indicate promising sustainable waste management business models, yet developers need to create proper infrastructure, build relationships with customers, and obtain government backing for actual implementation. Economic success, together with environmental sustainability, becomes achievable by merging PaaS models with take-back procedures enabled by digital technologies and renewable systems. Research must proceed to determine the exact operational challenges along with facilitating factors that affect waste management models across various settings, particularly within South Africa's developing economy. Organisational success in developing tailored solutions for South African waste-handling equipment industries becomes possible through the research findings that suit similar operations globally.

### 2.6 Conclusion

In conclusion, the combined application of circular economy principles with sustainability theory and innovation diffusion theory constitutes a practical framework to study South African waste-handling equipment manufacturers business model changes. These frameworks demonstrate that global environmental problems require the reduction of waste together with optimal resource usage and technological innovations for their solution. The path toward a circular economy faces multiple hurdles, including device price barriers

combined with weak systems and administration obstacles. However, producers now shift toward circular business models while integrating digital systems to boost sustainability and efficiency. AI and IoT technologies, together with evolving market demand for green products, give manufacturers opportunities to create and put service-driven business models into practice.

## CHAPTER 3: THE RESEARCH QUESTIONS

### 3.1 Introduction

This section establishes research questions that direct the assessment of South African waste-handling equipment manufacturer business models. Such questions explore the present operational environment, technological changes, regulatory conditions, and sustainable innovation practices in the sector. The study adopts circular economy (CE), sustainability theory, and innovation diffusion theory to find ways industrial companies can improve their business operations while tackling environmental and economic problems. The research questions seek to understand the performance of current practices while exploring futuristic business models that integrate technological and ecological environmental imperatives.

### 3.2 Research Questions

The research questions examine several aspects of the South African waste-handling equipment manufacturer's business models/approaches. Theoretical frameworks serve as foundations to understand what drives change within the sector because each research question uses them as core guidance. The sections below explain each research question and its examination, as well as its theoretical foundation.

**Research Question 1: What are the current business models of South African waste-handling equipment manufacturers and their market operations?**

The objective of this question is to reveal the business models alongside operational frameworks in South Africa's manufacturing sector that deal with waste-handling equipment manufacturing. The study of current business models needs proper analysis to enhance sustainability practices and fulfil circular economy principles. The adoption of circular economy principles involves transforming linear business systems that operate on a take-make-dispose framework into systems focused on resource optimisation together with waste minimisation and product lifecycle lengthening activities (Pieroni et al., 2021). According to the Sustainability Theory, business operations need to integrate social aspects with environmental and economic sustainability elements (Agrawal et al., 2022; Mhatre et al., 2021). The question investigates the strategies South African waste-handling equipment producers have adopted in order to integrate these sustainability principles for innovation across their market operations.

**Research Question 2: How do recent technological advancements and trends in waste-handling equipment impact business models in South Africa?**

Advanced technology functions as the main force behind business model changes occurring within manufacturing industries, especially in waste-handling sector. Advanced technologies, automated systems, and data analytics tools have transformed industrial operations to establish improved performance alongside waste reduction outcomes. Rogers's Innovation Diffusion Theory serves as a valuable tool for studying how different technologies propagate through companies and industries, which drives organisations to implement new business frameworks (Roger, 2003).

According to Sikander (2024), the combination of AI, IoT, and machine learning within waste handling equipment improves sorting efficiency, decreases expenses, and improves recycling efficiency. Manufacturers can extend product lifetime through Industry 4.0 technology, which includes additive manufacturing and smart sensors, leading to greater sustainability (Godfrey et al., 2021). The study investigates technological innovations that drive the South African waste-handling industry to adapt its business models while analysing the potential for promoting sustainability and reducing costs in the new business paradigms.

**Research Question 3: How do regulatory requirements and environmental policies influence the business models of South African waste-handling equipment manufacturers?**

The combination of regulatory standards and environmental regulations guides business model development while specifically affecting industries that cause substantial environmental damage, like waste management. South Africa continues to enact policies dedicated to boosting recycling operations, waste minimisation initiatives, and sustainable production standards. South Africa requires businesses to follow two regulations: the Waste Act (No. 59 of 2008) and Extended Producer Responsibility (EPR) schemes that force manufacturers to handle their products' entire life span.

The Sustainability Theory requires business organisations to align their operational systems with environmental regulations for sustainable performance and regulatory conformity (Awan & Sroufe, 2022). The regulatory policies generate both binding requirements and strategic prospects for innovating waste management hardware systems. Through their adoption of circular economy strategies, manufacturers can decrease waste generation while developing products for recycling and taking advantage of regulatory benefits. The study examines the

effects that these policies have on business decisions made by South African waste-handling equipment manufacturers concerning their adoption of CE principles.

**Research Question 4: How are data-driven and AI-enabled models adopted in South Africa's waste-handling sector, and what are their impacts and challenges?**

Through the application of AI and data-based models in waste management, the operation becomes more efficient while achieving sustainable practices. Implementing data analytics, along with predictive modeling and AI-based decision systems, optimises waste separation procedures, recycling activities, and equipment upkeep, which creates cost savings and advanced service performance (Sikander, 2024). Implementing these technologies throughout South Africa will encounter barriers stemming from insufficient infrastructure, privacy concerns, and a lack of qualified personnel.

According to Rogers (2003), the innovation diffusion theory clarifies the adoption process of AI-enabled technologies within the industry and the influential elements determining their integration. This perspective indicates that leading organisations characterised by their extensive resources lead as adopters, but other businesses that lack resources frequently face delays. This question analyses the extent to which AI, alongside data-driven models, has been adopted by South African manufacturers to evaluate their influence on business models and sustainability practices.

**Research Question 5: What innovative, sustainable business models can be proposed for the South African waste handling market, and how effective are they?**

The goal of this research question is to develop inventive, sustainable business models that use Circular Economy (CE) principles together with technological progress. The goal is to build models that fulfil regulatory conditions and simultaneously promote sustainable economic and environmental sustainability. The growing pressure from businesses to lower waste production and minimise environmental impact presents CE as a solution for creating continuous waste reduction systems that sustain resource use (Munsamy, 2022). The research question explores potential business strategies implementing remanufacturing alongside recycling and product-as-a-service alongside additional CE methods (Pieroni et al.,2021). This research question analyses how emerging technologies, including AI, automation, and Industrial Revolution 4.0 tools, support these business models (Ncube et al., 2023).

### 3.3 Conclusion

This chapter introduced the research questions that directed the business model examination in South African waste-handling equipment manufacturing. These questions verify present-day business operation performance and evaluate technological development alongside regulatory requirements and sustainable implementation. The research bases its findings on Circular Economy (CE) principles, sustainability Theory, and Innovation Diffusion Theory to investigate the possibilities for innovative business models in waste handling manufacring.

# CHAPTER 4: THE RESEARCH METHODOLOGY

## 4.1 Introduction

This chapter presents the research methodology employed in studying new business models within South Africa's waste-handling equipment manufacturing industry. It begins by describing and discussing the exploratory research design as appropriate for the current study, which is a relatively new, unstudied area of recent/new business models for waste-handling manufacturing equipment. It then presents the research philosophy with interpretivism, which is explained as the appropriate philosophy for understanding participants' perspectives. After that, the chapter clarifies the inductive research approach and elaborates on the multi-case study research strategy across six case study companies. Moreover, the time horizon, population, sampling method, and sample size are described, resulting in the measurement instrument, data collection process, quality control, data analysis, and ethical considerations.

## 4.2 Choice of Methodology

### 4.2.1 Research Design

An exploratory research design is a methodological approach that investigates a research problem in a context with limited existing knowledge or understanding (Saunders & Lewis, 2018). This design is especially suited for studying new business models in South African waste handling equipment manufacturing, as it provides flexibility in exploring participants' experiences and perspectives without rigid expectations. The study employs this design for three primary reasons. First, the research benefits from exploring a topic that has received limited attention in prior research; second, the design aligns with the use of semi-structured interviews that can elicit participants' perspectives; third, the open-ended interview offers a starting point for gaining further specifics about emerging themes in the knowledge area, which can be pursued in future research (Creswell & Poth, 2016).

Exploratory research design, therefore, is expected to discover new and adaptable business models among the waste-handling equipment manufacturing businesses. Exploratory research design is beneficial for producing exhaustive details of these models, and the findings might be helpful in the industry (Mir & Greenwood, 2021). Besides, collecting only qualitative data provides an opportunity to explore participants' perceptions, which, in turn, reveals crucial patterns and themes for examining new and existing practices in the industry of waste handling equipment in South Africa.

### 4.2.2 Research Philosophy

As Williamson (2021) noted, research philosophy defines the overall guidelines for the research that the research is following, as well as a set of beliefs about the acquisition of data and material, as well as the interpretation of such data and material. Williams (2021) also mentions that, more notably, scientific paradigms, including realism, interpretivism, pragmatism, or even positivism, contribute significantly to constructing the researcher's worldview. This study adopts an interpretive philosophy to examine the complex landscape of business models in South Africa's waste-handling equipment manufacturing industry, acknowledging that reality is constructed through subjective perspectives and that knowledge is individually shaped (Williamson, 2021; Strydom & Roestenburg, 2021). Interpretivism is suitable in this case since it enables researchers to consider context, regulatory, and technology factors and provides rich, qualitatively driven participant perspectives.

For this study, interpretivism is the most appropriate for three main reasons. Firstly, it allows us to comprehend the participants' views on sustainability, business model innovation in the South African waste sector, and the industry's dynamics and complexity (Merriam & Tisdell, 2015). Second, it values the participants' self-generated knowledge shaped by their experience with the waste industry (Pham, 2022). Lastly, the interpretivism approach enables decision-making based on findings that give room for a proper understanding of waste-handling practices and help achieve relevant industry results (Creswell, 2021; Wagner, Kawulich, & Garner, 2012). Thus, this interpretivism philosophy suggests applied knowledge that can approximate real-life strategies for successful waste management equipment manufacturing.

### 4.2.3 Research Approach

Research through inductive approach starts with data collection or observations to develop theories through analysis yet deductive research applies established theories to validate hypotheses (Bryman, 2022). The study initiated its research using participant observations and perceptions from the South African context about customised waste-handling equipment manufacturing. The research collected empirical evidence to develop seemingly new theories which would explain better how South African businesses modify their sector operations. Inductive research approach excel at studying innovative practices because they create new theories from direct observations which leads to better comprehension of new business models in waste equipment manufacturing (Mir & Greenwood, 2021). Through the

inductive approach the study can create new theoretical models by translating practical knowledge from managers and industry-specific obstacles in this developing field of study (Mir & Greenwood, 2021).

### 4.2.4 Methodological choice

The methodological choice of this study is qualitative, chosen for its capacity to capture context-specific, in-depth insights from industry experts (Creswell & Poth, 2016). A qualitative method is especially suited for exploring new business models in this emerging field, allowing a clear understanding of participants' perspectives on sustainability, innovation, and industry challenges within the South African waste-handling equipment manufacturing sector (Williamson, 2021). This choice of qualitative research methods is also motivated by the interpretivist philosophy underpinning the study, which emphasises subjective understanding and the complex social realities of business practices (Merriam & Tisdell, 2015). By adopting qualitative methods, the study not only gains flexibility in data collection through semi-structured interviews but also captures rich, detailed narratives that can inform sustainable and contextually relevant industry strategies (Saunders & Lewis, 2018).

### 4.2.5 Research Strategy

The multi-case study research strategy was adopted to explore new business models for waste-handling manufacturing equipment in South Africa. A case study, defined as an in-depth investigation of a particular instance or phenomenon within its real-life context (Creswell & Poth, 2016), offers insights into how specific companies approach sustainable practices. Involving multiple cases enables comparisons across varied perspectives (Diop & Liu, 2020). The multiple case study strategy was chosen for three reasons: it increases the use of triangulation, thus improving the validity of the study (Vilone & Longo, 2021); it can facilitate the examination of the sustainability of customised waste-handling vehicles, hence offering rich real-life data (Malik, 2020); and it is flexible, thus enabling cross-case analysis to arrive at conclusive findings (Saunders & Lewis, 2018). Therefore, the multi-case study research strategy suits the study’s goal of capturing a rich picture of sustainability business models in waste-handling equipment manufacturing.

### 4.2.6 Time Horizon

The lack of sufficient time makes this current study assume a cross-sectional time horizon, whereby data is collected at a single time rather than spanning a period (Saunders & Lewis, 2018). This cross-sectional time horizon is preferred over a longitudinal one because it allows for a quick evaluation of current business models for waste-handling manufacturing equipment, providing an understanding of the state of affairs in the industry without requiring follow-up after a particular time interval (Cresswell & Cresswell, 2021) To gain an in-depth understanding of new business models, semi-structured interviews will be conducted with managers (Pandey & Pandey, 2021). This choice also aligns with the study's objective to evaluate immediate industry challenges and responses.

## 4.3 Proposed Research Methodology

### 4.3.1 Population

In research, a population is the totality of subjects or objects being studied (Camic, 2021). The population of this research comprises 500 employees from South African waste-handling equipment manufacturers. According to Nayak and Singh (2021), the target population in the study is a specific subset of the larger population. The target population thereby restricts the larger companies to managerial personnel in these firms, from whom information about these new business models is expected to be obtained (Nayak & Singh, 2021). This group is chosen because of their practical involvement in strategic processes and ability to offer pertinent insight into business models of industries (Creswell & Poth, 2016).

### 4.3.2 Unit of Analysis

Saunders and Lewis (2018) define the unit of analysis as the entity being analysed in a study. The unit of analysis for this study includes a sample of managers employed at 6 companies anonymously identified as company A to F. These managers, with experience in new business models for waste-handling manufacturing equipment, provided valuable insights for the research. The study selects these managers because their firsthand expertise aligns with the research objectives and offers in-depth perspectives on the industry’s evolving business models.

### 4.3.3 Sampling method

The sampling technique involves selecting a small group of people to represent the entire group (Saunders & Lewis, 2018). In particular, a convenient non-probability sampling technique was used; in this approach, those selected to participate were easily reached and willing to participate in the interview process (Berndt, 2020). This approach is suitable as it allows quick data collection and cost efficiency. It also facilitates engagement with South African waste-handling equipment manufacturers directly involved in new business models (Nayak & Singh, 2021). Convenience sampling also enhances study feasibility and secures access to key participants, thereby capturing essential insights from practitioners who significantly contribute to the research objectives on waste handling equipment (Camic, 2021).

### 4.3.4 Sample Size

According to Saunders and Lewis (2018), a sample size refers to the number of individuals or observations included in a study, which should be adequate to ensure that the findings are representative and statistically significant. This study's sample size of less than or equal to 30 participants was appropriate, as it balances between being manageable and providing sufficient data to explore the new business models for waste-handling manufacturing equipment at the selected companies. The rationale for selecting less than or equal to thirty participants is based on the theory of saturation, whereby if a certain number of participants is reached, the next participant contributes nothing new to the study. Semi-structured interviews allowed the researcher to gain multiple views on waste handling practices and interviewed managers. Because of saturation, a total of 12 managers were interviewed across 6 companies. The focus was on managers directly involved with waste-handling equipment (Company A and B), senior managers experienced in new business models (Company C and D), managers with strategic roles (Company E and F).

### 4.3.5 Measurement Instrument

A measurement instrument is a tool used to collect data from respondents in a systematic and structured manner. The semi-structured interview schedule was selected as the primary measurement instrument for this study. It is designed to gather information on people's perceptions and life experiences. The interview guide starts with the speaker's introduction and an effort to break the ice with the respondents. The interview guide then develops issues pertinent to the structure of the organisation's business model, particularly its sources

of income, clients and customers, market position, and limitations or barriers to its growth, including matters related to technologies, regulations, or environmental issues. Thus, using the interview guide, the study seeks to familiarise the researcher with the company's new technology adoption agenda, sustainable production strategies, and data analytics

The researcher selected the semi-structured interview guide for two main reasons. First, it allows for developing the comprehensiveness essential for investigating certain topics in detail, such as the impact of technology innovations on business activities and sustainability initiatives (Creswell, 2021). Second, it allows for qualitative responses, which help the researcher collect vast, contextualised data that capture the respondents' broad variable view (Adeoye-Olatunde & Olenik, 2021). This approach also assists in untangling interrelationships between factors that drive business model change.

### 4.3.6 Data Gathering Process

Data collection for this study commenced with a pilot interview with 3 managers, using semi-structured interview questions to assess any problems with the data collection instrument. The semi-structured interview guide was slightly revised from the pilot test feedback to solve the potential issues that arise before data collection. This modification was essential as it made the research more effective and reduced the chances of mistakes (Camic, 2021). After participants were identified, invitation emails were forwarded to the participants containing details of consent forms for explicit and voluntary participant consent. The interviews were conducted online through Microsoft Teams to ensure that the participants were comfortable, and that the researcher also be easy to reach. It was hoped that each interview take roughly between 45 minutes to an hour, with all sessions being voice recorded for data accuracy. This approach aligns with the principles of doing qualitative research and was expected to give credible data with depth (Creswell, 2021: 73; Saunders & Lewis, 2018).

