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A Digital Platform Design to Support Food Waste Reduction in the Eastern Province of Saudi Arabia

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A Digital Platform Design to Support Food Waste Reduction in the Eastern Province of Saudi Arabia

By

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Preface

This research represents the culmination of my academic journey, combining rigorous study, practical insights, and a deep commitment to addressing the pressing issue of food waste in Saudi Arabia. The project was driven by a passion for sustainable development and a belief in the power of digital innovation to transform how we manage resources, particularly in the retail sector.

The choice of the Eastern Province of Saudi Arabia as the focal point for this research was deliberate, influenced by the region's unique socio-economic context and its critical role in the Kingdom's broader vision for sustainable development. Saudi Arabia's Vision 2030, which emphasizes sustainability and resource efficiency, provided a timely and relevant backdrop for this study, further motivating the exploration of how digital platforms can support circular economy principles.

Throughout this research, I have been privileged to engage with diverse stakeholders, including retailers, technology providers, and subject matter experts. Their insights, experiences, and challenges have contributed to the design of the digital platform proposed in this study. I am deeply grateful for their contributions, which have enriched this research and provided a real-world grounding for the theoretical concepts explored.

The Design Science Research (DSR) methodology guided the research, which offered a robust framework for systematically addressing the research question and ensuring that the resulting digital platform is both practical and innovative. The process of designing the platform was iterative and collaborative, involving constant feedback and refinement to ensure that the final design met the needs of all stakeholders and aligned with the principles of the circular economy.

This research would not have been possible without the support of my academic supervisors, colleagues, and family. Their encouragement and guidance have been invaluable throughout this journey. While I had unexpected challenges during my thesis development, my family and friends were always there for me when needed.

As I present this work, I hope it serves as a meaningful contribution to the ongoing efforts to reduce food waste in Saudi Arabia and globally. It is my sincere hope that the findings and the digital platform design proposed here will inspire further research, innovation, and action towards a more sustainable world.

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Executive Summary

The global challenge of food waste has emerged as a critical issue with far-reaching implications for the environment and human welfare [1]. Around 33% of globally produced food is wasted throughout the value chain [2]. The impact of food waste extends beyond environmental concerns; it has profound implications in relation to lost resources, including water, energy, and labor, contributing to the unsustainable use of our planet's finite resources [3]. It also leads to increased greenhouse gas emissions and food insecurity [4]. Additionally, the economic cost of food waste is substantial, affecting both producers and consumers [3]. When it comes to international ranking in food waste, Saudi Arabia has the number one global ranking in food waste, with an average of 250 kg of wasted food annually per person against the global average of 115 kg [5].

Saudi Arabia's larger national 2030 vision [6], which emphasizes sustainable development and resource efficiency across various industries, makes it a perfect time to introduce change and start new initiatives [7]. Circular economy initiatives have gained more recognition in Saudi Arabia in recent years as resource-conscious and sustainable strategies for economic growth [8]. Additionally, digitalization efforts are an essential integrated part of the Saudi Arabian 2030 national vision [9]The selection of a specific country for the research is necessary due to the differences in stakeholders' requirements between countries, which will affect the end design.

This research focuses on designing a digital platform that contributes to reducing food waste in Saudi Arabia. While a digital platform may not be an efficient and viable option to tackle this problem in countries with advanced waste management infrastructure, it is a feasible solution for tackling food waste in Saudi Arabia, given the current lack of infrastructure. It offers a quick and scalable approach that can be rapidly deployed to bridge existing gaps. Unlike traditional infrastructure projects requiring significant time and resources, a digital platform leverages existing technology to create immediate connections between retailers, consumers, and other stakeholders. The retail stage includes restaurants, cafes, and bakeries. The main stakeholders of interest are retail businesses. The main research question that guided this research is: *What digital platform design can contribute to reducing food waste in the retail sector in the eastern province of Saudi Arabia in alignment with circular economy principles?*

This study employed the Design Science Research (DSR) methodology to create a practical digital solution. The research process involved several phases. The problem identification phase analyzed the challenges of food waste in Saudi Arabia, focusing on the retail sector. This was followed by defining specific requirements for the digital platform based on identified challenges and stakeholder needs. The design phase involved creating the digital platform architecture using the ArchiMate framework, covering business, application, and technology layers. The evaluation phase assessed the platform against predefined requirements and challenges.

The initial research phase involved a comprehensive analysis of food waste challenges in Saudi Arabia. The key challenges identified include a lack of awareness, a lack of policies and regulatory frameworks, logistical and infrastructure issues, and technological barriers. Based on the identified challenges, the research established several requirements for the digital platform. These requirements included a user-friendly interface to ensure easy navigation and accessibility, secure transaction mechanisms complying with Saudi Arabian data protection laws, efficient inventory management to track and reduce food waste, and multilingual support to cater to diverse users.

Using the ArchiMate framework, the platform was designed with three primary layers: business, application, and technology. The business layer's core functions included food waste management, inventory tracking, and transaction processing. The business layer also defined stakeholder interactions, such as collaboration between retailers, consumers, and technology providers, and outlined streamlined processes for listing, searching, and redistributing food waste. The application layer focused on providing an intuitive, multilingual user interface, integrating RESTful APIs for seamless integration with existing systems and third-party services, and implementing analytics for performance tracking. The technology layer emphasized a cloud-based infrastructure for scalability

and reliability, robust data security measures, and a hybrid database management approach using relational and NoSQL databases to efficiently store structured and unstructured data.

The evaluation phase confirmed that the digital platform addresses the identified requirements and challenges to varying degrees. The platform provides a user-friendly interface, secure transactions, efficient inventory management, and multilingual support. The evaluation included an alignment analysis between the identified requirements and challenges and the final design.

We have developed two business models: a non-profit model and a for-profit model. The non-profit model focuses on sustainability and social impact, relying on grants, donations, and government support. Its strengths include high societal value and potential for widespread adoption, but it faces sustainability challenges due to funding dependency. The for-profit model aims at financial sustainability and scalability, leveraging service fees and advertisements. Its strengths include financial independence and scalability, but it must navigate public perception issues and regulatory compliance challenges.

Through this research, we have successfully designed a digital platform that addresses the critical issue of food waste in the eastern province of Saudi Arabia's retail sector. By aligning with the circular economy strategies, precisely R9:Recover, R7:Repurpose, R3: Reuse, and R2: Reduce, and incorporating advanced technological components, the platform offers a viable solution to reduce food waste, promote sustainability, and support national environmental goals. The findings and methodologies presented in this study provide a foundation for future research and practical applications in the field of food waste management and digital platform development.

The societal contributions of this research are profound, particularly in the context of Saudi Arabia’s growing emphasis on sustainability and waste reduction. The digital platform developed through this research provides a practical solution to the problem of food waste in the retail sector, supporting national goals related to food security and environmental sustainability. By enabling the redistribution of food waste to consumers, including farmers, the platform promotes circular economy principles, facilitating the repurposing of food waste for animal feed and composting. The research made scientific contributions by addressing gaps identified in the literature, particularly regarding stakeholder perspectives, technological integration, and business models to support food waste initiatives.

For implementation, transitioning from theory to practice is crucial, involving pilot tests, real-world deployments, and continuous refinement based on user feedback. Close collaboration with retailers and consumers will be essential to ensure the platform's functions meet their needs. For the non-profit model, exploring hybrid funding strategies will enhance sustainability, while the for-profit model should focus on multiple revenue streams, compliance, and transparent communication to navigate public perception and regulatory challenges. The platform will be better positioned to reduce food waste and foster a sustainable circular economy in Saudi Arabia by addressing these implementation aspects.

1 Introduction

In this chapter, we introduce the problem at a high level and outline the research project's objectives, core concepts, and knowledge gap. Furthermore, we discuss the main research question, sub-questions, and related research approaches. A well-crafted research design is essential as it lays the groundwork for the entire study and guides the research process [10]. It ensures that all involved parties have a shared understanding and commitment to the research goals, ultimately contributing to the successful completion of the research.

1.1 Problem Definition

The global challenge of food waste has emerged as a critical issue with far-reaching implications for the environment and human welfare [1]. Around 33% of globally produced food is wasted throughout the value chain [2]. The impact of food waste extends beyond environmental concerns; it has profound implications in relation to lost resources, including water, energy, and labor, contributing to the unsustainable use of our planet's finite resources [3]. It also leads to increased greenhouse gas emissions and food insecurity [4]. Additionally, the economic cost of food waste is substantial, affecting both producers and consumers [3].

We have selected Saudi Arabia as a location for our research. The selection of a specific country for the research is necessary due to the differences in stakeholders' requirements from one country to another, which will affect the design of the digital platform. Saudi Arabia's location selection is based on its number one global ranking in food waste, with an average of 250 kg of wasted food annually per person against the global average of 115 kg [5].Moreover, Saudi Arabia's larger national 2030 vision [6], which emphasizes sustainable development and resource efficiency across various industries, makes it a perfect time to introduce change and start new initiatives [7]. Circular economy initiatives have gained more recognition in Saudi Arabia in recent years as resource-conscious and sustainable strategies for economic growth [8]. Finally, digitalization efforts are an essential integrated part of the Saudi Arabian 2030 national vision [9]. A further clarification of the problem, including current challenges and barriers, will be discussed in detail in chapter three, Problem Identification.

1.2 Research Objective

This research focuses on designing a digital platform dedicated to tackling food waste in alignment with circular economy principles at the retail stage in the eastern province of Saudi Arabia. While a digital platform may not be a viable option to tackle this problem in countries with advanced waste management infrastructure, a digital platform is a feasible solution for tackling food waste in Saudi Arabia, given the current lack of infrastructure. It offers a quick and scalable approach that can be rapidly deployed to bridge existing gaps. Unlike traditional infrastructure projects requiring significant time and resources, a digital platform leverages existing technology to create immediate connections between retailers, consumers, and other stakeholders. The retail stage includes restaurants, cafes, and bakeries. The main stakeholders of interest are retail businesses. We have done this by following a design approach where a structured methodology (design science research) will address the problem's complexity, stakeholders' requirements, actors' behaviors, and technological innovations. The main question that guided the research is: ***What digital platform design can contribute to reducing food waste in the retail sector in the eastern province of Saudi Arabia in alignment with circular economy principles?*** By answering this question, the research aims to contribute to realizing a more sustainable, circular economy that promotes environmental stewardship and responsible consumption.

1.3 Complexity

The digital platform for reducing food waste in the eastern province of Saudi Arabia represents a complex socio-technical system where stakeholders, governance, policies, and technology interact. This system involves diverse stakeholders, including retailers, consumers, technology providers, and the government, each with their unique interests, roles, and responsibilities. Effective governance mechanisms and adherence to policy frameworks are essential to ensure compliance with data protection laws, cybersecurity standards, and environmental regulations. Additionally, technological components must be seamlessly integrated to support user needs and regulatory

requirements. The complexity arises from the need to harmonize these elements to create a cohesive platform that not only facilitates the exchange of food waste but also promotes sustainable practices in alignment with the circular economy principles. Balancing these socio-technical dynamics requires careful consideration of the interconnected roles of governance, stakeholder collaboration, and advanced technological solutions.

