An Econometric Analysis of the Cost of Fruit and Vegetable Waste in Retail Operations in Durban City, KwaZulu-Natal Province

by

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“An Econometric Analysis of the Cost of Fruit and Vegetable Waste in Retail Operations in Durban City, KwaZulu-Natal Province”

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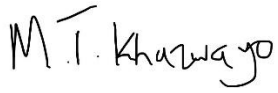

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Quantification of Costs of Fruit and Vegetable Waste in Retail Operations: Evidence from Durban, South Africa

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ABSTRACT

Food waste has become a major global sustainability challenge with significant environmental, economic, and social implications. In South Africa, approximately 10.3 million tonnes of food are wasted annually, resulting in substantial economic losses across the food supply chain. Despite increasing concern regarding food waste, limited empirical research has focused on the economic costs and operational determinants of fruit and vegetable waste within retail operations particularly in urban contexts such as Durban.

This study aimed to quantify the cost and monetary value of fruit and vegetable waste in retail operations in Durban City, KwaZulu-Natal Province and to identify the factors influencing waste generation. The study further sought to propose pathways for reducing fruit and vegetable waste within retail environments. A positivist research paradigm and quantitative cross-sectional research design were adopted. Data was collected from 100 selected retail stores located within the Durban Central Business District using structured questionnaires, waste composition analysis, and direct observation methods. Cluster sampling was used to group retail stores within four precincts of Durban CBD. Data were analysed using descriptive statistics, multiple linear regression and ordinal logistic regression through SPSS and Microsoft Excel.

The findings revealed that leafy vegetables constituted the highest category of fruit and vegetable waste while berries generated relatively lower waste volumes but higher monetary losses due to their high market value. The multiple regression model indicated that the predictor variables collectively explained a significant proportion of the variation in food waste costs (R^2=0.971, $p<0.001$). However, at the individual level, only the total quantity of fruits and vegetables sold per month significantly influenced food waste costs, while landfill disposal costs were not statistically significant independent predictor. The ordinal logistic regression results showed that none of the operational predictor variables independently explained food waste generation, suggesting that food waste within retail environments is systemic and multifactorial. Retailers identified infrastructure limitations, handling practices, demand forecasting challenges, and awareness as important contributors to food waste generation. The study

contributes to the limited body of knowledge on retail fruit and vegetable waste quantification within South Africa and provides evidence-based recommendations aligned with the National Waste Management Strategy (NWMS). The study recommends integrated interventions focusing on awareness, improved planning and forecasting, infrastructure investment, redistribution initiatives and technology-based waste management systems to reduce fruit and vegetable waste within retail operations.

Keywords: Fruits and vegetables, cost quantification, retail operations, food waste, waste management, South Africa

ISIFINYEZO

Imfucuza yokudla isibe yinselele enkulu yokuzinza emhlabeni wonke enemiphumela ebalulekile kwezemvelo, kwezomnotho, kanye nakwezenhlalo. ENingizimu Afrika, cishe amathani ayizigidi eziyi-10.3 okudla ayachithwa minyaka yonke, okuholela ekulahlekelweni okukhulu kwezomnotho kulo lonke uchungechunge lokuhlinzekwa kokudla. Naphezu kokukhathazeka okwandayo mayelana nemfucuza yokudla, ucwaningo olulinganiselwe olusekelwe emibonweni luye lwagxila ezindleleni zomnotho kanye nasezicini zokusebenza kwemfucuza yezithelo nemifino emisebenzini yokuthengisa ikakhulukazi ezindaweni zasemadolobheni njengeTheku.

Lolu cwaningo luhlose ukulinganisa izindleko kanye nenani lemali lemfucuza yezithelo nemifino emisebenzini yokuthengisa eDolobheni laseTheku, eSifundazweni saKwa-Zulu-Natali kanye nokuhlonza izici ezithonya ukukhiqizwa kwemfucuza. Ucwaningo luqhubeke nokuzama izindlela zokunciphisa imfucuza yezithelo nemifino ezindaweni zokuthengisa. Kwamukelwa indlela yokucwaninga ekhuthazayo kanye nomklamo wocwaningo oluhlanganisa izingxenye eziningana. Idatha yaqoqwa ezitolo zokuthengisa eziyi-100 ezikhethiwe eziseSifundeni Sebhizinisi Esiphakathi saseThekwini kusetshenziswa imibuzo ehlelekile, ukuhlaziywa kokwakheka kwemfucuza, kanye nezindlela zokubuka ngqo. Ukusampula kweqembu kwasetshenziswa ukuqoqa izitolo zokuthengisa ngaphakathi kwezindawo ezine ze-CBD yaseThekwini. Idatha yahlaziywa kusetshenziswa izibalo ezichazayo, ukuhlehla okuqondile okuningi kanye nokuhlehla kwe-ordinal logistic nge-SPSS kanye ne-Microsoft Excel.

Okutholakele kwembule ukuthi imifino enamaqabunga yakha isigaba esiphezulu semfucuza yezithelo nemifino kuyilapho amajikijolo ekhiqiza inani eliphansi lemfucuza kodwa elahlekelwa kakhulu yimali ngenxa yenani lawo eliphezulu lemakethe. Imodeli yokubuyela emuva okuningi ibonise ukuthi iziguquguquli zokubikezela zichaze ingxenye enkulu yokwehluka kwezindleko zemfucuza yokudla ($R2=0.971$, $p<0.001$). Kodwa-ke, ezingeni lomuntu ngamunye, inani eliphelele lezithelo nemifino ethengiswayo ngenyanga kuphela elithonye kakhulu izindleko zemfucuza yokudla, kuyilapho izindleko zokulahla imfucuza zazingeyona into ebikezela ngokuzimela ebaluleke kakhulu ngokwezibalo. Imiphumela yokubuyela emuva kwe-ordinal logistic ibonise ukuthi azikho iziguquguquli zokusebenza ezichaza ngokuzimela ukukhiqizwa

kwemfucuza yokudla, okuphakamisa ukuthi imfucuza yokudla ezindaweni zokuthengisa ihlelekile futhi inezici eziningi. Abathengisi bathole imikhawulo yengqalasizinda, imikhuba yokuphatha, izinselele zokubikezela isidingo, kanye nokuqwashisa njengezinto ezibalulekile ezibangela ukukhiqizwa kwemfucuza yokudla. Ucwaningo lufaka isandla olwazini olulinganiselwe mayelana nokulinganiswa kwemfucuza yezithelo nemifino ezitolo eNingizimu Afrika futhi lunikeza izincomo ezisekelwe ebufakazini ezihambisana ne-National Waste Management Strategy (NWMS). Ucwaningo luncoma ukungenelela okuhlanganisiwe okugxile ekuqwashiseni, ekuhleleni nasekubikezeleni okuthuthukisiwe, ekutshalweni kwezimali kwengqalasizinda, ekusatshalalisweni kabusha kwezinhlelo kanye nezinhlelo zokuphathwa kwemfucuza esekelwe kubuchwepheshe ukuze kuncishiswe imfucuza yezithelo nemifino emisebenzini yokuthengisa.

Amagama angukhiye: Izithelo nemifino, ukulinganiswa kwezindleko, imisebenzi yokuthengisa, imfucuza yokudla, ukuphathwa kwemfucuza, iNingizimu Afrika

OPSOMMING

Voedselvermorsing het 'n groot wêreldwye volhoubaarheidsuitdaging geword met beduidende omgewings-, ekonomiese en sosiale implikasies. In Suid-Afrika word ongeveer 10,3 miljoen ton voedsel jaarliks vermors, wat lei tot aansienlike ekonomiese verliese regdeur die voedselvoorsieningsketting. Ten spyte van toenemende kommer oor voedselvermorsing, het beperkte empiriese navorsing gefokus op die ekonomiese koste en operasionele determinante van vrugte- en groentevermorsing binne kleinhandelbedrywighede, veral in stedelike kontekste soos Durban.

Herdie studie het ten doel gehad om die koste en monetêre waarde van vrugte- en groentevermorsing in kleinhandelbedrywighede in Durban Stad, KwaZulu-Natal Provinsie, te kwantifiseer en die faktore wat afvalgenerering beïnvloed, teidentifiseer. Die studie het verder gepoog om paaie voor te stel vir die vermindering van vrugte- en groentevermorsing binne kleinhandelomgewings. 'n Positivistiese navorsingsparadigma en kwantitatiewe dwarssnitnavorsingsontwerp is aangeneem. Data is ingesamel van 100 geselekteerde kleinhandelwinkels in die Durban Sentrale Sakegebied deur gebruik te maak van gestruktureerde vraelyste, afvalsamestellingsanalise en direkte waarnemingsmetodes. Trossteekproefneming is gebruik om kleinhandelwinkels binne vier gebiede van Durban CBD te groepeer. Data is geanaliseer met behulp van beskrywende statistieke, veelvuldige lineêre regressie en ordinale logistiese regressie deur SPSS en Microsoft Excel.

Die bevindinge het aan die lig gebring dat blaargroente die hoogste kategorie van vrugte- en groente-afval uitmaak, terwyl bessies relatief laer afvalvolumes, maar hoër monetêre verliese as gevolg van hul hoë markwaarde, gegenereer het. Die meervoudige regressiemodel het aangedui dat die voorspellerveranderlikes gesamentlik 'n beduidende deel van die variasie in voedselafvalkoste verklaar het ($R2=0.971$, $p<0.001$). Op individuele vlak het slegs die totale hoeveelheid vrugte en groente wat per maand verkoop is, egter voedselafvalkoste beduidend beïnvloed, terwyl stortingsterreinverwyderingskoste nie statisties beduidende onafhanklike voorspeller was nie. Die ordinale logistiese regressie-resultate het getoon dat geeneen van die operasionele voorspellerveranderlikes onafhanklik die opwekking van voedselafval verklaar het nie, wat daarop dui dat voedselafval binne kleinhandelomgewings

sistemies en multifaktoriaal is. Kleinhandelaars het infrastruktuurbeperkings, hanteringspraktyke, vraagvoorspellingsuitdagings en bewustheid as belangrike bydraers tot die opwekking van voedselafval geïdentifiseer. Die studie dra by tot die beperkte hoeveelheid kennis oor die kwantifisering van kleinhandel-vrugte- en groente-afval in Suid-Afrika en verskaf bewysgebaseerde aanbevelings wat in lyn is met die Nasionale Afvalbestuurstrategie (NWMS). Die studie beveel geïntegreerde intervensies aan wat fokus op bewustheid, verbeterde beplanning en voorspelling, infrastruktuurbelegging, herverdelingsinisiatiewe en tegnologie-gebaseerde afvalbestuurstelsels om vrugte- en groentevermorsing binne kleinhandelbedrywighede te verminder.

***Sleutelwoorde**:* Vrugte en groente, kostekwantifisering, kleinhandelbedrywighede, voedselvermorsing, afvalbestuur, Suid-Afrika

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CBD- Central Business District

CGCSA -Consumer Goods Council of South Africa

COGTA- Department of Cooperative Governance and Traditional Affairs

CSIR - The Council for Scientific and Industrial Research

CSW- Cleansing and Solid Waste

DAFF - Department of Agriculture, Forestry and Fisheries

DFFE-Department of Forestry and Fisheries and the Environment

DSL- Dynamic Shelf -Life

DSW- Durban Solid Waste

EDTAE - KZN Department of Economic Development, Tourism and Environmental Affairs

EPA- Environmental Protection Agency

EU - European Union

F&V - Fruits and vegetables

FAO - Food and Agriculture Organisation

FFV - Fresh Fruits and Vegetables

FLW - Food Loss and Waste

FUSIONS-Food Use for Social Innovation by Optimising Waste Prevention Strategies

LCA -Life Cycle Assessment

LCC-Life Cycle Costing

NWMS - National Waste Management Strategy

SDG-Sustainable Development Goal

TPB-Theory of Planned Behaviour

TTI-Time-Temperature Indicator

UN - United Nation

UNDP-United Nations Development Programme

UNECE- United Nations Economic Commission for Europe

UNEP - United Nations Environment Programme

WWF - World Wildlife Fund

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1. BACKGROUND

Food waste remains a critical global issue with severe economic, social, and environmental impacts, particularly regarding fresh produce such as fruits and vegetables (Department of Agriculture, Forestry and Fisheries, 2020) and; (Food Agriculture Organisation, 2020). Globally, fruits and vegetables account for more than 40% of total food losses, primarily due to their perishable nature and stringent quality standards (FAO, 2020). Consequently, this places a burden not only on resources such as land, water, and energy but also contributes negatively to food insecurity (World Bank, 2020). From a microeconomic perspective, FAO (2020) estimates that the global economic costs of food loss and waste exceed USD 1 trillion annually, and this figure does not account for environmental damage and social consequences such as hunger and malnutrition.

The drivers of food waste vary in context (FAO, 2022). In high-income countries, retail operations contribute significantly to fresh produce waste due to overstocking, aesthetic rejections, and consumer demand for visually perfect produce (United Nations Development Programme, 2022). In contrast, the African Union (2022) and Todd & Faour-Klingbeil (2024) report similar findings regarding contributors to food waste in developing countries. However, these countries face additional, more severe contributing factors. These findings suggest that food waste reduction strategies should be context-specific and requires both behavioural and systemic interventions beyond generic waste-reduction campaigns.

Despite these contextual differences, studies reach similar conclusions about the factors contributing to food waste and the types of food that make up the largest share of waste. Some writers (Goodman-Smith et al., 2020; Mattsson & Williams, 2022) conclude that the most frequently wasted food commodities in retail operations include fruits, vegetables, meats, and bread.

United Nations Environment programme, (2021) highlights that retailers frequently discard large volumes of edible fruits and vegetables, because of strict cosmetic and quality standards Goodman-Smith et al. (2020) emphasise that this results in both

financial loss and increased carbon emissions. Studies in Europe and North America suggest that 8%-10% of food waste in the supply chain occurs at the retail level (Mmereki et al., 2023; UNEP, 2021).

In the African context, however, food waste patterns differ due to underdeveloped infrastructure, limited cold chain facilities, and inefficiencies in handling and logistics (African Union, 2022). Post-harvest losses in Africa can reach up to 50% of fresh produce, before reaching consumers (FAO et al., 2020). These inefficiencies create a significant economic burden and mainly impact small-scale producers and retailers, especially in urban areas where food security remains an issue (FUSIONS, 2020).

In South Africa, these losses occur within a context of increasing food insecurity, climate related agricultural pressures, rising food prices, and resources scarcity, which continues to threatens the sustainability of South Africa's food systems. The Council for Scientific and Industrial Research (CSIR, 2021) reported that food waste amounts to approximately 10.3 million tonnes per year, with fruits and vegetables accounting for approximately 44% of this figure (Oelofse et al., 2021). Aschemann-Witzel et al., (2021) state that the retail sector is a critical node in this chain, and Kazancoglu & Ipek (2022) indicate that inefficiencies in inventory management, spoilage, and packaging damage result in significant losses. These losses erode market value and impose a disproportionate financial burden on smallholders and retailers (World Wildlife Fund South Africa, 2020).

Durban, one of South Africa's largest cities and a key economic centre in the KwaZulu-Natal province, is governed by the eThekwini Municipality and hosts a diverse range of retail food operations, including supermarkets, fresh produce markets, and informal traders (Oelofse & Muswema, 2021). However, Dlomo (2021) notes that despite the diverse economic activities in the eThekwini Municipality, limited localised data quantify the financial impact of food waste in retail outlets within Durban. This knowledge gap hampers the development of targeted interventions to enhance supply chain efficiency and promote sustainable food systems at the city level (WWF, 2017; UNEP, 2021).

To address these challenges, South Africa adopted the National Waste Management Strategy (NWMS), which aims to divert waste from landfills and promote sustainable

practices such as recycling and recovery (Department of Forestry Fisheries and Environment, 2021). The NWMS achieves this by encouraging waste reduction through awareness programs and improved infrastructure, as well as fostering collaboration among stakeholders as a method to minimise waste (DFFE, 2021). DFFE & CSIR (2021) further explain that this framework recognises retail stores as key players in fighting food waste, especially for fresh produce, ensuring responsible management from procurement to sale. However, despite these national policy commitments, there is limited empirical data on how retail stores in Durban implement waste strategies, particularly for fruits and vegetables (Dlomo, 2021).

This study therefore seeks to address this knowledge gap by quantifying economic costs of fruit and vegetables waste within the Durban's retail sector and identifying pathways for reducing waste in alignment with sustainable food system objectives.

1.2. PROBLEM STATEMENT

In South Africa, an estimated 10.3 million tonnes of food are wasted annually imposing high costs on retailers, requiring careful management controls (Department of Agriculture Forestry and Fisheries, 2021). According to the WWF report (2020), the Council for Scientific and Industrial Research (CSIR) has estimated the financial value of food waste and loss in South Africa at R61.5 billion, accounting for 2.1% of the country's GDP.

Despite these striking statistics, the economic dimensions of food waste remain underexplored. UNEP (2021) also highlights that global and national studies increasingly document the environmental and social impacts of food waste. However, few studies have explicitly examined the economic costs associated with food waste disposal, despite this being a recognised as a major sustainability concern with the United Nations 2030 Agenda. This concern is also extensively discussed in the literature and by experts. However, these bodies of literature remain fragmented and focus on specific issues, such as waste quantification and waste causes, rather than on costs and the quantification of costs linked to food waste (Ishmeal, 2023). Goodman-Smith et al. (2020) and Hobson (2023) call for more studies to prioritise quantifying waste volumes and identifying drivers. Oelofse & Nahman (2022) further explain the massive food wastage that occurs when food does not meet retail standards or when complications

arise in the distribution process. Additionally, this represents a critical knowledge gap, given that retail operations are simultaneously sites of waste generation and potential hubs for redistribution or recovery initiatives (Olabode et al., 2025).

Studies in South Africa have quantified high national volumes of food loss and waste, particularly in urban retail environments. However, most analyses primary focus on tonnage estimates and the drivers of food waste without consistently translating losses into monetary value or examining the operational drivers of food waste (DFFE & CSIR, 2021). Despite increasing national and global concerns regarding food waste, little empirical evidence exists on the economic costs and operational determinants of fruit and vegetable waste at the retail level within urban contexts such as Durban. This highlights the need for local-level studies focusing on the financial and operational dimensions of retail food waste (CSIR, 2021). Research conducted in South Africa provides limited empirical evidence on fruit and vegetable waste at the retail level, mostly in urban contexts such as Durban (Dlomo, 2021). Durban faces challenges with large volumes of edible produce being wasted and food insecurity persisting among vulnerable populations (Drimie et al., 2025). Therefore, policymakers are encouraged to design targeted, cost-effective interventions aimed at reducing food waste within local retail systems.

Previous studies in South Africa have predominantly focused on household food waste, with comparatively limited empirical attention given to retail-level fruit and vegetable waste. A major challenge with food waste is that its costs are often underestimated and underreported (Carvalho et al., 2024), making them 'hidden' and unaddressed, which slows down investment in solutions (De Moraes & Colombo, 2020; FAO, 2022). Raising awareness of these 'hidden' costs could be a starting point as retailers begin to understand the scale of the problem and its effects (Eriksson & Rastergar, 2021). This study addresses these gaps by quantifying the volumes and economic value of fruit and vegetable waste in Durban's retail sector. Furthermore, the study proposes context specific pathway for reducing fruit and vegetable waste within Durban retail operations, aligned with global best practices and the National Waste Management Strategy (NWMS).

1.3. RESEARCH QUESTIONS

I. What types of fruit and vegetable are wasted by retailers in the City of Durban?
II. How much fruit and vegetables are wasted by retailers in the study area?
III. What are the drivers of fruit and vegetable waste in the study area?
IV. What are the mitigation strategies that could be adopted to reduce/eradicate fruit and vegetable wastage in the study area?

1.4. AIM AND OBJECTIVES OF THE STUDY

1.4.1. Aim

The overall aim of the study is to assess retail fruits and vegetable wastage in selected retailers within the city of Durban in KwaZulu-Natal Province to quantify the volume and the cost associated with the waste as a basis for more informed and effective management strategies to reduce the waste.

1.4.2. Specific objectives of the study

To achieve the aim of this study, the following specific objectives were be pursued.

I. To profile the socio-economic and operational characteristics of selected retail stores in the city.

II. To classify the types of fruits and vegetables mostly wasted by retailers in the city of Durban.

III. To quantify the volume and estimate the monetary value of fruit and vegetable waste generated by retailers in the study area.

IV. To identify the factors influencing the generation of retail fruit and vegetable waste in the study area

V. To develop a pathway to minimise/eradicate fruit and vegetable waste in the study area.

1.5. MOTIVATION OF THE STUDY

Food waste is a controversial issue at a time when hunger among the poor remains prevalent and vulnerable populations are at risk of food insecurity due to rising food prices (The World Bank, 2025). Widespread hunger and food insecurity are often cited as motivations for reducing losses and waste in agriculture and food systems (Wang et al., 2021). However, pathways explicitly tailored for retail operations to assist with food waste diversion have not been studied in Durban retail, and most empirical research has focused on food loss and waste at the production and household levels. By examining fruit and vegetable waste in Durban's retail sector, this study contributes to the existing body of literature, closing the knowledge gap and adding depth to studies focusing on highly perishable products such as fruit and vegetables.

This study also provides practical insights into the factors that influence food waste generation and the drivers of fresh produce waste. Additionally, it highlights practical and effective interventions within the Durban retail community. This is achieved by allowing retailers to recommend approaches to reduce waste, thereby identifying pathways and interventions retailers can prioritise. Therefore, this study offers actionable solutions for Durban retailers to reduce operational costs, minimise waste, and enhance profitability.

This study demonstrates the policy relevance of the National Waste Management Strategy (NWMS), which promotes waste minimisation, food redistribution to address food insecurity, and diversion from landfills, contributing to South Africa’s commitments to the United Nations Sustainable Development Goal 12.3. The findings can inform national policymakers and the municipality, particularly the eThekwini Municipality, where high levels of food insecurity coexist with large quantities of fresh produce waste. The study provides evidence-based recommendations tailored to retail operations in urban South Africa. For the eThekwini Municipality, the findings offer insights into improving local waste management planning and implementation as the city faces increasing landfill pressure with two landfills closed, high maintenance costs, and persistent food insecurity. In relation to waste management, the city aims to divert 90% of waste from landfill sites by 2050. By 2030, eThekwini plans to achieve a 50% increase in locally produced food and to divert 90% of waste disposed of at landfill sites by 2050, and to reduce the volume of good-quality leftover food waste by 80%

(eThekwini Municipality Durban and Solid Waste, 2019). With this goal for the city of Durban, studies have shown that more work and research are required to ensure it is achieved.