### 4.3.7 Analysis Approach

In the current study, the approach of reflective thematic analysis was utilised for the analysis of semi-structured interview data as modified by Virginia Braun and Victoria Clarke (2019), building from the original six-step thematic analysis framework founded by Braun and Clarke (2006). Braun and Clarke (2019) emphasize a more reflexive and iterative process, making it suitable for analysing the subjective meanings found in qualitative data. Reflective thematic analysis emphasises the researcher's active role in interpreting the data instead of simply identifying patterns (Braun & Clarke, 2006). In this case, the six steps of thematic analysis—

familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and writing up—were followed but with important modifications. For example, in the familiarisation phase, there is a deeper engagement with the data to reflect on one's positionality, a change from the earlier framework. Similarly, the coding step was iterative, constantly revisiting data to ensure that the codes reflect the researcher's ongoing reflections (Braun & Clarke, 2019). The analysis was supported by Atlas ti software, a Computer Assisted Qualitative Data Analysis Software (CAQDAS) tool, facilitating the organisation and categorisation of codes, themes, and patterns within the data.

This reflective approach, therefore, was helpful for this study as it allows the researcher to avoid superimposing themes onto the data. Further, it was flexible in that the analysis was modified as the study is carried out to allow new ideas to emerge. This approach has been chosen over general thematic analysis because it better accommodates the subjective, dynamic nature of the semi-structured interviews, allowing for a richer, more context-sensitive understanding of the participants' perspectives on waste handling equipment manufacturing (Camic, 2021).

### 4.3.8 Quality Controls

Ensuring the study's trustworthiness is crucial for guaranteeing the credibility and integrity of the findings (Cypress, 2017). Guba and Lincoln (1989) emphasise trustworthiness in qualitative inquiry to support the argument that the research findings are valid and reliable. Moreover, Guba and Lincoln (1989) proposed four criteria for assessing the trustworthiness of qualitative research: credibility, dependability, confirmability, and transferability. The quality criteria of this study were established through these four elements to ensure that findings, analysis, evaluation, and recommendations are of high quality. Then, to ensure that the research is valid and reliable, some elements that make it trustworthy will be discussed.

#### *4.3.8.1 Credibility*

Credibility refers to the accuracy and believability of the study's findings (Guba, 1981). To achieve credibility, the researcher must engage in practices such as triangulation, member checks, and data saturation (Guba & Lincoln, 1985). The sources of data and information used in this study was also legitimised through member checking and strict maintenance of ethical norms observed by organisations under study. Thus, by maintaining data collection and analysis transparency, the study present credible findings without falsified data (Abidin et al., 2024).

#### *4.3.8.2 Dependability*

Dependability refers to the repeatability and consistency of results across time (Guba, 1981). To ensure dependability, the current research meticulously documented all methodological procedures that include the data collection and analysis approaches, enabling others to replicate the study (Guba & Lincoln, 1989). This study implemented a pilot test with employees to adjust the questions for clarity and reliability (Abidin et al., 2024). By recording every stage of the research process, the results become verifiable and replicable by future researchers, thus ensuring stability in the research outcomes.

#### *4.3.8.3 Confirmability*

Confirmability ensures that the research findings are the result of the participants' input rather than the researcher's biases (Guba, 1981). To achieve confirmability, the researcher kept an audit trail of all decisions, including analytic choices and justifications, to ensure objectivity (Ghafouri & Ofoghi, 2016). By meticulously adhering to the approved research methodologies without any data manipulation, the study produced credible findings. This approach supported the transparency and neutrality of the study results, making them accessible for verification.

#### *4.3.8.4 Transferability*

Transferability refers to the extent to which the study's findings can be applied to other contexts or populations (Guba, 1981). To support transferability, the researcher provided a thick description of the study context and process, allowing future researchers to assess whether the findings apply to their settings (Cypress, 2017). Detailed contexts, such as how waste handling equipment is manufactured identified organisations under study, also enable researchers to relate these findings to similar settings (Ghafouri & Ofoghi, 2016). This should guarantee that the study has general value within the context of the particular research and other kinds.

### 4.4 Ethical Considerations

Ethical considerations are crucial in qualitative research to protect participants' rights and ensure the research process remains valid and trustworthy. This study adhered to several key ethical principles, which will be practically ensured throughout the research process.

In this research, ethical clearance was sought from GIBS to ensure that the research followed the set ethical standards recommended by Kang and Hwang (2021). This also helped to get the research officially endorsed, and the institution’s ethical code boosts the overall credibility of the study.

Before participants are recruited, they should be provided with information through informed consent about the aim and objectives of the study, the course of action, and any risks involved (Kwame & Petrucka, 2024). During interviews, participants were told the study's objective, their rights, and the fact that they are free to participate. This practice empowered the participants since they have a right to be informed of the event, allowing them to choose whether to participate. The achievement of ethical sensitivity and stability from the preceding research activities is a clear testimony of how subjects can be empowered by providing information to make a unique decision on their involvement in research.

Confidentiality and anonymity protect participants' identities, and the information shared during interviews. This study saved all data on a password-protected computer that only the researcher can unlock (Nii Laryeafio & Ogbewe, 2023). The assignment of numbers to the participants and the overall summary of the work into general patterns also maintain the anonymity of the participant's responses, thus developing confidence in the research process.

The beauty of voluntary participation is that participants must be willing; they cannot be coerced into the study. Participants were told in advance that they could withdraw from the interview without quarrel (Sadeghi & Smith, 2024). It is particularly important to observe the ethical imperatives set within this study with minimal pressure on participants, as their autonomous decision-making is valued.

Risk assessment and participants' welfare require the researcher to minimise harm and protect the well-being of participants throughout the study. In this research, the study was designed so that participants were not subjected to any physical/ emotional harm during the research activity (Kwame & Petrucka, 2024). The participants would have been assured that the study protected their safety and welfare because the following issues were explained: The interviews conducted by the study followed protocols laid down.

Researcher reflexivity involves the researcher’s awareness of their potential biases and the impact these may have on the study. The researcher continually reflected on their role and potential influence throughout the data collection process (Nii Laryeafio & Ogbewe, 2023).

By maintaining a reflexive stance, the researcher ensures that personal assumptions do not affect the integrity of the data, thus enhancing the study's ethical transparency and rigor.

Therefore, ethical considerations are fundamental to ensuring the integrity and credibility of qualitative research. By adhering to ethical principles such as obtaining permission, securing informed consent, maintaining confidentiality and anonymity, ensuring voluntary participation, conducting risk assessments, and practicing researcher reflexivity, the study on new business models for waste handling manufacturing equipment were carried out responsibly and ethically. These considerations protected participants and contributed to the reliability and validity of the research findings, reinforcing the study's commitment to ethical research practices throughout its process.

### 4.5 Chapter Summary

The research methodology for studying new business models in South African waste handling equipment manufacturing adopts an interpretivism philosophy to understand complex industry dynamics from participants' subjective perspectives. Using an exploratory, inductive approach, it applies a multi-case study strategy focused on six companies, with a cross-sectional time horizon for capturing current insights. Therefore, the target population was set at 500 managers, with a manageable sample of 12 managers obtained from convenience sampling. The measurement instrument underpins the semi-structured interviews and was tested for efficiency before application. It also allowed the author to provide a rich and complex reflective thematic analysis of the identified participants' beliefs regarding sustainability and innovation of business models for industry development.

# CHAPTER 5: PRESENTATION OF FINDINGS

## 5.0 Introduction

This chapter presents the findings of research aimed at understanding new business models for waste-handling manufacturing equipment among South African waste-handling equipment manufacturers. This research was guided by the main research question, "How are emerging business models applied within the waste-handling manufacturing industry?" These were explored using the following sub specific Research Questions:

- RQ1-What are the current business models and market operations of South African waste-handling equipment manufacturers?
- RQ2-How do technological advancements and trends impact the business models of waste-handling equipment manufacturers in South Africa?
- RQ3-What is the influence of regulatory requirements and environmental policies on the business models of South African waste equipment manufacturers?
- RQ4-What is the level of adoption and impact of data-driven and AI-enabled models in South Africa's waste-handling sector?
- RQ5- What innovative, sustainable business models apply to South Africa's waste-handling market, focusing on effectiveness and efficiency?

The findings are structured around these five questions, with dedicated sections for each. In this chapter, the researcher provides an analysis of the key themes and subthemes that emerged from the data analysis and interpretation, supported by relevant quotations from participants

## 5.1 Overview of the Sample

Table 5.1 displays respondent information for twelve individuals working in South African waste-handling equipment manufacturing companies (A to F). This table reveals the business model focus while displaying participant roles and providing their age groups, educational backgrounds, and industry experience.

**Table 5-1: Demographic distribution of participants**

| Participant Name | Company | Role/Title | Business Model Focus | Age Group | Gender | Education | Experience |
|---|---|---|---|---|---|---|---|
| Participant 1 | A | Executive | Circular Economy, Sustainability | 40-49 | Male | Bachelor's Degree | 15+ years |
| Participant 2 | A | Manager | Waste Equipment Sales & Service | 30-39 | Male | Master's Degree | 10+ years |
| Participant 3 | A | Sales Manager | Waste Handling Equipment | 30-39 | Female | Bachelor's Degree | 8+ years |
| Participant 4 | B | Manager | Local Manufacturing of Waste Equipment | 40-49 | Male | Bachelor's Degree | 12+ years |
| Participant 5 | B | Executive | Manufacturing & Servicing | 50-59 | Male | Master's Degree | 20+ years |
| Participant 6 | C | Manager | Customer-Centric Solutions | 30-39 | Male | Bachelor's Degree | 7+ years |
| Participant 7 | C | Executive | Manufacturing & Solutions Provider | 40-49 | Male | Bachelor's Degree | 15+ years |
| Participant 8 | D | Manager | B2B Waste Equipment Sales | 30-39 | Male | Master's Degree | 10+ years |
| Participant 9 | D | Executive | B2B Waste Equipment Sales | 40-49 | Male | Bachelor's Degree | 15+ years |
| Participant 10 | E | Manager | Manufacturing & Supply | 40-49 | Male | Bachelor's Degree | 12+ years |
| Participant 11 | E | Executive | Lifters, Compactors, Hook Lifts | 50-59 | Male | Bachelor's Degree | 25+ years |
| Participant 12 | F | Executive | Manufacturing & Distribution | 40-49 | Male | Master's Degree | 18+ years |

Twelve participants from six South African waste-handling equipment manufacturing companies (A to F) are described through a demographic profile presented in Table 5.1. Within the responding group, fewer than a quarter of participants (only one) was a female; in contrast, a majority of participants who are male belong to the 30-49 age range, and a smaller portion falls into the 50-59 bracket. Participants spanning multiple academic backgrounds include holders of both bachelor's and master's degrees. Most employees have accumulated more than ten years of industry experience, and several individuals have extended their employment beyond twenty-five years. Business leaders and managers in executive and managerial positions work in various domains of sustainability, innovation equipment, equipment production, and after-sales care. The significance ascribed to these demographics suggests a male-dominated workforce with an experienced and well-educated

group, mainly contributing to key strategic areas like sustainability and innovation within the industry.

## 5.2 Thematic Analysis Procedure

The study performed thematic analysis with the assistance of Atlas.ti software running tests on qualitative interview data generated from 12 business participants working at South African waste handling equipment manufacturing companies. The analysis aimed at discovering major themes and subthemes which supported research questions and provided windows into modernised business models of the waste handling industry. Regarding the coding process next an outline is given on the operational steps with analytical choices explaining their rationale.

### 5.2.1 Analytic Logic and Use of Atlas.ti Software

The analytic logic functioned through a bottom-up approach since thematic and sub-thematic elements materialised directly from data itself. The initial phase of coding started by analysing each individual response to specific sub-research questions. The process aimed to identify every possible perspective to create abstracted and consolidated themes later in the analysis. The coding process evolved from initial first-order coding to consolidated second-order coding and subsequent grouping of these codes into sub-themes before creating broad themes from the sub-themes.

The code generation process and management of qualitative data executed through Atlas.ti software. The software system facilitated an effective data management process through its dynamic system for data organisation and visualisation to handle an extensive number of interview responses with associated codes. Through Atlas.ti the researcher could implement first-order coding and transform them into second-order codes which eventually organised into sub-themes before becoming themes. Atlas.ti played a role in data organisation and initial pattern detection. ATLAS.ti provided double-check capabilities for the manual coding process to validate consistency and correctness of the processes.

### 5.2.2 Codebook or Master List

The researcher did not develop any official codebook before starting the analysis process. Initial coding took place inductively from interview data instead. The coding process excelled in adaptability and data responsiveness by letting the information guide the analysis instead of following predetermined codes. A Master Table emerged during the analysis process in order to present the code and sub-theme and theme relationships (see Appendix D) thereby

ensuring evaluation transparency and analysis trackability. As such, the master table presents systematic connections between analysis levels such as codes and sub-themes as well as themes.

### 5.2.3 Number of Codes Generated

The coding at first stage started from about 150 first-order codes. The research data directly extracted from participants' statements led to numerous first-order codes that widened across various concepts and ideas. During the refinement stage the original first-order codes which shared related meanings and phrasing were merged into second-order categories/codes.

### 5.2.4 Consolidation of Codes

The researchers grouped analogous first-order codes into 90 second-order categories to produce the refined set of codes. The procedure deleted duplications to establish separate codes for unique concepts. The research decreased from 150 to 90 codes because it merged concepts expressed through different terms which contained equivalent fundamental ideas. The consolidation method helped identify the main and essential ideas that should be included in the study.

### 5.2.5 Sub-themes, Themes and Logic behind Symmetry

Once all codes were refined into the second order phase the researcher grouped them into 50 sub-themes to represent unique response components. The analysis utilised 25 broader themes to structure the analysis after the researcher grouped the sub-themes. The researcher employed assessment themes that closely matched five sub-research questions concerning business models, technological patterns, Data-Driven and AI Models, regulatory requirements as well as potential sustainability within the sector. Themes and sub-themes were then structured as follows:

- **RQ1: Business Models & Market Operations**
    - Five Themes
    - Ten Sub-themes
- **RQ2: Technological Advancements & Trends**
    - Five Themes
    - Ten Sub-themes
- **RQ3: Regulatory & Environmental Policies**

    - five Themes
    - Ten Sub-themes
- **RQ4: Adoption of Data-Driven & AI Models**
    - Five Themes
    - Ten Sub themes
- **RQ5: Innovative & Sustainable Business Models**
    - Five Themes
    - Ten Sub themes

The equal spread of themes and sub-themes across five research questions (five themes and ten sub-themes for each research question) naturally developed as a result of consistent data patterns. Research questions have an equal number of themes together with sub-themes that mirror the wide range of gathered participant responses. An abstract analysis structure produced more sub-themes inside specific themes though these components maintained their base in participant statements and stayed focused on the research questions. The researcher kept the explanation in each sub-theme short and focused to maintain attention on the detected key patterns. Since the study had a restricted sample of twelve participants so the main objective is on delivering a brief explanation of essential waste management equipment industry elements while abstaining from presenting all details. The research concentrated on the essential information about waste management equipment while using direct quotes from interview participants.

### 5.2.6 Achieving Data Saturation

A total of 12 participants composed the research sample but data analysis achieved data saturation. Insights stopped forming as the data became repetitive after the research achieved saturation point (see Table 5.2). Each study question focused on a distinct portion of business models which brought diversity in research results.

**Table 5-2: Saturation Table**

| Research Question | Number of Codes | Sub-themes Identified | Themes Identified |
|---|---|---|---|
| **RQ1** | 20 | 10 | 5 |
| **RQ2** | 18 | 10 | 5 |
| **RQ3** | 18 | 10 | 5 |
| **RQ4** | 18 | 10 | 5 |
| **RQ5** | 16 | 10 | 5 |

The data saturation table (Table 5.2) indicated saturation after examining data from twelve participants because fresh insights ceased to appear, and the data cycle continued to reproduce itself. The research addresses different aspects of business models through the examination of five research questions (RQ1-RQ5) which generated separate findings. The research questions included between 16 to 20 different codes which collectively generated 10 sub-themes among all investigation avenues. The research obtained 5 themes for each research question which demonstrated a consistent level of analysis and saturation throughout the study.

### 5.3 Business models and market operations

Multiple stakeholders from South African waste-handling equipment manufacturing companies have shared insights to answer the first sub-research question*: What are the current business models and market operations of South African waste-handling equipment manufacturers*? This sub-research includes a single all-encompassing central theme: Business models and market operations. This theme consists of five key themes, with each having two sub-themes of its own, as given in Table 5.3.

**Table 5-3: Themes and Sub-Themes Relating to Research Question One (RQ1)**

| Research Question One (RQ1) | Themes | Sub-Themes |
|---|---|---|
| What are the current business models and market operations of South African waste-handling equipment manufacturers? | **1. Business Model Variations** | 1.1 Direct Sales vs Service Contracts |
| | | 1.2 Product Customisation and Tailored Solutions |
| | **2. Innovation and Sustainability** | 2.1 Product Innovation |
| | | 2.2 Environmental and Circular Economy Practices |
| | **3. Customer Relationship and Retention** | 3.1 After-Sales Services |
| | | 3.2 Long-Term Client Partnerships |
| | **4. Local Manufacturing vs Importation** | 4.1 Advantages of Local Manufacturing |
| | | 4.2 Challenges with Imported Equipment |
| | **5. Strategic Partnerships and Market Reach** | 5.1 Industry and Municipal Partnerships |
| | | 5.2 Supplier and Dealer Relationships |

Next, the main themes and their corresponding sub-themes will be elaborated on to highlight insights about business strategies and market operations employed by South African waste-handling equipment manufacturers.