1.4 Core Concepts

This section details the core concepts guiding this research and presents their interrelationship. The main concepts are digital platform, digitalization, food waste management, circular economy, and circular economy strategies. The research on digitalization and the circular economy underscores the increasing significance of the Circular Economy (CE) since its inception in the early nineties, gaining attention from academia, policymakers, and industry alike [11].

1.4.1 Digital Platform

Digital platforms are software-based frameworks facilitating user interactions, enabling them to create, exchange, and consume content or services [12]. These platforms can vary widely in purpose and design, encompassing everything from social media networks and e-commerce websites to cloud computing services and online marketplaces [13].

Digital platforms provide tools and environments where users can interact with each other and the platform itself [12]. This interactivity is often real-time and allows for dynamic communication and transactions [14]. They are designed to handle varying degrees of user engagement and transaction volumes, capable of scaling up or down as demand changes. These platforms often collect and analyze large amounts of data to personalize experiences, optimize services, and drive decision-making processes [12], [14]. Data analytics enable them to tailor content, advertisements, and user interactions. Digital platforms connect various stakeholders, such as consumers, service providers, and producers, facilitating interactions and transactions that might not otherwise be possible [14]. For example, a platform like Uber connects drivers and passengers, while eBay connects buyers and sellers. Many digital platforms foster an ecosystem around them, encouraging third-party developers, content creators, and service providers to contribute to the platform's value [14]. Digital platforms often have various monetization strategies, including advertising, subscriptions, transaction fees, and premium service offerings [12].

1.4.2 Digitalization

Digitalization involves converting information into a digital format and integrating digital technologies into all aspects of business and daily life. This transformation enhances efficiency, improves data accessibility, and enables new business models and services [15]. Digitalization is essential because it can drive innovation, boost productivity, streamline operations, and provide better customer experiences [16]. It plays a crucial role in economic growth and competitiveness in the modern digital economy.

Integrated research combining CE and digitalization indicates the potential for a swift transition to a circular economy, offering advantages like enhanced economic growth, reduced CO2 emissions, cost savings in materials, and heightened innovation [17]. Digital technologies such as digital platforms have emerged as pivotal enablers of the Circular Economy, facilitating circular business models, optimizing resource utilization, and extending product lifecycles. This synthesis is anticipated to foster a harmonious relationship between environmental and economic systems, fostering sustainable resource management practices [11].

1.4.3 Food Waste Management

Food Waste Management in the context of circular economy refers to the strategies and processes implemented to reduce, reuse, and recycle food waste, thereby minimizing its environmental impact [2]. It is crucial for addressing the global challenge of food loss, with significant environmental, economic, and social implications. Managing food waste is vital for conserving resources, reducing greenhouse gas emissions, and improving food security [18]. In a circular economy, food waste management is essential for closing the loop of food systems, minimizing waste, and reintegrating it into the economy sustainably [18]. Digitalization enhances food waste management through

innovative tools and technologies, facilitating better inventory management and optimizing food production and consumption patterns [17].

1.4.4 Circular Economy

The circular economy focuses on minimizing waste and maximizing resource use [19]. It prioritizes sustainability by promoting product longevity, reuse, and recycling, creating a closed-loop system that minimizes environmental impact [20]. The circular economy is crucial in reducing resource depletion, cutting greenhouse gas emissions, and driving economic growth through sustainable practices [19]. It encourages innovation and efficiency while balancing economic development and environmental protection [21].

1.4.5 The Circular Economy Strategies

The 10 Rs circular economy strategies in Figure 1 present ten strategies to guide businesses to move from a linear into a circular economy model [21]. The 10 Rs circular economy strategies guide the transition towards a more sustainable and circular economy. These strategies focus on reducing resource consumption, promoting reuse, recycling materials, and extending product lifecycle[21]. The 10 Rs include Rethink, Refuse, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover. By following these strategies, businesses and policymakers can minimize waste generation, conserve natural resources, and create a more sustainable economic system.

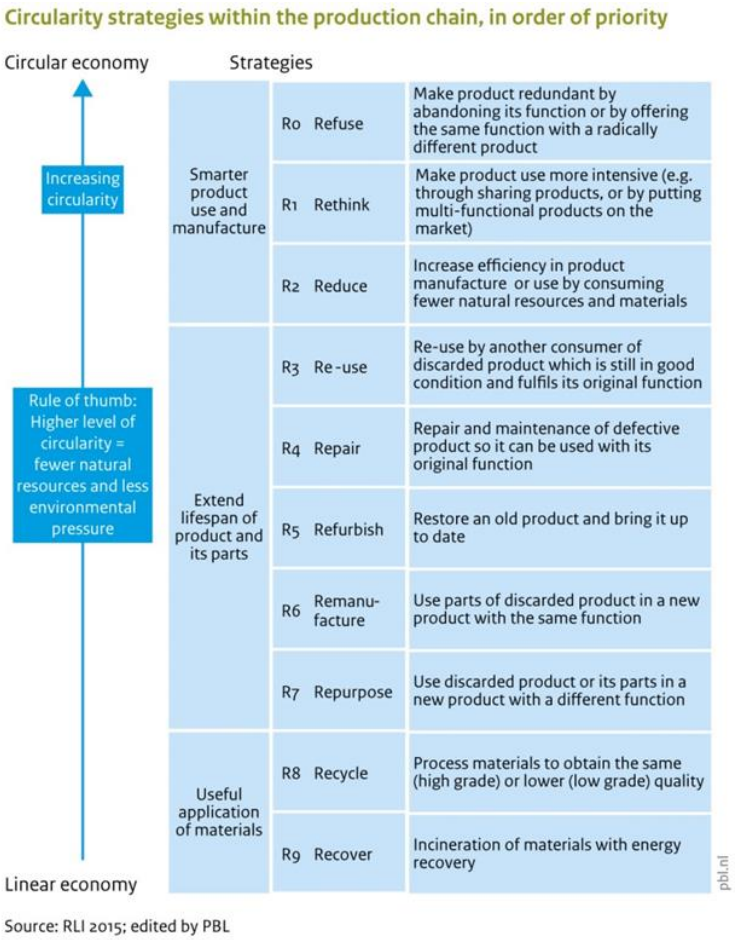

Figure 1: Circular Economy 10Rs framework, copies from [14, p. 5]

For our digital platform scope, we integrated the following strategies:

R9 (Recover): Connect retailers with individuals or organizations that recover value from food waste through composting or energy recovery.

R7 (Repurpose): Connect retailers with customers looking for food waste for various purposes, such as farming fertilizers or animal feeding.

R3 (Reuse): Connect retailers to non-profit organizations providing food to needy people.

R2 (Reduce): Selling nearly expired product items to other retailers looking for immediate product use. Additionally, provides analytics to improve decision-making and assist in better food waste management, leading to food waste reduction.

The selection of R9 (Recover), R7 (Repurpose), R3 (Reuse), and R2 (Reduce) aligns seamlessly with the objectives of our digital platform to mitigate food waste in Saudi Arabia's retail sector. R9 (Recover) focuses on connecting retailers with organizations or individuals that recover value from food waste through composting or energy recovery. This direct connection ensures food waste is directed towards appropriate recovery processes, maximizing its value and reducing the environmental impact.R7 (Repurpose) focuses on connecting retailers with customers who can utilize food waste for purposes like farming fertilizers or animal feed, thereby ensuring that waste is diverted from landfills and put to beneficial use. This not only supports agricultural productivity but also reduces the environmental footprint of food waste. R3 (Reuse) involves connecting retailers with organizations and charities that provide food to those in need, which addresses social issues of hunger and food insecurity while ensuring that edible food is not wasted. Lastly, R2 (Reduce) aims to analyze the types and amounts of wasted food listed on the platform, providing retailers with insights to make informed decisions that minimize waste. This analytical approach enhances operational efficiency and promotes sustainable practices within the retail sector.

While the other Rs (R0 Refuse, R1 Rethink, R4 Repair, R5 Refurbish, R6 Remanufacture, R8 Recycle, R10 Rethink) are essential components of a comprehensive circular economy strategy, the selected R 2,3,7, and 9 are most prevalent in the chose domain of research (the food retail sector). R0 (Refuse) and R1 (Rethink) are more relevant to production and consumer purchasing behavior stages beyond the direct influence of our platform focused on post-retail food waste. R4 (Repair), R5 (Refurbish), and R6 (Remanufacture) are primarily applicable to the lifecycle of durable goods rather than perishable food items. R8 (Recycle) pertains to the end-of-life processing of materials, which involves complex logistical and industrial processes unsuitable for our platform’s current scope. Lastly, R10 (Rethink) emphasizes systemic change at a broader level, which, while important, is more abstract and less actionable in the context of our targeted digital solution aimed at practical, immediate food waste reduction in the retail sector.

1.5 Literature Review

The literature review is critical to any research project and serves as the foundation for new research. It involves a comprehensive survey of existing scholarly works, articles, and studies related to the research topic [22]. This section aims to explore and provide a detailed understanding of the current state of knowledge regarding food waste management and the circular economy. The objective is to analyze the current strategies for tackling food waste management and identify a knowledge gap.

1.5.1 Literature Search and Selection Process

The literature search and selection process for this exploratory literature review were conducted using the PRISMA methodology. PRISMA helps search, select, assess, and report relevant papers and literature for review-based studies [22]. The PRISMA flow diagram, Figure 2, presents the literature search process.