This study provides valuable findings that support policy alignment and collaboration between the private sector and municipal waste strategies. The pathway developed can provide opportunities to strengthen collaboration and partnership with relevant stakeholders to optimise landfill diversion targets and promote the community-based redistribution programmes. This can help alleviate food insecurity in Durban through redistribution programmes that address hunger while reducing fruit and vegetable waste in retail stores. In turn, this fosters stronger connections between local and provincial government, retailers, and communities, creating a more inclusive and sustainable food system.

1.6. DELIMITATION OF THE STUDY

The delimitations of this study were deliberately established to define its scope and focus, ensuring the research remained feasible and aligned with its objectives. These boundaries are outlined as follows:

- Geographic scope: The study was conducted within the Durban Central Business District (CBD) under the eThekwini Municipality in KwaZulu-Natal Province, South Africa. The research focused specifically on retail stores located within the Central, Market (Berea), Grayville, and Point (North and South Beach) precincts of Durban CBD. These areas were selected because they represent major urban retail and fresh produce trading zones within the city.
- Time Scope: Data collection was conducted over a one-month operational period during the 2024-2025 study period. The study therefore reflects a cross-sectional assessment of fruit and vegetable waste within participating retail stores and does not capture long-term or seasonal variations in food waste generation patterns.
- Supply chain focus: The study concentrated solely on the retail sector of the food supply chain. Wholesalers, distributors, producers, and consumers were excluded to keep the research manageable.

- Variable Scope: The study focused specifically on fruit and vegetable waste generated within retail operations. The key variables examined included waste categories, waste volumes, monetary value of food waste, landfill disposal costs, sales volumes, date-labelling practices, handling practices, and waste management practices. Other food categories such as meat, dairy products, grains and processed foods were excluded because fruits and vegetables are highly perishable and account for a substantial proportion of food waste.
- Excluding other food items such as meat, dairy, and grains. This delimitation was made because fruits and vegetables are highly perishable and account for a significant proportion of food waste.

1.7. JUSTIFICATION OF THE STUDY

1.7.1. Academic Contribution

This study contributes to the limited empirical literature on fruit and vegetable waste within South African retail operations, particularly in urban context such as Durban. While previous studies have largely focused on household food waste, post-harvest losses and general food waste quantification, limited research has examined the economic costs and operational determinants of fruit and vegetable waste at the retail level. The study therefore contributes to the growing body of knowledge by integrating waste quantification, monetary valuation, and econometric analysis to better understand food waste generation within retail environments. Furthermore, the study contributes to sustainable food systems literature by linking food waste management to operational practices, resource efficiency and environmental sustainability.

1.7.2. Policy and Practical Relevance

The study also has important policy and practical relevance. The findings support the objectives of South Africa's National Waste Management Strategy (NWMS) and Sustainable Development Goal 12.3 which aim to reduce food waste and improve sustainable resource management across food systems. By identifying the categories, costs and operational drivers of fruit and vegetable waste within retail operations, the study provides evidence-based insights that assist policymakers, municipalities, retailers and waste management stakeholders in designing targeted interventions to reduce

food waste. The study further supports awareness creation, improved planning and forecasting, redistribution initiatives and infrastructure investment aimed at strengthening sustainable food systems within urban retail environments.

1.8. DEFINITION OF KEY TERMS

This section provides definitions of key concepts and technical terms used throughout the study. The definitions are intended to clarify the meaning of important concepts within the context of fruit and vegetable waste management, retail operations and econometric analysis as applied in this research.

- **Food waste:** Food waste refers to edible food intended for human consumption that is discarded, lost or uneaten within the food supply chain particularly at the retail and consumer levels (FAO, 2020).
- **Food loss:** Food loss refers to the decrease in quantity or quality of food occurring during production, post-harvest handling, processing and distribution stages before reaching retail or consumers
- **Retail Operations**: Retail operations refer to activities undertaken by businesses involved in the selling and distribution of goods directly to consumers, including supermarkets, grocery stores, and fresh produce markets.
- **Fruit and vegetable waste**: Fruit and vegetable waste refers to discarded or unsold fruits and vegetables that no longer intended for human consumption because of spoilage, cosmetic standards, expiry or operational inefficiencies.
- **Multiple Linear Regression**: Multiple linear regression is a statistical technique used to examine the relationship between one continuous dependent variable and two or more independent variables.
- **Ordinal Logistic Regression**: Ordinal logistic regression is a statistical modelling technique used to analyse relationships between predictor variables and an ordinal dependent variable with ordered categories.
- **National Waste Management Strategy (NWMS)-** Is South Africa's national policy framework at reducing waste generation promoting recycling and improving sustainable waste management practices.
- **Sustainable Development Goal 12.3**: Sustainable Development Goad 12.3 refers to the United Nations target aimed at halving global food waste at retail

and consumer levels and reducing food losses along production and supply chains by 2030.

- **Monetary Value of Food Waste:** Monetary value of food waste refers to the estimated financial cost associated with discarded food products, calculated using quantities and retail market prices.
- **Landfill Diversion:** Landfill diversion refers to waste management practices aimed at reducing the amount of waste disposed of in landfill sites through recycling, redistribution, composting or recovery initiatives.

1.9. STRUCTURE OF THE DISSERTATION

The dissertation comprises five chapters,

Chapter one introduces the research, providing background to the study, the problem statement, the significance of the study, the research aim, specific objectives, and the limitations of the study.

Chapter two presents a literature review of food waste and loss, specifically in retail operations, the focus of this study. This chapter provides insights from previous studies and the academic literature on different levels of food waste along the supply chain, presents practical solutions for mitigating food waste in South Africa, discusses the quantification of food waste costs, and finally, presents the theoretical framework for analysing food waste in the retail sector.

Chapter three provides the research methodology used in the study to address the objectives and explains the selected methodologies. This chapter includes the research design, a description of the study area, the sampling method and size, and an explanation of the recruitment of retail grocery stores. It also details how the pilot study was conducted and describes the data collection process. This chapter concludes by discussing the study's limitations and the ethical clearance obtained.

Chapter four presents the findings and results according to the methodology described in chapter three and discusses them in relation to the study's objectives.

Chapter five presents the conclusions from the previous chapter and offers recommendations based on the study's objectives, specifically regarding fruit and vegetable waste management in retail operations.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

This chapter reviews literature related to food waste particularly fruit and vegetable waste within retail operations. The review examiners global, African, and South African perspectives on food waste generation, operational drivers, economic implications, and waste reduction strategies. Food waste remains a major sustainability challenge within urban food systems and retail supply chains (FAO et al., 2021).

The chapter further discusses theoretical frameworks underpinning the study, including sustainability and resource management perspectives relevant to food waste reduction. Empirical studies related to food waste quantification, operational determinants, and retail waste management practices are also reviewed to identify existing knowledge gaps within the South African and Durban context. The chapter concludes with a synthesis of the literature and the identification gaps that informed the objectives and direction of the study.

2.2. HIERARCHICAL ANALYSIS OF FOOD WASTE ACROSS THE SUPPLY CHAIN

Food loss and waste occur at various stages of the supply chain from production to consumption, reflecting both systemic inefficiencies and behavioural dynamics. The Food and Agriculture Organisation (FAO) identify five key stages at which food loss occurs: harvest and post-harvest, storage and transport, food processing, retail, and consumer level (FAO, 2023). Recent studies estimate that approximately 75% of food loss occurs in the first three stages: harvest and post-harvest operations (28%), storage and transport (22%), and processing (26%). The retail sector accounts for 16%, while consumer wastage accounts for 8% of overall food wastage (Bennett et al., 2022; Shoffe & Johnson, 2024). This distribution suggests that interventions should focus on the earliest stages of the food supply chain and may yield greater systemic impact than consumer-focused interventions alone. Nevertheless, Chau et al. (2021) emphasise that the retail level remains significant due to its position between producers and consumers, influencing both supply and the demand flow.

Many inefficiencies along the supply chain led to food waste, as highlighted by Arowosegbe et al. (2024), who note that these inefficiencies not only increase food

insecurity but also disproportionately harm disadvantaged communities, where they could otherwise help alleviate hunger. Similarly, Hobson & de Lange (2024) and Rahman et al. (2024) highlight that food waste in developing countries significantly impacts food security and deepens socio-economic inequalities. Thus, analysing food waste hierarchically provides insights into where interventions may be most effective.

2.2.1. Farm-level Waste

At the farm level, food loss varies by crop type, available facilities, and cultural practices (O' Connor et al., 2024). Produce from farmers often fails to reach markets due to retailers' strict cosmetic requirements for size, colour, and shape (Tempia et al., 2023). Magalhães et al. (2022) further explain that this leads to avoidable farm losses and significant income losses for farmers. Academic studies confirm that strict cosmetic requirements remain an important driver of farm-level food waste and loss. Both Kusumowardani et al. (2022) and Sarkar et al. (2022) agree that these not only lead to wasted resources but also result in revenue losses for farmers, particularly smallholders who already operate under market uncertainty and environmental risks. Figure 2.2 illustrates other avenues to recover revenue lost due to waste. The figure shows that agricultural waste can be used to produce other products, providing economic benefits and enhancing environmental benefits. Scholars such as Haque et al. (2023) highlight that, in most developing countries, the potential for value addition and by-product utilisation illustrated in Figure 2.2, or any other strategies or solutions used to utilise waste, may be hindered by a lack of knowledge among farmers regarding the production of by-products from food waste using the technology and other methodologies. Khan et al. (2023) mention that the absence of incentives and knowledge also leads to low demand for these agricultural waste-derived products.

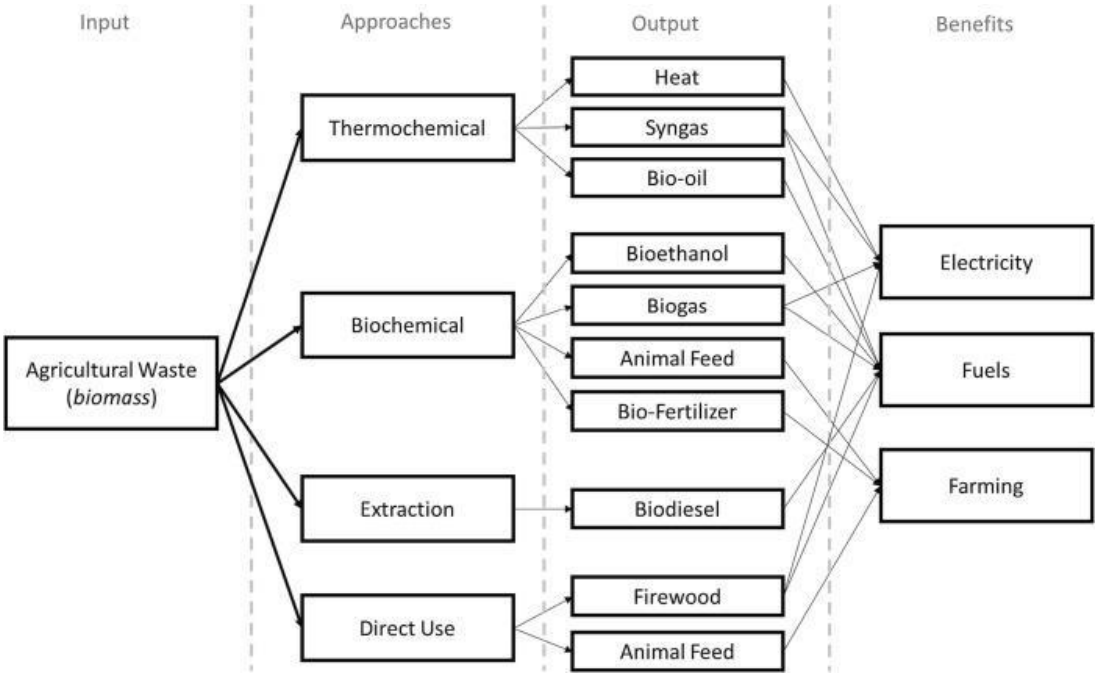


Figure 2.1: The illustration showing the different ways to utilise agricultural waste

Source: Khan et al. (2023)

This reinforces the notion that agricultural waste is not merely a technical constraint, but also a governance and market-structure issue (Magalhães et al., 2022). Various research and studies have provided considerable evidence that smallholder agricultural producers are particularly vulnerable and face multiple challenges in effectively reaching markets due to the small scale of their operations, as well as exposure to uncertainty in environmental factors and market fluctuations (Maponya, 2021; Rajveer & Qianna., 2023). Moreover, the inability to control these factors in agriculture reduces market appeal and lowers the economic value of crops, thereby rendering them undesirable for human consumption and for market entry (Villar et al., 2023). Increasing input costs associated with agrochemicals, high energy costs, pest infestations and diseases, and high post-harvest losses of perishables are additional issues confronting the South African fruit and vegetable industry (Ndlovu et al., 2021). Evidence from various studies and reviews demonstrates that produce aggregation and contract design can reduce farm-level food waste when implemented at scale. However, Abbas et al. (2023) discuss that the success of these interventions also depends on reliable infrastructure, efficient logistics, and functioning market linkages.

Recent studies among South African citrus farmers in Eastern Cape Province found that social (marital status, age, education), economic (yield), institutional (markets), extension, credit, and farming practices are principal factors in the level of postharvest loss (Nohamba et al., 2022), underlining the importance of institutional and extension support in reducing farm-level waste. Therefore, in South Africa, producers need improved postharvest practices and better market arrangements to minimise waste.

2.2.2. Post-harvesting, handling, and storage loss.

Postharvest loss throughout the food value chain includes spoilage, quality deterioration, nutritional loss, and economic loss (Debebe, 2022). The scale of loss varies by crop type, region, and economic status (Singh et al., 2024). Recent assessments indicate that in South Africa, about 30% of fruit and leafy vegetables are lost each year due to a lack of storage facilities and management practices (CSIR 2021). These figures align with broader patterns across developing countries, where between 20% and 40% of fruits and vegetables are wasted annually (Mmereki et al., 2023).

Postharvest losses in South Africa reflect a broader pattern observed in developing countries. Comparative studies highlight stark differences with developed countries, where an average of 12% of production is lost from production to retail warehouses, while developing countries lose much more due to inadequate facilities and a lack of appropriate postharvest technologies among farmers. Nohamba et al. (2022) also note the drivers of postharvest loss are both technological and institutional, such as weak coordination between farmers, distributors, and retailers, as well as limited access to finance. Comparative reviews also discuss the cold chain gap between high-income countries and the low-income countries, where the low-income countries, such as those in Africa, still rely on conventional, labour-intensive methods and poor storage techniques with low market integration, in contrast to middle and high-income countries with advanced systems (Dlomo, 2021; Mmereki et al., 2023; Ndlovu, 2021). The absence of efficient systems, such as reliable logistics and cold storage, not only accelerates spoilage but also creates price volatility and minimises farmers' bargaining power (Igilar, 2023).

Fruit and vegetable losses in the supply chain are due to postharvest losses (Turnbull et al., 2021). Debebe's (2022) findings estimate that about 37% of fresh vegetables in Sub-Saharan Africa are lost at this level. Poor post-harvesting handling and value addition in South Africa result in over 10 million tons of food waste (Singh et al., 2021). Abbas et al. (2023) explain that the complexity of vegetable loss at the level is due to many factors, including seasonality, short shelf life, and demand fluctuations, which pose a significant challenge. Stathers et al. (2020) highlight that the high perishability of fruits and vegetables exacerbates the risk of postharvest loss, as evidenced in the global supply chain. Rajapakshe et al. (2024) provide recommendations to reduce food waste at the level; the review notes that proper handling and processing are critical for reducing vegetable waste. As scholars debate technological solutions and adoption at this level, Makule et al. (2022) emphasise that although the scholars' suggestions might help reduce waste, their adoption could remain limited in resource-constrained regions.

2.2.3. Retailers- Consumer Waste Level

At the consumer and retail levels, food loss also encompasses not only the economic value of food production but also a broad array of resources utilised, including agricultural inputs such as land and agrochemicals (Raquel et al., 2025). Oelofse et al. (2022) and Wu et al. (2025) highlight that, while the retail phase generates comparatively little waste compared to other phases in the food supply chain, it is a critical gatekeeper with extensive control over upstream and downstream food flows. Hobson & de Lange (2024) note that in developing countries, retail waste remains a significant contributor, especially for perishable fruits and vegetables. Research has been well conducted and has deepened understanding of this stage, clarifying key topics and providing findings and evidence on the scale, causes, and drivers of waste, particularly in developing contexts, and exposing both opportunities and challenges for mitigation strategies.

Meanwhile, Hobsons (2023) investigates how retailers in South Africa can accurately quantify food loss and waste using the global accounting protocol for this stage of the supply chain. The author, Hobsons (2023), also notes that retailers in South Africa do not accurately track waste against targets or identify appropriate mitigation strategies.

Horo (2021) previously noted that retail store managers use their own strategies to quantify and reduce waste, based on their experience and management style. This further emphasises the academic discussion that quantification of food waste at this stage has not been carried out accurately, leading to inaccurate cost accounting, as highlighted by Marchetti et al. (2025).

In the context of food waste prevention, studying the retail sector separately seems appropriate given its theoretical savings potential. Horós et al. (2022) article on “Avoidance of Food Waste from a Grocery Retail Store Owner’s Perspective” highlights that avoidable food waste in this sector is estimated at 84%. In a literature review on retail food waste, Henrique et al. (2021) identify the most significant factors leading to food waste in the retail sector as delivery issues, including tardiness and overstocking situations, and frequent restocking practices that enable customers to select the freshest items. Hobson’s (2023) study notes that these issues stem from a lack of measurement practices under the South African Food Loss Waste voluntary agreement, resulting in inefficiencies. The studies by Ismael (2023) and Todd & Faour-Klingbeil (2024) emphasise that without accurate data on both the quantities of food waste and the costs associated with it, retailers and policymakers struggle to understand the scope of the problem. Therefore, the proposed Accounting and Reporting Standard by Hobson (2023) can assist retailers in South Africa in better tracking waste.

Numerous studies worldwide agree that retailers play a critical role in shaping the dynamics of food waste across the supply chain (Bagherzadeh et al., 2020). Their adherence to stringent quality, aesthetic, and labelling standards, often guided by consumer preferences, can inadvertently lead to the removal of perfectly edible food from shelves (Jayathilake et al., 2023). The emphasis on uniformity and freshness tends to marginalise products that deviate slightly from expected norms, even when they are nutritionally adequate. This results in the premature disposal of food that does not meet subjective consumer standards, intensifying waste, particularly in high-turnover retail environments (Bhattacharya & Wisniewski, 2023).

Economic considerations further exacerbate this issue. Traders and retailers, under pressure to maintain profitability, frequently remove or mark down items approaching their expiry dates or lacking market appeal (Todd & Faour-Klingbeil, 2024). While such

practices are economically rational, they often neglect the broader implications of loss, especially the resource-use and environmental-impact embedded in the production chain (Ismael, 2023).

The urgency to address food waste in the retail sector is heightened by its direct relevance to Sustainable Development Goal 12.3, which promotes responsible consumption and production. Policy tools such as waste generation taxes have been proposed as mechanisms to incentivise reductions (Qian et al., 2023). However, Luca et al**.** (2023) caution that such regulatory interventions may lead to unintended economic consequences, including retail price distortions and welfare losses if not properly calibrated. Thus, there is a pressing need to develop integrated policy frameworks that align environmental sustainability with economic viability.

In the South African context, the retail food sector has increasingly implemented adaptive strategies to minimise waste while complying with food safety standards (DEFF & CSIR, 2021). Some formal retailers have entered partnerships with informal traders, allowing the resale of near-expiry goods at discounted prices. The model, documented by Spang et al. (2019), offers a viable solution to extend product life cycles, reduce waste, and support food access in low-income communities. However, there have been controversies around this model, as other academics raise concerns about avoidable versus unavoidable food waste and issues with food safety rules regarding expiry date policies.

Additionally, non-profit organisations have emerged as significant actors in mitigating retail-level food waste. SA Harvest in KwaZulu-Natal province, for example, has developed a robust food recovery and redistribution network capable of rescuing nearly 100 tonnes of surplus food weekly, diverting it from landfills and channelling it to food-insecure populations through certified distribution channels (DAFF & CSIR, 2021). These initiatives illustrate that, when integrated with safety protocols and logistical support, food redistribution can serve as an effective complement to retail waste reduction strategies (Riesenegger & Hübner, 2022). This demonstrates that many interventions are proposed, but few have been evaluated in real retail operations, such as the Warwick Zero Waste Project in Durban. This includes the model's redistribution and donations or markdowns, which many academics discuss in different studies but

lack empirical evidence of effectiveness and the most efficient way to address barriers such as logistical, safety, and consumer acceptance at this level (Drimie & de Plessis, 2025). The various findings on food waste at this stage highlight the scale and causes of the phenomenon, allowing for some preliminary conclusions on possible actions to reduce its dimensions and potential impacts.

2.2.4. Food waste drivers in the grocery retail sector

The grocery retail sector plays a critical role in the food supply chain and is a significant contributor to food waste (Gustavsson et al., 2011). Food waste drivers at this stage arise from various operational, logistical, and consumer-related factors (Riesenegger & Hübner, 2022). Understanding these drivers is essential for developing targeted strategies to reduce waste and its associated economic and environmental costs (Henderson, 2021). This literature identifies different drivers of retail-level food waste grouped into four main categories.

I. Operational and logistical drivers

Operational inefficiencies are among the primary drivers of food waste in grocery retail. These include overstocking due to inaccurate demand forecasting, poor inventory management, and insufficient cold chain systems (Swaffield et al., 2021). Overstocking often results in perishable items reaching their expiration dates before the sale, leading to disposal (Eriksson et al., 2021). Furthermore, stringent cosmetic standards for fresh produce, such as size, shape, and colour, result in the rejection of otherwise edible items (Aschemann-Witzel et al., 2020). Logistic challenges, transportation delays, and inadequate storage conditions significantly contribute to food spoilage. A lack of adequate temperature control during transit can cause rapid deterioration of perishable goods, exacerbating waste in the retail sector (Filimonaun & Gherbin, 2021).

II. Consumer Behaviour and Retail Practices

Consumer preferences and shopping behaviours also influence food waste in grocery stores. Promotions like “buy one, get one free” or bulk discounts often encourage over-

purchasing, leading to spoilage before products are consumed (Van der Werf et al., 2020). Additionally, consumers' preference for aesthetically pleasing products pressures retailers to discard imperfect items even when they are nutritionally sound (Chaboud & Daviron, 2020). Retailers' commitment to maintaining fully stocked shelves to project abundance and attract customers, further drives food waste (Priefer et al., 2025). This practice, often termed "stock pressure", leads to surplus inventory, particularly for perishable goods that may not sell before expiration (Leberdorger & Schneider, 2021).