### 5.3.1 Theme 1: Business Model Variations

The business models of South African waste handling equipment manufacturers vary significantly, with two distinct approaches (here to be sub-themes) emerging from the data: direct sales and service contracts, as well as a focus on product customisation and tailored solutions. These subthemes are presented next, supported by verbatim quotations.

#### Subtheme 1.1: Direct Sales vs Service Contracts

Several manufacturers combine equipment sales with maintenance services as their business model because this approach creates enduring client partnerships and steady post-sale income streams. Company A's direct sales and service contracts constitute a vital portion of their business strategy, according to Participant 2, who said, "*We supply waste handling equipment including compactors and balers and sorting machines while providing maintenance service to keep the equipment operational*." Similarly, Participant 5 from Company B stated, "*We have a strong focus on customer relationships and tailor our solutions based on specific customer needs... maintenance and repair services are key to our offering*."

#### Subtheme 1.2: Product Customisation and Tailored Solutions

The provision of customised solutions across the industry represents a common practice since manufacturers create specific equipment that meets individual customer needs based on their operational demands and site requirements. Participant 7 from Company C explained*, "We work closely with clients to tailor solutions that fit their specific needs, particularly when it comes to adjusting for local waste types, volume, or specific regulatory requirements*." Participant 8 from Company D indicated, "*We operate on a B2B model where our strategy includes providing standard and customised solutions that match customer-specific requirements*."

### 5.3.2 Theme 2: Innovation and Sustainability

Many waste-handling equipment manufacturers base their business approaches on innovation and sustainability principles. The market demands sustainability initiatives, which lead waste-handling equipment manufacturers to adopt new technologies and environmentally conscious practices. Two relevant subthemes were derived from the

innovation and sustainability theme. These are presented next, supported by verbatim quotations.

**Subtheme 2.1 Product Innovation**

Competitive success in the waste-handling equipment market depends heavily on innovation. The primary focus of numerous businesses involves creating products that are more efficient and durable with advanced technologies. Participant 12 from Company E emphasises that "*innovation stands as a fundamental element for sustaining high-quality standards while the company constantly enhances its product range*." Relatedly, Participant 3 from Company A emphasised that "*the company maintains a commitment to designing equipment which combines efficiency and environmental awareness*."

**Subtheme 2.2: Environmental and Circular Economy Practices**

Several manufacturers today use a circular economy approach to design equipment that can be reused, recycled, or converted into new products. According to Participant 1 from Company A, *Our organisation follows a circular economy model by designing products for use then re-use and recycling, which simultaneously minimises waste and lengthens product life cycles*." Participant 6 from Company D stated that "*sustainability has become increasingly vital; thus, business strives to meet this demand*."

### 5.3.3 Theme 3: Customer Relationship and Retention

The interviews show that building stable relationships with customers occurs frequently throughout the discussions. The companies provide waste handling equipment alongside valuable services, including after-sales support, maintenance, and training programs for customers. Two relevant subthemes were derived from the Customer Relationship and Retention theme. These are presented next, supported by verbatim quotations.

**Subtheme 3.1: After-Sales Services**

Equipment lifetime depends heavily on after-sales services, which also help companies build enduring customer relationships. According to Participant 2, " *the company model extends beyond equipment sales to include post-purchase technical support and training along with equipment update capabilities*." Similarly, Participant 8 from Company D stated that their after-sales service includes providing "*maintenance, repairs, and spare parts*" to customers.

**Subtheme 3.2: Long-Term Client Partnerships**

Most businesses strive to build enduring client partnerships, which include municipalities and private waste management firms alongside industrial clients. Participant 7 from Company C indicated, "*Our strategy involves not only providing equipment but offering continuous support, maintenance, and after-sales services*." This method enhances customer loyalty and maintains consistent market demand for upcoming business operations.

### 5.3.4 Theme 4: Local Manufacturing vs Importation

The decision between local production and equipment importation significantly influences how South African waste-handling equipment manufacturers organise their business operations. Two relevant subthemes were derived from the Local Manufacturing vs Importation theme. These are presented next, supported by verbatim quotations.

#### Subtheme 4.1: Advantages of Local Manufacturing

The production of products at local facilities offers businesses the opportunity to manage order timelines easily while minimising dependency on suppliers who might delay shipments due to customs issues. The regional manufacturing of compactors at Company B allows Participant 4 to state that "*such operations enable quick response to customer demands and higher operational flexibility*." According to Participant 11 from Company E, "*We offer products that are tailored to local conditions, thereby ensuring the product is entirely South African*."

#### Subtheme 4.2: Challenges with Imported Equipment

The local manufacturing capability presents benefits, but the Company faces difficulties because it depends on imports for valves and specialised machinery. For example, Participant 4 at Company B said, "We *still require imported Italian valves, but all other components originate from local manufacturers*." The results, therefore, reveal that manufacturers who depend on imported components experience delivery delays and increased costs that they need to handle effectively.

### 5.3.5 Theme 5: Strategic Partnerships and Market Reach

Manufacturers need strategic alliances to extend market coverage and enhance their competitive standing. The Strategic Partnerships and Market Reach themes are derived from two relevant subthemes, which are presented next and supported by verbatim quotations.

**Subtheme 5.1 Industry and Municipal Partnerships**

Most manufacturers create partnerships with municipal waste management and large waste management organisations to achieve extended contracts, which expands their market reach. For example, Participant 10 from Company E said, "Our organisation *builds strong supplier relationships across local and international markets for maintaining product quality*." Such collaborative methods obviously guarantee continuous material availability and enhance product reliability.

**Subtheme 5.2: Supplier and Dealer Relationships**

The connection between manufacturers, suppliers, and dealers enables them to deliver a wide range of products and services that sustain their competitive position. Participant 11, the staff at Company E, said, " *We work hand-in-hand with dealers to obtain equipment*."

In summary, results show that the South African waste-handling equipment manufacturing industry operates under different business models that represent both market difficulties and industry prospects. South African waste-handling equipment manufacturers succeed in competitive markets through parallel initiatives of product innovation and sustainable operations combined with strong client partnerships. Through local production combined with customised solutions post-sale maintenance, and strategic alliances, the business demonstrates dedication to providing dependable and high-quality waste management technology products. Manufacturers benefit from these tactics to maintain their operational responsiveness, which fulfils local needs and global sustainability goals.

**5.4 Technological advancements and new trends.**

New technological developments and emerging trends have revolutionised operational methods for waste management and equipment businesses. The analysis focuses on major industry trends that experts in various companies commonly discuss. The examined themes demonstrate technology-driven changes that affect operational activities, manufacturing procedures, product development, and customer service operations (see table 5.4). The following analysis includes main themes and subthemes supported by direct participant statements that demonstrate their experiences.

**Table 5-4: Research Question Two (RQ2), Themes, and Sub-themes**

| Research | Themes | Sub-themes |
|---|---|---|

| Question | | |
|---|---|---|
| **RQ2** | **1. Technological Integration** | 1.1 IoT and Smart Equipment |
| | | 1.2 Automation and Robotics |
| | **2. Sustainability Trends** | 2.1 Eco-friendly Equipment |
| | | 2.2 Green Manufacturing Processes |
| | **3. Operational Efficiency** | 3.1 Automation in Manufacturing |
| | | 3.2 Digitalisation and Data-Driven Operations |
| | **4. Predictive Maintenance** | 4.1 Real-time Monitoring and Diagnostics |
| | | 4.2 Reduced Downtime and Service Optimisation |
| | **5. Customer-Centric Innovations** | 5.1 Smart Waste Management Systems |
| | | 5.2 Improved Customer Relationship Management (CRM) |

Next, the main themes and their corresponding sub-themes will elaborate to highlight recent advancements in technology and new trends that have had a profound impact on the way businesses in the waste management and equipment sectors operate in South Africa.

### 5.4.1 Theme 1: Technological Integration

Business operations have experienced fundamental changes through the adoption of IoT and automation technology, specifically in waste management industries. Service quality and operational efficiency have improved because several companies have adopted both smart machinery and automated processes. Two relevant subthemes were derived from the Technological Integration theme. These are presented next, supported by verbatim quotations.

**Subtheme 1.1: IoT and Smart Equipment:** The participants observed the growing use of Internet of Things (IoT) devices throughout their operational activities. According to Participant 2 from Company A, "*The increasing number of IoT devices enables our company to provide connected equipment that sends operational data instantly to operators for predictive maintenance*." Different companies can use this technology to track their machines remotely because it provides instant updates about machine performance, which enhances operational dependability while decreasing equipment downtime. Participant 3

from Company A stated, "*We integrate automation into machines to decrease operational costs and boost customer processing speed*."

**Subtheme 1.2: Automation and Robotics**: Automation is the primary element that enhances operational efficiency. The manufacturing automation at Company B "*brought about lower operating expenses and raised production accuracy,*" Participant 5 said. Robotics automation in manufacturing production areas creates both lower operational costs and high-speed assembly and advanced quality control systems.

### 5.4.2 Theme 2: Sustainability Trends

The focus on sustainability has compelled companies to develop environmentally friendly products because such innovations have become essential for market competitiveness. Two relevant subthemes were derived from the Sustainability Trends theme. These are presented next, supported by verbatim quotations.

**Subtheme 2.1: Eco-friendly Equipment**: Businesses are meeting customer demands for sustainable, greener alternatives by creating energy-efficient equipment. One participant said, "*The environmental trends toward sustainability and awareness have compelled Company F to create environmentally friendly products that their customers steadily request more often*." Participant 12 added. These results show that the commercial sector is adapting to sustainable waste management solutions because consumers demand energy-efficient waste management systems that use electric-powered vehicles together with eco-friendly sorting technologies.

**Subtheme 2.2: Green Manufacturing Processes**: The sustainable movement goes further than product creation because it now affects the manufacturing approach. According to Participant 7 from Company C,' *we have integrated fuel-efficient systems with equipment designed to minimise carbon emissions, including electric-powered waste trucks*.' This result shows that Company C strives to achieve sustainable production methods through its strategy to support global sustainability objectives and draw environmentally mindful customers.

### 5.4.3 Theme 3: Operational Efficiency

Modern technology advances have enhanced operational efficiency throughout manufacturing institutions and service organisations. Two relevant subthemes were derived

from the Operational Efficiency theme. These are presented next, supported by verbatim quotations.

**Subtheme 3.1: Automation in Manufacturing**: Manufacturing automation methods are now standard because they enhance production efficiency. Participant 1 at Company A mentioned that “automation *and machine learning systems help our company produce better quality manufacturing products at reduced costs*." Business operations became more cost-effective through automation because companies implemented procedures for routine tasks while achieving higher product consistency.

**Subtheme 3.2: Digitalisation and Data-Driven Operations**: Organisations now embrace digital instruments to improve their operational procedures. Participant 5 explained, "*Our Company now uses remote diagnostics systems for equipment that enables technicians to track the health of the machine in real-time*. " These tools improve operational efficiency by speeding up problem detection and troubleshooting processes. Participant 10 from Company E also noted that "*Waste management keeps evolving toward data-driven systems as customers request connected smart solutions that deliver current equipment performance details*."

### 5.4.4 Theme 4: Predictive Maintenance

Technological advancements now allow equipment malfunction prediction, which results in improved operational efficiency and satisfied customers. Two relevant subthemes were derived from the Predictive Maintenance theme. These are presented next, supported by verbatim quotations.

**Subtheme 4.1: Real-time Monitoring and Diagnostics**: New technology allows equipment manufacturers to embed sensors for monitoring systems in real time so equipment maintenance can be predicted. Participant 7 said, "*The equipment at our facility uses sensors to track performance data, which sends feedback in real time to our team for improving maintenance operations and diagnostic procedures*." This shows that businesses are utilising this technology to handle their equipment actively, which results in fewer equipment breakdowns.

**Subtheme 4.2: Reduced Downtime and Service Optimisation**: Predictive maintenance minimises equipment stoppages because it enables organisations to identify potential problems before equipment breakdown occurs. The integration of IoT sensors into

manufacturing equipment enables Participant 8 from Company D to observe, “We *perform real-time equipment performance monitoring, thus delivering proactive maintenance services. This has reduced downtime significantly*." These technologies obviously assist companies in enhancing their service operations while sustaining the operation of their equipment at optimal levels.

### 5.4.5 Theme 5: Customer-Centric Innovations

Because of modern technological developments, businesses use smart systems and customer relationship management (CRM) tools to transform their customer interactions. Two relevant subthemes were derived from the Customer-Centric Innovation theme. These are presented next, supported by verbatim quotations.

**Subtheme 5.1: Smart Waste Management Systems**: The market now shows strong interest in innovative waste management solutions because clients want equipment that shows real-time data while maximising operational efficiency. Participant 3 from Company A pointed out that "*smart waste equipment demand is on the rise due to its ability to deliver real-time performance monitoring together with maintenance data and waste processing optimisation*." This pattern obviously enables clients to enhance operational efficiency along with resource management capabilities.

**Subtheme 5.2: Improved Customer Relationship Management (CRM)**: Organisations use CRM software to optimise their customer relationship operations. Participant 12 said, "*The Company tracks customer needs and delivers prompt service by using customer relationship management (CRM) software*." Through this technology, businesses obviously achieve better relationships with clients and enhanced service performance while better-addressing customer requirements.

In summary, these themes collectively show how recent technological developments, together with industrial patterns, have substantially altered how businesses work in waste management and waste handling equipment distribution. Organisations use smart technologies, emphasising sustainability and improving operational efficiency to maintain market competitiveness among evolving customer requirements.

## 5.5 Government regulations and environmental policies

The research investigates the influence of government regulations and environmental policies on business practice for waste management and equipment manufacturing through

analysis of five central themes alongside their supporting sub-themes. The statements provided directly from participants bring life to regulatory elements that affect product development alongside innovative prospects, regulation standards, and market implications. The interview results show that regulations function simultaneously as obstacles and opportunities by encouraging companies to find new ways to meet their requirements. Table 5.5 shows both research themes and their sub-themes.

**Table 5-5: Research Question Three (RQ3), Themes, and Sub-themes**

| Research Question (RQ3) | Theme | Sub-Theme |
|---|---|---|
| What role do government regulations and environmental policies play in shaping your business practices? | 1. Compliance with Regulations | 1.1 Adapting to Environmental Standards |
| | | 1.2 Legal and Operational Compliance |
| | 2. Innovation and Market Opportunities | 2.1 Technological Advancements |
| | | 2.2 Green and Eco-friendly Solutions |
| | 3. Waste Management and Recycling | 3.1 Waste Separation and Recycling Technologies |
| | | 3.2 Municipal Waste Diversion Goals |
| | 4. Sustainability and Green Technology | 4.1 Energy Efficiency |
| | | 4.2 Circular Economy and Product Design |
| | 5. Challenges and Cost-Effectiveness | 5.1 Meeting Stringent Regulations |
| | | 5.2 Balancing Compliance with Profitability |

Next, the main themes and their corresponding sub-themes will elaborate on ways government regulations and environmental policies shape business practices in the waste management and equipment manufacturing sectors in South Africa.

### 5.5.1 Theme 1: Compliance with Regulations

The theme investigates how organisations implement domestic and global environmental standards, particularly regarding their release of pollutants, waste management, and operational compliance requirements. Two important subthemes emanate from the key theme of compliance with regulations. This section presents findings together with direct quotations.

**Subtheme 1.1 Adapting to Environmental Standards:** Businesses must adapt because the government mandates strict requirements about emissions and waste disposal together with energy consumption. Multiple participants explained why it is crucial to fulfil updated regulatory requirements because this action keeps organisations in compliance and improves their market standing. “We *operate under the principle that every piece of equipment must fulfil environmental standards that promote low emissions and recyclability*,” said Participant 9. According to Participant 5, the South African market follows international sustainability standards: “The *South African market often aligns with international standards, especially in terms of sustainability*."

**Subtheme 1.2 Legal and Operational Compliance:** Businesses must maintain compliance with standards originating at the international level and from their local jurisdictions. They need to update their processes and redesign their equipment to fulfil particular environmental standards. Participant 1 said, "*The regulations enable us to operate within the law while supporting our sustainability goals*." Similarly, Participant 10 said*, "We must maintain up-to-date knowledge of new regulations as there is an increasing demand to guarantee product compliance with current legislative requirements."*

### 5.5.2 Theme 2: Innovation and Market Opportunities

The theme analyses how official regulations bring about technological progress, which establishes new opportunities for sustainable products to enter the market. The Innovation and Market Opportunities theme generated two applicable sub-themes. The following are the results presented based on subthemes with supporting direct quotes.

**Subtheme 2.1 Technological Advancements** -Businesses innovate technology because government regulations create demanding environmental standards that they must fulfill. For example, Participant 2 pointed out that "*regulations drive customers to seek energy-efficient machines, forcing us as manufacturers to modify our products according to these*

*requirements*." The implementation of stricter waste management regulations creates specific technological needs: "*Waste management regulations have become stricter, especially concerning recycling targets and landfill diversion*, " said Participant 7.

**Subtheme 2.2 Green and Eco-friendly Solutions:** Total compliance with environmental policies affects demand or creates fresh business opportunities for sustainable products. Participant 8 explained*, "Although regulatory hurdles are difficult to overcome, they enable companies to lead sustainable innovation through green technological advancements*." Participant 3 similarly explained that legislative requirements increase the need for sustainable waste handling equipment requirements, explaining, "*These regulations generate demand for eco-friendly technology leading to better competitiveness among businesses*."