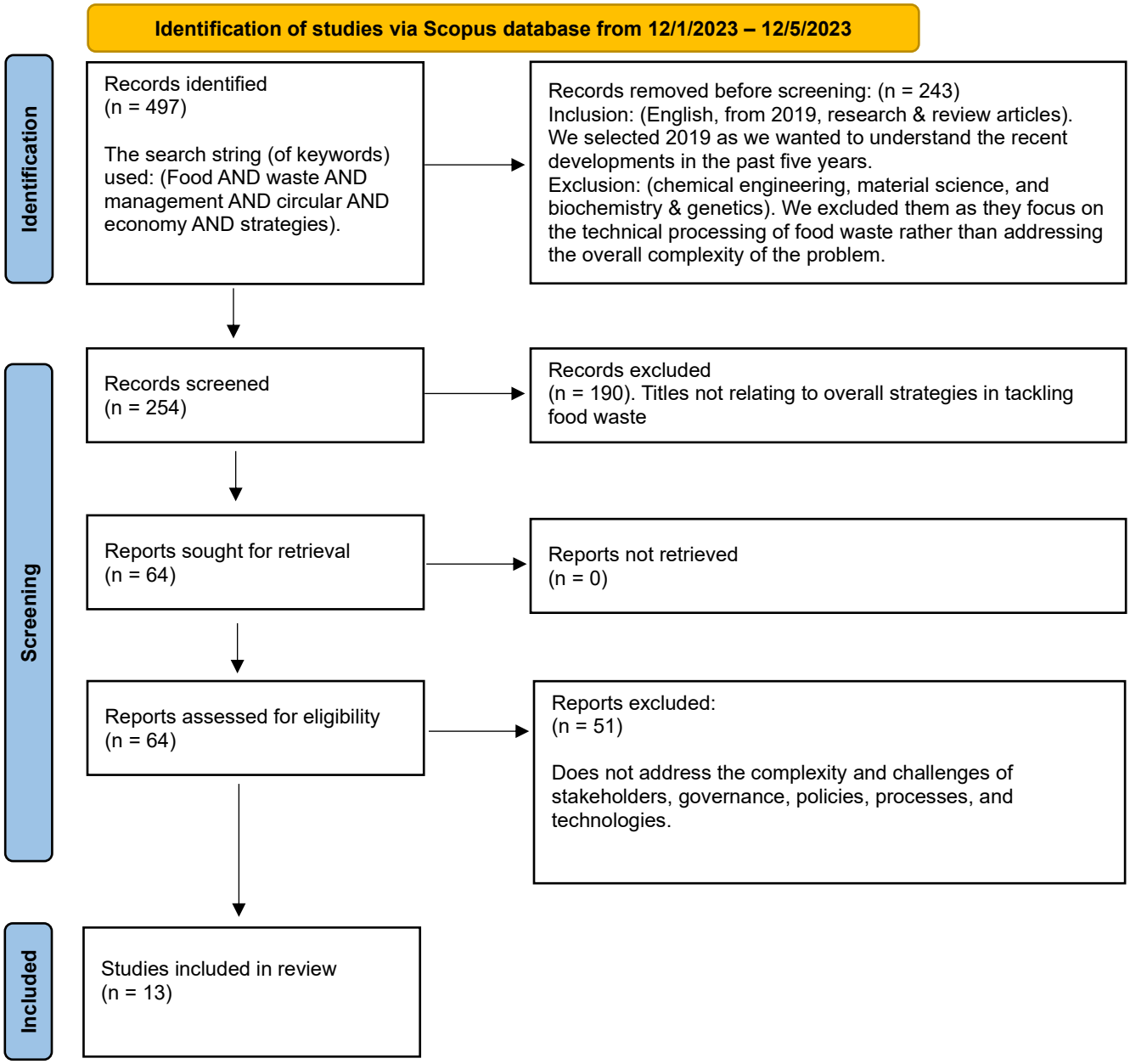

Figure 2: PRISMA Flow Diagram

1.5.2 Literature Results

We have developed Table 1 based on the PRISMA search protocol, inclusion, and exclusion criteria. The third column presents the literature's strengths.

Table 1: Literature review Table

Author	Title	Year	Literature Strength
Facchini, Francesco	Agri-food loss and waste management: Win-win strategies for edible discarded fruits and vegetables sustainable reuse	2023	A comprehensive overview of strategies for managing edible food loss and waste within the circular economy framework is provided [1].
Santagata, R.	Food waste recovery pathways: Challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment	2021	Provides insights into the challenges and opportunities in food waste management across the supply chain [2].
Möslinger, Margot	Circular economy and waste management to empower a climate-neutral urban future.	2023	Highlights the importance of technological innovations in addressing food waste challenges [4].
Massari, Giovanni Francesco	Digital technologies for resource loop redesign in circular supply chains: A systematic literature review.	2023	Provides a comprehensive overview of the principles of circular economy applied to food waste management and the use of digital technologies [20].
Peffers, Ken	A research agenda for circular food waste management in Bavaria.	2022	Discusses the potential application of end-to-end technologies to increase efficiency and ensure low investment costs in food waste management [21].
Camana, Daniela	Assessing environmental sustainability of local waste management policies in Italy from a circular economy perspective. An overview of existing tools.	2021	Provides insights into strategies for the reuse of food waste, highlighting the importance of environmental sustainability [23].
Chojnacka, K.	Valorisation of agri-food waste to fertilisers is a challenge in implementing the circular economy concept in practice	2022	Discusses the methodologies for evaluating consumer acceptance of discarded or upcycled food, emphasizing the use of surveys and interviews [24].
Joshi, Prabhat	Sustainable management practices of food waste in Asia: Technological and policy drivers	2019	Discusses the potential application of end-to-end technologies to increase efficiency and ensure low investment costs in food waste management [25].
Kfouri, Tanes	Sustainable solid waste management in restaurants: The case of the Ecozinha Institute, Brazil.	2022	Highlights the importance of food safety and consumer acceptance in the context of upcycled food [26].
O'Connor, Grace	Shifting the value of food and organic waste management in the food services sector in Brisbane, Australia.	2021	Provides insights into the principles of circular economy and their application to food waste management [27].
Ryen, Erinn G.	The role of U.S. policy in advancing circular economy solutions for wasted food.	2022	It provides insights into consumer acceptance methodologies, which can inform the design of a digital platform focused on consumer engagement [28].
Teigiserova, Dominika Alexa	Towards transparent valorization of food surplus, waste, and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy	2020	Discusses the challenges and opportunities in food waste management, emphasizing the need for a holistic, integrated approach to address food waste across the supply chain [29].
Velasco-Muñoz, Juan F.	Circular economy implementation in the agricultural sector: Definition, strategies, and indicators	2021	It focuses on reusing food waste for human feeding, emphasizing the importance of environmental sustainability in waste reuse strategies [30].

1.5.3 Literature Analysis

The literature analysis section discusses significant strategies, challenges, and opportunities for tackling food waste in which we aim to discover a knowledge gap that we want to contribute to.

The key concepts related to the global challenge of food waste discussed in this literature review include the urgency to shift from a linear to a circular economy, the need for a comprehensive approach to reducing food waste across the supply chain, the challenges and opportunities in food waste management, the importance of policy interventions in promoting circular economy principles for food waste reduction, and the potential of digital technological innovations in addressing food waste challenges. Additionally, it highlights the importance of considering social factors and stakeholder perspectives in developing effective strategies for reducing food waste.

The analysis of the thirteen articles provides a comprehensive overview of the strategies and challenges associated with addressing food waste within the circular economy framework. The literature highlights the importance of governmental interventions in promoting circular economy principles for food waste reduction [23], [24].

Simultaneously, the increasing demand for energy and resources to cater to the needs of a rapidly growing and resource-intensive population is driving a transition to a circular economy [4]. In the circular economy, waste is regarded as a secondary resource, representing a fundamental shift in perspective [1]. The European Union (EU) has instituted an action plan for the Circular Economy, aligning with the global Sustainable Development Goal (SDG) 12.3 to halve per capita food waste and reduce food losses across production and supply chains by 2030 [25]. This transition is reshaping the foundational aspects of waste management for various types of waste, leading to novel business prospects [26]. Food waste, a component of this circular approach, can be repurposed to generate biomaterials, bioenergy, and high-value products, contributing to resource efficiency [2].

However, several obstacles delay the progress toward sustainable food waste management within the evolving circular economy [24]. The primary challenge stems from the complexity of economic, social, policy, and technological dimensions, leading to the failure of many initiatives [25], [27], [28]. Successful implementation of food waste reduction and recycling hinges on substantial commitment, coordination, and communication among diverse stakeholders, necessitating the adoption of new business models and incentive structures [18], [29], [30]

Establishing partnerships throughout the food supply chain is crucial for initiating changes in food policy, potentially extending beyond direct involvement in the food system to collaboratively explore and assess digital technologies [17]. Additionally, addressing social factors becomes imperative to comprehend how underlying drivers of social responsibility can reduce waste along the supply chain. Policies targeting the prevention or reduction of wasted food must consider consumer preferences, values, and beliefs, emphasizing efforts to 'nudge' behavior modification without necessitating attitude changes, increased effort, or education [23]. While specific industries subject to regulations tend to favor flexible market-based approaches, advocacy groups lean towards regulations ensuring pollutant or waste reductions [4].

1.6 Knowledge Gap

Overall, the literature provides a foundation for identifying key strategies for addressing food waste within the circular economy framework. The literature offers valuable insights into waste reduction, consumer acceptance, reuse strategies, and the challenges and opportunities in food waste management. The literature highlights the importance of digital technological innovations in addressing food waste challenges besides the need for a comprehensive approach to tackle the complexity of solving food waste challenges [24], [28], [31]. However, the knowledge gap lies in the insufficient understanding of diverse stakeholder perspectives and requirements and the limited exploration of integrating technological innovations. Furthermore, there is a lack of new business models and incentive structures to support food waste initiatives [18], [29], [30]. Closing these gaps requires interdisciplinary research and collaboration with industry experts. Therefore, to close this knowledge gap, we have decided to design a digital platform and support it with a business model. We chose the design science research (DSR) methodology to guide us in the design of the digital platform. The following section will discuss the DSR methodology and its relevance to the design of a digital platform.

2 Research Approach

The **design science research** method is well-suited to address the main research question and the complex challenge of designing a digital platform. The primary advantages of employing design science in Information Systems research lie in its forward-looking approach toward technology [32]. It centers on designing and assessing innovative IT artifacts, empowering organizations to tackle crucial information-related challenges [33]. Furthermore, design science has the potential to actively contribute to addressing the core challenges that have long affected IS research, encompassing concerns about rigor, relevance, and the boundaries of discipline, behavior, and technology [34]. This methodology's strength lies in its pragmatic approach, focusing on creating practical and applicable solutions to real-world problems [32]. Given the specific context of food waste reduction in retail, design science allows for an iterative and user-centric development process. Through iterative design and testing, the methodology ensures that the digital platform evolves based on feedback, enhancing its usability and effectiveness. The user-centric approach aligns with the necessity to actively engage and collaborate with diverse stakeholders in the retail sector, ensuring that the final platform is technologically robust and intuitively aligned with stakeholder needs [35].

Design science research follows a structured and iterative process consisting of the following phases, activities, and outcomes as per Table 2, presented below. It is essential to mention that we have combined the communication phase with the evaluation phase.

Table 2: Design Science Research Phases [32], [35]

Phase	Activity	Outcome
Problem Identification	Define the problem clearly and justify the need for a solution.	A detailed problem statement highlighting the issue's significance and context.
Requirements	Establish the goals and requirements for the artifact based on the problem.	Clear, measurable objectives that the artifact needs to achieve.
Design	Create the artifact. This phase includes conceptual design, system design, and technology selection.	The developed artifact is ready for demonstration and evaluation.
Evaluation	Assess the artifact's performance in addressing the problem against the objective, stakeholder requirements, and feedback.	Analytical data and feedback indicate the artifact's effectiveness and areas for improvement.

It is essential to highlight that design science research could have limitations depending on the execution of the research and the methodology. For example, the applicability of a design artifact within one project might not extend to diverse settings [33]. Furthermore, design-science research has a limited lifespan, given that swift technological advancement has the potential to render research findings obsolete before their practical implementation in the business environment or before organizations can realize sufficient returns on the investment of resources to enact those findings[32].