III. Regulatory and Policy Influences

Government and industry regulations also contribute to food waste in the retail sector. Labelling policies such as "use-by" and "best-before" dates are often misunderstood by consumers and retailers, leading to the premature disposal of safe and edible food (Shukla & Jharkharia, 2022). In some cases, liability concerns discourage retailers from donating unsold food, despite legislation designed to protect such donations (De Moreas & Colombo, 2024).

IV. Technological and cultural factors

Limited adoption of advanced technologies such as artificial intelligence and machine learning for demand forecasting and inventory management exacerbates waste (Riesenegger & Hübner, 2022). Innovative solutions can more accurately predict consumer purchasing patterns, reducing overstocking and spoilage (Erikssons et al., 2021). Moreover, cultural norms that prioritise visual perfection in fresh produce drive wasteful practices at both the retail and consumer levels (Ascheman-Wilzel et al., 2020).

While the primary focus of this study is on quantifying the costs of food waste in the retail sector, it is important to place this within the broader food systems. Recent studies by Kopaei et al. (2023) suggest that the drivers of food waste in retail operations are multifaceted, stemming from operational inefficiencies, consumer behaviours, regulatory frameworks, and cultural norms, explained by the Theory of Planned Behaviour. Addressing these drivers requires a systemic approach that combines technological advancements, policy reforms, and consumer education to create more sustaina-

ble food systems and potentially mitigate retail food waste (Nichofor et al., 2025). Together, these drivers demonstrate that retail waste is not the product of a single factor but rather the intersection of diverse dimensions, and addressing them requires integrated approaches (Olabode et al., 2025).

2.3. PRACTICAL SOLUTIONS FOR MITIGATING FOOD WASTE IN SOUTH AFRICA

Fuentes et al. (2016) were among the scholars to first elaborate on the Environmental Protection Agency food hierarchy (EPA), describing this as one of the waste management approaches, listing in order of preference from most to least desirable: source reduction, food donation to the needy, animal use, industrial use, composting, and finally landfilling. Diverting excess food to beneficial channels, such as food banks and hunger relief programs, alleviates the issue at its source (Haque & Lee, 2023). Figure 2.3 illustrates the proposed approach to managing food loss and waste, along with the causes before it reaches the landfill.

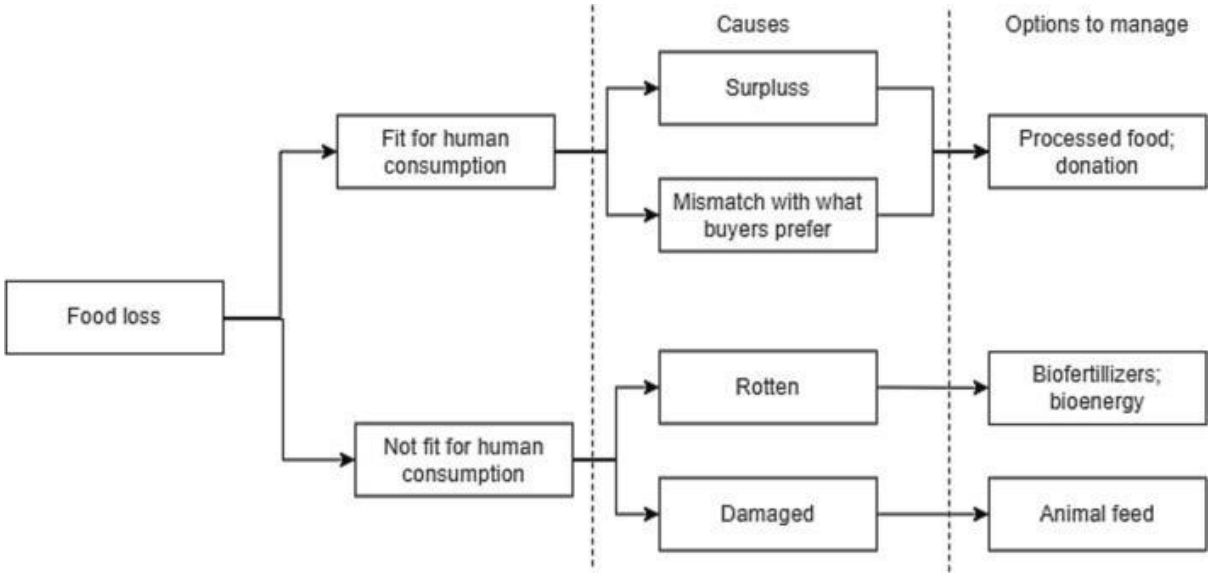


Figure 2.2: Illustration of food loss causes and options to manage it

Source: Kusumowardani et al. (2022)

Civil society organisations play a crucial role in reducing food insecurity in South Africa (Dubbles et al., 2020). These organisations have the unique ability to provide localised

insights regarding the needs of at-risk populations (Adelle et al., 2021). Food banks and other institutions also play a significant role in offering education and knowledge exchange on diet and food systems, as well as providing training in nutrition and agriculture (Lartey, 2024).

Within the South African situation, current studies confirm the implementation of circular economy strategies in waste management (DEFFb, 2020). The implementation of these strategies will be capable of minimizing waste by diverting edible food products to charity and finding other uses for food that is not fit for human consumption, such as converting it into energy or animal feed (WWF, 2017; Haque & Lee, 2023). The implementation of circular economy principles can improve the well-being of South African society, its economy, and the environment. However, a successful transition needs to be supported by relevant policy interventions (DEFFa, 2020).

South Africa is formulating advanced policies aimed at tackling the issues of food waste, as part of broader sustainable waste management initiatives that align with circular economy principles **(**DEFFa, 2020; DEFF & CSIR, 2021). The province of Western Cape has implemented programs introducing the Organic Waste Landfill Ban which calls for 50% organic waste diversion by 2022 and 100% by 2027 (Green Cape, 2020). The program represents one of the nation's most ambitious organic waste diversion policies, establishing a framework for sustainable waste management practices that support the transition from a linear economic model to a circular economy.

The province of Western Cape in South Africa is setting by example in addressing the issue of food waste particularly in retail operations (DEFF & CSIR, 2021). Kaskakis & Stratigea (2024) argue that effective food waste management in the retail industry is crucial for achieving Sustainable Development Goals, especially SDG 12. In practice, implementing the right policy interventions could involve imposing taxes on retail waste generation to incentivise waste reduction efforts (Oluwole et al., 2025). However, Luca et al. (2023) have shown that efforts can impact retail prices and overall welfare, potentially forcing retailers to lower prices significantly below equilibrium. This highlights the need for policies that balance economic interests with environmental goals. Here are some strategies that can be implemented to reduce food waste in retail, particularly focusing fruits and vegetables in alignment with the circular economy model.

2.3.1. Diverting Food Waste to Animal Feed

Converting food waste to animal feed is a key aspect of the circular economy approach. Caldeira et al. (2020) discuss initiatives like circular farms that compost food waste onto fields and feed it to insects for protein production. These practices promote sustainable agriculture principles while diverting organic waste from landfills. The regulatory framework governing the use of food waste as animal feed in South Africa must prioritise safety and biosecurity concerns (DAFF, 2008). In many industrialised countries, regulations either prohibit feeding food waste to livestock or restrict the types of waste what can be used, underscoring the importance of ensuring feed safety to prevent negative impacts on animal health, welfare, biosecurity, food safety, economics, market access, and food security (Nath et al., 2023). In South Africa, the implementing circular economy strategies can help reduce waste by redirecting edible food to donations and finding alternative uses for food unsuitable for consumption, such as converting it into energy or animal feed. However, policy essential to fully transition to a circular economy model (DEFFb, 2020; Wilson et al., 2022).

Some of the emerging technologies for food waste conversion to animal feed include processes such as processes such as controlled decomposition and microbial fermentation which maintain nutritional value while ensuring pathogen destruction (Sola & Güzel, 2025). Solid-state fermentation, a microbial fermentation process, is a viable and efficient approach that transforms discarded agro-industrial wastes into nutrient-rich animal feed while ensuring pathogen destruction (Yafetto, 2023). The application of solid-state fermentation by different microorganisms including fungi, yeasts, and bacteria has successfully been used to produce several value-added products (Prakash et al., 2024). Thermal processing has been shown to be effective in inactivating all biological agents of concern in food waste, with adequate thermal processing demonstrated to inactivate pathogens within specific timeframes during thermophilic conditions (Wu et al., 2025).

These innovations allow retailers to divert food not fit for human consumption into valuable agricultural products instead of disposal streams (Mak & Tiffany, 2020). Food waste from retail and food service can be effectively and safely utilised in commercial production systems when correct processing and safety measures are implemented

(Todd & Faour-Klingbeil, 2024). The transition from food waste to food security focuses on repurposing organic waste products generated throughout the food supply chain into valuable resources, with bio wastes being transformed into fertilizers, animal feed, and even new food products through strategies such as composting, bioconversion, and innovative recycling technologies (Sarangi et al., 2024; Wu et al., 2025). Research has demonstrated that discarded fruits, vegetables, and bakery products from retailers can be successfully ensiled and assessed for their nutritional value, contributing to a sustainable livestock feed supply with mature silages showing higher crude protein content compared to traditional silages (Garcia Rodriguez et al., 2024; Hensen et al., 2025).

2.3.2. Retail inventory management: Dynamic shelf-life (DSL) systems

One emerging technology for reducing food waste in retail environments is the implementation of Dynamic Shelf-Life systems. Dynamic Shelf-Life Systems are used to adjust the product's expiration date or quality indication based on real-time factors like temperature or microbial growth, rather than relying on a fixed, predetermined date (Wu et al., 2025)

Unlike traditional static expiry dates that rely on generalised assumptions about food degradation, DSL systems use real-time data, including temperature, humidity, and handling conditions, to dynamically adjust the estimated shelf-life of perishable products (Leena, 2024). These systems enable retailers to make more informed decisions about stock rotation, discounting strategies, and inventory prioritisation, thereby minimizing losses from unsold expired goods (Nwani, 2025). Consequently, products sold are safe for consumption, thereby minimising losses from unsold, expired goods (Kuiper & Cui, 2021; Singh et al., 2024).

Globally, several countries have adopted DSL systems with notable success. Countries like Sweden have one of the largest grocery chains that implement a Time-Temperature Indicator (TTI) system across chilled food lines, reducing food waste by 20% (Eriksson et al., 2020). In the United Kingdom, retailers have intelligent packaging technologies that link shelf-life data to supply chain systems, while in the Netherlands, the implementation of the Dynamic shelf-life (DSL) systems combined with dynamic

pricing resulted in a 40% reduction in food waste (Buisman et al., 2017; Fatorachian et al., 2025).

In the South African context, where food waste at the retail level is a growing concern, DSL technologies present a valuable opportunity to enhance the efficiency and sustainability of inventory management practices (Jere et al., 2021). South African retailers in urban areas experience high levels of waste in fresh produce, dairy, and meat categories, and can significantly benefit from DSL tracking. The study by Wu et al. (2025) emphasises the value of integrating DSL with First-In-First-Out (FIFO) systems, allowing retailers to promote or discount products nearing the end of the adjusted shelf life rather than defaulting to waste.

DSL systems also hold potential to align with digital inventory systems and block chain technologies, which are gaining attention in African retail chains for improving transparency, traceability, and loss prevention (Nwani, 2025). However, challenges to DSL adoption in South Africa include the high cost of sensor technology, lack of local expertise, and limited awareness among small to medium-sized retailers (Jere et al., 2021). Despite these barriers, pilot projects in Cape Town, Western Cape, and Johannesburg, Gauteng, have shown promising results in reducing daily discard rates by 15-25%, particularly for temperature-sensitive goods (Van der Merwe & Gilland, 2024).

In conclusion, Dynamic Shelf-Life systems represent a viable and forward-looking solution for mitigating food waste in the South African retail sector (Dlomo, 2021). The success, however, depends on stakeholder investment, capacity building, and policy support that incentivises technology adoption across the value chain, especially among small and medium-sized retailers (Jere et al., 2021). Dynamic Shelf-Life systems hold considerable potential to reduce retail food waste in South Africa through investment in digital systems, training, and cross-sector collaboration (Mmereki et al., 2023).

2.3.3. Mitigation solutions for food waste: eThekwini Municipality

Efforts to mitigate food waste have gained momentum globally, particularly as part of Sustainable Development Goal 12.3, which aims to halve food waste by 2030

(Quested et al., 2021). Globally, mitigation strategies include food redistribution networks, dynamic shelf-life technologies, waste-to-energy conversion, and food waste tracking systems, consumer education campaigns, and AI-powered forecasting to minimise spoilage and overstocking (FAO, 2021).

One emerging solution is the Dynamic Shelf-Life (DSL) system, which adjusts product expiration dates based on real-time temperature and storage conditions. Countries such as Sweden, the Netherlands, and the United Kingdom have piloted DSL systems to extend the usable life of perishable produce, thereby reducing unnecessary waste at the retail level (Albrecht et al., 2020; Han et al., 2021). These technologies not only improve stock management but also ensure that fruits and vegetables are sold before spoilage occurs.

In the African context, mitigation efforts are often constrained by limited infrastructure and resources (Jinwon et al., 2025; Mukwevho et al., 2024). However, several innovations have shown promise. For instance, Kenya has seen success with mobile-based surplus food redistribution platforms that connect retailers and consumers with food banks and informal traders (Hering & Kohrs, 2021). Rwanda and Ghana have implemented cold chain cooperatives and decentralised composting hubs to repurpose organic waste (African Union, 2022; Kiprugut, 2025).

In South Africa, the mitigation of food waste has received increasing attention in policy and research circles (DEFF, 2023). The South African Loss and Waste Voluntary Agreement, launched in partnership with the Consumer Goods Council of South Africa (CGCSA), encourages food retailers to measure, report, and reduce their waste through industry collaboration and knowledge sharing (DEFFa, 2020). This is particularly relevant for cities like Durban, located within the eThekwini Municipality, where a significant portion of food waste originates from the urban retail sector (Kawole et al., 2025).

In the eThekwini Municipality, pilot initiatives have included public-private partnerships to redirect surplus food to feeding schemes and food bank organisations such as FoodForward SA. Additionally, private organisations, the eThekwini Municipality- Durban Solid Waste (DSW), now called Cleansing and Solid Waste (CSW), and the Business Support Unit have worked to expand food redistribution networks and integrate

organic waste into municipal composting programs (eThekwini Municipality projects nexus 2025). The municipality has also supported educational campaigns aimed at reducing retail food waste through awareness and behaviour change, as well as local sustainability (IDP, 2020/21).

Despite these efforts, challenges remain, including inadequate data on food waste volumes, limited adoption of digital waste tracking tools, and poor integration between informal and formal food systems (Ndlovu, 2021). Moreover, storage facilities continue to hinder efficient waste management in the fruits and vegetable supply chain (Nwani, 2025). Addressing food waste in eThekwini requires a combination of data-driven planning, infrastructure investment, public awareness, and alignment with national strategies. Strengthening food recovery logistics and incentivizing could significantly reduce the social and economic burden of food loss in the city (Dlomo, 2021; eThekwini Municipality nexus projects, 2020/21).

2.4. QUANTIFICATION OF FOOD WASTE AND LOSS COSTS

According to Barco et al. (2019) and Antonelli et al. (2024), methods for quantifying the costs of food loss and waste have been used to evaluate both economic and environmental impacts. Understanding the full impact of waste requires quantifying its environmental, social, and economic costs. O'Mahony (2021) argues that quantifying these costs is essential for justifying investments in waste reduction strategies, enabling policymakers and businesses to prioritise cost-saving actions with environmental benefits. Additionally, there are economic and social implications of FLW, as well as indirect costs such as increased food prices and social costs, particularly affecting low-income countries by reducing food security and nutritional access due to food waste (FAO, 2021).

Hoehn et al. (2023) discussed methods for quantifying economic costs, specifically mentioning the market price method. This method uses current market prices of food products to estimate the financial value of FLW. Vázquez-Rowe et al. (2020) noted that while the market price method accounts for direct costs to businesses and customers, it may not fully capture indirect costs, such as environmental impacts. Nyahuna et al. (2023) explained that quantifying food waste involves systematically evaluating losses at different supply chain stages. At the harvest level, expected yields are

compared with actual outputs to identify discrepancies caused by spoilage, damage, or suboptimal practices. In transportation and storage, metrics such as weight loss, spoilage due to poor temperature control, and damage during handling provide insights (Igilar, 2023). In the retail sector, unsaleable produce and customer-level waste due to expiration or mismanagement are key indicators (Todd & Faour-Klingbeil, 2024).

Practical formulas help estimate these losses (Nohamba et al., 2022). For instance, at the distributor level, the difference between the produce sent for packing and the final packed quality quantifies loss. Such methods are essential for identifying hotspots in the supply chain where interventions can have the most significant impact (UNECE, 2020). The economic repercussions of food waste are significant, affecting various stakeholders across the supply chain. Retailers face revenue losses from unsold goods, while producers experience reduced profitability due to inefficiencies (Yumei et al., 2021). Moreover, these losses translate into broader economic burdens, including increased waste management costs and lost opportunities to alleviate food insecurity (Gage et al., 2024). The FAO (2023) argued that addressing food waste could improve supply chain sustainability and contribute to economic resilience in urban cities. The quantification of food waste and loss is a critical step toward addressing inefficiencies in the food supply chain (Ismael, 2023). By employing robust measurement methodologies and implementing targeted interventions, stakeholders can reduce economic losses, improve food security, and contribute to environmental sustainability (Eriksson, 2022; Todd et al., 2024).

The article by Chadbound & Daviron (2020) delves into the complexities of FLW and its economic and policy dimensions, examining its implications for global food security and the economic policies that can address these challenges. Priefer (2020) argued that FLW is not just a technical issue but also a socio-economic problem with economic implications that require comprehensive policy intervention. Filimonau & Ermolaev's (2021) paper discussed both direct and indirect financial costs. The direct financial costs include production, transportation, and storage costs, as well as market value (Martin-Rios). The production costs represent financial losses directly borne by producers, including the costs of seed, fertilizers, labour, and other inputs invested in food production but never reaching the consumer (Dhillon & Moncur, 2023). The potential

market value of the lost or wasted food represents a significant economic loss, as the revenue that could have been generated if the food had been sold and reached consumers is lost (Kechagias et al., 2024; Todd et al., 2024).

The indirect economic impacts include supply chain inefficiencies, environmental costs, and opportunity costs (Olabode et al., 2025). Food loss can lead to inefficiencies in the supply chain, increasing costs for all stakeholders involved (Papargyropoulos et al., 2021). According to Stuart (2021), this can result in higher prices for consumers and lower profit margins for the producers and retailers. Caldeira & De Laurentiis (2020) also expanded more on the environmental costs and their impact on FLW. The paper discusses the environmental impact of food loss and waste, such as greenhouse gas emissions from the decomposition of food and wasted resources like water, land, and energy used in the production phase, leading to economic costs. According to Warsaw et al. (2021), food loss represents a missed opportunity to address food insecurity and hunger. Oluwele et al. (2025) further emphasise that the resources used to produce lost food could have been allocated to other productive uses, contributing to economic growth and development.

The government may incur costs in implementing and enforcing policies to reduce food loss. This includes the costs of monitoring, regulation, and providing incentives for best practices (Todd & Faour-Klingbeil, 2024). Financial support programs for farmers and businesses to adopt practices that reduce food loss can also represent a significant economic investment (WWF-UK 2021). According to Okawa (2015), food loss can affect a country's trade balance by reducing the amount of food available for export. Chadbound & Daviron (2020) further emphasised that this can impact national income and economic stability. Vander Werf et al. (2020) broadened this by explaining that the economic burden of food loss and waste is often disproportionately borne by lower-income countries and communities, exacerbating economic inequality. An article by Raquel et al. (2025) calls for comprehensive policy interventions and stakeholder collaboration to effectively tackle this multifaceted issue.

2.5. THEORETICAL FRAMEWORK FOR ANALYISING FOOD WASTE IN THE RETAIL SECTOR

To comprehensively address the complexities of food waste in the retail sector, particularly in fruits and vegetables, a robust theoretical framework is essential (Carvalho et al., 2025). Drawing upon interdisciplinary perspectives from economics, sustainability science, and systems thinking (Chauhan et al., 2021). This approach facilitates a nuanced understanding of the multifaceted challenges and quantification of associated costs (Todd & Faour-Klingbeil, 2024). Adopting a theoretical economics perspective, the study examines the Life Cycle Costing and Life Cycle Assessment frameworks as appropriate tools for identifying win-win solutions. This approach aims to maximise environmental impact reduction and enhance economic resource efficiency (Barbhuiya et al., 2024; Wang et al., 2020). These frameworks enable the quantification of both direct and indirect costs associated with food waste, aligning with circular economy principles that advocate for the revalorisation of waste and resource recovery through recycling and redistribution throughout the supply chain (Alonso-Muñoz et al., 2022). The overstatement of food waste issues may misdirect resources, potentially affecting public policy (Cicatiello & Franco, 2023). Therefore, requires precise and reliable measures (Carvalho et al., 2025).

However, food waste is not only a material flow problem it reflects broader questions of collective stewardship and the ethics of resources utilised across the supply chain (Ozili, 2025; Tamasinga et al., 2022). Furthermore, Conduit et al. (2023) explain that this model integrates all actors along the supply chain, including suppliers, retailers, and customers, and calls for shared responsibility to reduce waste and the environmental impact, ensuring that resources are sustainable for future generations. At the operational level, waste outcomes are directly influenced by the attitudes and behaviours of key decision makers and consumers. This reveals the importance of behavioural models such as the Theory of Planned Behaviour (TPB) (Ajzen, 1991).

Given the importance of consumer behaviour in generating food waste, understanding the factors that influence consumers' actions is crucial. These factors can be summarised into consumer behaviours, consumer perception, and socioeconomic factors (Jere et al., 2021; Raquel et al., 2025; Vicky & Sebastian, 2025).

Therefore, this study's literature examines these three models and builds a conceptual framework that integrates them. This integrated framework provides a holistic lens for analysing food waste in the retail sector by combining efficiency LCC/LCA, ethical and intergenerational responsibility, collective stewardship, and behavioural determinants. The TPB model enables a comprehensive understanding of the structural, organisational, and consumer-driven drivers of food waste (Obuobi et al., 2022; Rastegari et al., 2024). Together, this integrated framework provides the lens through which fruit and vegetable waste can be analysed.