### 5.5.3 Theme 3: Waste Management and Recycling

The theme investigates the governmental influence on technological advancement while helping the market develop sustainable products. The Waste Management and Recycling theme led to the off shooting of two related sub-themes.

**Subtheme 3.1 Waste Separation and Recycling Technologies:** Product development obtains vital direction from existing waste separation and recycling regulations. According to Participant 7, it is essential to develop equipment technology that enables recycling. He said, "*Some of the recycling and waste separation standards now require specialised machinery to ensure that different waste streams are effectively handled*." Similarly, Participant 1 explained the role of regulations in motivating the development of solutions to waste management: "*They set the standards for waste management and recycling, which we must adhere to*."

**Subtheme 3.2 Municipal Waste Diversion Goals:** The participants observed how regulatory requirements to decrease landfill disposal and boost recycling performance levels drive companies to develop new solutions. Participant 8 observed that "*Government bodies actively promote sustainable eco-friendly solutions*," and Participant 10 added, "*Municipalities' sustainability requirements create new business opportunities through equipment investments that support their targets*."

### 5.5.4 Theme 4: Sustainability and Green Technology

This theme discusses how sustainability goals and green technology regulations influence product design and energy-efficient practices within the industry. Two relevant subthemes were derived from the Sustainability and Green Technology theme. These are presented next, supported by verbatim quotations.

**Subtheme 4.1 Energy Efficiency:** Organisations address energy efficiency requirements from both domestic and international pressures. Participant 5 explained that "*the company needs to either modify existing vehicles or create new technologies to fulfill upcoming energy efficiency standards*." Relatedly, Participant 9 acknowledged that "*the government demanded all waste handling equipment manufacturers to comply with environmental standards which included low-emission requirements."*

**Subtheme 4.2 Circular Economy and Product Design:** Industry regulations about circular economy inspired businesses to redesign products with long-term usability while making them suitable for recycling. Participant 12 highlighted this, saying, "*The Company protects itself from penalties while building its reputation as an environmentally concerned business through compliance with regulatory requirements*." Similarly, according to Participant 11, "*the circular economy drives designers to build equipment which can easily be fixed while maintaining easier recyclability."*

### 5.5.5 Theme 5: Challenges and Cost-Effectiveness

This theme explores the challenges faced by businesses in an attempt to balance profitability with compliance and the cost-effectiveness of meeting stringent environmental government regulations. Two relevant subthemes were derived from the Challenges and Cost-Effectiveness theme. These are presented next, supported by verbatim quotations.

**Subtheme 5.1 Meeting Stringent Regulations:** Companies face hurdles when trying to fulfil mandated regulations, mostly because adapting new systems and adopting technological innovations pose difficulties. According to Participant 5*, "Running a business operation requires the ability to adapt to regulations while achieving business profitability goals*." Participant 3 expressed similar feelings concerning the pressure point where she confirmed that "*We are always ensuring our designs comply with the latest legislation*."

**Subtheme 5.2 Balancing Compliance with Profitability:** Participants emphasised that compliance is necessary for business operations but achieving it effectively without harming

revenue remains their main difficulty. In this case, Participant 6 said, "*The regulatory landscape drives innovation at the company but presents challenges regarding cost-effectiveness maintenance*." Participant 10 also noted*, "There is a need to keep ahead of regulations and below cost limits so clients can find their products affordable*."

Overall, these themes make the relationship between official regulations, environmental guidelines, and business strategies in waste management services complex. Businesses confront regulatory obstacles, yet these rules simultaneously develop market possibilities that organisations need to manage to gain compliance while maintaining their competitive edge.

### 5.6 Data-driven and AI-enabled models

Multiple important themes have become apparent when investigating data-driven and AI-enabled model implementation alongside their effects in South Africa's waste-handling industry. The themes show how South Africa uses advanced technologies with waste management and what applications these systems may develop into in the coming years. The analysis includes a detailed exploration of each theme supported by sub-themes (see table 5.6). This analysis investigates participant verbatim statements to understand better how data-driven and AI-enabled models are applied in waste handling operations despite facing various obstacles and presenting multiple opportunities.

**Table 5-6: Research Question (RQ4), Themes, and Sub-themes**

| Research Question (RQ4) | Themes | Sub-Themes |
|---|---|---|
| What is the adoption and impact of adopting data-driven and AI-enabled models in South Africa's waste handling sector? | Adoption of Data-Driven and AI Technologies | 1.1 Data Analytics Integration<br>1.2. AI Adoption in Equipment |
| | Benefits of Data-Driven and AI Models | 2.1 Operational Efficiency<br>2.2 Cost Reductions |
| | Challenges in Data and AI Adoption | 3.1 Integration with Existing Systems<br>3.2 Skilled Labor Shortage |
| | Industry-Specific Applications | 4.1 Predictive Maintenance<br>4.2 Route Optimisation |
| | Future Trends and Development | 5.1 Innovation and Market Growth<br>5.2 AI in Waste Sorting |

Next, the main themes and their corresponding sub-themes will be elaborated on to highlight the adoption and impact of implementing data-driven and AI-enabled models in South Africa's waste-handling sector.

### 5.6.1 Theme 1: Adoption of Data-Driven and AI Technologies

Data-driven and AI technologies have become prominent in South African waste-handling operations because companies use them to improve their service delivery methods. The participants agree that data analytics reveals important market direction data while showing customer preferences and enabling operational efficiency optimisation. Participant 1 from Company A explained that "*data analytics helps our organisation understand market patterns and customer needs and equipment behavior to enhance operational effectiveness, thus improving customer satisfaction*." Relatedly, Participant 8 from Company D describes how "*Our company monitors machine usage patterns and wear and tear data and equipment health through data analytics and AI to predict maintenance requirements*."

AI technology uses for equipment, including predictive maintenance along with design optimisation, are currently developing in specific organisations. Participant 7 from Company C stated, "*The production department at our firm employs AI-based design tools that enhance machine efficiency while minimising production waste versus offering predictions about material behavior across different environmental settings*." The implementation of these technologies faces challenges mainly because of their high complexity and integration expenses. Two relevant subthemes were further derived from the theme of the adoption of data-driven and AI technologies. These are presented next, supported by verbatim quotations.

#### Sub-Theme 1.1: Data Analytics Integration

Data analytics integration has emerged as the fundamental component within the industry because it enables businesses to base their decision on data-driven information. Participant 3 from Company A notes, "*The employees at Company A utilise predictive maintenance software to assess machine behaviors, which warns customers about upcoming component failures. The equipment maintenance system becomes more efficient because of this approach, which results in enhanced service reliability for our clients*." Similarly, Participant 11 from Company E said, "*Through the lift logger system, Company E tracks performance data, which provides analytical tools for both clients and staff to detect operational flaws in*

*their waste collecting processes*." Operations streamlining and efficiency reduction have been the most substantial successes for businesses utilising data optimisation methods.

**Sub-Theme 1.2: AI Adoption in Equipment**

The utilisation of AI technology remains an emerging industry pattern because multiple organisations have begun adding AI components to their equipment. According to Participant 5 at Company B, "*the waste collection industry utilises AI to optimise autonomous routes through waste collection trucks, which are described as systems that combine traffic data and waste density information for ideal routes*." However, Limited AI implementation in equipment continues to occur because organisations face two barriers: high initial expenditure cost and specialised workforce requirements to operate these systems.

**5.6.2 Theme 2: Benefits of Data-Driven and AI Models**

Integrating data-driven and AI models offers numerous advantages, mainly enhanced operational efficiency while decreasing costs. The Benefits of Data-Driven and AI Model themes are derived from two relevant subthemes, which are presented next, supported by verbatim quotations.

**Sub-Theme 2.1: Operational Efficiency**

Companies increase their operational efficiency through AI-driven data technologies primarily by predicting maintenance requirements while optimising workflow methodologies. Participant 1 from Company A said, "*AI serves predictive maintenance alongside quality control and process automation. The technology tools will then create more efficient operations and achieve lower downtime periods as well as better quality results*." Relatedly, Participant 7 from Company C reports that "*predictive maintenance has produced two benefits: it decreased equipment downtime, and it enhanced operational efficiency*." The predictive features obviously assist organisations in avoiding expensive equipment failures and enhance their service delivery stability.

**Sub-Theme 2.2: Cost Reductions**

When combined, these technologies produce long-term financial benefits. Participant 8 from Company D explains, " *Our organisation uses data analytics for machine service prediction. The advantages of AI and data analytics drive ongoing technology investigation because*

*they lead to diminished breakdowns and superior customer interaction*." As such, by improving equipment functionality and minimising unplanned maintenance instances, businesses reduce their maintenance costs while cutting down operational suspension periods.

### 5.6.3 Theme 3: Challenges in Data and AI Adoption

Despite their clear advantages, the waste management sector in South Africa faces various obstacles during the implementation of data-driven and AI-enabled models. These are presented next as sub-themes, supported by verbatim quotations.

#### Sub-Theme 3.1: Integration with Existing Systems

The main challenge arises from merging AI with data analytics solutions into existing operational systems, especially older ones. Participant 2 from Company A highlights, "*The challenge...lies in the integration of these advanced technologies with our existing systems. The collection of data remains simple, yet developing practical insights from this information demands specialised personnel together with an expensive software infrastructure.*" Participant 5 from Company B states that "*developing and integrating advanced technologies into present systems represents a crucial financial challenge*." As such, companies in this sector face a significant challenge because they need to integrate new technologies smoothly with their existing legacy systems.

#### Sub-Theme 3.2: Skilled Labor Shortage

The industry faces difficulties in recruiting personnel who possess the necessary expertise in data science and AI technologies. Participant 9 from Company D explained that "*managing extensive data volumes needs trained personnel, so the organisation had to provide data science and analytics training to its staff despite encountering new difficulties*." Moreover, according to Participant 3 from Company A, "the *market faces difficulties in skilled staffing to operate these tools because skilled labor remains scarce in their industry*." The shortage of personnel with appropriate qualifications acts as a barrier to accelerating the quick implementation of advanced technologies.

### 5.6.4 Theme 4: Industry-Specific Applications

AI, together with data technologies within waste management, has created innovative industrial applications such as route optimisation and predictive maintenance, which modify everyday operation procedures between industries.

#### Sub-Theme 4.1: Predictive Maintenance

Data analytics is the main application of predictive maintenance in the industry, boosting equipment dependability and lessening operational stoppages. According to Participant 12 from Company F, "*Data analytics enables our organisation to make prudent decisions through its market pattern analysis and customer preference insight along with operational efficiency examination...We examine machine data to forecast maintenance requirements and avoid equipment failure, thus increasing customer happiness and lowering maintenance duration*." All companies in the industry today choose this approach to expand the operational duration of their equipment.

#### Sub-Theme 4.2: Route Optimisation

AI-based route optimisation operates as an essential operational tool for waste management companies to increase their efficiency. According to Participant 5 from Company B, "*In waste collection, AI technologies generate routes which prove most beneficial for waste trucks. Waste management efficiency increases through such systems that play a vital role in cutting down fuel use*." Similarly, one participant said, “The *lift logger from Company E assists us in detecting operational weaknesses and enhances waste collection routes as well as service delivery*, “Participant 11 added.

### 5.6.5 Theme 5: Future Trends and Development

The South African waste handling sector shows strong prospects for data-driven and AI technologies to produce substantial market expansion through innovative developments in the future. Two relevant subthemes were derived from the Future Trends and Development theme. These are presented next, supported by verbatim quotations.

#### Sub-Theme 5.1: Innovation and Market Growth

The industry progression, along with the increasing power of artificial intelligence, leads to intensified research in advanced waste-sorting systems and autonomous transportation

solutions. Participant 3, employed at Company A, said, "*We have been researching AI's potential when it comes to smart waste sorting technology that can help machines identify and separate different types of waste more efficiently, which is a big area of development for us*." The waste sorting method aligns itself with global trends regarding automation while promoting sustainability objectives.

**Sub-Theme 5.2: AI in Waste Sorting**

AI technology used in waste sorting matches experts' opinions and is an essential development for better waste management methods. According to Participant 8, who works in Company D's team, "*AI models permit us to conduct waste management simulation tests which maximise the technical capabilities of our equipment*." AI-based sorting methods can transform waste recycling and waste reduction through improved sorting processing.

Overall, the obtained data demonstrates that the waste handling sector actively adopts predictive and data analytics systems as it deals with multiple operational obstacles. Modern companies use these technologies to enhance waste operations through reduced costs, optimised business strategies, and innovative waste management solutions. AI and data analytics integration continues as an ongoing process that demands monetary investment, skilled personnel, and acceptance of modern technological changes.

**5.7 Innovative and sustainable ideas**

The South African waste-handling equipment industry is experiencing an essential shift toward advanced, innovative, sustainable process implementation. Industrially, through interviews, results revealed several important themes that point to development potential. Businesses in this sector can enhance operations through innovative solutions by following sustainability targets using the identified themes. The study delivers the following results, which are organised into five main themes with connected sub-themes. (see table 5.7) The information collected from industry professionals contributes to both market and developmental perspectives that enable significant change throughout South Africa's waste management sector.

**Table 5-7: Research Question (RQ5), Themes, and Sub-themes**

| Research Question (RQ5) | Themes | Sub-Themes |
|---|---|---|
| RQ5: What innovative or sustainable ideas could improve the way waste-handling equipment businesses operate in South Africa? | 1. Circular Economy and Modular Equipment | 1.1 Modular Equipment Design |
| | | 1.1 Circular Economy Principles |
| | 2. Renewable Energy Integration | 2.1 Solar-Powered Equipment |
| | | 2.2 Energy-Efficient Equipment |
| | 3. Advanced Technology and Automation | 3.1 Smart Waste Management Systems |
| | | 3.2 AI and IoT Integration |
| | 4. Waste-to-Energy Solutions | 4.1 Waste Conversion to Energy |
| | | 4.2 Energy Efficiency |
| | 5. Collaborative Business Models | 5.1 Leasing and Service Models |
| | | 5.2 Partnerships with Local Governments |

Next, the main themes and their corresponding sub-themes are elaborated on to highlight innovative or sustainable ideas that could improve the way waste-handling equipment businesses operate in South Africa.

### 5.7.1 Theme 1: Circular Economy and Modular Equipment

The theme studies how circular economy concepts should be implemented in waste-handling equipment manufacturing and operational systems. Participants advocate that waste-handling equipment needs to provide both waste management functionalities and waste reduction potential through recycling and device repurposing systems at the end of its lifecycle. Participant 1 explains that "*promoting modular equipment designs represent one idea which enables user-friendly upgrades as well as maintenance to prolong the equipment lifetime*." The modular design structure enables waste management equipment to receive needed adaptions or upgrades that increase its lifespan.

A number of participants highlighted that equipment manufacturers should create products that enhance recycling processes. Participant 2 said, "*The circular economy provides a strong business opportunity for waste handlers to work directly with recycling methods so manufacturers can repurpose material in new items*." This highlights that the ability to achieve waste reduction can come from equipment design as well as through creating sustainable recycling pathways. Two relevant subthemes were derived from the Circular Economy and Modular Equipment theme. These are specifically presented next, supported by verbatim quotations.

**Sub-theme 1.1: Modular Equipment Design**

Modular design makes updates or modifications to equipment possible because it enables complete refreshment without a full replacement. Through its adaptable features, the equipment achieves prolonged operational duration. Participant 8 explained that "*modular systems enable municipalities along with businesses to expand their waste management services without requiring replacements*." The modular design improves equipment value and minimises the requirement for new resources.

**Sub-theme 1.2: Circular Economy Principles**

The main goal of circular economy principles is to reduce equipment's environmental consequences throughout its entire life cycle. Participant 7 said, "*The team should investigate business models that would provide equipment leasing with dedicated end-of-life management solutions*." These principles work toward recycling waste-handling equipment and remodelling it for reuse while lowering both landfill waste and improving operational sustainability.

**5.7.2 Theme 2: Renewable Energy Integration**

Solar and wind power systems are essential components to reduce the environmental influence of waste-handling equipment, according to many participants. Participants stressed that renewable-powered equipment should replace current energy systems because it would decrease carbon footprint while eliminating dependence on fossil fuels. The use of solar-powered and hybrid equipment represents a possibility mentioned by Participant 2 "*to achieve solar energy utilisation which minimises dependence on traditional power supply.*" Moreover, the use of renewable sources for equipment operations would present dual benefits of cost reduction and compliance with global sustainability goals.

**Sub-theme 2.1: Solar-Powered Equipment**

The potential for solar-powered equipment is substantial because South Africa gets plenty of sunlight. Participant 12 stated that "*using solar or wind power for equipment running would decrease operational expenses while diminishing environmental impact*." Business operations that use solar power for waste handling can decrease their need for grid-generated electricity, save money, and support environmental sustainability.

**Sub-theme 2.2: Energy-Efficient Equipment**

The installation of efficient energy-saving equipment allows organisations to diminish their energy requirements, thus improving their waste-handling sustainability. "*Using sustainable, recyclable materials for constructing trucks and machines would result in massive reductions of our environmental impac*t," said Participant 5. As such, protecting the environment requires waste management to apply lighter materials along with optimised machine operation, which reduces the total environmental effects of waste handling activities.