We have considered several mitigation measures to address the limitations of design science research (DSR) by applying different research methods under each sub-question. These measures include engaging with various stakeholders, providing varied perspectives, and ensuring the artifact meets diverse needs and settings. Second, we conducted an exploratory literature review to identify food waste management challenges related specifically to Saudi Arabia. Third, we have developed business models through a business model canvas and conducted a SWOT analysis to ensure that the proposed design is feasible and covers relevant business aspects. Third, we have interviewed subject matter experts who designed, developed, founded, and operated digital platforms in the eastern province of Saudi Arabia to ensure relevant design requirements.

2.1 Research Methods

The research method section below discusses the data requirement from each sub-question and the data collection methods. We have conducted all interviews using Microsoft Teams. We are aware that interviews might lead to

biases; therefore, we ensured that more than one interview was conducted for each stakeholder to help us mitigate this challenge.

SQ1: What are the critical challenges for reducing food waste in the retail stage within the circular economy framework in Saudi Arabia?

To gather data, we have conducted a qualitative analysis to identify and describe the challenges. Interviews with key stakeholders have provided qualitative insights into the challenges faced concerning tackling food waste. Additionally, analyzing existing literature on food waste management and sustainability initiatives in Saudi Arabia has contributed to identifying current challenges.

SQ2: What are the stakeholders' requirements for a digital platform to reduce food waste at the retail stage in Saudi Arabia in alignment with circular economy principles?

We have interviewed all relevant stakeholders, providing insights into expected outcomes based on their experiences, values, and requirements.

SQ3: What digital platform design fulfills the identified requirements?

We have applied the ArchiMate framework and analyzed best practices through desk research that helped us finalize ArchiMate's farmwork layers and design components.

SQ4: To what extent does the digital platform address the identified problem and requirements?

We have conducted an alignment analysis against the identified requirements and challenges to ensure that all aspects are covered during the evaluation process.

SQ5: What business models fit a digital platform aimed at reducing food waste at the retail stage in the Eastern Province of Saudi Arabia?"

We have completed two business models using the Business Model Canvas and SWOT analysis. To facilitate the completion of the required input, we have conducted desk research.

2.2 Research Flow Table

The research flow table below presents the sequence of activities along with each phase's main input/output and research methods for each phase. MRQ = Main research question. SRQ = Sub research question.

Table 3: Research Flow

Research Phase and Chapter	Input	Process	Output	Research Question	Method
Problem Identification (Chapter 3)	1- Literature on Food Waste Management Challenges 2- Stakeholder Interviews	Conduct qualitative analysis through literature review and stakeholder interviews to identify and describe challenges related to food waste management in Saudi Arabia.	1- List of Challenges 2- Challenges Definitions	Sub-Question 1	Literature review & Interviews (Qualitative Analysis)
Requirement (Chapter 4)	1- Stakeholder Interviews	Interview all relevant stakeholders, providing insights into expected outcomes based on their experiences, values, and requirements.	1- Stakeholer Analysis 2- Design Requirements	Sub-Question 2	Interviews (Qualitative Analysis)
Design (Chapter 5)	1- Literature on ArchiMate Framework 2- Literature on Digital Platform Design 3- Stakeholders Requirements	Apply the ArchiMate framework and analyze best practices through desk research to help finalize ArchiMate's farmwork layers.	1- Design Components 2- ArchiMate Model & Layers	Sub-Question 3	ArchiMate Framework (Desk Research)
Evaluation (Chapter 6)	1- Digital Platform Design Components 2- ArchiMate Model & Layers	Conduct an alignment analysis against the identified requirements and challenges.	1- Completed Evaluation 2- Areas of Improvement	Sub-Question 4	Alignment Analysis
Business Model (Chapter 7)	1- Literature on Business Models 2- Literature on SWOT Analysis 2- Design requierments 3- Digital Platform Design Components	Conduct desk research to complete the Business Model Canvas and SWOT analysis for two business models	1- Business Models 2- SWOT Analysis	Sub-Question 5	Business Model Canvas and SWOT Analysis (Desk Research)
Conclusion (Chapter 8)	1- Conclusions from Previous Chapters	Summarize previous chapters' conclusions and add all conclusions requirements	1- Final Design 2- Scientific Contribution 3- Societal Contribution 4- Research Limitations 5- Recommendation For Future Work	Main Research Question	Integration of previous chapters

3 Problem Identification

The Problem Identification chapter is a critical first step in the Design Science Research (DSR) methodology, laying the foundation for the entire research project. In DSR, problem identification involves defining and understanding the core issue that the research aims to address [35]. The sub-question that guided this chapter is (*What are the critical challenges for reducing food waste in the retail stage in the eastern province of Saudi Arabia?).* We have employed qualitative analysis to answer this question. Interviews with key stakeholders provided qualitative insights into the challenges faced concerning tackling food waste. Additionally, analyzing existing literature on food waste management and sustainability initiatives in Saudi Arabia contributed to identifying current challenges. While the literature review highlighted challenges in food waste in Saudi Arabia, the expert interviews focused on identifying challenges specifically related to the retail stage in the eastern province of Saudi Arabia and aided in confirming the findings of the literature review. The envisaged result of this chapter is a list of challenges related to food waste management in Saudi Arabia. We start this chapter by detailing the food waste problem in Saudi Arabia. Second, we present the literature review following a PRISMA methodology for the literature search. Third, we detail the retail business owners' interviews. Last, we present the conclusion to answer the sub-research question regarding the challenges.

This chapter sets the stage by clearly articulating the problem, its relevance, and the context of Saudi Arabia. By comprehensively analyzing the situation, we ensured that the subsequent phases of the research are grounded in a deep understanding of the challenges and opportunities. This initial phase not only justifies the need for the research but also guides the formulation of requirements and the design of the artifact.

3.1 Problem Overview

Saudi Arabia, officially known as the Kingdom of Saudi Arabia, is a sovereign state in the Middle East, covering most of the Arabian Peninsula. With a land area of approximately 2.15 million square kilometers, it is the largest country in the Middle East and the 13th largest globally [36]. Home to around 34.8 million people, Saudi Arabia is known for its vast deserts, rich cultural heritage, and significant economic influence as a major player in the global oil market [37].

Despite its economic prosperity, Saudi Arabia is grappling with a multitude of challenges, among them environmental sustainability and resource management [38]. One issue that has surged to the forefront in recent years is food waste, a problem of staggering proportions. Globally, a third of all food produced for human consumption is lost or wasted annually, totaling about 1.3 billion tons [3]. In Saudi Arabia, this problem is not just a statistic but a pressing reality that presents a formidable economic, environmental, and social challenge [39].

Food waste is a mounting issue in Saudi Arabia, a challenge that is further complicated by evolving lifestyles, increasing incomes, and shifting dietary preferences [40]. The country's reliance on food imports, its arid climate, and its limited agricultural capacity all contribute to the complexity of food waste management [41]. However, it's not just these factors that are responsible. Cultural norms and consumer behaviors, such as extravagant hospitality and excessive consumption, significantly contribute to food waste [42].

While previous initiatives to combat food waste in Saudi Arabia have primarily targeted the household and industrial sectors, the retail stage emerges as a pivotal point in the food supply chain [40], [43]. This is where significant food is lost or discarded [44]. Retailers greatly influence consumer behavior, inventory management, and purchasing decisions. Therefore, addressing food waste in the retail sector offers a unique opportunity and holds the potential for substantial waste reduction and promoting circular economy principles [43].

3.2 Literature review

The literature review section involves an exploratory literature review of existing scholarly works, articles, and studies on the challenges associated with food waste management in Saudi Arabia. This section details the literature search and selection process, literature results, and literature analysis. The objective is to identify and define the

challenges related to food waste management in Saudi Arabia, these challenges are used to guide the collection of the requirements and the design of the digital platform.

3.2.1 Literature Search and Selection Process

The search methodology for this review was conducted by applying the PRISMA methodology. We used it to help us with our exploratory literature review. It helps to search, select, assess, and report relevant papers and literature for review-based studies [22]. The PRISMA flow diagram, Figure 3, presents the literature search process.

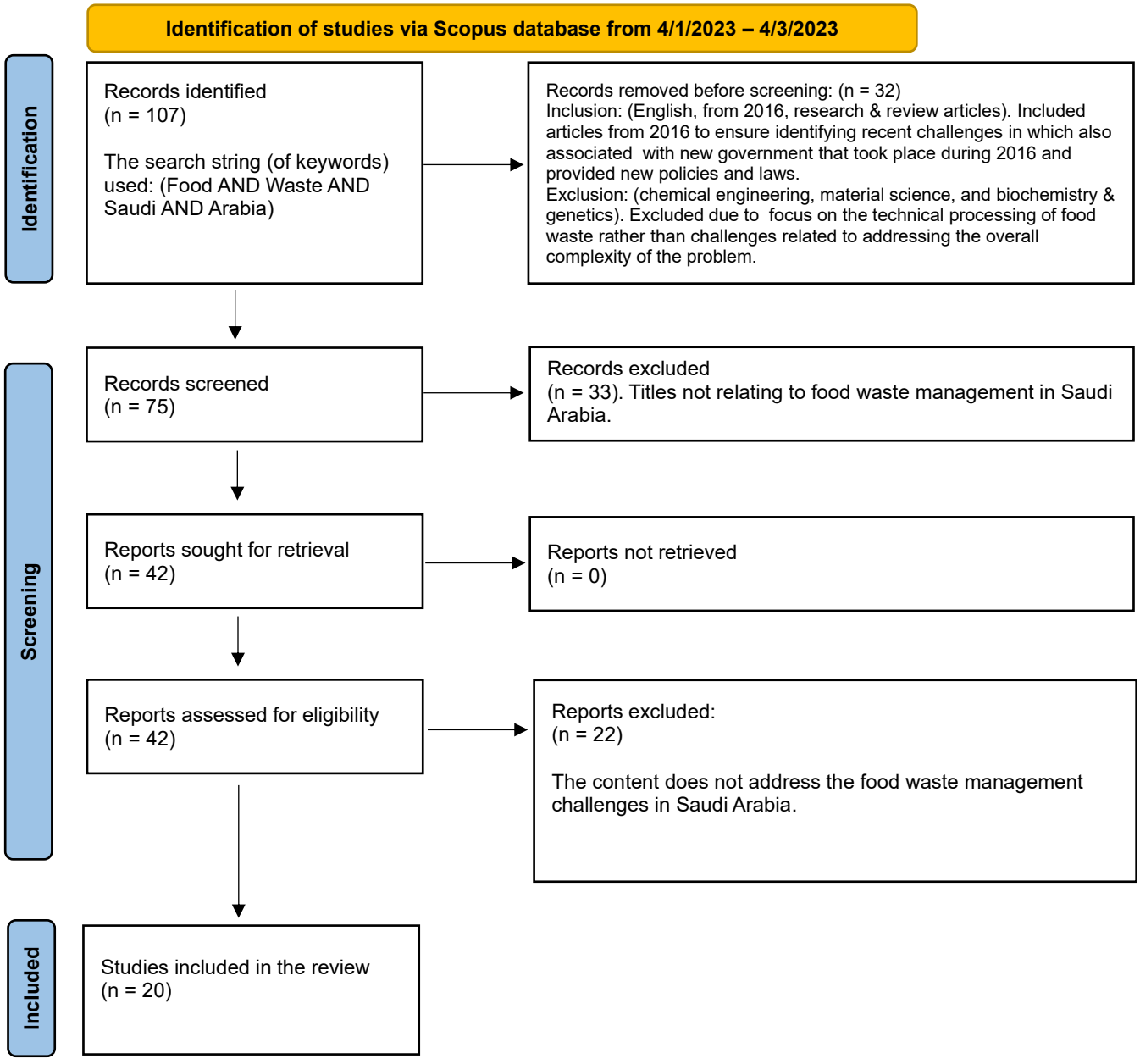

Figure 3: PRISMA Flow Diagram

3.2.2 Literature Results

Based on our search methodology, we have developed Table 4, which presents each piece of literature's authors, title, and year.