2.5.1. Life Cycle Costing and Assessment Frameworks

The United Nations has established a global target to halve food loss and waste by 2030 (SDG target 12.3), due to the vast quantity of food that is wasted annually, with adverse effects on the economy, the environment, and general well-being (Ardra & Kumar, 2024; Nazatul et al., 2025). It is estimated that more than a third of the food produced worldwide, approximately 1.3 billion tonnes, is wasted annually (WWF-UK 2021). This has grave environmental consequences, primarily due to its significant contribution to greenhouse gas emissions, further fuelling the current climate change problem (Quintieri et al*.,* 2023). Other scholars have concluded that numerous problems and adverse consequences follow food waste; hence, there is an urgent need to identify sustainable methods to ensure sufficient food is available for the growing global population. Achieving this objective can be facilitated by demand management, improved governance, and reduced waste across the supply chain.

Food waste at the retail level poses multifaceted problems, including financial losses, environmental harms, and social effects (Todd & Faour-Klingbeil, 2024). The last decades have seen rising economic and environmental impacts due to growing food demand, intensified production processes, and disparate standards in the global supply chain (Marchetti et al., 2025; Todd & Faour-Klingbeil, 2024). Understanding these issues requires a strong theoretical foundation. The subsequent frameworks offer insights into the dynamics of food waste within retail operations, particularly with fruits and vegetables.

There are numerous studies outlining the analytical framework of food waste from a theoretical economic perspective. The study adopts the Life Cycle Costing (LCC) and

Life Cycle Assessment (LCA) frameworks (Mudiyanselage et al., 2025). According to De Manna et al. (2020), these frameworks are the appropriate tools for identifying win–win solutions, maximising environmental impact reduction, and promoting economic resource efficiency. Life cycle inventory (LCI) data is essential for quantitatively evaluating management and policy choices for food waste using life cycle assessment. It includes quantification of all known pollutant releases to air, water, and soil to estimate potential environmental and human health impacts (McGaughy et al., 2024). These models help measure the direct and indirect costs of food waste. They are supported by circular economy theory principles that advocate redefining waste and promoting resource recovery through recycling and resource reallocation within the supply chain (Aleisa & Alsaleh, 2024; Bisinella et al., 2024).

Valorisation or utilisation of food waste helps resolve issues related to environmental pollution, while reducing in the carbon footprint throughout the food supply chain makes the entire process eco-friendlier. In the context of food waste, initiatives such as composting or feeding waste to livestock have been successful (Yafetto et al., 2023; Bhatia et al., 2023). Initiatives by the eThekwini Municipality, such as SA Harvest, Warwick Zero Waste Project, and food redistribution to informal traders and select formal retailers, have cultivated partnerships with informal retail enterprises. Formal retailers sell food nearing its expiration date to the informal market at a reduced price (Abadi et al., 2020). This model aims to close the gap and maintain the significance of food within the system (DAFF & CSIR, 2021).

2.5.2. Collective Stewardship and Sustainability Development

The crucial need for enhanced food waste management stems from a growing awareness of dwindling natural resources, accentuating the importance of adhering to the principles of sustainable development. This was initially articulated in the Brundtland Report of 1987 (Kostakis et al., 2024). This paradigm also emphasises the collective stewardship strategy for sustainable development, as proposed by Ozili (2025), advocating developmental initiatives that address current needs without jeopardising future generations' ability to meet their own requirements. Retail food waste reduction aligns with environmental sustainability, economic viability, and social equity, promoting a sense of shared responsibility and ethical conduct throughout the supply chain and aiming for a sustainable future (Economous et al., 2024; Manzoor et al., 2024). The

exponential surge in population growth has led to a disproportionate increase in the consumption of natural resources, outstripping the natural productive capacity (Maja et al., 2021). Practical and advanced waste management systems are therefore essential to manage the immense volumes of waste generated, addressing the discrepancy between waste production and disposal capacity (Campitelli et al., 2020; Urogo et al., 2024; Wibisono et al., 2025).

The need for better management of food waste arises from the realisation that natural resources are diminishing. Therefore, there is a growing interest in the principles of sustainable development, as advocated in the Brundtland report of 1987 (Alapassi, 2001; Anne et al., 2021; UN, 1987; WWF -UK, 2021). This also aims to outline the collective stewardship approach to sustainable development, as suggested by Ozili (2025). The theory promotes developments that aim to meet current needs without compromising future needs (Olabode et al., 2025). Retail food waste reduction aligns with environmental sustainability, economic viability, and social equity, supporting a sense of shared responsibility and ethical behaviour throughout the supply chain to achieve a sustainable future (Manzoor et al., 2024).

The rapid increase in population has led to disproportionate consumption of natural resources relative to the natural productive capacity (Todd & Faour-Klingbeil., 2024). Practical and advanced waste management systems are needed to address the massive volume of waste and bridge the gap between waste generation and management (Bhatia et al., 2023). Efficient management of food waste at retail levels plays a crucial role in achieving the Sustainable Development Goals (Arowosegbe et al., 2023). From a theoretical perspective, an appropriate policy instrument would be to tax waste generated by retailers to incentivise them to adopt waste reduction strategies, such as reducing the price of end-of-life products or donating to feeding programmes (Celdeira et al., 2020). However, according to Luca et al. (2023), measures to reduce food waste may lead to distortions in retail prices and in social welfare. Retailers may be pressured to lower prices significantly below equilibrium levels. While this could increase consumer welfare, it could also reduce retailer profits. Nonetheless, some studies suggest that effective food waste management can reduce costs and increase retailers' income (Cicatiello et al., 2023). Research shows that food waste treatment scenarios can be environmentally feasible when safe recovery rates exceed 48%, which is

achievable for food waste collected at the initial stages of the food supply chain (Al-saleh & Aleisa, 2022).

2.5.3. Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) predicts behaviours in which individuals have incomplete voluntary control and hypothesises that an individual's intention is influenced by attitude and by norms, which then turn into behaviour (Ajzen, 1991). In the retail sector, the TPB explains how retailers can decide whether to handle, discard, or redistribute food. Studies like those of Graham-Rowe et al. (2015), Filimonau & Gherbin (2017), and more recent studies of Carvalho & Marta-Costa. (2025) shows that the perception of consumer demand and the cosmetic standards of fruits and vegetables influence retailers' waste management practices. Papargropoulou et al. (2021) further explain that utilising the TPB model in food waste studies shows that positive attitudes, combined with supportive norms, can significantly increase the likelihood of sustainable waste management practices at both the consumer and organisational levels. This can be used to examine how managers' decision-making practices in retail operations can contribute to reducing the waste of fruits and vegetables (Lien et al., 2002; Obuobi et al., 2022; Rastegari et al., 2023).

2.5.4. Integrated framework of fruits and vegetables in the retail sector

As shown in Figure 2.4, the integrated framework situates the retail sector of fruits and vegetables at the centre of waste generation. It illustrates how retailers' decisions, influenced by internal and external drivers of waste, determine the volume and costs of fruit and vegetable waste. The framework shows how intervention strategies can mitigate these losses.

Retailer decision-making interacts with economic and environmental assessments and commitments to sustainability and shared responsibility. These dynamics influence the adoption of circular economy practices and the alignment of the FLW hierarchy with the National Waste Management Strategy (NWMS) and Sustainable Goal 12.3. These factors determine the scale and extent to which waste is minimised, costs are reduced, and sustainability is achieved. This integrated framework not only integrates theoretical models but also provides practical guidance and a comprehensive lens through which fruits and vegetables in urban areas like Durban can be studied

and assists in designing strategies to reduce food waste while advancing sustainable and social equity goals.

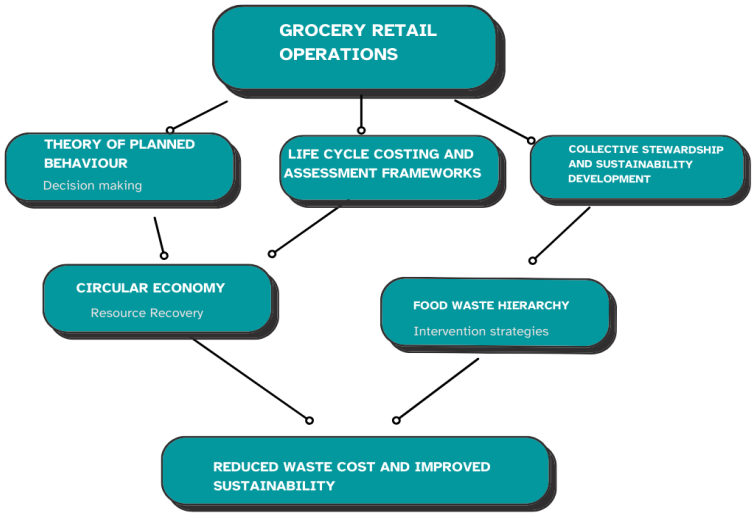


Figure 2.3: The integrated framework for the LCC/LCA, collective stewardship, and the TPB model

*Source***:** Author's own work

2.6. CHAPTER SUMMARY

This chapter reviewed literature related to food waste generation within retail operations, with a particular focus on fruits and vegetables. The chapter examined global, African, South African, and Durban perspectives on food waste, including the environmental, economic, and social implications associated with food loss and waste within the retail sector. Key drivers of food waste, such as perishability, inventory management, handling practice, infrastructure limitations, and consumer behaviour, were also discussed. The chapter further reviewed theoretical and conceptual frameworks relevant to the study, including the Theory of Planned Behaviour (TPB), Collective Stewardship Theory, and Life Cycle Costing/Life Cycle Assessment perspectives. These frameworks provided the foundation for understanding the behavioural, economic and sustainability dimensions of fruits and vegetable waste generation. The reviewed literature revealed significant gaps relating to retail food waste quantification and cost estimation within the Durban context, thereby justifying the need for the current study.

The following chapter presents the research methodology adopted to achieve the study objectives.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter explains the reliability and validity of the research by detailing the methodological approach used to investigate the quantification of fruit and vegetable waste in retail operations within Durban, KwaZulu-Natal Province. It outlines the research methodology used to address the study objectives and serves as the blueprint that guides the entire study.

Given the aim of the research to identify, classify, and quantify fruit and vegetable waste and estimate its monetary value, a quantitative approach was adopted. Since the study seeks to generate numerical evidence on the types, volumes, causes, and monetary value of fruit and vegetable waste, the quantitative method was employed. Structured questionnaires, waste composition analysis, and a cost estimation method were used to capture objective data on waste generation. At the same time, statistical tools, including SPSS software, were employed to analyse relationships among variables and model the factors influencing waste generation.

In line with the best global practices, this study drew on established frameworks such as the Food Use for Social Innovation by Optimising Waste Prevention Strategies (FUSIONS) quantification manual and the National Waste Management Strategy. These guided the design of the data collection instruments and analytical procedures to ensure consistency and comparability with international studies on retail food waste.

The chapter presents the research design and the study area (providing an overview of Durban), outlines the sampling method and sample size, and details the recruitment of retail stores. It also presents the pilot study and its role in refining the research instruments. It discusses data collection methods and the data analysis techniques used to address each research objective. It further highlights the methodology's limitations while outlining the ethical considerations that guided the study.

3.2. STUDY AREA

This study was conducted in Durban, KwaZulu-Natal Province. Durban is part of the eThekwini Municipality located in the province of KwaZulu-Natal, South Africa (COGTA 2021). It includes neighboring cities and has a population of approximately 3,301,000 in 2025, a 1.2% increase from 2024. eThekwini is the sole Category A metropolitan municipality in the KwaZulu-Natal Province. This makes the whole community one of the largest cities on the African continent, Indian Ocean coast. Durban is an ethnically diverse city with a large Zulu, White, and Indian population (Govender & Reddy, 2019).

The eThekwini Municipality allows for a wide range of land uses, both formal and informal, including urban and rural settlements as well as public and social infrastructure (Hailu et al., 2024). Durban is a central economic hub with a diverse retail sector that includes supermarkets, grocery chains, and independent outlets (Musvito & Hansmann, 2016).

The eThekwini Municipality contributes 54.66% towards KwaZulu-Natal's Gross Value Added, where Retail Trade contributes 16.60%, and agriculture, fisheries, and forestry contribute less than 2% (KZN EDTA, 2021).

The city has four landfill sites: Bisasar Road Landfill Site, Mariannhill Landfill Conservancy, Buffelsdraai Landfill Conservancy, and the Lovu Landfill Site, and they play a vital role in managing municipal waste (Abdelmegeed, 2022). According to the municipality's Cleansing and Solid Waste (CSW. 2025), the municipality aims to remove green waste away from landfills and find alternative disposal methods. The municipality's major concern is that food disposed of at the landfill is easily accessible to the public, who often scavenge for edible items, resulting in cases of food poisoning, a persistent public health concern (Vergara et al., 2012).

In a major tourist destination city, unmanaged waste and pollution can harm the city's natural resources and, consequently, its economy (Aliamutu & Mkhize, 2024). Like many other cities, eThekwini lacks adequate recycling infrastructure, sufficient support mechanisms, and incentives for waste segregation (Govender & Reddy, 2020).

The eThekwini Cleansing and Solid Waste Unit faces severe operational challenges (Ernstson & Swyngedouw, 2023); its landfills are reaching capacity, and two landfills have begun refusing general solid waste, placing increased pressure on Buffelsdraai, which is already distant from the city center and most metropolitan areas (CSW, 2025).

The eThekwini Municipality, therefore, needs to find sustainable, scalable solutions to divert waste from landfills and to adopt effective strategies to encourage recycling initiatives and programmes within the municipality. Given Durban's critical role in food distribution and consumption, and the substantial challenges the city faces in managing retail-level food waste (Dlomo, 2021), it is an appropriate and relevant location for this study. The map of eThekwini Municipality is illustrated in Figure 3.1 overleaf.

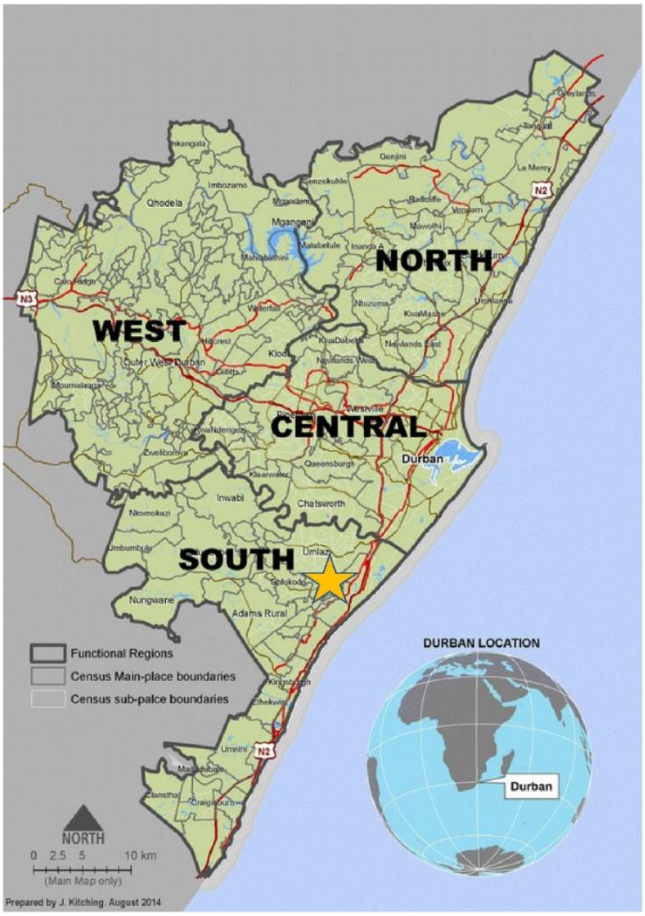


Figure 3.1: The map of the eThekwini Metro

***Source*:** Municipalities of South Africa -eThekwini Metropolitan Municipality Article:municipalities@co.za (2021).

3.3. RESEARCH PARADIGM AND RESEARCH APPROACH

This study was guided by the positivist research paradigm which is appropriate for studies that seek to measure observable phenomena, test relationships between variables, and generate findings using objectives and statistical procedures (Park et al, 2020). Positivism was suitable for this study because the research focused on quantifying fruits and vegetable waste estimating its monetary value and analysing the relationship between selected variables influencing waste generation in retail operations. This study adopted a quantitative research approach. This approach was appropriate because the study relied on numerical data collected from selected retail stores through structured questionnaires, waste composition analysis, and cost estimation. Quantitative methods enabled the use of descriptive statistics, multiple linear regression and ordinal logistic regression to analyse the volume, monetary value and factors associated with fruit and vegetable waste in Durban retail operations.

3.4. RESEARCH DESIGN

The research design outlines the structure and methodology of the research process, including how data were collected and analysed, ensuring that the collected data are reliable, valid, and relevant to the research objectives. The study used a quantitative research design, with outcomes represented in the form of graphs, charts, and numbers. Quantitative research was used to gather data that provides answers to the research questions within the population (Hans et al., 2023).

The descriptive analysis enabled the collected data to be structured by type, volume, and cause of fruit and vegetable waste. The quantitative approach was an appropriate method because it emphasises measurable data, including the estimation of waste volume and monetary values. Similar studies have shown the effectiveness of this approach in food waste research. The study by Du Toit (2018) applied regression-based modelling to sales and waste data from 6,677 retail stores, highlighting how quantitative methods can effectively capture retailer-level waste dynamics. In a Paraguay study, Ismael (2023) applied a quantitative method to conduct a study on the quantification of food waste in retail operations, measuring fruit and vegetable waste in six retail stores, and distinguishing warehouse versus post-shelf losses.

This study used the FUSIONS (2020) quantification manual as a guideline, which involves on-site food waste characterisation and structured surveys with key retail store personnel.

The study adopted a cross-sectional research design because data was collected from retail stores at a single point rather than over an extended period. The cross-sectional design was appropriate for assessing the quantity, monetary value, and factors associated with fruit and vegetable waste within the selected retail stores during the study period.

3.5. SAMPLING METHOD AND SAMPLE SIZE

The study sample size was influenced by the timeframe, retailers' availability, and available resources. The target population was the retail stores in Durban that sell fruits and vegetables. This included supermarkets, small shops, and large grocery stores within the central business district. The focus areas were Central, Grayville, the Market precinct, and Point (North and South Beach), and cluster sampling was used to group these areas into four clusters and retail grocery stores were then randomly selected within each cluster.

The eThekwini Municipality Business Licensing Unit has registered 49,100 retail businesses in eThekwini from 2018 to 2023, of which 18,320 are grocery stores. Cluster sampling was used because of the large population of retail stores in eThekwini. Similar approaches have been used before in previous food waste studies, where researchers had large populations and used clusters to group the sampling frame. Studies by Eriksson et al. (2012) and Lebersorger and Schneider (2014) also used method across retail outlets in the UK and Spain. More recently, Jayathilaker et al. (2023) adopted a cluster sampling strategy in Colombo, Sri Lanka, to quantify food waste in wholesale and retail stores.

Durban CBD is divided into four precincts and falls under Region Two, specifically the Victoria Mxenge and Gedley’hlekisa Political Zones, which were used as clusters (KZN-EDTA 2021; COGTA 2024). The initial sample size for the study was determined using the Krejcie and Morgan (1970) sample size determination formula, which is suit-

able for finite populations. The Krejcie and Morgan (1970) formula was selected because it is widely used in social science and population-based studies to determine representative sample size from finite populations. The formula is presented as follows:

$$S = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)}$$

Where:

S= required sampled size

x^2= the table value of chi-square for 1 degree of freedom at the 95% confidence level (3.841)

N= population size

P=population proportion (assumed to be 0.5)

d= degree of accuracy expressed as a proportion (0.05)

Using this formula, the initial target sample size was calculated at 384 retail stores. To ensure proportional representation across the four clusters, the following proportional allocation formula was used:

$$\text{Proportion of Cluster} = \frac{\text{Cluster size}}{\text{Total Population}}$$

Table 3.1. presents the proportional distribution of the calculated sample across the four clusters.

Table 3.1: Proportional distribution table of the sample size across the four clusters

Cluster	**Total population**	**Sample size**
Central	5 580	118
Market (Berea)	5 220	109
Grayville	2 786	58
Point (North and South Beach)	4 734	99
Total		**384**

Source: Author's own compilation (2025)

However, during the data collection process, several retailers declined to participate in the study, while some stores identified in the original sampling frame were no longer selling groceries or fresh produce. Consequently, the final achieved sample consisted of 100 consenting and eligible retail stores. Although the achieved sample was lower than the initially calculated sample size, it was considered adequate for the purpose of the study, given the accessibility constraints and non-response challenges encountered during fieldwork.

3.6. SELECTION OF PARTICIPATING RETAIL STORES

The retail stores were approached in February 2025, and authorisation was required from retailers before data collection could commence. Similar to Hobson (2023), who collaborated with a South African retail chain under a formal agreement, this study also required authorisation to enable in-depth data sharing. The selection process was challenging, as some retail stores were unwilling to participate in the study. Consequently, a negotiation process was necessary, as recommended by Lewis (2003), who emphasises the importance of engaging retail gatekeepers when conducting research within retail environments. In this study, senior store managers and authorized personnel were approached to request participation.

The consent form from the University of South Africa and a non-disclosure agreement (NDA) were signed. However, the store managers did not provide their historical data on waste quantification, and data access was denied; only data for selected months were provided, and these were often based on staff estimations rather than documented measurements. These challenges are common in retail food waste research. Eriksson et al. (2017) observed that retailers frequently resist sharing historical waste data because of confidentiality concerns and inconsistent waste classification. Similarly, Filimonau & Gherbin (2017) and Sander et al. (2023) found that at the retail level, waste estimations are often inaccurate or unavailable, reducing quantitative precision.

Comparable challenges were also reported by Dlomo (2021) when conducted a study in Durban, where only one retail store agreed to participate. Stuart (2021) further noted that many retailers rely on estimations or summary-level data due to limitations in their systems.

To mitigate the impact of these limitations, this study incorporated direct observations during the pilot phase and cross-referenced retailers' responses with municipal data from the Cleansing and Solid Waste (CSW) Unit and secondary sources to improve overall validity and reliability of the findings.

3.7. PILOT STUDY

The pilot study was conducted prior to the commencement of complete data collection to test the clarity, relevance, and reliability of the questionnaire. A total of 30 retail stores were approached across Durban, and not within the CBD as initially proposed. The pilot covered different parts of the city to capture diversity in store types, operational practices, and geographic locations, and the participants in the pilot study were not used in the main data collection.

Feedback from the pilot study led to minor revisions in wording, as some terms were not relevant to the retail context. Additional information was obtained from the municipality to understand the costs associated with landfill waste disposal, waste collection services, and bin rentals.