**5.7.3 Theme 3: Advanced Technology and Automation**

Research participants established the vital function of state-of-the-art technologies, including AI, IoT, and automation, that drive waste management process transformation. Advanced technologies deliver enhanced operational efficiency and optimised waste collection route planning and reduce environmental wastage in the process. Participant 6 notes that "*an innovative solution for improving equipment would be refurbishing older units, but municipalities remain resistant to this approach*." AI technology combined with innovative systems operates as efficiency boosters that make operations more productive by decreasing waste and energy consumption. Two relevant subthemes were derived from the Advanced Technology and Automation theme. These are specifically presented next, supported by verbatim quotations.

**Sub-theme 3.1: Smart Waste Management Systems**

The combination of IoT and AI technology in waste management systems offers optimisation benefits to waste collection activities. Participant 7 said, "*The introduction of AI-driven optimisation systems that analyse current data to enhance route collection operations, minimise fuel expenses, and optimise performance.*" This technological advancement helps waste management operations improve performance while minimising their environmental impact.

**Sub-theme 3.2: AI and IoT Integration**

AI, together with IoT, when integrated into waste-handling equipment, enables the immediate tracking and maximal efficiency of waste management systems. Participant 12 says*, "The creation of intelligent waste management solutions which unite AI and IoT shapes better waste management procedures while enhancing environmental friendliness and system performance*." Such integration presents the capability to decrease operational expenditures while increasing operational efficiency of waste management operations.

### 5.7.4 Theme 4: Waste-to-Energy Solutions

People often mention waste-to-energy technologies, which create electricity and biogas, among the most important innovative solutions. Participant 8 observed that "*the waste-to-energy market is expanding, which provides the potential to create improved equipment that would boost process efficiency*. “Reducing waste through this method helps resolve energy supply issues alongside waste volume reduction. Two relevant subthemes were derived from the Waste-to-Energy Solutions theme. These are specifically presented next, supported by verbatim quotations.

**Sub-theme 4.1: Waste Conversion to Energy**

Waste transformation into energy establishes a durable method to deal with both waste disposal issues and power generation needs. According to Participant 5's statement*, "The main focus should be on converting waste into energy since it would minimise waste quantities while addressing the national energy shortage*." Through waste-based energy generation, businesses protect the environment while establishing a more secure energy future.

**Sub-theme 4.2: Energy Efficiency**

Reducing environmental impact depends heavily on energy-efficient equipment management. According to Participant 12's guidance, "*the promotion of circular economy design for easy repairable and reusable equipment serves to minimise waste while promoting sustainability*." Energy efficiency, in combination with waste-to-energy approaches, lowers the environmental impact that waste-handling operations create.

### 5.7.5 Theme 5: Collaborative Business Models

The last key theme demonstrates the need for active collaboration among equipment manufacturers, government entities, and waste management firms. Businesses that partner will develop waste management systems that combine sustainability with reduced costs. According to Participant 11, "*Equipment manufacturers, government entities, and waste management firms should work together because this could enable comprehensive and efficient systems to be developed*." The establishment of cooperative partnerships creates enhanced possibilities for developing practical solutions for waste management issues. Two relevant subthemes were derived from the Collaborative Business Models theme. These are specifically presented next, supported by verbatim quotations.

#### Sub-theme 5.1: Leasing and Service Models

An upcoming business model combining leasing with service provision sets out to provide customers with adaptable solutions that cut costs. Participant 10 suggested "*a new concept of providing equipment as a service instead of machine sales to make large and small businesses more cost-efficient*." Leasing allows companies to acquire modern equipment with proper disposal arrangements for obsolete machines, which minimises the continuous production of new products.

#### Sub-theme 5.2: Partnerships with Local Governments

Waste management solutions must be adjusted to local community needs by working together with local government authorities. Participant 7 expressed his interest, " *I'd like to witness increased cooperation between private enterprises and municipal governments for developing waste processing facilities and recycling centers*." Sustainable waste management infrastructure will emerge through business and local community alliances to benefit both organisations and communities.

The research results reveal positive prospects for developing waste-handling equipment businesses through innovative, sustainable solutions within South Africa. South African waste-handling equipment businesses can transform their sector and create a sustainable future through circular economy models, the integration of renewable energy, technological developments, and collaborative strategies.

## 5.8 Conclusions

The study's findings offer significant insights into the current business models and market operations of South African waste-handling equipment manufacturers. Research question one, which explored the existing business models, revealed that manufacturers in South Africa employ diverse strategies, including direct sales, service contracts, and product customisation. These models are complemented by innovation and sustainability practices, along with a strong focus on customer relationships and post-sale services. The emphasis on local manufacturing, along with strategic partnerships, allows manufacturers to remain competitive while addressing both local needs and global sustainability goals. These findings highlight the dynamic and multifaceted nature of the waste-handling equipment sector in South Africa.

Technological advancements and trends, as addressed in research question two, have had a profound impact on the business models of waste-handling equipment manufacturers. The adoption of IoT, innovative equipment, automation, and eco-friendly practices has reshaped operational processes, making them more efficient and sustainable. The incorporation of real-time monitoring, predictive maintenance, and automation in manufacturing has significantly improved operational efficiency and customer relationship management. These findings underscore the growing importance of technological integration in the industry, not only to enhance productivity but also to meet the increasing demand for sustainable and innovative solutions in waste management.

The influence of government regulations and environmental policies, explored in research question three, has been a key driver in shaping business practices in the waste-handling sector. Manufacturers face the dual challenge of complying with stringent environmental standards while balancing profitability. However, these regulations also present opportunities for innovation, particularly in developing green technologies and sustainable waste management solutions. The themes identified, such as waste separation, recycling technologies, and energy-efficient product design, emphasise the critical role that government policies play in driving both challenges and opportunities for manufacturers to remain competitive in a regulated environment.

The adoption of data-driven and AI-enabled models in South Africa's waste-handling sector, as discussed in research question four, is an ongoing process with notable benefits and challenges. Manufacturers are increasingly adopting predictive maintenance, data analytics, and AI to optimise operations, reduce costs, and enhance efficiency. However, the

integration of these technologies is not without obstacles, including a shortage of skilled labor and the need for substantial investment in technology. Despite these challenges, the integration of data and AI technologies is proving to be transformative, with a positive impact on waste management operations and long-term business growth in the sector.

Finally, the study's findings regarding innovative and sustainable business models, as addressed in research question five, suggest that South Africa's waste-handling equipment manufacturers are moving toward adopting circular economy principles, renewable energy solutions, and advanced technology. These models focus on improving energy efficiency, promoting waste-to-energy solutions, and encouraging collaboration between businesses and local governments. The integration of modular equipment design, solar-powered systems, and AI-driven innovations provides a promising route for creating a more sustainable future in the waste management industry.

In conclusion, the study provides a comprehensive overview of how emerging business models, technological advancements, regulatory influences, and sustainable practices are transforming the South African waste-handling equipment manufacturing sector. Manufacturers are adapting to market pressures through innovation, technology integration, and strategic partnerships while also navigating the complexities of environmental regulations and operational challenges. The findings highlight the sector's potential to drive both economic growth and sustainability in the face of evolving global and local demands. Overall, the study underscores the importance of innovation, sustainability, and technological advancement in shaping the future of waste handling in South Africa.

# CHAPTER SIX: DISCUSSION OF RESEARCH RESULTS

## 6.0 Introduction

The chapter discusses findings from the study on South African waste-handling equipment manufacturers' business models, technological enhancements, regulatory factors, and potential sustainable developments. Research results will be presented with reference to a thematic analysis done in Chapter 5 and then connect them to established knowledge about circular economy (CE), sustainability theory, and innovation diffusion theory (IDT). The discussion demonstrates how the findings correlate with global trends while revealing specific obstacles and opportunities that exist in the context of South Africa. The research addresses practical applications that arise from research results. The study achieves its goal of developing practical enhancement strategies by discussing detailed insights into the elements that affect industry business operations in waste handling equipment management.

## 6.1 Research Question 1: What are the current business models and market operations of South African waste-handling equipment manufacturers?

The study examines the business model of South African waste-handling equipment manufacturer, as well as market operations through five main themes along with specific subthemes emanating from Chapter 5. The study delivers an advanced understanding of present-day market dynamics since it examines the different approaches manufacturers utilise regarding business models (theme 1), innovation strategies (theme 2), customer relationship (theme 3), decisions between local production and imports (theme 4) and strategic partnerships (theme 5). The results of South African waste handling equipment manufacturers reveal consistent and few contradictory points through critical analysis against theoretical frameworks from Chapter 2, including the circular economy (CE) theory, sustainability theory, and innovation diffusion theory (IDT) alongside business model literature related to waste handling equipment manufacturers.

The first theme under RQ1, ***Business Model Variations***, suggests established manufacturers follow several business models by mainly using both direct sales and service contracts where specific companies prioritise creating customised products and solutions. The dual strategy matches current literature-based business model transformations because it integrates product sales with service contracts (Moalem & Kerndrup, 2023). Service contracts as business strategy mirrors recurring revenue streams described by Agrawal et al. (2022), and product customisation caters to industry needs in waste management that

require tailored solutions because of local operational conditions (Kanda et al., 2021). These research findings align international patterns of service-based business models in the manufacturing sector yet demonstrate how South African enterprises balance proven practices with modern client-based strategies. The study findings demonstrate how combined models support a theory that indicates service-oriented procedures produce more loyal customers with long-term business relationships.

In the second theme under RQ1, ***Innovation, and Sustainability***, results align with CE as it serves to lower waste production, maximise resource value, and extend the product life cycle. (Geissdoerfer et al., 2017). The study shows that manufacturers now develop equipment aimed at reusable and recyclable functions consistent with Bocken et al. (2014) recommendations to integrate circular economy strategies into manufacturing business models. However, the literature document both the advantages of circular practices but also reveal significant barriers to implementation in South Africa—such as financial limitations and the need for expert technology (Godina et al., 2020). These barriers emerge as a significant discussion topic because they reveal South African manufacturers' practical challenges in implementing circular economy principles, unlike optimistic projections available in the literature. Therefore, research results expand the current academic knowledge by revealing various obstacles experienced by South African manufacturers beyond what has been investigated previously.

The third research theme under RQ1, ***Customer Relationship and Retention***, demonstrates the value of long-term client partnerships and after-sales services for customer relationship retention. After-sales service and customer training form essential pillars in business sustainability through manufacturer recognition of their dual role as product providers and continuous support deliverers(Godina et al., 2020). The findings apply directly to business models described in the literature because after-sales services serve as essential tools to boost customer satisfaction and retention (Agrawal et al., 2022). The study demonstrates how companies focus on sustaining enduring relationships with both municipalities and private waste management companies, which matches academic findings about essential customer-focused business strategies in modern competitive industry conditions. The evidence indicates that successful customer relationship management practices lead to better market prospects and operational steadiness in waste management operations. The identified theme validates established theoretical perspectives which prioritise customer relationship management for achieving sustainable business success.

The fourth theme under RQ1, ***Local Manufacturing vs Importation***, demonstrates a conflict between beneficial domestic manufacturing and the problems that result from importing components. The study results indicates the operational agility of locally produced waste handling products and their intelligence to market changes, yet it recognises the risks companies encounter from obtaining specific materials abroad. The theme connects to the literature that supports local manufacturing benefits by minimising costs while securing supply chains, as noted by Mhatre et al. (2021). However, the research shows that product quality consistency, coupled with logistical management, faces issues because of foreign component dependency; this supports Fetanat et al.'s (2021) observation that operational risks increase because of such dependencies. The research results differ from existing studies because operational risks appear more extensive within South African settings stemming from particular domestic limitations.

The final theme under RQ1, ***Strategic Partnerships, and Market Reach*** illustrates how manufacturers in South Africa achieve market expansion by forming strategic partnerships with municipal waste management services together with suppliers. Study results show that partnerships between waste handling manufacturing companies and municipal waste management services and suppliers achieve two objectives: market expansion, improved product stability, and reliable supply chains. Similar to the academic research findings including Teece (2010), strategic partnerships act as necessary tools to break market entry barriers while securing better competitive positions. The innovation diffusion theory by Rogers (2003) supports the importance of establishing collaborative relationships, as it acknowledges social networks and communication channels as key factors for new technology success. The academic studies highlight partnership advantages yet fail to provide sufficient details about practical management challenges that developers face, particularly within South African developing environments. The study validates existing research while filling knowledge gaps by specifically handling practical implementation barriers and theoretical details.

An evaluation of the research findings against existing literature establishes complete agreement regarding business model changes within waste-handling equipment manufacturing. All available research and published works support a significant business transformation toward service-based models coupled with sustainability product, innovation, and enhanced customer relationship management practices. However, South African manufacturers face more significant barriers, including financial constraints, infrastructure limitations, and the need for technological advancements for circular economy adoption than

what the research demonstrates according to the existing literature. Research results show different results compared to other studies which present a more positive perspective of circular economy adoption that reveals specific obstacles facing South Africa.

The theoretical framework in Chapter 2, comprising circular economy and sustainability theory, validates all the observed findings. These theories demonstrate compatibility with business models used by South African manufacturers by following environmental responsibility and resource efficiency standards found in the literature. Innovation diffusion theory also confirms that technological developments, such as AI and IoT, are the sector's main transforming elements. However, the findings suggest that adoption challenges continue as a result of cost barriers and a lack of expertise.

Study findings provide a detailed answer to the investigation of South African waste equipment manufacturers' existing business models and market approaches by studying service contracts and product development alongside customer retention and home manufacturing along with business strategic partnerships. The study results support existing literature but demonstrate how South African waste equipment producers need to overcome isolated difficulties by implementing circular economy practices and maintaining domestic production along international supply networks. Forthcoming research and policy assistance should remain the focus because they enable the industry transformation toward sustainable, innovative business models. These study results confirm past industry research although they emphasise the particular obstacles which South Africa faces specifically in financial resources and infrastructure requirements during circular economy implementation. Further examination and policy creation should tackle these obstacles to enable production sector evolution toward sustainable innovative business patterns.

### 6.2 Research Question 2: How do recent technological advancements and trends in waste-handling equipment impact business models in South Africa?

The analysis in Chapter 5 studies how technology influences South African waste-handling equipment manufacturer business models through five main areas: integration of technology with the industry, sustainability growth patterns, efficient operational methods, predictive maintenance solutions, and the development of customer-oriented innovations. The study findings directly address Research Question 2, focusing on the effects of technological developments and trends on South African waste-handling equipment manufacturing business models. A crucial discussion explores the research findings by closely reassessing its relevance to theory and empirical literature from Chapter 2.

The study's findings for Theme 1 under RQ2, ***Technological Integration*** demonstrates closely aligning aspects with the literature, which highlights advanced technologies, including automation robotics and IoT, as agents of operational enhancement and business model integration. Results show that people tend to prefer production systems combining IoT and innovative equipment (Subtheme 1.1 under RQ2) and automation and robotics (Subtheme 1.2 under RQ2) to enhance operational effectiveness and decrease operational expenses and boost productivity. Leveraging these technologies corresponds with the broader technological literature review in Section 2.3 because automation and IoT act as primary drivers for waste handling sector efficiency and sustainability. Manufacturers can achieve predictive maintenance and minimise equipment downtime by monitoring of equipment performance through IoT devices as observed in Chapter 5 observations. Nascimento et al. (2019) agree with this conclusion stating that modern technological advancements allow manufacturers to transition from product distribution to service provision through added services including predictive maintenance and data analytics. However, Mhatre et al. (2021) made contrasting observations about the implementation barriers, which include cost barriers and skill gaps. Findings in Chapter 5 establishes that South African manufacturers face major barriers to use contemporary systems despite evident advantages since they need extensive implementation. The data in this theme consists of evidence that matches our theory yet demonstrates important obstacles that block complete implementation.

The study's findings for Theme 2 under RQ2, ***Sustainability Trends*** present evidence about escalating mandates for manufacturing companies to establish eco-friendly practices and products. The findings showcase that technological advance by manufacturing companies toward sustainability through Subtheme 2.1, Eco-friendly Equipment and Subtheme 2.2, Green Manufacturing Processes, like Company F, which has developed energy-efficient equipment due to consumer demand for sustainable products. The data aligns with sustainability theory, as detailed in Section 2.1.2, because organisations need to balance environmental, social, and economic elements to maintain lasting sustainability. The implementation of environmentally friendly production methods using electric-powered vehicles and fuel-efficient systems follows the circular economy framework by minimising waste while maximising resource reuse. These industry trends follow global sustainability movements, but technical obstacles still need to be overcome for complete innovation implementation. Munsamy (2022) identifies financial difficulties and inadequate policy backing as primary hurdles, while participants in Chapter 5 explain the implementation expenses for green technologies. The evidence demonstrates that manufacturers have started embracing sustainable practices, yet multiple policy-level and monetary incentives

will be essential to expand their implementation. In this theme, the data confirms the theory, but the practical barriers identified challenge its widespread adoption.

The study's findings for Theme 3 under RQ2, ***Operational Efficiency,*** captures the transformative effects of digital technologies, such as machine learning and data-driven operations, on the manufacturing process. The two subthemes, *Automation in Manufacturing* (Subtheme 3.1 under RQ2) and *Digitalisation and Data-Driven Operations* (Subtheme 3.2 under RQ3), demonstrate these technologies' capacity to enhance product quality, decrease costs, and enhance consistency, respectively. Operational flexibility alongside efficiency outcomes increases due to digitalisation, according to the literature (Ferasso et al., 2020). Manufacturers achieve better customer service through optimised maintenance and solutions by adopting data-driven systems, as presented in Chapter 5. However, the literature reveals that manufacturers face major hurdles when implementing these technologies, specifically in South African emerging markets, despite the apparent advantages of digitalisation. According to Guldmann and Huulgaard (2020), the adoption process faces delays because of both upfront expenses and employee resistance to change. The results from Chapter 5 show similar findings, with respondents expressing concern over financial and technical obstacles. The data here largely confirms the theory but underscores challenges that are specific to the South African context.