Table 4: Identified Literature

Author	Title	Source	Year
Baig et al.	Food Waste in Saudi Arabia: Causes, Consequences, and Combating Measures	[3]	2022
Almulhim et al.	Towards a Greener Future: Applying Circular Economy Principles to Saudi Arabia's Food Sector for Environmental Sustainability	[36]	2024
Al-Zahrani et al.	Food waste in the Kingdom of Saudi Arabia: Implications for extension education	[37]	2018
Radwan et al.	Municipal Solid Waste Management Practices and Opportunities in Saudi Arabia	[38]	2019
Oelofse et al.	Food Waste within South Africa and Saudi Arabia	[39]	2020
Alqahtani et al.	Smart Planning of Waste Management System in Saudi Arabia; Challenges and Opportunities	[40]	2022
Shahrah et al.	Sustainable Management of Food Waste in Saudi Arabia	[41]	2024
Gorski et al.	Understanding and addressing waste of food in the Kingdom of Saudi Arabia	[42]	2021
Alshabanat et al.	Quantifying Food Loss and Waste in Saudi Arabia	[43]	2021
Miandad et al.	Solid waste management in Saudi Arabia: A review	[44]	2016
Abdullah et al.	Integrated Approach to Achieve a Sustainable Organic Waste Management System in Saudi Arabia	[45]	2022
Mu'azu et al.	Food waste management current practices and sustainable future approaches: a Saudi Arabian Perspective	[46]	2023
Sobaih et al.	Exploring the 5Rs Holistic Model for Zero Food Waste in Saudi Arabian Food Service Outlets	[47]	2023
Baig et al.	Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia	[48]	2019
Al-Khateeb et al.	Battling food losses and waste in Saudi Arabia	[49]	2021
Malibari et al.	Analysis of Attitudes towards Food Waste in the Kingdom of Saudi Arabia Using Fuzzy Logic	[50]	2023
Aleshaiwi et al.	A step in the journey to food waste: How and why mealtime surpluses become unwanted	[51]	2021
Alshuwaikhat et al.	Sustainability matters in national development visions-Evidence from Saudi Arabia's vision for 2030	[52]	2017
Alkorbi et al.	Participation and Strategic Communication of Saudi Food Banks through Twitter to Enhance Food Waste Awareness among Saudi Arabian Citizens	[53]	2022
Elshaer et al.	The impact of religiosity and food consumption culture on food waste intention in Saudi Arabia	[54]	2021

3.2.3 Literature Analysis

In this section, we utilize thematic analysis, a widely recognized qualitative research method, to uncover patterns and themes within our data. The thematic analysis offers a systematic approach to understanding the complexities of our research topic, allowing us to organize and interpret textual data to address our research questions effectively [52]. It enables us to generate insights and contribute to a deeper understanding of the phenomena under investigation by identifying recurrent patterns and exploring diverse perspectives.

As we know that different people might interpret the presented challenges with various meanings, we have developed Table 5 to clarify the meaning of each identified challenge. These definitions were developed based on our understanding of the literature.

Table 5: Definitions for Identified Food Waste Management Challenges

#	Challenge	Definition
1	Awareness	The level of understanding and consciousness among individuals and organizations regarding the issue of food waste and its implications.
2	Policies & Regulations	The legal frameworks, rules, and guidelines established by governments or regulatory bodies that govern and influence food waste management practices.
3	Inventory Control	The process of monitoring, managing, and optimizing the inventory of food products within the food supply chain to minimize waste through efficient stock management.
4	Economical Concerns	Financial considerations and constraints related to implementing food waste reduction strategies.
5	Efficient Technologies	Technologies and tools designed to enhance food waste management processes, improve efficiency, and reduce waste generation in retail operations.
6	Cultural Practices	The social norms, beliefs, and behaviors within a society or community influence attitudes and practices related to food consumption, disposal, and waste management.
7	Waste Categorization	The classification and categorization of food waste based on factors such as its content and potential for recycling or reuse.
8	Waste Processing	The methods and techniques used to treat, recycle, or dispose of food waste.
9	Infrastructure	The physical infrastructure, transportation systems, and logistical processes involved in handling, storing, and distributing food waste.
10	Waste Measurement	The process of quantifying or assessing waste materials' quantity, volume, weight, or other relevant attributes.
11	Stakeholders Collaboration	The cooperation and coordination among various stakeholders, including businesses, government agencies, non-profit organizations, and communities, to address food waste challenges collectively

To conduct the thematic analysis, we first familiarized ourselves with the data by thoroughly reading through it to understand the challenges. Next, we generated initial codes by labeling relevant sections of the data. Then, we grouped these codes into their relevant broader Themes. Table 6 presents the codes and relevant themes. We manually conducted the thematic analysis as the number of literature pieces is manageable. We did it through an Excel sheet presented in Table 7.

Table 6: Themes & Codes

#	Themes (Challenges)	Codes
1	Awareness	Awareness, Education, Knowledge.
2	Policies & Regulations	Policies, Regulations, Legislation, Laws, Framework.
3	Inventory Control	Inventory Control, Demand Forecasting.
4	Economical Concerns	Economic Concerns, Financial Concerns, Financial Feasibility, Economical Challenge, Economical Balance.
5	Efficient Technologies	Efficient Technologies, Technology Integration, Advanced Technologies.
6	Cultural Practices	Cultural Practices, Behavior.
7	Waste Categorization	Categorization, Segregation, Separation.
8	Waste Processing	Processing, Utilization, Recycle, Disposal.
9	Infrastructure	Infrastructure, Logistics, Supply Chain, Network Capacity.
10	Waste Measurement	Waste Measurement, Data Measurement, Data Accuracy.
11	Stakeholders Collaboration	Stakeholders Collaboration, Active Participation of Agencies, Public Participation.

Table 7: Identified Challenges Per Literature

Challenges	[3]	[36]	[45]	[41]	[38]	[46]	[37]	[47]	[48]	[42]	[49]	[50]	[51]	[43]	[44]	[52]	[40]	[53]	[54]	[39]
Awareness	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X
Policies & Regulations	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X		X
Inventory Control	X										X									
Economical Concerns				X				X		X				X						
Efficient Technologies		X	X	X						X				X	X	X	X			
Cultural Practices	X	X		X		X	X	X	X	X	X	X	X	X					X	X
Waste Categorization	X	X	X			X									X		X			
Waste Processing	X	X	X	X	X	X		X	X			X			X	X	X	X		
Infrastructure & Logistics	X	X		X	X		X	X	X	X	X			X		X	X			
Waste Measurement	X			X					X	X	X									X
Stakeholders Collaboration			X	X				X	X	X							X			

3.2.3.1 Analysis

The challenges related to food waste in the Kingdom of Saudi Arabia encompass various aspects that intersect with societal, economic, and environmental factors [52]. This section analyzes these challenges, focusing on critical areas such as lack of awareness, inadequate policies and legislation, absence of incentives, infrastructure and logistics, technology integrations, stakeholder collaborations, inventory control, financial concerns, and cultural attitudes.

Lack of awareness is a significant challenge to combating food waste in Saudi Arabia. Studies indicate a widespread lack of understanding among the general population and corporate entities regarding the extent and implications of food waste. The absence of targeted awareness campaigns and educational initiatives contributes to a shortage of informed decision-making and actions toward waste reduction [3], [39], [40], [41], [46], [51], [53], [54].

Inadequate policies and legislation further exacerbate the challenge. The Kingdom lacks comprehensive food waste management policies and regulations [37]. Without clear directives outlining responsibilities and standards for waste reduction, efforts may lack cohesion and efficacy [47], [49]. Establishing robust policies is crucial for fostering a conducive environment for sustainable waste management practices [45]. Moreover, the absence of incentive policies presents a significant hurdle to waste reduction efforts, as businesses and individuals may lack the motivation to adopt sustainable practices without tangible benefits or rewards [37], [38]. Implementing incentive programs incentivizing waste reduction and recycling can catalyze behavioral change and adopt sustainable practices [49].

Inventory control poses a significant challenge in reducing food waste in the retail sector. The difficulty lies in accurately predicting demand and managing inventory levels to minimize waste while meeting customer needs [3],

[47]. Inaccurate forecasting can lead to overstocking and spoilage or understocking and lost sales. Perishable items further complicate inventory management due to their limited shelf life [47]. Standardizing inventory practices and leveraging technology and data analytics can help improve forecasting accuracy and optimize inventory turnover [47]. Addressing this challenge requires retailers to implement robust inventory management systems and flexible supply chain practices to minimize waste and enhance sustainability.

Financial and economic concerns associated with food waste underscore the need for cost-effective waste management solutions that benefit both the environment and the economy [48]. Implementing sustainable practices can mitigate economic losses and resource depletion while contributing to long-term environmental sustainability [38].

Integrating efficient technology offers promising solutions for food waste reduction, but challenges such as high costs, limited technical expertise, and technology integration may impede its widespread adoption. Overcoming these barriers requires embracing technological advancements and fostering a culture of innovation to enhance the efficiency of waste management processes [36], [45]

Cultural attitudes towards food waste, shaped by societal norms, pose a unique challenge in Saudi Arabia [37], [48]. Leveraging cultural values to promote sustainable practices and addressing deep-rooted attitudes towards waste disposal are imperative. Educating the public on food waste's environmental and ethical implications can shift cultural perceptions and behaviors toward waste reduction and resource conservation [36].

Food waste categorization and processing present significant challenges in reducing waste in the retail sector. Correctly categorizing food waste is essential for implementing effective management strategies tailored to different types of waste, such as perishable versus non-perishable items or edible versus inedible waste [43], [51]. Additionally, processing food waste for disposal or repurposing requires efficient and environmentally sustainable methods. ***Inadequate waste processing*** facilities and infrastructure can increase landfill usage and environmental pollution [44]. To address these challenges, retailers need to invest in waste categorization systems and collaborate with waste management authorities to develop efficient processing methods.