The pilot study revealed that using secondary data, especially for average fruit and vegetable prices per kilogram, would be necessary, and some questions were removed from the questionnaire due to redundancy or irrelevance.

3.8. DATA COLLECTION

The data was collected using a structured questionnaire, and store managers along with other relevant staff members responsible for produce sections were chosen to respond to the questions. This approach mirrors that of Horoś & Ruppenthal (2021), who surveyed and conducted semi-structured interviews in the German region, selecting grocery retail store owners as respondents. This ensured that the study targeted knowledgeable store owners who could provide reliable insights into waste drivers and management practices.

Primary data were gathered from the store and through on-site food waste assessments, which enabled the researcher to verify practices for handling, promotion, storage, and disposal of fruits and vegetables. The CSW Unit verified the collected data

to determine the municipal fees for landfills and the green bins used by retailers. The study also used inventory and archival documents provided by a few retail stores that agreed to share this information, for specific months only, to confirm the findings. This is supported by de Moraes & Colombo (2020), who applied a mixed-methods approach, combining data from 16 retail stores with interviews to estimate volumes and identify the causes of food waste. Their study highlights the strength of on-site audits in producing accurate findings supported by secondary data.

Cicatiello & Franco (2016) and Mattsson & Williams (2022) demonstrated that administrative records, when integrated with direct measurement, can reveal previously unrecorded retail food waste. These examples show that partial access to store records is common, and using them along with primary data strengthens the overall reliability of the findings. The use of structured questionnaires for this study reflects a deliberate methodological choice to triangulate evidence across multiple data sources.

The questionnaire consisted of three parts. The first part focused on quantifying FLW; the second on quantifying the costs associated with FLW; and the third on its causes and waste management practices.

3.8.1. Analysis of the Secondary Data

Data from the eThekwini Municipality Cleansing and Solid Waste (CSW) directorate was used to determine landfill and other disposal costs retailers face, based on records from 2023 to 2025. This included landfill fees per kg, collection services, and bin rentals. Some large retail groups had private service providers that managed waste within the store and did not rely solely on municipal services. This information was used to calculate the monthly costs retailers incur to achieve Objective 2 of the study and to understand the monetary value lost due to waste.

The average price of fruits and vegetables was used to calculate the total monetary value lost using the formula:

Total monetary value per category = Total discarded waste (kg) × Average price (R/kg).

The data on the average prices of fruits and vegetables were sourced from the dominant South African retail chains (SPAR, Checkers, and Pick n Pay) based on 2022–2024 average prices (Competition Commission, 2024). This approach ensured consistency across the diverse sample of 100 retail stores and helped reduce bias caused by price variation. The method was also used by Lebersorger & Schneider (2014) and Eriksson et al. (2017), who applied category-based average prices to estimate the economic losses of food waste in Swedish retail.

Similarly, Hobson (2023) adopted the same approach due to limited access to uniforms, detailed store pricing. The use of publicly available retail average prices is practical and endorsed by FAO (2020), which recommends average category-level prices to maintain consistency across diverse products.

3.8.2. On-site Primary Data Assessment

The on-site inspections were conducted to achieve Objective 2 for waste composition analysis and to categorise the waste. This method enabled direct observation of food-handling practices, spoilage identification, and waste management processes in the produce sections. Some retail stores used private waste management service providers that integrated technology into their waste-tracking processes. Packaged produce that was unsellable was scanned through barcode systems, which automatically recorded their removal from inventory.

For fresh fruits and vegetables, spoilage was primarily detected through visual inspections, as they had no best-before or expiry dates. Employees in the produce section were responsible for removing spoiled or deteriorated items, and the manager had the final authority to declare whether produce should be discarded.

During inspections, some stores' receiving department managers were responsible for measuring discrepancies between dispatched stock and the quantities returned as waste. However, this did not include the destination of the waste, whether recycled, donated, or discarded.

To achieve Objective 2, spoiled or discarded produce was separated from shelves and storage areas, and the total waste discarded in each store was recorded. Fruits and

vegetables were sorted and classified, and the waste was weighed using store scales. Some stores lacked functional scales or had old equipment, which affected accuracy.

This process took four months to complete, from February (piloting) to June 2025. Stores were asked to record their waste for thirty days. Due to the large number of stores, managers were asked to record waste in the researcher's or assistant's absence. In cases where stores failed to maintain records, senior managers provided estimated total waste volumes for the month in question.

3.9. DATA ANALYSIS

The data collected for this study were quantitative, and both primary and secondary data were systematically recorded and entered into Microsoft Excel for organisation and analysis. Separate worksheets were created for each objective to ensure clarity and consistency during the analysis process. Microsoft Excel has been widely used in different studies as an initial platform for data cleaning, organisation, and descriptive analysis (Martins et al., 2025).

For inferential statistical analysis, the Statistical Package for the Social Sciences (SPSS) was used perform regression analyses. Microsoft Excel was used to compute descriptive statistics, including percentages and means. These analyses provided a summary of key trends, including the most wasted fruit and vegetable categories, waste volumes, and the average monetary value lost within retail stores. Graphical representations were generated in Excel to present the findings visually.

The data analysis approach used in this study follows similar studies conducted by other researchers. Table 3.2. summarises the data analysis tools and analytical approaches used for each research objective. The table presents a structured overview of how the study objectives were operationalised and analysed.

Objective 1: To profile the socio-economic and operational characteristics of selected retail stores in the city of Durban, descriptive statistical analysis was used to summarise respondent positions, retail store characteristics, and operational activities. Frequencies, percentages, and graphical representations were generated using Microsoft Excel to provide an overview of the retail stores included in the study. Descriptive

profiling is widely used in quantitative retail and food systems research to contextualise the characteristics of study participants and operational environments.

Objective 2: To classify the types of fruits and vegetables most frequently wasted by retailers in the city of Durban, the Waste Composition Analysis (WCA) was used to categorise discarded fruits and vegetables into categories such as citrus, leafy vegetables, tomatoes, stone fruit, and melons. The effectiveness of this method has been demonstrated in retail waste audits, as seen in New Zealand (Goodman-Smith et al., 2020) and in South Africa by Hobson (2023), who utilised the FLW Accounting and Reporting Standard.

Objective 3: To quantify the volume and estimate the monetary value of fruit and vegetable waste generated by retailers in the study area, quantitative estimation methods were used to measure the weight of fruit and vegetable waste and compute its corresponding monetary value using average retail prices from 2022 -2024 data obtained from major South African retailers, including SPAR, Checkers-Shoprite, and Pick n Pay as reported by the Competition Commission (2024). This approach allows for statistical summaries of losses in both physical and financial terms. It is widely applied in retail studies, such as FAO's Sri Lankan case study (2022) and ReFED's (2025) retail waste quantification models.

Objective 4: To identify the factors influencing the generation of retail fruit and vegetable waste in the study area, structured questionnaires were used to capture influencing factors, including labelling, handling, promotions, planning, infrastructure, and food safety. These categorical and Likert-scale variables were analysed descriptively and prepared for ordinal logistic regression to determine which factors most strongly predict higher waste-generation frequencies. Du Toit (2018) applied a similar approach in South Africa, and Mattsson & Williams (2022) used survey-linked retail datasets in Europe, demonstrating the utility of regression-based methods in modelling store-level waste drivers.

Objective 5: To develop a pathway to minimise fruit and vegetable waste in the study area, the study synthesised findings from all objectives and used retailers' Likert-scale recommendations on potential strategies. These were mapped against the National

Waste Management Strategy (NWMS 2012), which emphasises prevention, redistribution, recycling, and landfill diversion. The recommendations were also benchmarked against international evidence (FAO, 2022; Riesenegger & Hübner, 2022; ReFED 2025).

Table 3.2: Data Analysis Techniques and Statistical Software used in the Study

Objectives	Statistical Software	Analysis Technique
RO 1: To profile the socio-economic and operational characteristics of selected retail stores in the city of Durban	**EXCEL**	Descriptive statistics (frequencies, percentages and charts)
RO 2: To identify and classify the types of fruits and vegetables wasted mainly by retailers in the city of Durban	EXCEL	Descriptive analysis (frequencies, percentages) of waste composition
RO 3: To quantify the volume and estimate the monetary value of fruit and vegetable waste generated by retailers in the study area	EXCEL / SPSS	Computation of the total monetary losses and Multiple Linear Regression Analysis
RO 4: To identify the factors influencing the generation of retail fruit and vegetable waste in the study area	SPSS	Ordinal logistic regression analysis
RO 5: To develop a pathway to minimise/eradicate fruit and vegetable waste in the study area	EXCEL	Descriptive statistics of Likert-scale descriptive analysis

3.9.1. Variable Specification for the Multiple Linear Regression Model

The Multiple Linear Regression Model was used to estimate the relationship between the total cost of the food waste generated and the selected independent variables. The variables used in the model are presented in the Table 3.3.

Table 3.3. Variables used in the Multiple Linear Regression Model

Variable Type	**Variable Description**	**Measurement**
Dependent Variable (Y)	Total cost of waste produced	Rand value (R)
Independent Variables (X_1)	Total quantity of fruits and vegetables total weight sold per month	Kilograms (kg)
Independent Variables (X_2)	Total cost of redirecting food waste from landfill	Rand value (R)

Source: Author's own compilation (2025)

The multiple linear regression model used in the study was expressed as follows:

$$Y = ß_0 + ß_1X_1 + ß_2X_2 + £$$

where**:**

Y=Total costs of waste produced (R)

x_1=Total quantity of fruits and vegetables sold per month (kg)

x_2=Total costs of redirecting food waste from landfill (R)

ß1 and ß2= estimated regression coefficients

£= Error term

3.9.2. Variables Specification for the Ordinal Logistic Regression Model

Ordinal Logistic Regression analysis was used to identify the factors influencing fruit and vegetable waste generation in retail stores. The ordinal logistic regression model was selected because the dependent variable was ordinal in nature and measured the

frequency of waste generation across retail stores. The variables used in the model are presented in Table 3.4.

Table 3.4: Variables used in the Ordinal Logistic Regression Model

Variable type	Variable Description	Coding/Measurement
Y	Generation of fruits and vegetables waste	Yes = 1 No = 2 Sometimes = 3
X_1	Date Labelling	Categorical
X_2	Promotions	
X_3	Food safety standards	Categorical
X_4	Handling practices	Categorical
X_5	Poor waste management practices	Categorical
X_6	Poor planning	Categorical
X_7	Lack of infrastructure and use of recovery technology	Categorical

Source: Author's own compilation (2025)

3.9.3. Analysis of Research Objective 5

For Research Objective 5, descriptive statistics and Likert-scale analysis were used to analyse retailer recommendations and proposed pathways to minimise fruit and vegetable waste in Durban retail operations. The Likert scale used in the study was coded as follows:

Table 3.5: Four-point Likert scale coding

Likert Scale Response	Coding
Highly recommended	1
Recommended	2
Not recommended	3
Highly not recommended	4

Source: Author's own compilation (2025)

3.10. LIMITATIONS OF THE METHODOLOGY

The selected methodology is appropriate for achieving the research objectives. However, there are several limitations, and these include:

- Although the final initial sample size calculated using the Krejcies and Morgan (1970) formula was 384 retail stores, the final achieved sample consisted of 100 retailers due to non-response and accessibility challenges encountered during the field work. Retailers were initially randomly selected within the identified clusters; while others no longer sold groceries or fresh produce products. Consequently, the final sample was limited to retailers that were accessible and willing to participate in the study.
- Time was a constraint, as store managers or appointed staff members were available only at specific times, and there were limitations with respect to scheduling. Several store visits were delayed or rescheduled, slowing the data collection process.
- The quantification of data represented only a one-month period, which limits the research to a relatively short timeframe, reducing the ability to capture seasonal variations in fruit and vegetable waste, such as peak summer spoilage or winter demand fluctuations.

3.11. ETHICAL CONSIDERATIONS

The ethical approval for this study was obtained from the University of South Africa, College of Agriculture and Environmental Sciences. Participation in the study was voluntary, and a consent form was provided to ensure confidentiality. To ensure anonymity, no identifying information about the retail stores or individual participants was recorded or disclosed. Approval and consent were obtained from the retailers prior to data collection.

Upon approval, some retail stores provided Non-Disclosure Agreements (NDAs) for their representatives and the researcher to sign. The Supply Side Area-Based Operations of the eThekwini Municipality granted permission to conduct the study, and the Business Support Unit provided the necessary information on the total number of grocery retail stores in Durban.

The data analysis and modelling were refined based on feedback received from retailers during the pilot study to ensure accuracy, transparency, and ethical integrity.

3.12. CHAPTER SUMMARY

This chapter presented the research methodology adopted in the study. The chapter described the positivist research paradigm and quantitative research approach underpinning the study as well as the cross-sectional research design used to collect data from retail stores within Durban CBD. The sampling procedures, sample size determination, data collection method, and ethical considerations were also discussed.

Furthermore, the chapter explained the statistical and analytical techniques used to analyse the data including descriptive statistics, waste composition analyse, multiple linear regression and ordinal logistic regression. The chapter also outlined the validity, reliability and limitations associated with the methodology. The following chapter presents and discusses the findings obtained from the empirical investigation.

CHAPTER 4: DATA ANALYSIS

4.1. INTRODUCTION

This chapter presents and discusses the results based on the five objectives of the study on the cost quantification of fruit and vegetable waste in Durban, KwaZulu-Natal province, in retail operations. The purpose of this chapter is to provide results from the data collected and statistical analyses and interpret these findings in the context of the previous literature.

The presentation of the findings is structured according to these four specific objectives.

i. To profile the socio-economic and operational characteristics of selected retail stores in the city of Durban

ii. To identify and classify the types of fruits and vegetables wasted mainly by retailers in the city of Durban

iii. To quantify the volume and estimate the monetary value of fruit and vegetable waste generated by retailers in the study area.

iv. To identify the factors influencing the generation of retail fruit and vegetable waste in the study area

v. To develop a pathway to minimise/eradicate fruit and vegetable waste in the study area.

4.2. DESCRIPTIVE ANALYSIS

The descriptive statistics outlined below provide an overview of the retailers surveyed, showing that most have considerable experience in food retailing and primarily deal in fresh produce. These characteristics are important because they shape how retailers perceive, manage, and respond to food waste challenges. However, while descriptive analysis highlights the general profile of the respondents, it does not explain the specific operational and structural factors influencing food waste at the retail level. To address this, the study employed a regression model to test the relationship between

key predictor variables such as expiry date management, markdowns strategies, re-distribution, and demand planning.

4.2.1. Background of the interviewed retailers

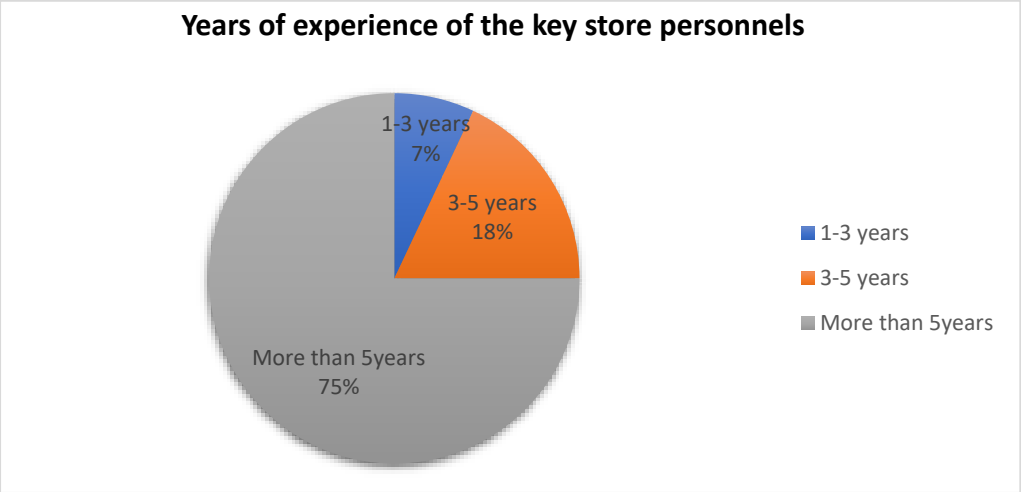


Figure 4.1: The pie chart showing the number of experiences of the key store personnel interviewed

Source: Author's own compilation (2025)

Most of the respondents, 75% reported having more than 5 years of experience working in a grocery store, while 18% had 3-5 years of experience working, and 7% had 1-2 years of experience (Figure 4.1). This suggests that most respondents were highly experienced and well-versed in retail operations. This implies that they have familiarity with inventory management, customer experience, and issues related to food waste. This strengthen the reliability of the information provided since their insights are based on years of practical experience in the sector like Mena et al (2011), Lebersorger & Schenider (2014) and Dlomo (2021) who find the similar findings in Durban retailers.

The high proportion of respondents with extensive retail experience strengthens the reliability of the findings because experienced personnel are more likely to possess operational knowledge regarding stock handling, spoilage patterns, inventory management and waste generation within retail environments.

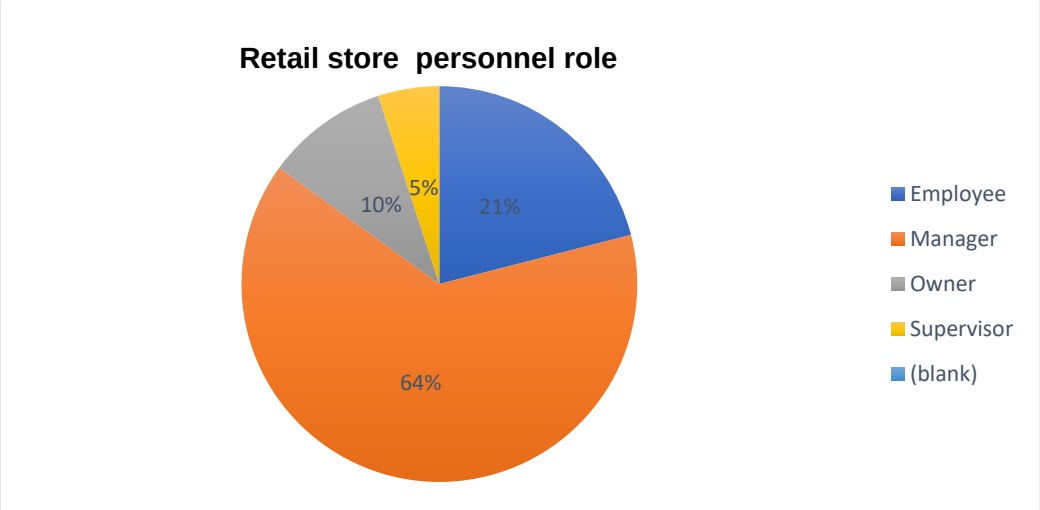


Figure 4.2: The pie chart showing the role of the key personnel who responded to the questioners

Source: Author's own compilation (2025)

Key personnel were part of the study to obtain the relevant information, as shown in Figure 4.2. The above shows that 64% of the key personnel were store managers, 21% were supervisors, 10% were owners, and the remaining 5% were part of the study. Dlomo (2021) also mainly interviewed retail managers, the key store personnel, who participated in the study. Horo & Ruppenthal. (2021) highlighted that store managers and owners are most likely to provide reliable food waste data because of their direct responsibility for store operations, offering the deep insights into the causes and impacts of waste that external data may miss, and can provide valuable context for developing effective, practical prevention strategies.

The inclusion of store managers and senior retail personnel was important because these participants are directly involved in operational decision-making processes relating to procurement, inventory control, waste handling and disposal practices within retail stores.

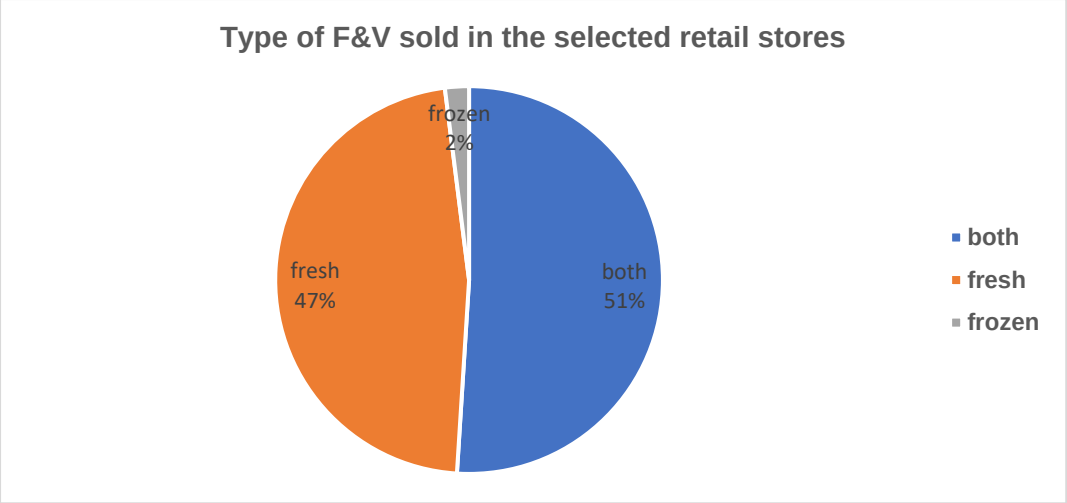


Figure 4.3:The type of fruits and vegetable sold in the store

Source: Author's own compilation (2025)

Regarding the types of fruit and vegetables sold, Figure 4.3 shows that 51% of retailers reported selling both fresh and frozen produce, 47% reported selling only fresh produce, and 2% reported selling only frozen produce. The dominance of fresh produce or combined sales reflects the high demand for perishable items in grocery stores. Given that fresh produce is more prone to spoilage. These findings suggest that retailers in Durban are likely to encounter food waste challenges related to perishability. These findings are consistent with Gustavsson et al. (2011), Eriksson et al. (2021), Ismael (2023), and Todd & Faour-Klingbeil (2024), who found that fruits and vegetables account for the largest share of food waste in the retail sector.

The diversity of fruits and vegetables sold across the sampled retail stores provided a broader understating of waste generation patterns across different categories of highly perishable products, thereby strengthening the comprehensives of the study findings.

4.3. WASTE COMPOSITION ANALYSIS

Waste composition analysis was used to identify and classify the types of fruits and vegetables mostly wasted by retailers in the city of Durban.

Different fruit and vegetable categories were observed and assessed using the Waste Composition Analysis during the on-site inspection in 100 selected retail stores in Durban. One of the surveyed retailers highlighted that their aim in the produce section is not to generate more than 2% to 5% of waste. The results show the physical waste

that was produced and weighed on-site in kilogrammes. Table 4.1 presents the total discarded waste weight (in kilogrammes) per category and the associated monetary value.