The study's findings for Theme 4 under RQ2, ***Predictive Maintenance*** , demonstrates how real-time monitoring systems help identify potential equipment failure before physical breakdown occurs. The maintenance operations receive enhancement from IoT technologies through *Real-time Monitoring and Diagnostics* (Subtheme 4.1) and *Reduced Downtime and Service Optimisation* (Subtheme 4.2). Research confirms the findings of Mamudu et al. (2024) who report that predictive maintenance is a fundamental benefit of modernised waste handling systems. Manufacturers who embed sensors onto their equipment enable proactive issue detection before equipment breakdowns occur, thus benefiting customers and enhancing operational performance. These results validate the theoretical basis of sustainability theory and circular economy principles since predictive maintenance techniques enable sustainable production cycles by extending its service durations and reducing replacement needs. However, the data also highlights that high initial investment remains a barrier to adoption in South African markets, which contrasts with the theory's emphasis on seamless implementation.

The *study's* findings for *Theme 5 under RQ2*, ***Customer-Centric Innovations***, follows a business model evolution toward customer-focused approaches through *Smart Waste Management Systems* (Subtheme 5.1) and *Improved CRM* (Subtheme 5.2). This theme reflects a growing trend in the waste management industry whereby businesses within the waste management sector make a strategic move as they concentrate on developing customised, innovative solutions to improve customer experiences and operational efficiency. The emerging technologies of Industry 4.0 align with the modern business strategies that result from customer requirements for real-time connected solutions (Bányai et al., 2019). The combination of CRM tools with innovative systems provides manufacturers with enhanced capability to understand customers better, along with improved operational efficiency and service performance. However, the promising developments in customer-focused innovations face ongoing challenges regarding customer learning, infrastructure provision, and managing expenses. The data indicates that while these innovations align with global trends, their implementation is hindered by a lack of adequate ecosystem support, confirming the theory on the need for broader collaboration.

The findings presented in Chapter 5 provide comprehensive answers to Research Question 2, which proves that technological development has created substantial transformations in South African waste-handling equipment manufacturers' business models. South African waste-handling equipment manufacturers intensify the efficiency of their operations through the implementation of IoT, automation, and predictive maintenance systems while pursuing sustainable practices that deliver better customer experiences and environmental stewardship. The progress of waste-handling equipment manufacturers in South Africa aligns with sustainability and circular economy theory. However, financial limitations, together with infrastructure needs and policy backing, continue to form substantial hurdles. These contextual challenges need to be addressed through future research to understand the deeper causes of these barriers and to explore potential solutions. Knowledge of these trends is crucial to guide South African manufacturers toward the successful adoption of the evolving technological landscape and sustainable global efficiency models.

### 6.3 Research Question 3: How do regulatory requirements and environmental policies influence the business models of South African waste-handling equipment manufacturers?

Chapter 5 presents how government regulations and environmental policies influence the business practices of South African waste-handling equipment manufacturers as part of

studying how these regulations form their business models. The study results have been structured into five main themes, which build an extensive regulatory analysis of how these forces affect both innovation development and market difficulties in the sector. A critical examination of these results exists within the academic context, which integrates the CE framework along with Sustainability Theory and Innovation Diffusion Theory (IDT) as well as the specifications from Section 2.4.

The first theme under RQ3, **Compliance with regulations** shows that Operational strategies heavily rely on regulatory standards. The results in Chapter 5 reveal that businesses need to implement severe environmental standards, including the promotion of low emissions and recyclability. The study findings confirm previous theoretical findings presented in Section 2.4 about regulatory standards providing both innovation-promoting advantages and obstacles. Mouton (2020) reinforces the argument that the National Environmental Management: Waste Act, along with other regulations, forces manufacturers to innovate while achieving sustainability targets. The difficulty lies in finding an equilibrium between regulatory adherence and business profitability since participants addressed this dual objective in their discussion of compliance subtheme 1.2. The financial burden faced by manufacturers during regulatory compliance requirements further confirms Munsamy's (2022) perspective, yet manufacturers can use standards for competitive advantage. This theme supports the theory but highlights the difficulty in balancing regulatory compliance with profitability.

The second theme under RQ3, ***Innovation and Market Opportunities*** strengthen the concept of how government regulations influence technological advancement. The statements from participants indicate that environmental regulations make customers search for energy-efficient machines. This shows how fulfilling environmental policies creates both technological advancements and increased market interest in sustainable solutions. The findings match the CE and Sustainability Theory in Chapter 2 because regulations push businesses to stop pursuing practices that have adverse environmental consequences while enhancing sustainability (Bocken et al., 2014). Munsamy (2022) agrees with this finding that companies that successfully innovate can benefit from regulatory requirements by developing new business opportunities, including the creation of energy-efficient machines and green technologies. The research outcomes illustrate that theoretical statements about innovation advantages are accurate although financial barriers coupled with expensive implementation (Subtheme 5.2) contradict the main academic discourse. This theme

stretches the original theory to show that although innovation exists it faces substantial obstacles to adopting widespread implementation.

The third theme under RQ3, ***Waste Management and Recycling***, directly responds to mandatory waste separation requirements with recycling obligations along with landfill diversion rules. Participants stressed how essential it was to produce equipment that meets waste management compliance standards, stating that recycling and waste separation standards now require specialised machinery. The literature supports this observation by Godfrey et al. (2021), who state that waste-handling innovation excitedly emerges from new recycling equipment regulations. The concepts within the Circular Economy match well with research about product design and waste valorisation. However, the findings also demonstrate the implementation of these standards continues to encounter financial hurdles that limit full adoption, in line with Maama et al. (2021) and Godfrey et al. (2021). The importance of waste management for innovation development is confirmed by this theme yet financial challenges demonstrate these innovations are difficult to execute.

The fourth theme under RQ3, ***Sustainability and Green Technology*** theme demonstrates how companies integrate sustainability targets into their models for producing products that fulfil circularity principles while being power efficient. Participants recognise low-emission requirements and energy efficiency needs through their references (Subthemes 4.1 and 4.2, respectively) that match regulatory sustainability requirements. The circular economy model receives direct support because product designers now base their work on making items reusable with long-term functionality (Godfrey et al., 2022). Relying on Chapter 5, research data reveals results that are identical to those of previously published studies focusing on green technology adoption under both environmental regulations and pressure from market requirements. Research by Epoh et al. (2024) confirms that barriers regarding initial expenses for green technology continue to exist while the problem of cost-effective compliance persists. This theme confirms the theory regarding sustainability but also mentions that the adoption of green technology is still restricted by initial financial capital outlay.

Finally, the fifth theme under RQ3, **Challenges and Cost-Effectiveness** analyses how manufacturers manage rigorous regulatory requirements that compete with profitability needs. Manufacturers who take part in Subtheme 5.2 demonstrate how their attempts to align compliance requirements with profitability standards result in challenges for cost-effective compliance maintenance procedures. The concern is in line with Mouton (2020) as

well as Munsamy (2022), who shows that regulatory compliance generates financial challenges for businesses when they implement new rules. The study results demonstrate that government incentives represented by tax breaks and subsidies perform an essential function in managing these costs (Godfrey et al., 2021). The findings here are mixed, as they support the literature on the financial burden of compliance but also suggest that government support could mitigate these issues, offering a potential extension to existing theory.

The research findings from Chapter 5 support previous studies regarding how regulatory needs and environmental policy tools affect waste-handling equipment business models. The combination of CE and sustainability with IDT throughout the research demonstrates that regulatory requirements drive innovation from manufacturers while creating market space for adaptational businesses. Regulatory requirements propel companies to use green technologies, but high expenses and inadequate infrastructure constitute significant obstacles against their adoption in South Africa. The literature supports government incentive programs, which aid businesses in facing the mentioned challenges, according to research results (Godfrey et al., 2021). Additional evidence supports existing theories until inconsistencies arise from insufficient implementation support combined with expensive integration costs which recommends developing an extended theoretical framework about practical obstacles.

The research question regarding regulatory requirements and environmental policies impacting South African waste-handling equipment manufacturer business models has received a complete response through Chapter 5 analysis of key themes and subthemes. The findings clearly show that regulatory pressures continue to direct business strategies toward sustainable and energy-efficient circular models while simultaneously generating both productive and adverse impacts on innovation development. However, full adoption of sustainable business practices in the waste-handling equipment industry faces substantial financial and infrastructural barriers that need additional policy assistance. This conclusion reflects the findings' contribution to the body of knowledge, where the results both confirm and extend existing literature by emphasising practical barriers to adopting sustainable practices.

### 6.4 Research Question 4: How are data-driven and AI-enabled models adopted in South Africa's waste handling sector, and what are their impacts and challenges?

The study findings in Chapter 5 presented data-driven and AI-enabled model adoption and its effects on South Africa's waste-handling industry to study profound technological changes in this sector. The study outcomes match the themes and subthemes established in the literature review, which operate under three theoretical models: Circular Economy (CE), Sustainability Theory, and Innovation Diffusion Theory (IDT). The frameworks provide a practical understanding of how AI models operate when used to enhance efficiency and environmental response as well as sustainable practice operations. The study findings validate theoretical models of adoption yet present new information about implementation challenges specifically related to adoption practical barriers.

The first theme, ***Adoption of Data-Driven, and AI Technologies*** under RQ4, represents a vital theme within South African waste management operations, which shows the increasing importance of these technologies. Companies merge AI with data analytics systems to execute better operations because they predict maintenance requirements while optimising their service delivery process. Different companies discovered that their AI systems monitor equipment deterioration to improve maintenance planning for preventing system stoppages while boosting operational output. The framework described by Geissdoerfer et al. (2017) as a Circular Economy relates specifically to this theme of maximising product lifecycle value. Organisations use predictive maintenance techniques as well as AI-based design optimisation approaches to extend equipment lifespan and minimise waste production while fulfilling their sustainability goals. However, companies continue to face integration complexities and high expenses for merging modern technology systems with their legacy platforms despite the efforts mentioned in Geissdoerfer et al. (2017). The research results validate the Circular Economy theory, yet they identify implementation barriers faced by companies which demonstrate weaknesses when applying this theory primarily through integration complications. The theoretical work supports technological innovation and infrastructure growth due to these obstacles in the field.

Data-driven and AI models provide multiple advantages that serve as the focus of the second thematic group (Theme 2 under RQ4). The significant advantages identified by participants included operational efficiency along with cost reduction. Users recognise that predictive maintenance systems based on AI technology promote equipment durability, decrease breakdowns, and decrease maintenance expenses. This aligns well with the fact

that businesses should merge both environmental and economic sustainability targets into their operations following the Sustainability Theory (Nocenzi & Sannella, 2020). The findings of Sikander (2024) about operational efficiency as a critical business factor for sustainability support how AI enhances efficiency through cost reductions. Participants validate the Sustainability Theory by linking AI operational efficiency to sustainability goals yet show some constraints exist in operationalising these technologies. Companies must spend money on state-of-the-art technology and skilled personnel to maximise their AI capabilities, although efficiency benefits may be achieved. The establishment of artificial intelligence brings many benefits, but businesses must implement systematic planning during implementation.

In contrast, ***data and AI adoption obstacles***(Theme 3 under RQ4) present significant difficulties in implementation, with a focal point on how to merge modern technologies into previous systems and obtain sufficient staff members. The process of integrating data analytics with operational systems presents difficulties, according to market participants, which aligns with the findings of Rusch et al. (2023) about how high implementation expenses and expertise gaps create barriers to AI adoption. These hurdles are explained through the Innovation Diffusion Theory (IDT) (Rogers, 2003) because it illuminates why organisations struggle to adopt AI by requiring structural transformations. Barriers for adoption examined in this theme go beyond IDT yet generate fresh knowledge about the extent of integration challenges and resource deficiencies that differ from the focus on the diffusion process in IDT. Organisations in the industry face affordability issues when implementing AI, as well as a shortage of workers who are able to operate these technical systems. The shortage of expert personnel poses an essential barrier against quick AI technology expansion because this challenge extends into global emerging technology limitations.

AI applications in waste management fulfil specific industrial needs through the fourth theme, under RQ4, ***Industry-Specific Applications***, which includes Predictive Maintenance and Route Optimisation (Sub-themes 4.1 and 4.2, respectively). Industrial systems apply predictive maintenance worldwide since this technique results in reduced operational interruptions while delivering improved services. AI technology for route optimisation enables waste management companies to decrease their fuel expenses and enhance operational effectiveness, according to industry participants in a range of organisations. These applications mirror the benefits discussed by Sikander (2024), who identified that AI applications optimise both operational processes and resource. The Circular Economy

theoretical approach is supported when predictive maintenance works together with route optimisation systems because these functions help decrease resource usage and produce fewer adverse effects on the environment. The findings largely confirm the Circular Economy theory, although the applications remain in development stages, which limits their immediate impact. The industry-specific applications exist in the development phases because the industry needs more innovation to enable complete deployment. Although the Circular Economy theory proves valid its practical application in this setting still needs development and possibly future adjustments. The shift from traditional waste management practices to AI-based operations marks a pivotal development toward eco-friendly waste handling while this field continues its evolution.

Finally, the **Future Trends and Development** (Theme 5 under RQ4) point to a promising horizon for AI and data-driven technologies in South Africa's waste handling sector, particularly with innovations in **AI for Waste Sorting** (Sub-theme 5.2) and the potential for **Market Growth** (Sub-theme 5.1). Companies are investing in AI-driven systems that promise to enhance the efficiency of waste sorting, a critical component for improving recycling rates and reducing waste. These trends align with the growing demand for AI technologies in global waste management and sustainability efforts, as noted by Bashynska and Prokopenko (2024). While these developments are still in their nascent stages in South Africa, they indicate a significant shift toward more sustainable and efficient waste-handling practices. The research expands previous concepts by demonstrating how waste sorting implementation with AI both supports environmental sustainability together with the development of advanced resource management operations. As businesses begin to prioritise innovation and market expansion, the integration of AI into waste sorting could be transformative, potentially setting the foundation for a more sustainable and circular economy within the sector.

Chapter 5 presents findings that answer the research question about data-driven and AI-enabled model adoption in South Africa's waste management industry, as well as their resulting impacts and challenges. South African industries demonstrate a dominant movement toward AI-based data analytics integration, which leads to enhanced operation rates, monetary savings, and sustainable practices. Several significant hurdles for implementation emerge from the research, including complex integration obstacles, requirements for experienced employees, and high adoption prices. Data from the study supports the theoretical models discussed in Chapter 2 through Circular Economy and Innovation Diffusion Theory because they focus on technology-driven organisational

transformations. Proof from this research shows that South Africa's waste-handling industry continues to advance its AI-driven model implementation. Still, extensive barriers linked to infrastructure constraints staff needs, and budget limitations stand in the way of unlocking maximum technology potential.

### 6.5 Research Question 5: What innovative, sustainable business models can be proposed for the South African waste handling market, and how effective are they?

This section provides a detailed analysis of sustainable waste management approaches in the South African market by reviewing key findings from professional interviews in the waste management industry. The study analyses pioneering strategies to optimise waste-handling equipment operations while sustaining business success for the proposed new business models. The study findings about innovative waste-handling concepts get evaluated through theoretical frameworks introduced in Chapter 2 that focus on CE, sustainability theory, and IDT to determine potential future impacts on South Africa's waste industry.

The first theme under RQ5 centers around ***Circular Economy and Modular Equipment*** principles. The examined data indicates that waste-handling equipment needs to adopt circular economy approaches that combine modular equipment features, which enable future updates and maintenance operations for longevity improvement. Participants support modular design principles because they help decrease resource usage and waste production, thus adhering to CE requirements for developing reusable and durable products for recycling (Geissdoerfer et al., 2017). As described by Bocken et al. (2014), the concept of circular economy taught how to integrate waste-reduction techniques into equipment by repurposing materials after product expiration. However, the implementation of these models faces difficulties in South Africa because of insufficient infrastructure and minimal regulatory backing (Godfrey et al., 2021). The theme demonstrates how modular design systems serve as a sustainable solution to reduce waste within the industry by addressing current restrictions. The research demonstrates an overlap with CE principles though it reveals differences with the theory about local adoption because the primary obstacle is complete implementation of these principles at a local level. This theme verifies part of the theory yet demonstrates vital barriers that exist in the local implementation context.

Results present ***Renewable Energy Integration*** as the second core theme under RQ5, where solar and wind power systems demonstrate potential opportunities to lower environmental impacts from waste equipment systems. Study participants advocate for renewable energy to serve as an alternative to traditional power supply systems, thus aiding

in attaining the nation's sustainability targets. This is in line with the literature on sustainability, which indicates that renewable energy functions as a primary element in reducing carbon emissions (Awan & Sroufe, 2022). The sub-theme of Solar-Powered Equipment shows how South Africa can take advantage of its abundant sunlight to implement solar energy as a method for cost reduction and environmental improvement. The incorporation of renewable sources of energy within Chapter 5 supports the sustainability theory by emphasising balanced environmental, social, and economic factors in business operations (Nocenzi & Sannella, 2020). However, the study findings show that renewable energy holds promise but its practical deployment differs from theoretical expectations since more financial investments together with infrastructure measures are needed before it can reach broader acceptance. Renewable energy integration as an all-inclusive solution meets extra obstacles which need stronger infrastructure systems together with sustained fiscal backing before it can be implemented on a large scale.