Effective waste management also hinges on robust ***infrastructure*** and efficient logistics systems. However, Saudi Arabia faces challenges, with inadequate facilities and transportation networks hindering proper waste handling. Investing in infrastructure development and streamlining logistics processes are essential steps towards enhancing waste management practices in the Kingdom [37], [41]

Additionally, the lack of accurate data related to ***food waste measurement*** in Saudi Arabia presents a significant challenge, as data-driven decision-making is essential for developing targeted interventions and measuring the effectiveness of waste reduction strategies [49]. Investing in comprehensive research studies and data collection efforts can provide valuable insights for informed policy development and implementation [42].

Collaboration among stakeholders is paramount for effectively addressing food waste challenges. However, the lack of coordinated efforts and partnerships among government entities, businesses, NGOs, and the public may challenge food waste reduction initiatives. Encouraging stakeholder collaborations and fostering shared responsibility for waste management are crucial strategies for success [42], [47].

In conclusion, the analysis of food waste challenges in Saudi Arabia reveals significant issues intersecting societal, economic, and environmental factors [52]. There is a widespread lack of awareness about food waste, necessitating targeted educational campaigns [48]. The absence of comprehensive policies and incentives hampers waste reduction efforts, highlighting the need for robust regulations and incentive programs [49]. Infrastructure and logistics limitations, high costs, and limited technical expertise hinder effective waste management, requiring investments in infrastructure and technology [40]. Stakeholder collaboration is crucial but currently lacking, emphasizing the need for coordinated efforts [42]. Inaccurate data impedes informed decision-making, necessitating comprehensive research and data collection [41]. Additionally, inventory control issues, waste categorization, and processing challenges must be addressed to optimize food waste management. Cultural attitudes also play a

significant role, indicating that leveraging cultural values and education can promote responsible waste management.

Understanding these challenges is vital for designing the digital platform. The platform can offer targeted, practical, and culturally appropriate solutions by addressing these issues. Incorporating awareness mechanisms, integrating advanced technologies, proposing incentives, and fostering stakeholder collaboration will aim to enhance the platform's effectiveness. Accurate data collection enables informed decision-making. Aligning the platform's design with these challenges will seek to support reducing food waste within the retail sector and support the circular economy's broader goals.

3.3 Interviews

The interviews section is pivotal in understanding the perspectives and challenges of retail business owners involved in the project. By conducting in-depth interviews, we aim to gather qualitative data that provides rich, contextual insights into the problem. This section explains the interview data analysis process to extract meaningful patterns and themes to confirm the literature review findings and discover additional challenges. By understanding their challenges and perspectives, we can design a digital platform that meets their needs and addresses the identified challenges. This ensures the solution is practical, relevant, and more likely to be successfully designed and adopted. Figure 4 presents the interview process.

Figure 4: Interviews Process

3.3.1 Interview Protocol

The interview protocol is a detailed guide outlining the process, ensuring consistency and thoroughness. It is important because it standardizes the interview process, enhancing the reliability and validity of the data collected. It helps manage time efficiently, maintains ethical standards, and provides a structured framework that minimizes interviewer bias and ensures all relevant topics are covered, ultimately contributing to the overall rigor and credibility of the research study.

3.3.1.1 Objective

The interviews aim to identify the challenges related to food waste management in the retail business in the eastern province of Saudi Arabia and to confirm the literature review findings.

3.3.1.2 Interviewee Selection

For the selection of the interviewees, we have targeted retail business owners from the eastern province of Saudi Arabia. We identified and selected the interview candidates by contacting retail business owners through professional contacts. We have chosen retail business owners representing different categories: restaurant, café, and bakery owners. We aimed to interview only retail business owners, not employees, as they will have the overall business perspective. Those who showed a willingness to participate were selected for the interviews. Table 8 provides overview information about the interviewees.

Table 8: Interviewee Overview

Category	Function	Experience	Date	Interview	Means	Source
Restaurant	Owner & Operation Manager	3 years	4/28/2024	#1	Online	Appendix B
Café	Owner & Business Manager	7 years	4/28/2024	#2		
Bakery	Owner & Business Manager	12 years	4/30/2024	#3		

3.3.1.3 Interview Questions

The following is the list of questions we used during the interviews. We developed these questions to capture insights into the current problem of food waste management from the perspective of retailers in the food sector in the eastern province of Saudi Arabia.

- What do you know about food waste management and its impact?
- Are you currently involved in any food waste reduction efforts or initiatives? And are you aware of any?
- What are your main challenges in managing and reducing food waste in your business?
- What existing policies or regulations are you aware of that hinder or facilitate efforts to reduce food waste in the retail sector?
- What infrastructure and logistical limitations do you encounter or imagine encountering when participating in food waste management circularity initiatives in your retail operations?
- Have you experienced barriers or challenges in integrating technology to address food waste in your retail business?
- How do cultural attitudes toward food waste influence behaviors and practices in the retail sector?
- What incentives are you seeking to implement food waste reduction strategies in your retail business?

3.3.1.4 Interviews Structure

We start each interview by introducing ourselves and the objective. Following that, we review the consent form in Appendix C and get a verbal recorded agreement. It is important to note that the consent form aligns with TU Delft guidelines on Data management and HREC, aligning with the GDPR. After that, we start the interview questions. We close the meeting by informing them about our upcoming research phase. Lastly, we generate a summary of each interview, which is available in Appendix B. We have used semi-structured interviews to ensure exploring and understanding with follow-up questions, if needed, under each prepared question.

3.3.2 Interview Analysis

Our interviews validated the challenges identified in the literature review, provided additional insights into these challenges, and added a couple of new challenges.

Regarding general awareness, the interviews revealed a **low level of awareness**. While participants acknowledged the impact of wasted food on the environment, they were not fully aware of the extent of its effect on our world. Notably, none of the interviewees knew that Saudi Arabia leads the world in food waste. However, their willingness to engage in systematic efforts to reduce food waste, provided such efforts do not disrupt their daily operations, is a hopeful sign. None reported being involved in formal food reduction programs or initiatives, but each mentioned implementing individual, self-directed efforts. For instance, one interviewee mentioned providing untouched leftovers to employees, while another mentioned collaborating with a local farmer to collect unused bread.

Across the interviews, there is a strong commitment to reducing food waste, driven by a combination of ethical, cultural, and operational motivations. Interview #1 highlights an intrinsic motivation where the interviewee's satisfaction comes from ensuring that food is not wasted but rather processed or shared. This reflects a broader cultural and ethical stance, where, despite the lack of monetary incentives, there is a deep-rooted desire to mitigate waste, particularly in a society where food holds significant cultural and religious value. This sentiment is echoed in Interview #3, where efforts are voluntary and driven by ethical considerations rather than enforced regulations.

As highlighted in all three interviews, **cultural attitudes** significantly influence food waste practices. Interviews #1 and #2 discuss how the culture of generosity and the religious prohibition against wasting food play critical roles in shaping behaviors, particularly in social settings where over-ordering is common. However, as mentioned in Interview #2, while there is a religious reverence for food, the lack of financial repercussions for wasting food diminishes the urgency of addressing waste at the individual level. This cultural context complicates efforts to reduce waste, as it requires balancing respect for these cultural practices with the need for more sustainable behaviors.

Technological integration poses a significant challenge to effective food waste management. Interview #1 highlights the necessity of integrating food waste management processes with existing systems within restaurants to streamline operations. This need for seamless technology integration is also noted in Interview #2, where logistical challenges, such as distant garbage bins and the need for specialized devices, create barriers to implementing efficient recycling processes. Interview #3 further emphasizes the operational difficulties caused by a lack of support from municipalities or third parties for waste collection, pointing to infrastructure and logistical limitations as significant hurdles. Despite these challenges, interviews revealed that retailer owners are willing to adapt to technological changes. They also emphasized that the additional food waste management processes should not impose **financial or operational burdens** on their businesses.

A recurring theme in the interviews is the **absence of policies and regulations** for food waste management, which hampers structured efforts to address the issue. Interviews #2 and #3 both highlight the lack of awareness and enforcement of existing policies, with Interview #3 stressing that current waste management efforts are voluntary, as there is no regulatory framework in place. This regulatory gap creates inconsistencies in managing food waste and underscores the need for government intervention to provide clear guidelines and enforce regulations.

In addition to confirming and validating the identified challenges, Interviews # 1 and 2 revealed the challenge regarding the **lack of incentives** from municipalities for food waste management. They stressed that recognition from municipalities, whether monetary or non-monetary, is important to motivate the retail business to participate in food waste management initiatives. The interviews suggest that incentives could play a crucial role in promoting food waste reduction. Interview #2 discusses the potential for non-monetary rewards, such as municipal certifications, to enhance a business's image and encourage compliance with food waste management practices.

Lastly, interview # 2 highlighted the need to have a **safe environment** when exchanging food waste. Knowing how this waste will be utilized or who the people/ organizations behind it are will make the retail business more comfortable participating.

3.4 Conclusion

In conclusion, this chapter answered the sub-question (*What are the critical challenges for reducing food waste in the retail stage in the eastern province of Saudi Arabia?).* To do that, we have employed qualitative analysis. We have conducted a literature review on food waste management challenges in Saudi Arabia, contributing to identifying current challenges. Additionally, we have conducted interviews with retail business owners, which provided qualitative insights into the challenges faced in tackling food waste, specifically in the Eastern Province of Saudi Arabia. While the literature review highlighted challenges in food waste in Saudi Arabia, the expert interviews helped us identify challenges specifically related to the retail stage in the eastern province of Saudi Arabia and aid in confirming the literature review findings.

Through the literature review, we have identified that addressing food waste challenges in Saudi Arabia requires an approach that considers the interplay of technological, regulatory, behavioral, and socioeconomic factors [36], [40], [42], [47], [50]. The identified challenges are presented in Table 9.

Table 9: Identified Challenges

#	Identified Challenges
1	Awareness
2	Policies & Regulations
3	Inventory Control
4	Economical Concerns
5	Efficient Technologies
6	Infrastructure
8	Cultural Practices
10	Waste Categorization
11	Waste Processing

The interviews with restaurant and cafe owners confirmed the challenges identified in the literature regarding food waste management in Saudi Arabia's retail sector. Low awareness levels, inventory control issues, lack of government policies, minimal technology integration, logistical challenges, and cultural practices contribute to the problem. Participants expressed a willingness to engage in food waste reduction efforts but emphasized the need for systematic approaches that do not disrupt daily operations, a safe environment, and possible incentives. The findings underscore the importance of government intervention, incentives, and user-friendly technology solutions to address these challenges effectively.