The data collected shows that the total discarded waste weight for all categories was 52 550.7kgs and the total monetary value lost was R119,052.00. Among the fruit categories, tomatoes and avocados were the highest producers of waste, with 7,517.7 kg, followed by citrus fruits, with 5,838.2 kg. The vegetable with the highest waste was leafy greens, with a recorded waste of 8,839 kg. The berry fruits were recorded as having the lowest waste, totalling 1495.8kg. These findings are consistent with growing research demonstrating that tomatoes and leafy vegetables are the most perishable produce due to their short shelf life and high susceptibility to spoilage.

Table 4.1: The amount (kilogrammes) of fruits and vegetables waste produced and lost monetary value per category

Category	Total Discarded (kg)	Avar Price/kg (R)	Monetary value (R)
Citrus	**5 838,2**	10	**58 382**
Stone Fruits	**4 206,7**	28	**11 778**
Tropical & exotic fruits	**2 904,6**	35	**10 166**
Berries	**1 495,8**	70	**10 470**
Melon	**1 843,6**	17	**33 184**
Tomatoes and avocado	**7 517,7**	30	**22 553**
Apples and peaches	**4 351,2**	20	**87 024**
Root vegetables	**7 510,9**	15	**11 266**
Stem vegetables	**3 547,1**	14	**49 659**
Leafy green vegetables	**8 839**	25	**22 097**
Cruciferous vegetables	**4 385,9**	18	**78 946**
TOTAL	**52 440,7**		**119 052**

Source: Author's own compilation (2025)

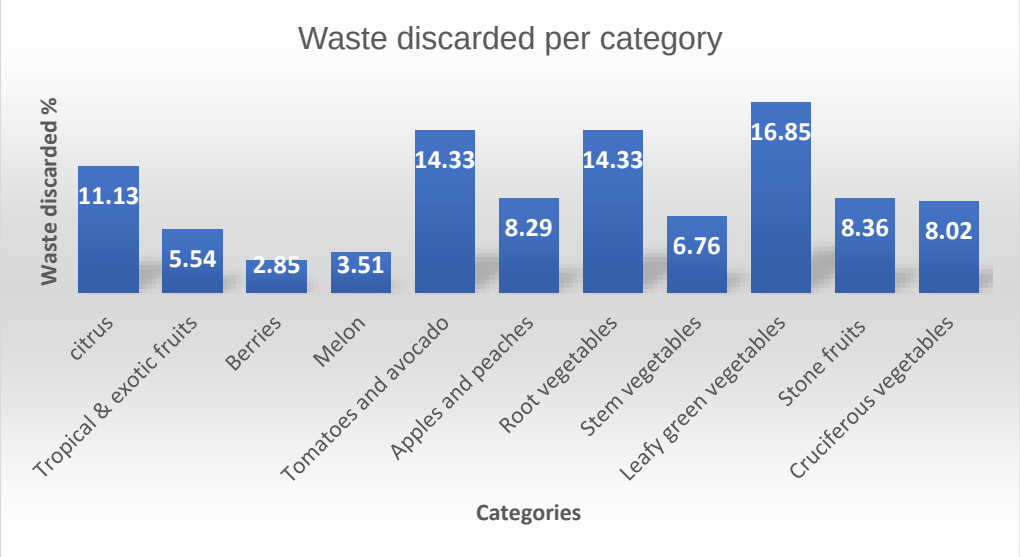


Figure 4.4: The type of fruits and vegetables wasted in the store

Source: Author's own compilation (2025)

The fruits and vegetables produced approximately 52,440.7 kg of waste in total, with leafy green vegetable waste accounting for 16.8%, making it the largest contributor, followed by tomatoes and avocados. Root vegetables, along with these categories, account for about 45% of the waste, as shown in Figure 4.4. In contrast, melons and berries together make up less than 6% of the total discarded waste. This indicates that leafy vegetables, tomatoes, and avocados are considered highly perishable produce, consistent with global findings that produce with a shorter shelf-life are the most wasted in the retail sector. According to Shezi et al. (2024), leafy vegetables are considered highly perishable due to their high-water content, respiration rate, and sensitivity to temperature fluctuations. Similar research conducted in Brazil focusing on supermarkets found that leafy vegetables consistently accounted for the highest physical losses, exceeding 30% of fresh produce waste (Moradi et al., 2024). This is commonly caused by inadequate retail storage practices, poor infrastructure, and limited adoption of advanced technologies like Dynamic Shelf-life (DSL) systems, as proposed by Eriksson et al. (2020). However, challenges to DSL adoption in South Africa include the high cost of sensor technology, lack of local expertise, and limited awareness among small to medium-sized retailers (Ebrahim et al., 2024). Hobson (2023) confirms that in South Africa, leafy vegetables are the most wasted vegetables due to factors such as poor refrigeration capacity and high consumer sensitivity to freshness cues.

The root vegetable had 8.39% waste, although it is relatively less perishable, indicating inefficiencies in inventory management and demand forecasting. This is similar to the results from Chagas et al. (2024) in United Kingdom (UK) supermarkets, where potatoes and carrots were in substantial quantities despite their long storage potential. Limited adoption of advanced technologies such as artificial intelligence and machine learning for demand forecasting and inventory management worsens waste (Sakthi et al., 2025). Innovative solutions can predict consumer purchasing patterns more accurately, reducing overstocking and spoilage (Amosa et al., 2024; Fatorachian & Shokri, 2025).

Melons and berries are the lowest in weight among wasted categories, but they show significant monetary value loss. This is because, according to van der Werf et al. (2022), melons have a thicker outer rind and a comparatively longer shelf-life. The study in the European Union demonstrates that melon waste volumes are generally lower than those of other fruits due to this resilience during transportation and extended storage potential (Eriksson et al., 2020). Berries are an extremely perishable fruit category and are commonly purchased in smaller quantities and sold in packages to reduce handling and contamination (Bhattacharya & Wisniewski, 2023; Drimie & du Plessi, 2025). According to Sobekova et al. (2013) and Casson et al. (2024), retailers who sell these categories often use technology and inventory management for berries, as they are expensive and have a high unit price.

Research conducted by others has confirmed that the fruits and vegetables category is among the most wasted food items. These findings align with previous literature, which reports that fruits and vegetables often make up the largest portion of the food waste stream. The study by Dlomo (2022) in Durban confirms that fruits and vegetables are the most wasted category, contributing more than 33% of the total food waste generated. Similarly, a study by Oelofse and Nahman (2020) shows that fruits and vegetables, combined with roots and tubers, accounted for 57% of the waste stream studied. This underscores the importance of implementing food waste reduction strategies targeting fruits and vegetables in the retail sector. Moreover, according to CIRS (2021), approximately 40% of fresh products are wasted in low- and middle-income countries before reaching consumers. Kayikci et al. (2022) and Hoehn et al. (2023)

explain that this is because perishable foods have limited shelf life and must be sold before a specific date.

4.4. QUANTIFICATION OF COSTS AND THE MONETARY VALUE ESTIMATE OF FRUITS AND VEGETABLES WASTE

Objective 2 aimed to quantify the volume and estimate the monetary value of fruit and vegetable waste generated by retailers in the study area.

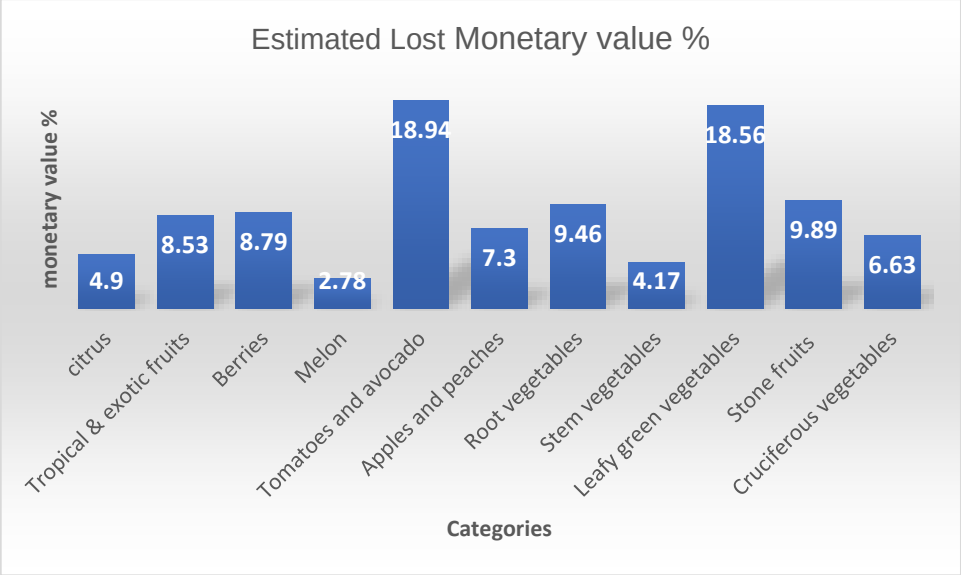


Figure 4.5: The estimated value of money lost per category in selected retail
Source: Author's own compilation (2025)

Figure 4.5 shows categories like tomatoes and avocados (R225.53) with 18.94% monetary loss, and leafy vegetables (R220.97) with 18.56% monetary loss, which represent the highest financial losses due to their large weight and mid-range retail prices. Berries, with the lowest discarded waste of 1,495.8kg and 8.79% monetary loss, interestingly, contributed R104,706, surpassing melons at R22,184.8. This is due to their average price per kg. Similarly, exotic and tropical fruits, which showed relatively modest volumes, experienced high financial losses (R101.66).

The paper published by the South African Journal of Economics and Management Sciences (2024) on food waste quantification found that spoiled stock can serve as a strong predictor of profit and sales volume loss in retail businesses. According to Riesenegge & Hübner. (2022), high-priced, highly perishable products like berries have a

disproportionately large economic impact on retail operations due to inventory shrinkage and other factors.

Table 4 2: Descriptive analysis of the Total Food Waste Value (Fruit and Vegetables)

	Total food waste quantity (Rand)
Mean	R11,911
Std. Deviation	R5, 568
Range	R2, 944-23,923

Source: Author's own compilation (2025)

The descriptive analysis was performed in SPSS, yielding measures of central tendency and dispersion for the dependent variable (Total food waste costs). The of food waste recorded across the sampled retailers was R1,191,109.5, based on the responses from 100 stores.

The mean monthly food waste cost was calculated as follows:

Mean $x = \frac{\sum X}{N} = \frac{R1,919,109.5}{100}$ R11, 911.10

The variance produced by SPSS was 31,010,708.141, indicating that food waste values were highly dispersed around the mean.

The Standard Deviation was calculated as follows:

$\sigma^2 = \sqrt{\sigma^2} = \sqrt{31,010,708.141} = 5,568.726$

The results presented in Table 4.2 show that the mean food waste cost (R) was approximately R11,911 per month, while the standard deviation was R5,569 per month. The range between R2,945 and R23,923 per month indicates the substantial variation in food waste costs across retail stores. Some stores experienced relatively low losses while other stores incurred significantly higher costs. The variation in waste costs across retail stores may be attributed to differences in operational practices, inventory management systems, and level of technology adoption. Previous studies indicate that larger retail stores often incur higher food waste costs because they stock larger quantities of perishable products compared to smaller retail outlets. Fatorachian & Shokri

(2025), further explains that food waste variation across retail stores is influenced by management practices, operational inefficiencies, store size differences, and overall approaches to handling surplus food. Similarly, Dlomo (2021) found variations in food waste quantities across retail stores in Durban, even among stores belonging in same retail group.

4.4.1. Multiple Regression Model

The multiple linear regression model was used to examine the relationship between the total cost of food waste produced (dependent variable) and the selected predictor variables, namely the total quantity of fruits and vegetables sold per month and the total costs of redirecting food waste from landfill.

Model assumptions

Before interpreting the regression output, diagnostic tests were conducted to verify that the model met the key assumptions of multiple linear regression:

- Linearity: The relationship between the predictors and the dependent variable was approximately linear, confirmed via scatterplots of standardised residuals versus predicted values.
- Independence error: The Durbin-Watson statistic fell within the acceptable range of 1.5-2.5, indicating independence of residuals.
- Homoscedasticity: Residual plots showed relatively constant variance, confirming homoscedasticity.
- No serious Multicollinearity was observed: The correlation matrix revealed a perfect positive correlation between stock received and total quantity sold (r=1.000) the stock received variable was excluded from the final model to minimise multicollinearity effects and improve model stability.

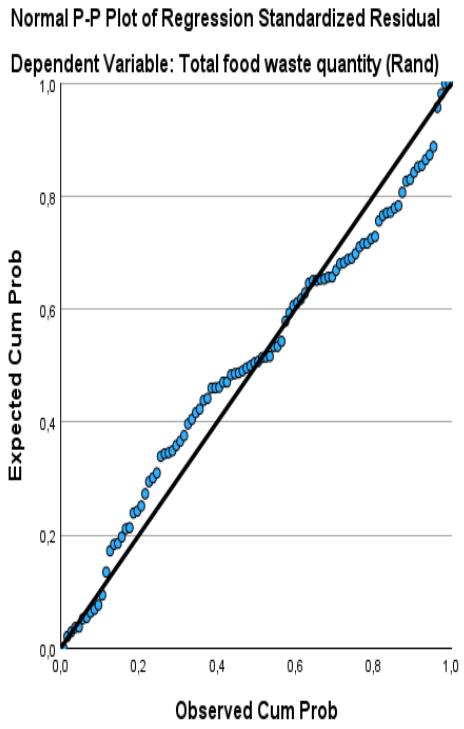


Figure 4.6: The P-P Plot of standardised residuals

Source: Author's own compilation (2025)

The normality of residuals was evaluated using the Normal P-P plot of standardised residuals generated by SPSS, as presented in Figure 4.6. The points on the P-P plot closely followed the diagonal reference line, indicating that the standardised residuals were approximately normally distributed. Although slight deviations were observed at the extreme ends of the distribution, these deviations were not severe enough to indicate substantial departures from normality. This observation is supported by the residual statistics output, which showed standardised residuals values ranging from -3.401 to 3.546, remaining within acceptable thresholds for regression analysis. This further confirms that there were no major outliers adversely affecting the model.

Therefore, based on the P-P plot and the residual diagnostic results, it can be concluded that the assumption of normality of residuals has not been violated in this model. This confirms that the regression analysis results, especially the regression coefficients indicating the relationship between total cost of food waste (Rand), and total landfill disposal cost and the total quantity of fruit and vegetables sold per month, can be interpreted with confidence. The normal distribution of residuals reinforces the validity of the regression findings and enhances the model's predictive reliability.

In the study, a One-Way ANOVA within the Multiple Linear Regression was performed, which tests a single model; it combines the significance of continuous predictors for a single continuous outcome.

Table 4.3: ANOVA results for Multiple Linear Regression Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2982341872,738	2	1491170936,369	1648,957	<,001[b]
	Residual	87718233,269	97	904311,683		
	Total	3070060106,008	99			
a. Dependent Variable: Total cost of waste produced (Rand)						
b. Predictors: (Constant), Total sold Fruits and Veg /month kg, Total cost to redirect waste to landfill						

Source: Author's own compilation (2025)

The ANOVA results presented in Table 4.3. indicate that the regression model was statistically significant, $F(2,97)=1648.957$ $p<0.001$. The regression sum of squares (SS=2,982,341,872,738) explained a substantial proportion of the variation in the dependent variable compared to the residual sum of squares (SS=87,718,233,269). The model produced a strong coefficient of determination ($R^2=0.971$), indicating approximately 97.1% of the variation in food waste costs could be explained by the predictor variables included in the model.

The fitted regression equation for the study was as follows:

$$Y = -228{,}306 + 0.068\ X_1 + 1.210\ X_2$$

where:

Y=Total costs of waste produced (R)

x_1= Total costs of redirecting food waste from landfill (R)

x_2=Total quantity of fruits and vegetables sold per month (kg)

The null and alternative hypotheses for the multiple linear regression model were specified as follows:

H0: ß1 = ß2 = 0

The null hypothesis stated that the predictor variables had no statistically significant influence on the total cost of food waste produced by retailers.

H1: At least one ß1 ≠ 0

The alternative hypothesis stated that at least one predictor variable significantly influenced the total cost of food waste produced.

The decision rule for the study was that if the p-value was less than or equal to 0.05, the null hypothesis would be rejected. Since the model significance level was p<0.001 the null hypothesis was rejected, indicating that the predictor variables significantly influenced the total food waste cost among retailers in the study area.

Holding all other variables constant, a one-kilogram increase in total fruits and vegetables sold per month was associated with an increase of approximately R1.21 in food cost, while a one-rand increase in landfill disposal cost was associated with an increase of approximately R0.068 in food waste cost.

Table 4.4: The Model summary (SPSS Output for Multiple regression model)

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,986[a]	,971	,971	950,95304	,971	1648,957	2	97	<,001
a. Predictors: (Constant), Total sold Fruits and Veg /month kg, Total cost to redirect waste to landfill									
b. Dependent Variable: Total cost of waste generated (Rand)									

Source: Author's own compilation (2025)

The model summary indicates that the predictors variables explained 97.1% of the variance in food waste (R^2=0.971, as shown in Table 4.4) suggesting that the model had a very strong explanatory power. The overall regression model was statistically significant (p<0.001) indicating that the predictor variables collectively influenced the food waste cost among the retailers. At the individual predictor level, the total fruits and vegetables sold was statistically significant (β=0.982, p<0.001). This suggests that holding all other variables constant, a one kilogram increased in the quantity of fruits and vegetables sold per month was associated with R1.21 in food waste cost. Practi-

cally, this suggests that retailers processing and selling larger volumes of fresh produce are also likely to experience higher food waste costs because highly perishable products move rapidly through retail systems and are more vulnerable to spoilage, damage, overstocking, and expiration. Total fruits and vegetables sold, (β=0.982) was also identified as a strong predictor of food waste cost generation within the model. This highlights the strongest operational relationship between retail sales volumes and waste generation particularly relationship within fresh produce departments where stock turnover is high.

In contrast, the total cost of redirecting food waste from landfill sites was not statistically significant at the 5% level (β=0.0068. p=0.229). Although the relationship was positive, the findings suggest that landfill diversion cost alone did not independently explain variations in total food waste costs among retailers. This may indicate that waste generation within retail operations is influenced by more strongly by operational factors such as stock movement, inventory management, handling practices and perishability rather than disposal costs alone. This suggests that reducing waste requires not just better disposal mechanisms but also upstream interventions, such as stock optimisation, improved demand forecasting, and targeted promotions to prevent overstocking, aligning with what the broader literature has reported over the years about inefficiencies, particularly procurement, as a central cause of food waste. According to the Waste Research, Development, and Innovation Roadmap Research Report (2021), landfill disposal costs may not reflect the actual cost of waste generated. This is due to hidden costs and factors like subsidies, which are the main reasons landfill costs do not fully influence waste costs, as many costs are external.

This may be because externalities related to landfilling are not reflected in financial statements. In this study, some retailers did not report how much they pay for disposal. According to Hobson (2023), waste service providers may not accurately calculate the full financial costs of collection and disposal, making landfilling appear cheaper than it is. Additionally, landfilling remains the dominant waste management option in South Africa and is preferred over initiatives such as recycling (Oelofse et al., 2021). Various studies (Jere et al., 2021) have shown this trend. This explains why landfilling costs tend to be low in South Africa (DEFF 2020b).

Residual and diagnostic statistics indicated a small number of observations with standardised residual values exceeding 3 suggesting the presence of minor outliers within the dataset. However, Cook's Distance values remained below critical thresholds, indicating that no single observation excessive influence on the regression model. Therefore, the model was considered sufficiently robust for interpretation.

This study echoes Fatorachian & Shokri (2025), which highlight that retailers with higher stock volumes, both incoming and sold, are more prone to waste and emphasise the need for integrating AI technologies that align with key theoretical perspectives supporting sustainable digital waste management. Prior literature reviews, such as those by Filimonau & Gherbin (2017) and Riesenegger & Hübner (2022), cite that food retailers like supermarkets and hypermarkets contribute to food waste due to purchasing problems and inventory miscalculations. Again, Bhatia & Gangwani (2021) and Olabonde (2025) emphasise the limited scope of existing literature on how management practices in the retail sector, such as inventory strategy and back-order rates, affect perishable food loss and waste (FLW). However, this study confirms that variations in food waste costs are strongly explained by sales and disposal cost factors, affirming the suitability of the chosen predictors in addressing objective 3 of the study.

Although the regression model produced a high coefficient of determination (R^2=0.971), this should be interpreted with caution. The strong explanatory power of the model may be attributed to the close operational relationship between stock movement, sales volumes, and food waste costs within retail environments, where increases in sales and inventory levels are naturally associated with increased waste generation. However, the unusually high R^2 value may also suggest overlap among operational variables or potential model sensitivity associated with the relatively small sample size (Frost, 2020). Although the regression model included variables measured in different units, such as kilograms and monetary values (Rand), this does not violate multiple regression assumptions because regression models permit the inclusion of predictors measured on different scales, provided that the variables are theoretically meaningful and appropriately interpreted. Future studies using larger datasets and additional explanatory variables may provide more robust modelling of food waste determinants with retail operations. Furthermore, the correlation matrix revealed a perfect positive correlation (r=1.00) between total fruit and vegetable stock received and

the total quantity sold per month indicating severe multicollinearity between these variables. This suggests that the two variables measured almost identical operational patterns within the retail stores. To improve model stability and reduce multicollinearity effect the stock received variable was excluded from the final regression model.

These findings further support the Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) perspectives discussed in Chapter 2, which emphasise that food waste extends beyond physical losses to include embedded economic and environmental costs throughout the supply chain. The significant relationship between stock movement and food waste costs demonstrates how inefficiencies in retail inventory management contribute to financial losses and broader sustainability concerns. The findings therefore reinforce the importance of integrating economic efficiency with sustainable resource management in retail operations.

Overall, the findings demonstrated that fruit and vegetable waste cost within the retail operations are strongly associated with retail throughput and operational handling patterns. These results further suggest that retailers with higher fresh produce turnover may require stronger inventory planning systems, improved demand forecasting, enhanced cold-chain infrastructure, and more effective waste minimisation strategies to reduce financial losses associated with food generation.

4.5. FACTORS INFLUENCING THE GENERATION OF RETAIL FRUIT AND VEGETABLE WASTE IN THE STUDY AREA

The objective of Research Objective 4 was to identify the predictors of fruit and vegetable waste generation among Durban retailers using an ordinal regression model. The model fitting information shown in Table 4.5 pertains to the ordinal logistic regression model. This model was selected because the dependent variable is ordinal with four ordered categories.