The findings show that ***Advanced Technology and Automation*** as the third theme under RQ5 represent an essential theme because they describe how AI, the Internet of Things (IoT), and automation help enhance waste collection and processing optimisation. Advanced technologies drive organisational changes in industries according to Innovation Diffusion Theory (IDT) developed by Rogers (2003). The study results demonstrate how waste-handling equipment firms gain benefits from AI optimisation for greater efficiency and waste reduction while minimising their energy usage through Smart Waste Management Systems and AI and IoT Integration. The implementation of innovative technologies enhances waste management systems (Mamudu et al., 2024). However, according to Rusch et al. (2023), the implementation of these technologies faces hurdles because of excessive launch costs alongside the necessity for technical specialists. Therefore, findings largely endorse digital technologies' rising significance in the industry, yet developers in South Africa and other developing nations face essential obstacles including financial and technical to embrace these technologies' adoption. Therefore, this theme extends the theory, as it acknowledges the technological advantages while recognising the difficulties faced in the context of developing countries.

The fourth theme under RQ5 involves **Waste-to-Energy Solutions** which has emerged as an innovative strategy in the research findings. Participants discussed the potential of converting waste into energy, which not only addresses waste disposal challenges but also provides a sustainable energy solution. The study findings feature Waste-to-Energy Solutions as an innovative strategy. Participants evaluated the energy creation potential of

waste transformation since this process solves garbage disposal issues while delivering a renewable energy approach. The theme correlates with circular economy principles by supporting material recovery and waste-to-energy transformation processes (Pieroni et al. 2021). Waste Conversion to Energy and Energy Efficiency implement practices that support the environmental advantages described by the literature regarding waste-to-energy technologies (Bányai et al., 2019). Moreover, the concept of waste-to-energy solutions offers the dual benefit of reducing waste volume while addressing energy supply issues in South Africa. However, to make these solutions successful, significant financial investments must be combined with proper regulatory measures to achieve effectiveness. The theme validates the theory although it shows the necessity of increased infrastructure and regulatory backing for South Africa's waste-to-energy solutions to become reality.

Lastly, fifth theme under RQ5 underscores the necessity of **Collaborative Business Models** to establish alliances between equipment manufacturers, government entities, and waste management companies, which will allow them to develop economical waste management solutions. The Subtheme of sustainable waste management depends on joint efforts between leasing programs, service contracts, and public government partnerships, according to the analysis. The sustainability theory supports adaptive management through stakeholder cooperation because it enables businesses to promote ecosystems of cooperation that encourage multi-organisational partnerships (Hengst et al., 2020). Through leasing models, businesses deliver waste management equipment as a service while lowering operational expenses and enhancing the sustainability of waste operation management. Implementing such models faces challenges due to the requirement for effective governance and regulatory support, as Langseth (2023) explains. The research indicates that working together between stakeholders represents a promising method to tackle South Africa's waste-handling market challenges.

In conclusion, the research findings present a comprehensive evaluation of new sustainable business models to enhance South African waste-handling equipment management strategies. The renewable energy sector can enhance waste-handling equipment businesses by using circular economy frameworks alongside sustainability concepts and waste-to-energy innovations along with collaborative strategies and modern technologies. However, the implementation success of these models remains dependent on solving three significant barriers, including limited infrastructure solutions as well as regulatory challenges, and the requirement for stakeholder joint efforts. The study incorporates circular economy alongside sustainability theory and innovation diffusion theory to expose essential

knowledge about South Africa's waste-handling market development prospects. Through this study, researchers have answered the research question by evaluating innovative and sustainable business models that could reshape the market alongside their necessary practical implementation needs. While the findings mostly confirm the theories, they also highlight practical constraints that need to be addressed to ensure full implementation.

### 6.6 Chapter Summary

The research findings about South Africa's waste-handling equipment manufacturing sector explore business models, technological advancements, regulatory effects, AI, and Data-driven technology while analysing potential innovative practices. The findings validate previous research work by establishing both matching and contrasting elements with global industry trends. The chapter seeks to establish an exhaustive grasp of operation influencing factors that will help develop improvement strategies for this sector.

South African waste-handling equipment manufacturers operate through a combination of direct sales coupled with service contracts and customised products, according to results that concern the first research question. The production methods align with international business patterns because they promote service-oriented operations that maintain ongoing relationships with customers and recurring revenue streams. South African waste-handling equipment manufacturers are adopting circular economy principles, yet financial obstacles alongside technological obstacles limit their ability to deploy CE principles into product design fully. The research demonstrates that South African manufacturers encounter serious obstacles when trying to adopt sustainable business practices. Strategic partnerships form a primary business strategy along with local manufacturing, which improves market penetration, but suppliers face logistical challenges when obtaining components from outside sources.

Technological advancement plays an essential role in the analysis of the second research question. The waste handling manufacturing sector in South Africa is experiencing transformative business model changes because of technological advancements like industrial automation and IoT, along with robotics systems. The implementation of innovative solutions faces two main barriers: initial expense requirements and limited technical understanding from operators. The adoption of eco-friendly solutions faces financial barriers as well as regulatory support limitations, even though sustainability theories and circular economy principles match the importance of green technology deployment. Important

obstacles continue to inhibit progress even though the technological environment is experiencing active development.

Business models are strongly influenced by regulatory requirements and environmental policies, which form the basis of the third research inquiry. Environmental regulations, together with compliance requirements, drive innovative development in different areas, including energy efficiency, recycling, and waste separation. However, businesses encounter sustained challenges because of the high costs of following regulatory requirements, which have little backing from relevant policies. Multiple factors derived from regulation act as a direct trigger for innovation within the business world yet have the constraint of balancing mandatory regulatory requirements for and maintaining profitability.

The fourth aspect of this investigation analyses how data-driven AI-enabled models function within the industry. Research findings confirm that AI, together with data analytics solutions, are progressively implemented for predictive maintenance, route optimisation, and operational efficiency purposes. Technology models work to decrease operational interruptions and enhance equipment durability while improving service operations, thus aligning with the sustainability targets of the circular economy. However, there are challenges to integrating these technologies into existing systems and the necessary shortage of qualified workers. The industrial sector can transform through the implementation of artificial intelligence systems despite the challenges that need to be overcome.

Lastly, the research businesses explore different novel sustainable business approaches in the fifth research question. The study presents circular economy principles and renewable energy integration alongside advanced technologies as foundational strategies to achieve sustainable waste handling improvements in South Africa's market. South African business models face challenges in implementation due to inadequate infrastructure, high expenses, and regulatory obstacles. The participants recommend forming cooperative business partnerships between manufacturers, waste management firms, and government entities to tackle existing obstacles.

Therefore, the research answers all five questions by identifying current business models, technological advancements, regulatory influences, AI and Data analytics, and innovative strategies. The findings reveal that while South African manufacturers are making strides towards sustainability and innovation, challenges such as financial constraints, technological gaps, and regulatory hurdles must be addressed to unlock the full potential of the sector.

The table 6.8 provides a concise summary of the research questions, corresponding themes, and the theoretical contributions made by each theme

Table 6-8: Summative Table of Research Questions, Themes, and Theoretical Contributions

| Research Questions (RQs) | Themes | Theoretical Contribution |
|---|---|---|
| RQ 1: What are the current business models and market operations of South African waste handling equipment manufacturers? | Theme 1.1: Business Model Variations | Confirms |
| | Theme 1.2: Innovation and Sustainability | Confirms and extends |
| | Theme 1.3: Customer Relationship and Retention | Confirms |
| | Theme 1.4: Local Manufacturing vs Importation | Contrasts |
| | Theme 1.5: Strategic Partnerships | Confirms |
| RQ 2: How do recent technological advancements and trends in waste handling equipment impact business models in South Africa? | Theme 2.1: Technological Integration | Confirms |
| | Theme 2.2: Sustainability Trends | Confirms |
| | Theme 2.3: Operational Efficiency | Confirms |
| | Theme 2.4: Predictive Maintenance | Confirms |
| | Theme 2.5: Customer-Centric Innovations | Extends |
| RQ 3: How do regulatory requirements and environmental policies influence the business models of South African waste handling equipment manufacturers? | Theme 3.1: Compliance with Regulations | Confirms |
| | Theme 3.2: Innovation and Market Opportunities | Confirms and Extends |
| | Theme 3.3: Waste Management and Recycling | Confirms |
| | Theme 3.4: Sustainability and Green Technology | Confirms |
| | Theme 3.5: Challenges and Cost-Effectiveness | Confirms |
| RQ 4: How are data-driven and AI-enabled models adopted in South Africa's waste handling sector, and what are their impacts and challenges? | Theme 4.1: Adoption of Data-Driven and AI Technologies | Confirms |
| | Theme 4.2: Advantages of Data-Driven and AI Models | Confirms |
| | Theme 4.3: Data and AI Adoption Obstacles | Contrasts |
| | Theme 4.4: Industry-Specific Applications | Confirms |
| | Theme 4.5: Future Trends and Development | Extends |
| RQ 5: What innovative, sustainable business models can be proposed for the South African waste handling market, and how effective are they? | Theme 5.1: Circular Economy and Modular Equipment | Confirms |
| | Theme 5.2: Renewable Energy Integration | Confirms |
| | Theme 5.3: Advanced Technology and Automation | Confirms |
| | Theme 5.4: Waste-to-Energy Solutions | Confirms |
| | Theme 5.5: Collaborative Business Models | Confirms |

Table 6.8 summarise that most of the identified study themes support/confirm existing research findings which demonstrates the practical value of established theories in South African waste-handling equipment management. Notably, a few themes extend or contrast

existing theories, showing where this research contributes new insights or challenges current thinking. The research produces new understanding of established theories through selecting conceptual developments yet also uses other findings to test and modify current scientific models. The research themes "Innovation and Sustainability" together with "Future Trends and Development" validated/confirm existing notions through specific analysis which highlighted South African industry conditions. The theme "Local Manufacturing vs Importation" contrast or stands in opposition to established research by showing how operational risks from imported components affect local operations despite other studies not addressing this aspect.

# CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

## 7.1 Introduction

This chapter presents the final recommendations and concludes the research. The section evaluates research results to determine findings that respond to the research problem. The chapter delivers essential recommendations to different stakeholders and their resulting implications. The evaluation describes study limitations together with academic recommendations for upcoming research investigations.

## 7.2 Overview of Study and Its Importance

The research analysed South African waste-handling equipment manufacturer business models, paying attention to their implementation of circular economy and sustainable approaches. The combination of urban and rural infrastructure inequality in South Africa poses obstacles to the implementation of new waste management solutions (Fatimah et al., 2020). Knowing how these difficulties affect business operations proves essential since manufacturers usually maintain outdated linear business models. The research analysed whether sustainable circular economic approaches could bring simultaneous environmental and profit advantages. By assessing South African manufacturing opportunities and challenges, the study guides the development of a sustainable waste-handling industry with greater operational efficiency. These research insights will instruct the industry to develop progressive business models that promote sector expansion.

This investigation transcends local manufacturing problems since it examines international waste-handling sector developments alongside sustainability and innovative trends. Studies of international circular and sustainability models found success in Germany, Japan, and the United States (Ma et al., 2019). Local manufacturers in South Africa can use these models to create an innovation strategy that addresses environmental regulations. The study, focused on integrating new business models, arrives at a perfect time due to the expanding global emphasis on circular economy principles and sustainability practices (Geissdoerfer et al., 2021). The study works to unite theoretical sustainability practice with on-ground implementation in South African conditions, which yields vital knowledge for both regulatory and industrial actors, as well as manufacturing companies' representatives.

## 7.3 Research Context and Its Significance.

The waste management sector in South Africa embraces continuous pressure for sustainable practices and innovative technological solutions due to rising environmental factors and official regulatory requirements. The traditional linear waste management

systems used for waste disposal no longer provide adequate solutions to confront increasing waste management challenges (Fatimah et al., 2020). South African manufacturers move toward Circular Economy principles alongside global trends by implementing sustainable models that enhance efficiency alongside cost reduction (Forti et al., 2020). The present shift represents a necessary transformation because South Africa faces different infrastructure challenges that affect its current waste management systems (Fatimah et al., 2020). This research evaluates how waste equipment manufacturers in the local sector could implement CE principles, which would enhance their business strategies while achieving environmentally beneficial results.

More so, the global waste management realm is changing because of advanced technologies, including automation, artificial intelligence (AI), and data analytics, which simultaneously provide advantages while also posing challenges to most South African manufacturers. These advanced technologies enhance operational efficiency, reduce waste output, and optimise resource management (Nascimento et al., 2019). South African manufacturers face barriers to technology adoption because of high implementation costs along with a shortage of qualified professionals and low technological capabilities in the area (Guldmann & Huulgaard, 2020). The waste management sector requires AI-driven models and data-centric solutions at this point because these approaches support sustainability alongside efficiency targets, according to Bányai et al.(2019).The research analyses these new technologies to provide valuable insights into their implementation success within South Africa's prevalent conditions of limited infrastructure and financial constraints.

The results from this research hold significant value for waste-handling manufacturers operating in South Africa because the country supports sustainable practices yet creates hurdles during the manufacturing stage. The National Environmental Management: Waste Act sets environmental compliance standards that place financial and operational strains on organisations (Fatimah et al., 2020; Munsamy, 2022). Manufacturers have to manage such regulatory challenges by finding a balance between product innovation and regulatory requirements. The research shows that organisations need methods that pass regulatory criteria and simultaneously benefit long-term sustainability. The research results will guide policy recommendations to assist manufacturers and policymakers in finding compatible circular economy implementation approaches that support profitability goals. The above provides for the research context.

### 7.4 Existing Knowledge and Knowledge Gaps

Research shows how circular economy principles contribute to waste-handling equipment manufacturers both globally and in specific areas like Germany and Japan since sustainability models form central components of those industries (Geissdoerfer et al., 2017). South African waste-handling manufacturers have begun implementing circular economy principles, yet an extensive adoption of complete circular economy models stays restricted because of funding limitations, regulatory complications, and technological barriers (Pieroni et al., 2021). Although there is growing interest in adopting circular economy practices, their implementation in South Africa's waste-handling sector is still in the early stages, suggesting a need for further research into overcoming these obstacles.

Sustainability theory establishes a complete framework to achieve a balance between environmental aspects, economic elements, and societal measures in business operations (Nocenzi & Sannella, 2020). Manufacturers operating within South Africa now focus more on acquiring energy-efficient technologies along with environmentally sustainable materials. Lack of government support and financial constraints act as barriers to the widespread adoption of these technologies because they are too costly (Munsamy, 2022). Sustainable practices should merge better with local business operations because this would motivate long-term investments in sustainability to create competitive and efficient waste-handling businesses.

Waste management business models worldwide are experiencing substantial changes due to advancements in AI and IoT technologies, which enhance service quality and operational efficiency (Sikander, 2024). High implementation costs, combined with the limited availability of specialised skills, create significant barriers that prevent these technologies from transforming the industry in South Africa (Rusch et al., 2023). As such, research needs to develop affordable implementation strategies for local manufacturers to adopt waste management technology in order to support their sustainable business growth.

Waste-handling equipment manufacturing can benefit from integrating data-driven and AI-enabled models, although implementing them faces numerous challenges. The application of these models by manufacturers allows them to enhance their operations through improved lifecycle duration and sustainable business practices (Ferasso et al., 2020). South Africa's waste-handling sector must solve data privacy and change resistance issues to achieve complete implementation of these models. A comprehensive assessment of model expansion possibilities within local requirements is essential to guarantee their successful implementation.

### 7.5 Research Questions Answered

This study addresses five key research questions, each focusing on different aspects of business models for waste-handling equipment manufacturers in South Africa.

**Research Q1: What are the current business models and market operations of South African waste-handling equipment manufacturers?**

Results show that South African waste handling manufacturers conduct their business by using direct sales channels alongside service contracts while they mainly focus on customising their products. This customer retention approach matches global service-based sales models, which focus on generating repeated revenue streams (Agrawal et al., 2022). However, South African waste-handling manufacturers encounter barriers to implementing sustainable practices due to limited financial resources and the scarcity of advanced technology. The present gaps between international best practices and domestic operational situations require immediate resolution to enable future company development and operational efficiency.

**Research Q2: How do recent technological advancements and trends in waste-handling equipment impact business models in South Africa?**

South African waste-management businesses experienced fundamental changes in their business operations through technological developments in automation, robotics, and IoT technology. These innovations, which follow global sustainability trends, raise operational efficiency and lower costs (Nascimento et al., 2019). The adoption of new technologies faces challenges because of their initial prices and the shortage of qualified personnel in the labor force. Manufacturers should embrace these technological integrations because they create important prospects to boost their market standing and environmental performance despite existing challenges.

**Research Q3: How do regulatory requirements and environmental policies influence the business models of South African waste-handling equipment manufacturers?**

Regulatory requirements and environmental policies become vital factors for business model design because they motivate manufacturers to develop sustainable practices through innovative approaches. The National Environmental Management: Waste Act regulation has stimulated businesses to build eco-friendly equipment and green technologies (Mouton, 2020). Factory operators face substantial financial hurdles when implementing

environmental compliance because the government provides limited backing for green technology integration.