Despite the challenges, there are several opportunities for reducing food waste in the retail stage in Saudi Arabia. The country has been actively embracing digital technologies and innovation as part of its Vision 2030 initiative [6], which aims to diversify the economy, promote sustainable development, and enhance the quality of life for its citizens [40], [52]. With a growing emphasis on digital transformation and e-commerce, the country is well-positioned to leverage digital platforms and intelligent technologies to address food waste challenges in the retail sector.

During the design of the intended digital platform, we will be able to address most of the identified challenges with varying degrees to each challenge. However, the following challenges are beyond the direct scope of the platform. First, raising awareness about food waste requires widespread educational campaigns, which are primarily a societal and governmental responsibility. Second, developing the necessary infrastructure for efficient waste management involves significant governmental investment and coordination. Lastly, establishing and enforcing food waste management policies and regulations is also within the purview of government authorities. We will, however, cover the awareness and policies through the development of a business model in which we will propose the appropriate actions to tackle these challenges. The identified challenges will steer the development of the requirements in the next chapter and help evaluate the platform in the evaluation chapter. By deriving the requirements from the identified challenges, we ensure that the final platform design is directly aligned with the core issues, which will enhance the final product's relevance and effectiveness.

4 Requirements

This chapter details the essential requirements for designing the digital platform. It addresses the sub-research question: " What are the stakeholders' requirements for a digital platform to reduce food waste at the retail stage in Saudi Arabia in alignment with circular economy principles?

Requirements serve as the foundation for designing practical solutions to complex problems [55]. In design science research, understanding and documenting requirements are essential steps in the solution design process [33]. By systematically identifying stakeholders' needs and expectations, we can ensure that the resulting digital platform meets the intended objectives and delivers value to the intended users. Moreover, aligning the design with the requirements ensures that the solution is relevant, usable, and capable of addressing the identified challenges. Thus, a thorough exploration of requirements is critical for the success of the design science endeavor and the ultimate goal of mitigating food waste in the retail sector of the eastern province of Saudi Arabia.

To answer the sub-research question, we have interviewed all relevant stakeholders to identify the requirements, providing insights into expected outcomes based on their experiences and needs. We strive to remain unbiased and ensure our digital platform is grounded in empirical evidence, stakeholder input, and trusted and reliable sources. We categorize requirements as either functional or non-functional, with functional requirements addressing the functions of the artifact and non-functional requirements focusing on the artifact's non-functional qualities, such as coherence and modularity. The envisaged result at the end of this chapter is a list of functional and non-functional requirements to be used for the upcoming chapter, the design phase. In alignment with the DSR approach, we will start this chapter by outlining the artifact. Second, we will present the stakeholders analysis, which includes the roles and responsibilities, power interest matrix, and a value network diagram that presents the transaction among the stakeholders. Third, we will present the requirements collection, including the interview protocol and document analysis. Fourth, we will detail the identified requirements. Lastly, we will present the conclusion that answers the sub-research question and provide details on how the identified requirements will be used for the design phase.

4.1 Outline Artifact

We have selected to design a digital platform to tackle the issue of food waste in the retail stage of the eastern province of Saudi Arabia. Given the complexity of the problem, we have opted for an artifact in the form of a digital platform that integrates various stakeholders in the retail sector. These include the government, technology providers, retail business owners, and consumers. The platform's functionalities enable food waste reduction by connecting retailers with consumers and facilities to exchange food. The platform aims to optimize resource utilization, minimize waste generation, and promote sustainable practices in the retail stage. Our artifact provides an overview of its key functionalities, intended users, and overarching goals in addressing food waste challenges.

4.2 Stakeholders Analysis

To achieve efficient food waste management in the retail stage, our stakeholder analysis delves into the various actors in the retail stage, including retail business owners, end users, the government, and technology providers and experts. By identifying their roles and responsibilities and assessing their relationships, we comprehensively understand the dynamics of tackling food waste challenges. In the following subsections, we present the value network, roles and responsibilities, the power interest matrix, and collected requirements.

4.2.1 Roles and Responsibilities

The Roles and Responsibilities outline the specific duties and expectations of each stakeholder involved in the project. This section is critical for ensuring clarity and accountability among all participants, from technology providers to retail business owners and end-users. By clearly defining what each stakeholder is responsible for, we can enhance collaboration, streamline the project workflow, and address potential issues efficiently [56].

Understanding the roles and responsibilities is essential for several reasons. First, it ensures that every stakeholder knows their specific contributions to the project, which helps prevent overlaps and gaps in the workflow. Second, it fosters a sense of ownership and accountability, motivating stakeholders to fulfill their roles effectively. Third, it facilitates better communication and coordination, as each stakeholder understands how their role fits into the larger project framework. By laying out these roles and responsibilities, we create a solid foundation for collaboration, which is vital for the digital platform's successful design. [57]

Table 10: Roles and Responsibilities

Stakeholder	Roles & Responsibilities
Retail Business (Restaurant, Café, Bakery)	• Implement and promote the use of the digital platform within their establishments. • Monitor and manage food waste generation and disposal. • Provide feedback to the platform operator for continuous improvement. • Interact with end users to fulfill orders.
Government	• Approve the implementation of digital platforms in Saudi Arabia.
Platform Operator	• Develop and maintain the digital platform for food waste reduction. • Ensure the platform meets regulatory requirements and standards. • Facilitate stakeholder collaboration, including government agencies, technology providers, retail business owners, and end users. • Provide support and training to end users for effective use of the platform.
Technology Provider	• Develop and implement technological solutions for retail businesses. • Ensure the platform's functionality, security, and scalability. • Provide technical support and consultation services. • Collaborate with other stakeholders to integrate the platform with existing systems and processes. • Provide integration to their service, such as delivery service and inventory upload
End User (Consumer)	• Order the desired product through the platform. • Use the digital platform to access information and resources related to food waste reduction. • Provide feedback on the usability and effectiveness of the platform.

4.2.2 Value Transaction Network

We used the value transaction network to map out the flow of value—such as goods, services, information, or money—between various entities within the digital platform. This network helps visualize and analyze the interactions and exchanges between stakeholders, including businesses, customers, suppliers, and other participants in the ecosystem. The purpose of examining a value transaction network is to understand how value is created, distributed, and captured by different actors, which can inform strategic decisions and optimize the efficiency of these transactions.

Understanding value transaction networks is crucial because it allows organizations to identify key relationships and dependencies, uncover opportunities for value creation, and recognize potential bottlenecks or inefficiencies.

The process of creating and analyzing a value transaction network involves identifying the key entities involved, mapping out the transactions between them, and assessing the flow of value. This can be done using various tools and techniques, such as diagrams, matrices, or software platforms designed for network analysis. Through this analysis, organizations can gain insights into optimizing their operations, improving customer satisfaction, and driving sustainable growth. We have used whimsical.com, which is an online-based software, to create the values transaction network. Figure 5 presents the primary transactions among stakeholders facilitated by the digital platform.

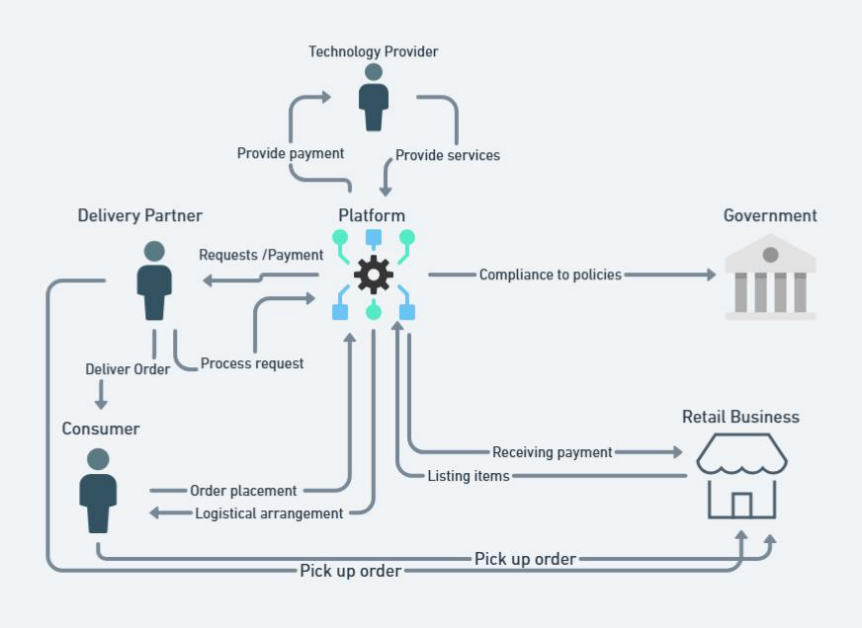

Figure 5: Value Transaction Network

4.2.3 Power Interest Matrix

The Stakeholder Power-Interest Matrix is a vital tool for analyzing and prioritizing stakeholders based on their level of influence and interest in the project. This matrix helps understand the dynamics between stakeholders and how they can impact the project's success [56].

The matrix categorizes stakeholders into four quadrants—high power/high interest, high power/low interest, low power/high interest, and low power/low interest—and provides a clear visual representation of where to focus engagement efforts. High-power/high-interest stakeholders must be closely managed and satisfied, as their support is crucial. Conversely, low-power and interest stakeholders may require minimal attention but should still be monitored. Based on their power and interest level, we have placed the stakeholders in Figure 6.

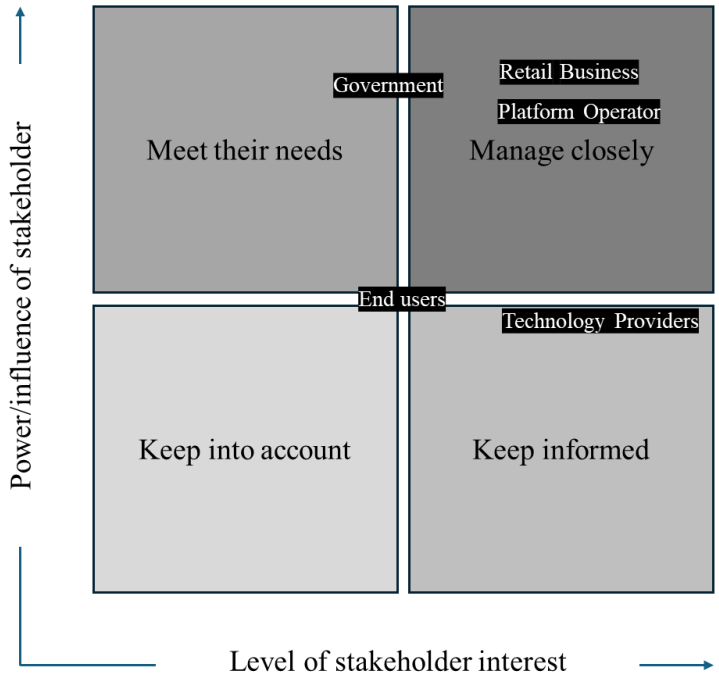

Figure 6: Power - Interest Matrix

- Manage Closely (High Power, High Interest)

Retail Business Owners: Retail business owners have high power as they directly influence the implementation of food waste management practices. They are also interested since reducing food waste can lead to cost savings and enhanced sustainability credentials, which are crucial for their business operations.