1= No
2= Yes
3= Sometimes

The ordinal logistic regression model was expressed as follows:

$$\log\left(\frac{P(Y \leq j)}{P(Y > j)}\right) = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$$

Where:
Y = Waste generation frequency
j= cumulative category (1= No, 2=Yes ,3= Sometimes)
αj= intercept for category j
$ß_1$ - $ß_7$= estimated regression coefficients
x_1 = Date labelling practices
x_2 = Promotions
x_3 = Food safety standards
x_4 = Handling
x_5 = Waste management practices
x_6 = Planning and forecasting
x_7 = Use of infrastructure and technology

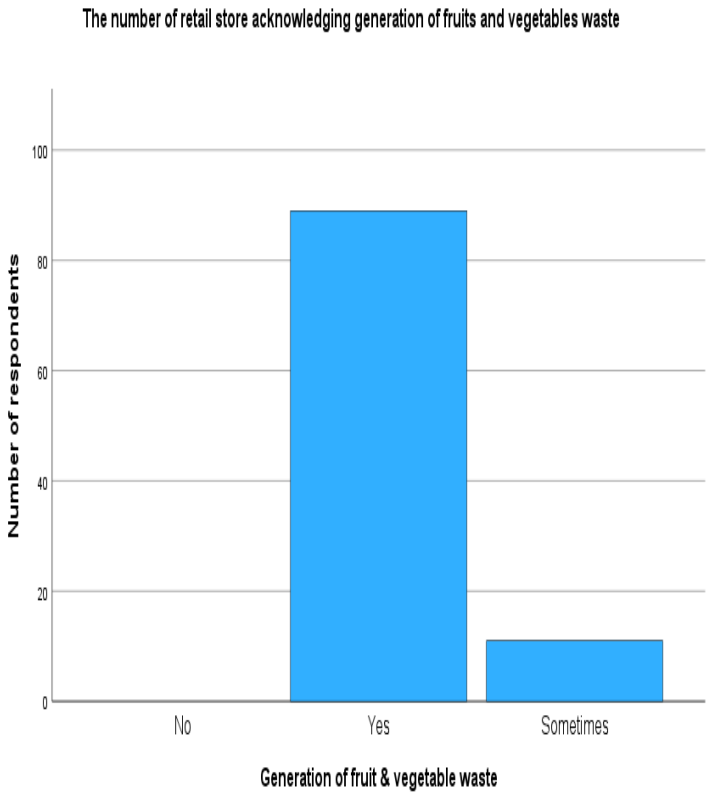


Figure 4.7: The Bar graph showing the number of retailers acknowledging the generation of waste in their stores

Source: Author's own compilation (2025)

Figure 4.7 below shows that 89% of retailers report generating waste regularly in their stores, while 11% say waste occurs sometimes, and no respondents chose 'No'. This indicates that most retailers recognise waste generation in their stores, but some do not fully accept it, highlighting the ongoing issue of food waste as an operational reality in the selected retail stores.

Previous studies confirm that the retail sector does see food waste as a significant problem, with numerous research studies highlighting its prevalence and contributing factors. The Institute for European Environmental Policy (IEEP) and FAO (2022) confirmed that a substantial portion of global waste occurs at the retail level. According to Riesenegger & Hübner (2022), grocery retailers experienced substantial food waste challenges for various reasons. Horoś, & Ruppenthal (2021), Oelofse et al. (2022), and Marchetti et al. (2025) studies show that many retailers are aware that food waste is a real problem and a challenge in the retail sector. The results, therefore, confirm

that awareness and reports on food waste acknowledge its presence in the retail sector.

Table 4.5: Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	67,917			
Final	22,536	45,380	18	<,001
Link function: Logit.				

Source: Author's own compilation (2025)

The analysis assessed the generation of fruit and vegetable waste in retail stores across different independent variables representing operational, managerial, and infrastructural practices. The model was analysed at a 95% confidence level to evaluate whether these factors significantly influence the likelihood of waste occurrence. The Chi-square value is 45.380, with df=18, $p<0.001$, as shown in Table 4.5, indicating that the model is statistically significant and confirming that the inclusion of the independent variables improved the model's predictive power.

Prior to interpreting the ordinal logistic regress model, the proportional odds assumption was assessed to determine whether the relationship between the predictor variables and the ordered response categories remained constant across response thresholds. The model diagnostics and goodness-of-fit statistics produced through SPSS indicated no major violations of the proportional odds assumption supporting the suitability of the model for the analysis. Furthermore, the Pearson Chi-square ($X^2 = 18.974$, $p=1.000$) and Deviance ($X^2=21.150$, $p=1.000$) suggested that the model adequately fitted the observed data.

The ordinal logistic regression model was statistically significant overall ($p<0.001$) indicating that the predictor variables collectively improved the model fit. However, the results indicated that none of the individual predictors were statistically significant at the 5% significance level. These predictors included expiry date monitoring, promotions, packaging faults, redistribution, and demand planning, none of which independently predicted fruit and vegetable waste generation in retail operations in Durban.

The absence of statistically significant individual predictors may be attributed to several factors. Firstly, the relatively small sample size (n=100) may have reduced the statistical power of the ordinal regression model, thereby limiting the likelihood of detecting statistically significant relationships between predictor variables and food waste generation. Secondly, food waste generation within retail environments is inherently complex and influenced by multiple overlapping operational, behavioural, infrastructural and supply chain factors making it difficult for single variables to emerge as independently significant predictors. Thirdly, some variables relied on self-reported retailer responses and estimations rather than directly measured operational records, which may have introduced measurement inconsistencies and reduced precision in the model estimates. These findings therefore suggest that fruit and vegetable waste generation in retail operations is multifactorial and may require broader systems-based analytical approaches.

Table 4.6 : Summary of predictor variables in the Ordinal Logistic Regression Model

Predictor Variable	**Direction of coefficient**	**Statistical significance (p-value)**	**Interpretation**
Date labelling practices	Negative	Not significant (p>0.05)	Improved date monitoring practices may contribute to lower food waste generation
Promotions	Mixed	Not significant (p>0.05)	Promotional strategies may influence waste reduction, although effects were inconsistent
Food safety standards	Mixed	Not significant (p>0.05)	Food safety compliance influences disposal decisions but did not independently predict waste generation
Handling practices	Positive	Not significant (p>0.05)	Poor handling and operational inefficiencies may contribute to increased waste generation
Waste management practices	Mixed	Not significant (p>0.05)	Waste redistribution and repurposing practices showed varied relationships with waste generation
Planning and forecasting	Negative	Not significant (p>0.05)	Improved planning and forecasting systems reduce food waste generation
Use of infrastructure and technology	Negative	Not significant (p>0.05)	Technological systems and infrastructure improvements may support waste reduction efforts

Source: Author's own compilation (2025)

Although none of the predictor variables were statistically significant at the 5% level, the signs of the coefficient estimates still provide useful directional insights regarding food waste generation. Positive coefficient estimates associated with handling practices and certain waste management practices, suggest that increases operational inefficiencies, inconsistent repurposing practices and waste handling systems may be contribute to increased levels of fruit and vegetable waste generation. In contrast, negative coefficient estimates associated with planning and forecasting, date labelling practices and the use of infrastructure and technology suggest that improved operational planning, stock monitoring systems and technological interventions ay contribute to lower levels if food waste generation. However, these relationships should be interpreted cautiously because the associated p-values were not statistically significant.

This may seem to conflict with published research from various sources that confirms these factors are key drivers of food loss and waste. However, the absence of individual statistical significance aligns with the systemic and multifactorial nature of fruit and vegetable wastage. This study indicates that fruits and vegetables, being highly perishable, do not go to waste due to a single cause but rather multiple factors. Appendix F shows that retailers in Durban share common practices, such as 58% monitoring expiry dates, 80% running promotions, and 100% adhering to hygiene standards. These findings suggest that these practices function as baseline operational behaviours rather than unique predictors explaining variations in food waste generation. The model demonstrates that these factors collectively contribute to food waste in an interconnected manner. This aligns with the findings of Swaffield et al. (2021), which suggest that food waste depends on multiple interconnected factors; for example, reducing waste through redistribution relies on efficient cold-chain logistics to prevent spoilage, and markdowns may not be effective if customer demand for discounted items is high. The growing body of literature, including Caldeira et al. (2020) and Kazancoglu and Ipek (2022), confirms that consumer demand volatility, infrastructure limitations, and supply chain inefficiencies, these systemic issues, are primary drivers of fresh produce waste in retail operations, leading to problems such as forecasting errors and inadequate storage infrastructure.

According to Peng et al. (2022), when certain practices are widely adopted their statistical effect in the regression model is reduced not because they are not essential, but rather their significant contribution becomes more meaningful when considered collectively in predicting the dependent variable. This interpretation aligns with Frost (2020) in the book emphasising that when interpreting the regression models a lack of individual statistical significance does not necessarily mean a variable is irrelevant, but it could mean it overlaps or interacts with other predictors. Frost further provides practical guidance for interpreting regression outputs in ways that account for both statistical and practical significance. Academics like Özbük, Raife & Coşkun (2019) explore the systematic drivers of food waste generation, emphasizing that waste in the retail sector results from interconnected processes rather than isolated incidents. Similarly, De Moraes et al. (2020), Bhattacharya et al. (2021), and Pimentel et al. (2022) point out that individual actions or in-store practices are not sufficient on their own, although they are central to the issue. The generation of food waste, especially highly perishable products like fruits and vegetables, requires integrated intervention targeting systemic issues such as demand planning, infrastructure investment, and redistribution logistics (Rahman et al., 2024). Consistent with this, studies in South Africa on food waste at the retail level also confirm these findings, indicating that food waste is a complex and systemic challenge rather than just an operational issue.

These findings align with the Collective Stewardship framework discussed in Chapter 2 which emphasises that food waste management requires shared responsibility among retailers, government institutions, supply chain actors, and consumers. The absence of individually significant predictors suggests that food waste generation cannot be explained by isolated operational practices alone, but rather through interconnected behavioural, infrastructural, and institutional dynamics across the food systems.

4.6. PATHWAY TO MINIMISE FRUIT AND VEGETABLE WASTE IN THE STUDY AREA

The aim of this objective was to develop a pathway to minimise fruit and vegetable waste in the Durban retail sector. This objective was addressed using findings from previous research objectives and in accordance with the National Waste Management Strategy (NWMS), which is an environmental management act for waste management in South Africa, established in 2012 and revised in 2020. Among its targets, it aims to improve waste diversion from landfilling to redistribution, recycling, and recovery.

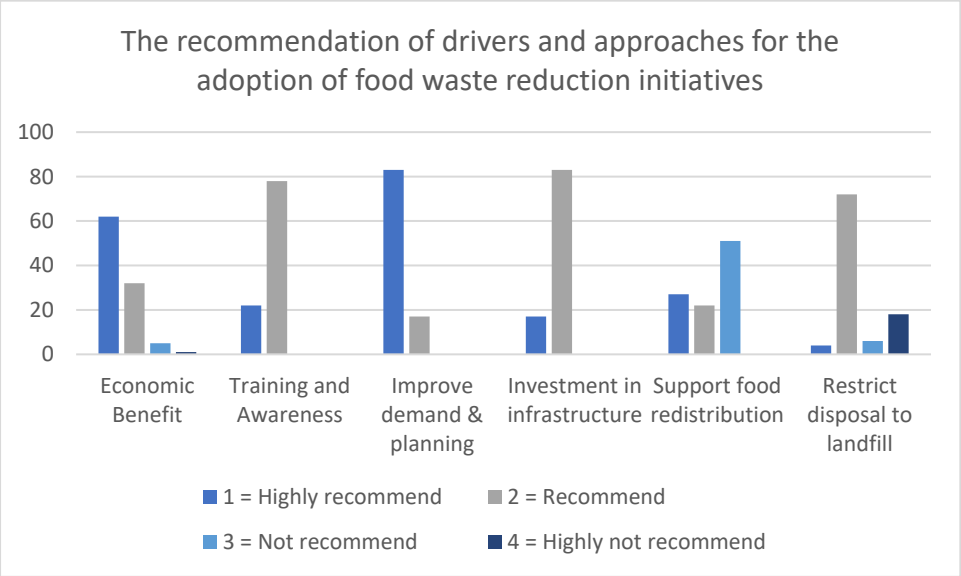


Figure 4.8: The bar graph showing drivers' recommendations and approaches to reduce fruit and vegetable waste in the retail sector.

Source: Author's own compilation (2025)

Retailers were asked to indicate their level of recommendation for the food waste reduction strategy using the Likert scale. The results shown in Figure 4.8 display the responses from the retailers. The improved demand and planning forecast received the highest endorsement, with 83% of retailers highly recommending it and 17% recommending it. This indicates that retailers support demand and planning as strategies to minimise fruit and vegetable waste in their stores. Improved demand and planning forecasting have been consistently recognised as effective strategies to reduce food waste, especially for perishable items. However, Perdana et al. (2023) state that this approach has its challenges despite the benefits, including factors like seasonality,

short shelf life, and unpredictable consumer behaviour, which require retailers to explore advanced technological solutions and collaborative planning.

Economic benefits are also highly recommended, with 94% of respondents strongly endorsing them as a key factor in reducing waste. According to Stangherlin & de Barcellos (2018), economic benefits are widely recognised in the literature as a major driver of reducing food waste. This is due to the financial incentive; circular economic models further support this by highlighting the economic advantages of reducing food waste and promoting resource efficiency (Aiguobarueghian et al., 2024; Goodman-Smith et al., 2020). Previous studies show that cost savings are a significant motivator for food waste reduction in the retail sector. The Life Cycle Costing approach, which analyses the economic costs of a product from production through consumer use and disposal, helps understand total costs and aids in making better economic decisions and optimizing costs (Degieter et al., 2022). Studies also indicate that the retail sector is highly motivated to increase profits by reducing waste (Nikolicic et al., 2021). These findings demonstrate that retailers in Durban recognise the financial implications of food waste, like Dlomo's (2022) study of food waste in Durban retail outlets.

The findings suggest that retailers in Durban recognise infrastructure limitations as a major operational barrier contributing to spoilage and waste generation, particularly for highly perishable products requiring cold chain storages and efficient transportation systems with 83% selecting it and 17% highly recommending it. According to Komijani et al. (2024) and Akinbamini et al. (2025), strong support for infrastructure investment stems from the understanding that reliable, advanced infrastructure is crucial for improving market access, ensuring adequate storage facilities, and enabling efficient cold-chain logistics to prevent spoilage (Igilar, 2023). Training and awareness programs are also highly supported by retailers, with 78% recommending them; this suggests that retailers see them as a complementary enabler rather than the primary driver. The results show that retailers in Durban favour training and awareness programs as one of the drivers to reduce waste. According to Jere et al. (2021), these efforts are important because they recognise food waste in the retail sector as a systemic challenge rather than just an operational problem. This demonstrates that retailers can address food waste by also focusing on behavioural change and including operational training for their employees (Clinton, 2023; Mattsson & Williams, 2022).

The emphasis placed on awareness, training and behavioural interventions by retailers further reflect the Theory of Planned Behaviour (TPB), which suggests that attitudes, perceived behavioural control and organisational norms and awareness influence operational decision-making and waste management behaviour within organisations. Improving staff awareness and strengthening positive waste management practices may therefore contribute to long-term behavioural change and improved waste reduction within retail operations.

Support for food redistribution is not strongly endorsed, as 49% of retailers recommend it and 51% do not. Food redistribution of fruits and vegetables is not a supported primary driver for reducing fruit and vegetable waste. This may be because retailers focus on other food waste interventions, such as inventory management. Retailers find it challenging to donate fruits and vegetables due to concerns about complying with regulations on safe food handling and redistribution (Gonçalves et al., 2025). This explains what Dorodeiko et al. (2018) and Borusiak et al. (2024) discussed: food redistribution lacks coordinated food banks and a reliable market to take the surplus, which may explain the division of responses. Olabode et al. (2025) emphasise that for an effective redistribution, the government must develop and maintain systems for collecting and distributing surplus food, as this can be expensive for retailers.

These results show that food redistribution is not fully supported as a key strategy to reduce fruit and vegetable waste in Durban, despite being recommended by the NWMS and global best practices. While 76% of retailers support restricting food disposal in landfills, 24% do not. According to the literature reviewed for this study, no academic research or studies indicate that retailers prefer landfills for waste disposal. Instead, academics strongly discourage landfills and explain why they remain widely used among retailers (WWF 2017; DEFF 2020; Rahman et al., 2024). The NWMS explicitly addresses the challenges of relying on landfills as a waste disposal method. Reports from Green Cape (2022) indicate that industries continue to use landfills due to a lack of viable alternatives for waste disposal sites.

4.7. THE PROPOSED PATHWAY BY THE STORE MANAGERS TO MINIMIZE WASTE GENERATION IN DURBAN

Hereunder is a proposed pathway that aligns with the NWMS Framework's three pillars: waste minimisation, reuse/redistribution, and diversion from landfills.

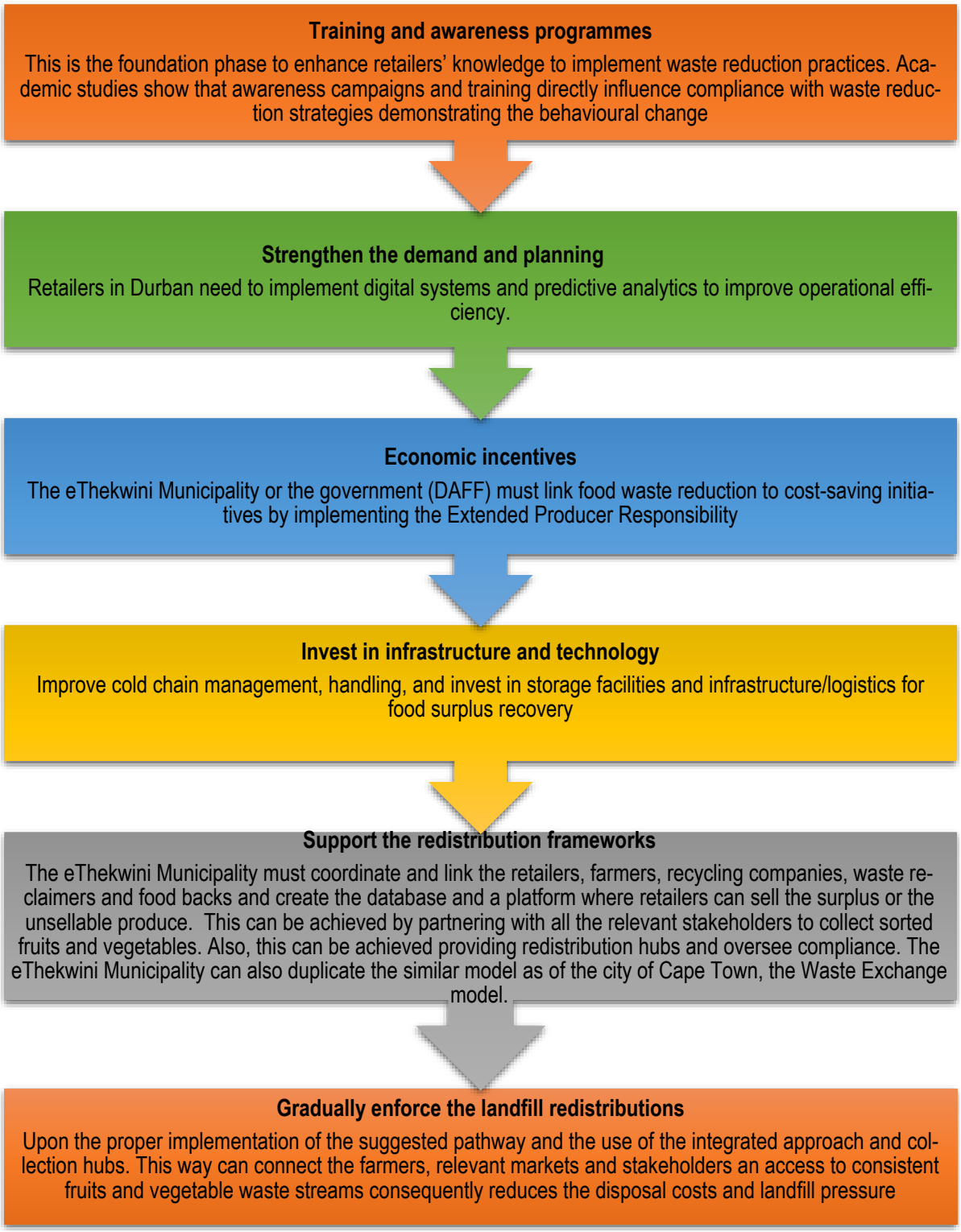
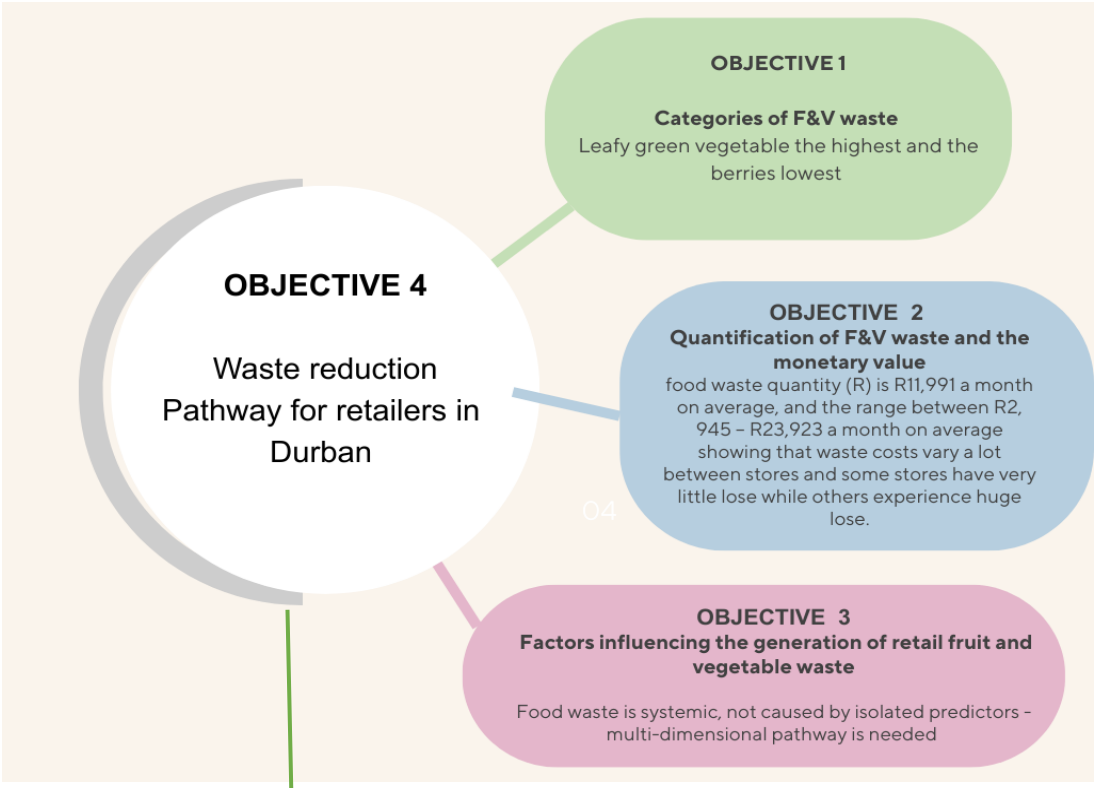


Figure 4.9: A recommended pathway by the retailers in Durban

Source: Author's own compilation (2025)

4.7.1. Conceptual Framework linking objective 4 with 2-5

To reduce and divert fruits and vegetables waste and other types of food waste from landfill sites the food waste redistribution and recycling and waste minimisation strategies require coordinated support from the local municipality, government and relevant stakeholders. The implementation of these strategies may contribute to reduced costs, improve food security and develop a sustainable value chain for farmers and waste collectors. The proposed framework aligns with the NWMS Framework and can create a circular economy that is beneficial to retailers, farmers, NGOs and other stakeholders. Figure 4.10 illustrates an integrated conceptual framework linking the research objectives.