**Research Q4: How are data-driven and AI-enabled models adopted in South Africa's waste handling sector, and what are their impacts and challenges?**

Results show that South Africa's waste-handling manufacturing sector uses AI and data-driven models to enhance operational efficiency and has started to improve predictive maintenance and customer relationship management. The technologies operate in line with Circular Economy principles through equipment lifetime extension while improving waste management processes (Geissdoerfer et al., 2017). High integration expenses alongside deficient skilled employees represent major challenges that prevent broader implementation in practice. These models require investment in infrastructure development and workforce training to fully realise their potential.

**Research Q5: What innovative, sustainable business models can be proposed for the South African waste handling market, and how effective are they?**

The South African waste-handling market will undergo transformation through business models that integrate Circular Economy principles, renewable energy, and modular equipment designs. Such business models help businesses minimise waste and keep products active longer while reducing environmental consequences. The adoption of these models faces barriers because South Africa lacks sufficient infrastructure and regulatory support (Godfrey et al., 2021). Sustainable growth in the sector depends on the collaboration between manufacturers and government-waste management firms to resolve existing obstacles.

### 7.6 Research Methodology and Approach

An exploratory design structure served this investigation to study innovative business models in waste handling equipment manufacturing. The exploratory design matched well with the understanding of participant viewpoints because it combined semi-structured interviews to identify new thematic patterns (Creswell & Poth, 2016). Interpretivist philosophy served as the chosen research philosophy because this philosophy focuses on uncovering the unique perspectives of members within the waste-handling manufacturing sector (Williamson, 2021). An inductive approach was employed to allow new theories and concepts to emerge from the data collected during the research process, rather than testing pre-existing theories (Bryman, 2022). This study employed qualitative research methods due to their ability to extract in-depth field knowledge from experts regarding the sustainability

and innovation dynamics of the sector (Creswell & Poth, 2016). Six companies participated in this multi-case strategy to show different methods of sustainable practices and business model creation (Diop & Liu, 2020).

Data collection through semi-structured interviews with 12 managerial experts was conducted using convenience sampling (Saunders & Lewis, 2018). The researcher employed reflective thematic analysis to correctly interpret the meanings of subjective data (Braun & Clarke, 2019). All participants provided voluntary consent, and the research maintained ethical security measures that protected participant anonymity and included their free consent to participate. The study utilised data triangulation in combination with methods to minimise self-report biases, despite sample restrictions (Fetzer, 2022). Through this study's design, researchers produced essential knowledge regarding innovative business methods for South African waste-handling manufacturing equipment operations.

### 7.7 **Summary of Findings**

The research provides a significant understanding of the waste-handling equipment sector in South Africa while investigating different business models, technological advancements, regulatory frameworks, and sustainability practices. Results show that South African waste management equipment manufacturers operate using multiple business strategies, including product customisation, direct sales, and service contracts. These businesses, by focusing on Local manufacturing and strategic partnerships, enable South African manufacturers to operate both locally and globally for sustainable solutions. The research demonstrates multiple dimensions of resilience in this particular sector.

Technological advancements have had transformative impacts on this sector. Findings indicate that combining IoT technology, automation features, and eco-friendly practices leads to improvement in operation efficiency and sustainability. It was established that establishing real-time monitoring together with predictive maintenance and automation by waste handling equipment manufacturers leads both to better industrial processes and strengthened customer relationships. The newly developed innovations proved essential for managing rising requirements in sustainable waste management practices.

Government regulations, together with environmental policies, proved essential in shaping business practices. It was established that manufacturers need to follow strict standards alongside business profitability yet get opportunities from developing environmentally friendly technologies and recycling systems. Manufacturers needed to adopt innovative strategies while following energy-saving product designs and waste separation standards through the examined policies.

The study analysed the implementation of AI-powered and data-driven models. Operational optimisation through such technological integration, along with its cost-reduction benefits, continues to face hurdles due to a lack of qualified personnel and significant startup expenses. Nevertheless, adopting data analytics and AI is proving transformative, contributing to long-term growth and boosting overall efficiency.

Lastly, the sector has shown commitment to sustainability by transitioning towards circular economy principles alongside renewable energy solutions. New business models combine efforts to enhance energy efficiency while building relationships between companies and local authorities that create prospects for industry advancement.

### 7.8 Contribution to Current Scholarly Debate

The application of Circular Economy principles, together with sustainability approaches to South African waste-handling equipment manufacturing, enhances existing research discussions about business sustainability practices. This research validates sustainability theory because it shows how industry producers can protect the environment through practices including energy-saving technology and material recycling (Nocenzi & Sannella, 2020). These research findings demonstrate the necessity of aligning manufacturing processes with global sustainability trends and provide essential knowledge about sustainable technology adoption by South African industries. However, South African businesses need policies that encourage transformation due to financial hurdles and insufficient regulatory backing despite these obstacles remaining key barriers to extensive adoption.

This research enhances knowledge about innovation diffusion theory (Teece, 2010), and it explores the implementation hurdles and benefits linked to data-driven and AI-enabled business model adoption. The empirical evidence shows that technological progress led by AI, IoT, and automation extends product lives and enhances business cycle efficiency, yet hardware costs, together with the lack of qualified staff, limit system-wide adoption (Rusch et al., 2023). Our comprehension expands about innovation implementation patterns in waste management services for developing nations thanks to these findings. The solution requires industry leaders and policy developers to work together with technology vendors to promote the broad adoption of powerful new technologies.

The research results confirm that regulatory frameworks determine how business models must develop. The research findings maintain earlier academic studies that show how government directives, together with environmental rules, prompt eco-friendly innovation (Mouton, 2020). Research findings show that although South African manufacturing

companies feel pressure from existing ecological legislation such as the National Environmental Management: Waste Act, they hesitate to fully embrace sustainability practices due to insufficient regulatory enforcement alongside meagre financial support from these regulations. South African authorities need to enhance regulatory measures that decrease manufacturers' financial risks to accomplish effective policy execution and drive widespread green technology adoption.

### 7.9 Limitations of the Study

Study limitations relate to aspects that can affect the validity and generalisability of the research findings (Theofanidis & Fountouki, 2018). Some limitations in this study of new business models for waste handling manufacturing equipment include sample size; this study only focus on waste handling equipment manufacturers in South Africa, and therefore, it is unlikely to provide more generalisable results for the more significant global manufacturing industry. Furthermore, the data was also collected by self-reports from manufacturers managers and might be biased in some way. To overcome these shortcomings, the following strategies was used: data triangulation by participants' self-reports and data collected online, and participants' anonymity helped to minimise biases inherent in the findings (Fetzer, 2022).

### 7.10 Implications and Recommendations

#### 7.10.1 Practical Implications

The research highlights that South African waste-handling equipment producers need to transform their business approaches in response to changing regulations, technological trends, and growing sustainability concerns. Waste handling equipment manufacturers who adopt circular economy principles together with innovation-based methods need to solve the identified financial gaps and technological shortcomings. Policymakers should develop supportive frameworks and economic programs that help companies adopt green technologies and sustainable operating protocols. Additionally, Waste handling equipment manufacturers will achieve better market penetration when they create alliances with municipal waste providers.

#### 7.10.2 Recommendations for Waste Handling Manufacturers

Business survival requires manufacturers to make digital technology implementation like IoT and AI their top priority for operational optimisation and cost reduction. Intelligent waste management systems funded by investments provide improved customer satisfaction and sustainability improvements. Companies should examine modular designs for waste-

handling equipment because these match CE principles through their ability to increase product existent time and minimise resource usage. Manufacturers must solve the problems of high initial expenses and worker qualification deficits if they plan to achieve these advantages in full.

### 7.10.3 Recommendations for Stakeholders

Support from regulatory organisations should come through financial programs that provide tax advantages and subsidy benefits for manufacturers to adopt sustainable systems. Partnerships between producers and industry organisations enable joint knowledge exchange as well as new creative approaches. Waste handling equipment manufacturers, together with waste management firms and municipal authorities, need to collaborate for infrastructure development and create a united approach to waste management practices. All stakeholders need to develop customer-focused models that establish sustained partnerships through specialised waste management solutions.

### 7.10.4 Recommendations for Future Research

Additional research is needed to identify all problematic barriers to manufacturers' adoption of sustainable technology and determine effective policy solutions. Analysis of AI and data-driven model adoption across regions would reveal vital scaling information about these innovations. Longitudinal research investigations will show how CE adoption influences the financial sustainability of manufacturers to evaluate their performance in South African.

## 7.11 Conclusion

The research investigated challenges and prospects related to implementing fresh business concepts for South African waste-handling equipment production that embraced sustainability methods and Circular Economy principles. Findings show that local manufacturers face several barriers to adopting sustainability practices due to financing limitations, technology gaps, and regulatory challenges. The manufacturing industry proves resilient by implementing innovation approaches that use IoT AI and modular design concepts to boost operational effectiveness and minimise environmental impact. The adoption of green technologies by local manufacturers requires government policies that offer increased support through targets and incentives in order to achieve their full potential. Further, the development of sustainable waste management through industry collaboration must include partnerships between manufacturers, stakeholders, and government policymakers. . The research enhances knowledge about sustainable business practices while demonstrating the necessity for ongoing technological investment to allow South African manufacturers to compete sustainably within evolving sectors.

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## APPENDICES

### Annexure A: Interview Schedule

Gordon Institute of Business Science
University of Pretoria

1. What are the current business models of South African waste-handling equipment manufacturers and their market operations?

2. How do recent technological advancements and trends in waste-handling equipment impact business models in South Africa?

3. How do regulatory requirements and environmental policies influence the business models of South African waste-handling equipment manufacturers?

4. How are data-driven and AI-enabled models adopted in South Africa's waste-handling sector, and what are their impacts and challenges?

5. What innovative, sustainable business models can be proposed for the South African waste handling market, and how effective are they?

**Appendix B: Participant Information and Consent**

Gordon Institute of Business Science
University of Pretoria

*I am currently a student at the University of Pretoria's Gordon Institute of Business Science and completing my research in partial fulfilment of an MBA.*

I am conducting research on **New Business Models for Waste Handling Equipment Manufacturers** as part of my MBA 2024. Our interview is expected to last approximately 30 to 60 minutes and will help us understand how new business models affect South African waste-handling equipment manufacturers. **Your participation is entirely voluntary, and you can withdraw at any time without penalty.**

By signing this letter, you are indicating that you have given permission for the following:

- The interview to be recorded.
- Verbatim quotations from the interview to be used in the report, provided they are not identified with your name or that of your organisation.
- The data to be used as part of a report that will be publicly available once the examination process has been completed.
- All data to be reported and stored without identifiers.

If you have any concerns, please contact my supervisor or me. Our details are provided below.

Researcher Name:

Email:

Phone:

Research Supervisor Name:

Email:

Participant name: _____

Signature of participant: _____

Date: _____

Signature of researcher: _____

Date: _____

## Appendix C: CONSISTENCY MATRIX

| RESEARCH QUESTION(S) | LITERATURE REVIEW | INTERVIEW | ANALYSIS |
|---|---|---|---|
| **RQ1.What are the current business models and market operations of South African waste-handling equipment manufacturers?** | Fatimah et al., 2020; Ma et al., 2019; Geissdoerfer et al., 2021; Agrawal et al., 2022 | Questions: 1-3 | Thematic analysis to explore the key business models used by South African waste-handling manufacturers, with a focus on direct sales, service contracts, and customisation, as well as the financial and technological barriers they face. |
| **R2.How do recent technological advancements and trends in waste-handling equipment impact business models in South Africa?** | Nascimento et al., 2019; Rusch et al., 2023; Sikander, 2024 | Questions: 4-6 | Thematic analysis to assess the role of technological innovations (IoT, AI, automation) in shaping business models in South Africa, and how these technologies impact operational efficiency and cost reduction despite barriers like high implementation costs and lack of skilled personnel. |
| **RQ3.How do regulatory requirements and environmental policies influence the business models of South African waste-handling equipment manufacturers?** | Munsamy, 2022; Mouton, 2020 | Questions: 7-9 | Thematic analysis to understand the influence of regulatory frameworks, such as the National Environmental Management: Waste Act, on business model adaptation in South Africa and the challenges posed by insufficient regulatory support and financial constraints. |
| **RQ4.How are data-driven and AI-enabled models adopted in South Africa's waste-handling sector, and what are their impacts and challenges?** | Bányai et al., 2019; Ferasso et al., 2020 | Questions: 10-12 | Thematic analysis to investigate the adoption of AI-powered and data-driven models in South Africa's waste-handling sector, focusing on operational optimisation, predictive maintenance, and customer relationship management, as well as the barriers of high initial costs and lack of skilled workers. |
| **RQ5.What innovative, sustainable business models can be proposed for the South African waste-handling market, and how effective are they?** | Geissdoerfer et al., 2017; Godfrey et al., 2021 | Questions: 13-15 | Thematic analysis to propose new sustainable business models integrating Circular Economy principles, renewable energy, and modular design, while assessing their effectiveness within the constraints of infrastructure challenges and regulatory limitations in South Africa. |

Appendix D: **Master Table**

| Research Question | Theme | Sub-theme | Code |
|---|---|---|---|
| **RQ1: Current business models and market operations** | 1. Business Model Variations | 1.1 Direct Sales vs Service Contracts | Sales, Service Models |
| | | 1.2 Product Customization and Tailored Solutions | Customization, Tailored Solutions |
| | 2. Innovation and Sustainability | 2.1 Product Innovation | Innovation, New Products |
| | | 2.2 Environmental and Circular Economy Practices | Sustainability, Circular Economy |
| | 3. Customer Relationship and Retention | 3.1 After-Sales Services | After-sales, Customer Support |
| | | 3.2 Long-Term Client Partnerships | Client Relationships, Retention |
| | 4. Local Manufacturing vs Importation | 4.1 Advantages of Local Manufacturing | Local Manufacturing, Domestic Production |
| | | 4.2 Challenges with Imported Equipment | Imported Equipment, Supply Chain |
| | 5. Strategic Partnerships and Market Reach | 5.1 Industry and Municipal Partnerships | Partnerships, Industry Relations |
| | | 5.2 Supplier and Dealer Relationships | Supplier Relations, Distribution Networks |
| **RQ2: Technological advancements and trends** | 1. Technological Integration | 1.1 IoT and Smart Equipment | IoT, Smart Technology |
| | | 1.2 Automation and Robotics | Automation, Robotics |
| | 2. Sustainability Trends | 2.1 Eco-friendly Equipment | Green Equipment, Eco-friendly |
| | | 2.2 Green Manufacturing Processes | Green Manufacturing, Sustainability |
| | 3. Operational Efficiency | 3.1 Automation in Manufacturing | Operational Efficiency, Automation |
| | | 3.2 Digitalization and Data-Driven Operations | Digitalization, Data Management |
| | 4. Predictive Maintenance | 4.1 Real-time Monitoring and Diagnostics | Predictive Maintenance, Monitoring |
| | | 4.2 Reduced Downtime and Service Optimization | Downtime, Service Efficiency |
| | 5. Customer-Centric Innovations | 5.1 Smart Waste Management Systems | Smart Systems, Waste Management |
| | | 5.2 Improved Customer Relationship Management (CRM) | CRM, Customer Service |

| | | | |
|---|---|---|---|
| **RQ4: Adoption and impact of data-driven and AI-enabled models** | 1. Adoption of Data-Driven and AI Technologies | 1.1 Data Analytics Integration | Data Analytics, Integration |
| | | 1.2 AI Adoption in Equipment | AI, Equipment Adoption |
| | 2. Benefits of Data-Driven and AI Models | 2.1 Operational Efficiency | Efficiency, AI Models |
| | | 2.2 Cost Reductions | Cost Reduction, Efficiency |
| | 3. Challenges in Data and AI Adoption | 3.1 Integration with Existing Systems | System Integration, AI Challenges |
| | | 3.2 Skilled Labor Shortage | Skilled Labor, Workforce |
| | 4. Industry-Specific Applications | 4.1 Predictive Maintenance | Predictive Maintenance, AI |
| | | 4.2 Route Optimization | Route Optimization, AI |
| | 5. Future Trends and Development | 5.1 Innovation and Market Growth | Innovation, Market Growth |
| | | 5.2 AI in Waste Sorting | AI, Waste Sorting |
| **RQ5: Innovative and sustainable business models** | 1. Circular Economy and Modular Equipment | 1.1 Modular Equipment Design | Modular Design, Circular Economy |
| | | 1.2 Circular Economy Principles | Circular Economy, Sustainability |
| | 2. Renewable Energy Integration | 2.1 Solar-Powered Equipment | Renewable Energy, Solar Power |
| | | 2.2 Energy-Efficient Equipment | Energy Efficiency, Sustainable Equipment |
| | 3. Advanced Technology and Automation | 3.1 Smart Waste Management Systems | Smart Waste Systems, Automation |
| | | 3.2 AI and IoT Integration | AI Integration, IoT |
| | 4. Waste-to-Energy Solutions | 4.1 Waste Conversion to Energy | Waste-to-Energy, Renewable Energy |
| | | 4.2 Energy Efficiency | Energy Efficiency, Waste-to-Energy |
| | 5. Collaborative Business Models | 5.1 Leasing and Service Models | Leasing Models, Business Collaboration |
| | | 5.2 Partnerships with Local Governments | Government Partnerships, Collaboration |

**THE END**