The eThekwini Municipality to track and monitor volumes of food waste diverted from landfills.

REDISTRIBUTION
- Edible fruits and vegetables → NGOs, or Food banks
- Unusable produce → Farmers for livestock
- Non-edible produce → Composting sites or bio-digestion plants to make organic fertilizers or energy

Figure 4.10: The integrated conceptual framework linking the research objectives

Source: Author's own compilation (2025)

4.8. CHAPTER SUMMARY

This study addressed five specific objectives and presented the analysed empirical findings relating to fruit and vegetable waste retail operations in Durban. The quantification of fruit and vegetable waste and its lost monetary value was examined across 100 retail stores in Durban, ranging from small to large retailers. The findings confirm previous research showing that fruit and vegetable are the mong the most perishable products. Results demonstrate that leafy vegetables were the leading category in waste generated, while melons and berries were the lowest. However, berries showed a significant loss of monetary value. In efforts to reduce waste, the findings revealed that retailers identified handling issues, poor demand forecasting, and a lack of proper infrastructure as drivers. However, these factors did not act as strong independent predictors. These findings suggest that fruit and vegetable waste in retail is not an isolated problem but a multifactorial one, and that isolated interventions are unlikely to produce a significant impact.

The synthesised findings proposed a pathway aimed at minimising fruit and vegetable waste in line with the South African National Waste Management Strategy (NWMS). Retailers strongly recommended improved demand forecasting and planning systems. Although improved demand forecasting was highly recommended by retailers, the researcher further emphasised the importance training and awareness programmes, emphasising the importance of human capacity building in supporting effective waste reduction strategies. The proposed pathway shows that reducing waste requires a multi-dimensional approach, encouraging the implementation of food waste redistribution and recycling strategies. These results demonstrate that fruit and vegetable waste in Durban is systemic and driven by both operational and structural factors.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. INTRODUCTION

This chapter synthesises the study's main findings regarding the research objectives, the literature review, and the theoretical framework that guided the investigation. The purpose of the study was to assess fruit and vegetable waste in Durban's retail operations, quantify its costs, and suggest ways to reduce it in line with the National Waste Management Strategy (NWMS). The chapter further presents recommendations for retailers, policymakers, and the eThekwini Municipality aimed at reducing fruit and vegetable waste within retail operations.

5.2. CONCLUSION

The findings of the study revealed that leafy vegetables were the most wasted category of fruits and vegetables in Durban retail operations due to their short-shelf life and high susceptibility to spoilage. In contrast melons and berries recorded lower waste levels because of better packaging improved storage potential, and stronger consumer preferences. These findings align with global studies indicating that highly perishable fresh produce, particularly leafy vegetables, contributes significantly to food waste within retail systems.

The study further demonstrated that fruits and vegetable waste resulted in substantial financial losses for retailers in Durban. Using average retail prices, the study quantified the economic cost associated with waste generation, highlighting the hidden financial burden often underestimated in retail operations. Beyond contributing to food insecurity and environmental degradation, food waste represents a measurable economic liability for retailers. The findings therefore reinforce the importance of investing in waste-reduction strategies as both an environmental and business imperative.

The ordinal logistical regression analysis revealed that none of the independent variables, including date labelling, promotions, handling practices, planning and forecasting, and infrastructure, independently predicted fruit and vegetable waste generation at the retail level. While previous literature frequently identifies these factors as key drivers of food waste, the Durban context suggests that food waste generation is shaped by broader systemic and structural factors rather than isolated operational

practices. The findings therefore indicate that food waste in retail operations is multi-factorial and requires integrated interventions rather than single variable approaches.

The findings further revealed that retailers strongly supported interventions aimed at reducing food waste, particularly improved demand forecasting, and planning, training and awareness emerged as foundational interventions because the effectives of waste reduction strategies depend largely on stuff knowledge, operational compliance and behavioural change within retail environments. Retailers also recognised the importance of redistribution initiatives, and reducing dependency on landfill disposal. These findings align with the National Waste Management Strategy (NWMS) and Sustainable Development Goal 12.3, which advocate for waste prevention, redistribution, and resource recovery approaches for sustainable waste management.

From a theoretical perspective, the integrated framework applied in this study proved useful in explaining the interaction between economic costs, sustainability considerations, and behavioural dimensions associated with food waste generation in retail operations. The findings reinforced the argument that food waste cannot be sufficiently addressed through a single analytical perspective, but instead requires integrated and multidisciplinary approaches that consider environmental, operational, economic, and behavioural factors simultaneously.

Overall, the study concludes that fruits and vegetables waste in Durban retail operations remains a significant economic and sustainability challenge. Although no single operational factors emerged as independently significant in predicting waste generation, the findings demonstrate that systemic interventions focusing on awareness, planning, infrastructure investment, redistribution systems, and improved operational coordination offer the greatest potential for reducing food waste in retail sector. The study therefore contributes to the growing body of knowledge on retail food waste within the South African context and provides evidence-based insights may assist retailers, policymakers, and local government in developing more integrated and sustainable food waste management strategies.

5.3. RECOMMENDATIONS

Achieving progress in the fruits and vegetables category in Durban requires a collective effort across all sectors, including the government and the local municipality, with attention to actions along the proposed pathway. Retailers must adopt innovative technologies and waste management strategies to minimise waste and reduce costs. Educational training should be targeted to retail managers and employees, providing training on practices that reduce waste.

5.3.1 Recommendations from the literature related to fruit and vegetable waste management.

A synthesis of the reviewed literature highlights several evidence-based strategies for addressing fruit and vegetable waste in retail operations. These recommendations span technical, managerial, behavioural, and policy interventions, recognizing the need for integrated, context-specific solutions.

5.3.2. Strengthen Forecasting and Inventory Management

Numerous studies emphasise the centrality of accurate demand forecasting and inventory control in minimising overstocking and subsequent waste (Eriksson et al., 2021). Retailers are encouraged to adopt advanced technologies, including AI and other solutions, to better align procurement with consumer demand patterns (Riesenegger & Hubner, 2022). In resource-constrained contexts, simplified digital platforms and collaborative forecasting with suppliers can provide cost-effective alternatives (Reynolds & Samantha, 2024).

5.3.3. Improve post-harvest handling and cold chain infrastructure

Literature consistently points to inadequate storage, transport, and handling practices as major causes of losses in perishable produce (CRIR, 2021; Obadebo et al., 2022). Investment in cold chain infrastructure, better packaging materials, and training in post-harvest handling is highly recommended. For developing countries like South Africa, partnerships between retailers, municipalities, and private investors could help bridge resource gaps and develop shared infrastructure models.

5.3.4. Review cosmetic standards and consumer education

Cosmetic specifications for size, colour, and shape remain a leading cause of waste at both farm and retail levels (Abadi et al., 2020; Wu et al., 2025). The literature recommends relaxing cosmetic standards, coupled with consumer education campaigns that normalise the purchase of “imperfect but edible” produce (Aschemann-Wilzet et al., 2020). Such interventions not only reduce waste but also increase food accessibility in disadvantaged communities.

5.3.5. Promote Food Redistribution and Secondary markets

The redistribution of unsold, still edible fruits and vegetables to NGOs and informal traders is highlighted as an effective mitigation strategy (Priefer et al., 2021). Successful models, such as SA Harvest in KwaZulu-Natal, demonstrate the potential for large-scale recovery networks when supported by logistical and regulatory frameworks (DAFF& CSIR, 2021). While scholars support food waste redistribution, they also raise concerns about food safety regulations that must be addressed through clear policy guidelines (Toma et al., 2022).

5.3.6. Foster Integrated Framework for retail store managers in Durban

From a theoretical perspective, the Theory of Planned Behaviour (TPB) and Collective Stewardship frameworks emphasise the role of managerial attitudes, perceived control, and shared responsibility in driving change (Hodges et al., 2025). The literature recommends embedding training and awareness programmes at the organisational level to shape norms and encourage sustainable practices (Cameron, 2025). When combined with life cycle assessment (LCA) and life cycle costing (LCC) approaches, such as programmes, the environmental and financial benefits of waste reduction can be made tangible for decision-makers.

5.4. PRACTICAL RECOMMENDATIONS FOR RETAILERS, LOCAL MUNICIPALITY, AND ACADEMIA

5.4.1. Recommendations for retailers

- **Prioritise training and awareness**

  Retailers should provide regular training and awareness programmes for employees on proper food handling, stock rotation, waste segregation, and consumer education. The eThekwini Municipality Cleansing and Solid Waste (CSW) Directorate and Business Support, Agri-Ecology Directorate, Tourism and Markets Directorates can support awareness initiatives through municipal waste minimisation programmes. At the provincial level, the KwaZulu-Natal National Department of Economic Development, Tourism and Environmental Affairs (ADTEA) can facilitate environmental awareness and sustainable business training programmes. Nationally, the Department of Forestry, Fisheries and the Environment (DFFE) can support national food waste awareness campaigns aligned with the National Waste Management Strategy (NWMS).

- **Adopt improved demand forecasting tools**

  Retailers should adopt improved forecasting systems, including AI-driven inventory management systems and dynamic shelf-life life technologies, to minimise overstocking and spoilage. The eThekwini Municipality Smart City initiatives and Economic Development Directorate can assist in promoting digital innovation partnerships. Provincial support may be provided by the KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs (EDTEA), while national support can be coordinated through the Department of Trade, Industry and Competition (DTIC) and the Department of Science, Technological innovation within the retail and agricultural sectors.

- **Strengthen redistribution partnerships**

  Retailers should strengthen partnerships with food banks, NGOs such as FoodForward SA, Greenway Africa and SA Harvest, and informal traders to redistribute edible surplus food. The eThekwini Municipality Community Participation

and Action Support Directorate, together with CSW and Agri-Ecology can facilitate local redistribution networks. At the provincial level, the KwaZulu-Natal Department of Social Development can assist with food security coordination programmes.

- **Implement transparent waste audits**
  Retailers should conduct regular waste audits to improve monitoring, reporting and accountability regarding food waste generation. The eThekwini Municipality Cleansing and Sold Waste Directorate can support waste audit alignment with municipal diversion targets.

5.4.2. Recommendations for eThekwini Municipality

- **Support infrastructure investment**
  The eThekwini Municipality should provide incentives and supports cold-chain logistics, storage infrastructure, and redistribution facilities. This may involve collaboration between the Economic Development, Cleansing and Sold Waste and Supply chain Management Directorate.

- **Enhance policy enforcement**
  The municipality should strengthen landfill diversion policies for organic waste while promoting recycling, composting, and recovery initiatives. This can be implemented through Cleansing and Solid waste Directorate and Environmental Health Directorate with the support from EDTEA and DFFE to ensure alignment with the National Waste Management Strategy.

- **Promote collaborative platforms**
  The municipality should establish collaborative platforms involving retailers, NGOs, food recovery organisations, informal traders, and community stakeholders to coordinate redistribution, composting and circular economy initiatives. This may be coordinated through the eThekwini Municipality Economic Development Directorate, Cleansing and Sold Waste and Supply Side and Area-Based Operations Directorate.

- **Integrate Findings into Waste Management Planning**
  The findings of this study should be integrated into municipal waste management planning and climate adaptation strategies. The eThekwini Municipality Climate Change Department and CSW can utilise the findings to support diversion targets aligned with the eThekwini Climate Action Plan, SDG 12.3 and broader sustainability objectives.

5.4.3. Recommendations for National Policy and academia

- **Align with NWMS and SDG 12.3**
  National government departments particularly DFFE should use the findings of this study to strengthen implementation of National Waste Management Strategy and Sustainable Development Goal 12.3 targets related to food waste reduction.

- **Promote research on systemic drivers**
  Academic institutions including the University of South Africa and research institutions such as CSIR should conduct further studies on structural, behavioural, and operational drivers of retail food waste in South Africa.

- **Encourage private-public partnerships**
  Government departments, municipalities, retailers, NGOs and private investors should collaborate to establish food redistribution systems, shared cold-chain infrastructure, and circular economy initiatives. The Department of Social Development, DTIC, DFFE and EDTEA can facilitate partnership frameworks supporting sustainable food recovery programmes.

- **Position retailers as key actors in achieving national waste minimisation**
  National and provincial government departments should recognise retailers as important stakeholders in achieving national waste minimisation targets and should incorporate retail-sector food waste reduction into broader environmental and food security policies.
- Future studies should explore seasonal variations in fruit and vegetable waste generation across different retail formats and geographical areas within South

Africa. Further research using longitudinal and mixed-method approaches may provide deeper insights into behavioural, operational, and systemic drivers of retail food waste.

5.5. FINAL REFLECTION

By situating Durban's retail sector within both national strategies and global discourses, this study has highlighted the urgent need to treat fruit and vegetable waste as more than an environmental issue, It is an economic, ethical, and social challenge requiring integrated interventions. The pathway developed here provides a practical roadmap for Durban's retailers and the municipality, and its successful implementation could contribute meaningfully to food security, cost reduction, and sustainability within the eThekwini municipality and beyond.

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APPENDICES

APPENDIX A: Consent form

CONSENT TO PARTICIPATE IN THIS STUDY

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the answering the questions in the provided questionnaire.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname…… (please print)

Participant Signature……..Date……

Researcher's Name & Surname……(please print)

Researcher's signature……..Date……

APPENDIX B: Ethical clearance approval

UNISA university of south africa

College of Agriculture and Environmental Sciences_Health REC

NHREC Registration # : REC-170616-051
Ref #: 2024/CAES_HREC/4616
Name: Miss Makhosazane Thandeka Khuzwayo
Student #: 21000646

Date: 17/10/2024

Dear: Miss Makhosazane Thandeka Khuzwayo

Decision: Ethics Approval from 17/10/2024 to 30/09/2027

Researcher: Miss Makhosazane Thandeka Khuzwayo
makhosazanekhuzwayo@gmail.com 0611686822

Supervisor: Mr Mokgoshi John Mamashila mamasmj@unisa.ac.za

Quantification of cost of fruits and vegetable waste in retail operations in Durban City, KwaZulu-Natal Province

Qualification: MSc Agriculture

Thank you for the application for research ethics clearance by the College of Agriculture and Environmental Sciences_Health REC for the above mentioned research study. Ethics approval is granted for three years, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report is submitted.**

Due date for progress report: 30 September 2025

The **low risk application** was **reviewed** by College of Agriculture and Environmental Sciences_Health REC on 16 October 2024 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the College of Agriculture and Environmental Sciences_Health REC.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data

Page 1 of 2

requires additional ethics clearance.

7. No field work activities may continue after the expiry date (30 September 2025). Submission of a completed research ethics progress report will constitute an application for renewal, for Ethics Research Committee approval.

Additional Conditions

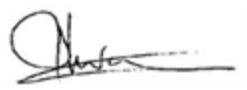
1. Disclosure of data to third parties is prohibited without explicit consent from Unisa.
2. De-identified data must be safely stored on password protected PCs.
3. Care should be taken by the researcher when publishing the results to protect the confidentiality and privacy of the university.
4. Adherence to the National Statement on Ethical Research and Publication practices, principle 7 referring to Social awareness, must be ensured: "Researchers and institutions must be sensitive to the potential impact of their research on society, marginal groups or individuals, and must consider these when weighing the benefits of the research against any harmful effects, with a view to minimising or avoiding the latter where possible." Unisa will not be liable for any failure to comply with this principle.

Note

The reference number 2024/CAES_HREC/4616 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,

Prof MA Antwi
Chair of College of Agriculture and Environmental Sciences_Health REC
E-mail: antwima@unisa.ac.za



Professor Monde Ntwasa
Executive Dean / By delegation from the Executive Dean of College of Agriculture and Environmental Sciences_Health REC
E-mail: ntwasmm@unisa.ac.za

APPENDIX C: Letter of approval to conduct the study

City Manager's Cluster
Head Office: Area-Based Management Unit
ITrump ABM
77 Monty Naicker Road
Durban
4000

Tel: 031 322 8406
Happy.mapena@durban.gov.za

To	**: Student Supervisor**
From	**: Head Area-Based Management Unit**
Date	**: 28 June 2024**
Subject	**: ACKNOWLEDGMENT LETTER**

This letter serves as an acknowledgment of the request from the student to collect data within the eThekwini Municipality.

The eThekwini Municipality Area-Based Management Unit confirms that Makhosazane Khuzwayo **(ID Number: 9507180449089, Student Number: 2100646)** has requested to be granted permission to collect data at eThekwini Municipality (Durban City).

The student is hereby granted permission to collect data for the purpose of attaining her qualification at the University of South Africa for a Master of Science in Agriculture.

We wish Ms. Khuzwayo success in her research and look forward to the valuable insights her study will bring.

Sincerely,

Linda Mbonambi
HEAD: Area-Based Management Unit

28/06/24
Date:

APPENDIX D : Key store personnel questionnaire

PART ONE -QUANTIFICATION

1. General Information

- What is your role in the organization**?**
    a) Owner
    b) Manager
    c) Employee
    d) Other (please specify): _____

- How long have you been in this role?
    a) Less than 1 year
    b) 1-3 years
    c) 4-5 years
    d) More than 5 years

    - What types of fruits and vegetables do you typically sell (fresh and frozen)?

      _____

    - What are the peak seasons for different fruits and vegetables in your store?

      _____

    - On average, how much fruit and vegetable stock do you receive per month (in kg)?

      _____

2. Quantifying Waste

- Can you provide the total weight (in kg) of fruits and vegetables discarded monthly?

  _____

- Of the discarded fruits and vegetables, how much is still considered edible (in kg)?

  _____

- How do you document or track the waste generated?

  _____

PART TWO-QUANTIFICATION OF COSTS

1. Cost Data

- What are the total monthly costs associated with managing and disposing of waste in your store?

  _____

- What are the monthly costs of redirecting food waste from the landfill (e.g., costs for donating, recycling, or other methods of waste diversion)?

  _____

2. Detailed Supply Information

- How often do you receive orders of fruits and vegetables? (Daily/Weekly/Monthly)

  _____

- What are the primary sources of your fruit and vegetable supplies (local farmers, wholesalers, etc.)?_____

3. What are the costs the store encounters due to redirecting waste to landfill?

Item	Estimated Costs (R)
Transport	
Landfill fee	
Labour	
Storage/ technology	
Other …….	
Total	

4. Food waste questionnaire (FWQ)

Food Category	Frequency of disposal			Estimated monetary value of each food wasted (R)
Fruits				
	Daily	Weekly	Monthly	
Citrus				
Stone fruits				
Tropic and exotic				
Berries				
Melon				
Tomatoes and Avocado				
Apples and peaches				

Vegetables				
root vegetables				
stem vegetables				
Leafy green				
Cruciferous				
TOTAL				

PART THREE- FOOD WASTE MANAGEMENT PRACTICES

1. **In your opinion what are the causes of the food waste in your store and what is the result of that?**

Causes		**Responses**		
		Yes	**No**	**Sometimes**
Data Labelling	● Do you check the selling dates on your fruit and vegetables?			
	● Is the expiry date important in your decision to sell or discard fruit and vegetables?			
Promotions	● Do you frequently mark down prices on fruits and vegetables nearing their expiry date?			
	● Do you run promotions on fruit and vegetables?			
Food safety standards	● Are food hygiene standards important in your business?			
	● Do food safety concerns affect your decision to discard fruit and vegetables?			
Handling	● Do you encounter handling equipment issues with fruit and vegetables?			
	● Do packaging faults or incidents occur in your business?			
Poor use of waste management practices	● Do you engage in social redistribution of unsold fruit and vegetables?			
	● Do you repurpose unsold fruit and vegetables?			
Poor planning	● Does poor planning lead to fruit and vegetable waste in your business?			
	● Do you experience issues with demand planning and forecasting?			
	● Do you find a lack of market information affects your inventory decisions?			
Lack of infrastructure and use of recovery technology	● Does lack of infrastructure contribute to fruit and vegetable waste in your business?			
	● Do you use technical solutions to manage fruit and vegetable waste?			

2. **Waste Management Practices**

- What procedures do you follow for managing unsold or expired fruits and vegetables?_____

1 = Disposal in landfill
2 = Discounted sale / promotions
3 = Donation / redistribution
4 = Animal feed
5 = Composting / recycling

- Do you have any partnerships with food banks or other organizations for donating unsold but still edible fruits and vegetables (Yes/No)?_____

3. **Identify the drivers and approaches for the adoption of food waste reduction initiatives that you recommend.**

1-Highly recommend 2-Recommend 3- Not recommend 4- Highly not recommend

Drivers and approaches to reduce food waste	**Responses**			
	1	2	3	4
Economic benefit				
Training and Awareness				
Improve demand and planning forecast				
Investment in infrastructure				
Support food redistribution (Donations)				
Restrict the disposal of food (Landfill)				

APPENDIX E : Editor Certificate

Professional EDITORS Group

EDITING CERTIFICATE

TO WHOM IT MAY CONCERN

This certifies that the research document whose title appears below has been edited for proper English language, grammar, punctuation, spelling, and overall style.

Level of document: Article

Title: Quantification of Costs of Fruit and Vegetable Waste in Retail Operations: Evidence from Durban, South Africa

Author: Makhosazane Khuzwayo

Date: December 2025

Signed

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