Platform Operator: As the primary entity operating the platform, the platform operator has considerable power in decision-making and is highly interested in its success. They oversee the platform's functionality, user engagement, and strategic direction.

- Meet their needs (High Power, Medium Interest)

Government: The government holds high power due to its regulatory authority and ability to set policies and standards for food waste management. However, its interest is medium as it balances this initiative with other national priorities. Furthermore, in the context of our platform, their primary role is only to approve the implementation of the platform according to governmental requirements.

- Keep Informed (Medium Power, High Interest)

Technology Providers: Technology providers have medium power because they contribute to the technological development and maintenance of the platform. Their interest is high as they benefit from the platform's success through potential business opportunities and innovation recognition.

- Meet their needs/Keep informed (Medium Power, Medium Interest)

End Users (Consumers): Consumers have medium power as their adoption and use of the platform directly influence its success. Their interest is medium because while sustainability initiatives are essential, their engagement level may vary based on convenience and perceived benefit.

The platform's success will largely depend on the active involvement of retail business owners and the platform operator, who have significant power and interest. While the government holds substantial power, its primary role will be only to approve the implantation of the platform as per its governmental digital platform requirements. Technology providers, with a moderate level of power and high interest, will be instrumental in shaping the platform's technological foundation, and it's important to keep them informed to ensure their continued practical contributions. End users will drive platform adoption with moderate power and interest, underscoring the need to prioritize their feedback and engagement.

4.3 Digital Platform Requirements

The requirements are derived from stakeholder interviews with retail business owners, technology providers and experts, and end users. The digital platform's success relies on its ability to address the diverse needs and expectations of all stakeholders involved in the food waste management process. Functional and Non-functional requirements are defined to ensure the platform's effectiveness, usability, security, and scalability.

4.3.1 Requirements Collection

We used interviews to gather requirements from retail business owners, technology providers, and end users. We conducted all interviews online and recorded them using Microsoft Teams. Following that, we summarized all interview transcripts, available under Appendix B. After that, based on the interview summaries, we generated the requirements for each stakeholder. We collected the governmental requirements from the technology providers, which are digital platform owners in Saudi Arabia and have trusted knowledge regarding the requirements.

4.3.2 Interviews

The Interviews section is pivotal in understanding the perspectives and requirements of stakeholders involved in the project. By conducting interviews, we aim to gather qualitative data that provides rich, contextual insights into the problem. This section explains the interview data analysis process to extract meaningful patterns and themes to identify stakeholder requirements. By understanding and identifying their requirements, we can design a digital platform that meets and addresses their needs. This ensures the solution is practical, relevant, and more likely to be successfully designed and adopted.

4.3.2.1 Interview Protocol

The interview protocol is a detailed guide outlining the process, ensuring consistency and thoroughness. It is important because it standardizes the interview process, enhancing the reliability and validity of the data collected. It helps manage time efficiently, maintains ethical standards, and provides a structured framework that minimizes interviewer bias and ensures all relevant topics are covered, ultimately contributing to the overall rigor and credibility of the research study.

4.3.2.2 Objective

The interviews aim to identify stakeholder requirements related to digital platform design to reduce food waste in the retail business in the eastern province of Saudi Arabia and align with identified circular economy principles.

4.3.2.3 Interviewee Selection

For the selection of the interviewees, we have targeted retail business owners, technology providers and experts, and potential consumers from the eastern province of Saudi Arabia. The retail business owners were already identified through our previous problem identification chapter. We have selected technology providers and experts located in and serving retail businesses in the eastern province of Saudi Arabia. We have identified potential end users (consumers) through personal contacts, which had to be anyone already using food waste or could benefit from it. Table 11 provides overview information about the interviewees.

Table 11: Interviewee Overview

Category	Function	Interview	Date	Means
Retail Business	Owner/Operation Manager	# 4	6/3/2024	Face to Face
Technology Provider (Retail Supply)	Cofounder/COO	# 5	6/7/2024	Online
Digital Platforms Subject Matter Expert	Cofounder/CEO	# 6	6/12/2024	Online
Technology Provider (Delivery Service)	Cofounder/Manager	# 7	6/12/2024	Online
End User (Consumer)	Farm Owner	# 8	6/1/2024	Online

4.3.2.4 Interview Questions

The following is a list of the questions we used during the interviews. We have developed these questions to ensure the proper collection of design requirements.

- Retail Business Owner Questionnaire
- What features or functionalities would you like to see in a digital platform? Make sure to include any governmental requirements if you are aware of any.
- What are your expectations regarding the digital platform's user interface?
- What integrations or compatibility requirements must the platform address?
- What specific data management & security requirements must we address?
- How willing are you to pay for a subscription to the digital platform? Please elaborate.
- Technology Provider/SME Questionnaire
- What features or functionalities would you like to see in a digital platform? Make sure to include any governmental requirements if you are aware of any.
- What are your expectations regarding the digital platform's user interface?
- What integrations or compatibility requirements must the platform integrate with your system?
- What specific data management & security requirements must we address?
- Can you describe the services or functionalities requiring API integration?
- Can you describe feasible business models?
- End User (Consumer) Questionnaire
- What features or functionalities would you like to see in a digital platform?
- What are your expectations regarding the digital platform's user interface?
- How willing are you to pay for a subscription to the digital platform? Please elaborate.

4.3.2.5 Interview Structure

We start each interview by introducing ourselves and the objective. Following that, we review the consent form in Appendix C and get a verbal recorded agreement. It is important to note that the consent form aligns with TU Delft guidelines on Data management and HREC, aligning with the GDPR. After that, we start the interview questions. We close the meeting by informing them about our upcoming research phase. Lastly, we generated a summary of each interview, available in Appendix B. Based on the interview summaries, we have developed a list of functional and non-functional requirements, presented in Table 12. We have used semi-structured interviews to ensure that we capture and understand the requirements with follow-up questions, if needed, under each prepared question.

4.3.3 Identified Requirements

The stakeholder interviews revealed a wealth of insights regarding the intricate aspects of developing digital platforms customized to meet food waste management in the eastern province of Saudi Arabia. These discussions emphasized the importance of seamlessly integrating these platforms with existing retail management systems. The stakeholders stressed the need for a user-friendly interface, efficient data management, secure data transfer protocols, and encryption.

Additionally, the stakeholders delved into the specific functionalities that would improve the platform's services through API integration. These included chat services, government data retrieval systems for user authentication such as Nafath, two-factor authentication, and map integration using services like Google Maps or Apple Maps.

The discussions also touched upon various business models, such as subscription-based services, commission structures, and innovative waste management strategies designed to create value for users and businesses.

The emphasis on user-centric design, multilingual support, and automation to reduce human interaction illustrates the importance of enhancing user experience and operational efficiency. Governmental requirements were highlighted, focusing on data privacy, location-based services, and adherence to local regulations to ensure legal compliance and user trust.

Table 12 lists all identified requirements, their type, collection methods, and sources. "F" refers to functional requirements, whereas "NF" refers to non-functional requirements. It is important to note that we have merged repetitive requirements mentioned by multiple stakeholders during the interviews. For example, multiple stakeholders mentioned the requirements regarding data privacy and usage of local servers; therefore, we have only listed them once as a must requirement. All interview summaries are listed under Appendix B.

Table 12: Digital Platform Requirements

Stakeholder	ID	Type	Requirement	Interview
Retail Business	1	NF	Must provide a user-friendly interface.	Interview # 4
	2	NF	Should integrate with the current business management system.	Interview # 2,3,4
	3	NF	Must be cost-effective.	Interview # 2,3,4
	4	F	Must authenticate users before granting access.	Interview # 2
	5	F	Must facilitate the process of food waste.	Interview # 2,3
	6	NF	Must offer training and support for platform usage.	Interview # 4
	7	F	Should enable generating analytics.	Interview # 4
	8	F	Should send alerts and notifications for products approaching their expiry dates.	Interview # 4
	9	NF	Should include incentive programs to encourage user participation.	Interview # 2,3
	10	F	Must enable waste categorization listing.	Interview # 4
Government	11	NF	Must align with data regulation and cybersecurity in Saudi Arabia.	Interview # 6
	12	NF	Must support approved payment gateways.	
Consumer	13	F	Should provide a mobile application.	Interview # 8
	14	F	Must allow filtration by location and product.	
	15	F	Should offer delivery service options.	
	16	F	Should support the segregation of food waste.	
	17	F	Must support online payment functionality.	
Technology Provider/SME	18	NF	Must have a scalable architecture to handle a growing user base.	Interview # 5, 6
	19	F	Must provide multilingual support, including Arabic and English.	Interview # 5, 6
	20	NF	Must ensure data security and privacy.	Interview # 5, 6, 7
	21	NF	Should generate awareness about food waste.	Interview # 6
	22	NF	Should incorporate engagement mechanisms.	Interview # 6
	23	F	Must collect location information for retail businesses and consumers.	Interview # 7
	24	F	Should include embedded chatting service	Interview # 6,7
	25	NF	Must utilize RESTful APIs for integration	Interview # 5

4.4 Conclusion

In conclusion, this chapter detailed the essential requirements for a digital platform to reduce food waste in the eastern province of Saudi Arabia in alignment with identified circular economy principles. We addressed the sub-research question: " What are the stakeholders' requirements for a digital platform to reduce food waste at the retail stage in Saudi Arabia in alignment with circular economy principles? To answer this question, we interviewed relevant stakeholders, providing insights into expected outcomes based on their experiences and needs.

Based on the interviews and generated requirements in Table 12, the requirements revolve around user experience, technical functionalities and security, and regularity compliance.

In the Design Science Research (DSR) methodology, the requirements collected serve as the foundation for the design phase [32]. These identified requirements ensure that our upcoming design chapter addresses the specific needs of stakeholders, aligns with the context of the eastern province of Saudi Arabia, and aims to achieve the intended objectives. The requirements will guide the digital platform's conceptual and detailed design and support the overall design evaluation. While the identified requirements will help us select applicable design features and functionalities, they will also support us in evaluating the degree to which these requirements were met.

5 Design

In this chapter, we detail the design activities in alignment with the third phase of the DSR approach, the design phase. The sub-research question that guided this chapter is "What digital platform design fulfills the identified requirements?". To answer this question, we have applied the ArchiMate framework and analyzed best practices through academic and grey literature to help finalize ArchiMate's farmwork layers. The envisaged result at the end of this chapter is a comprehensive and well-justified design for the digital platform, detailing its functionalities, components, and interactions. First, we introduce the ArchiMate framework. Second, we detail the design components, functionalities, and interactions by presenting the business, application, and technical layers. Last, we present a conclusion highlighting the final design and alignment with the identified requirements. We have also developed Table 21 under Appendix E, which presents the connection between the requirements, challenges, and design components.

5.1 The ArchiMate Framework

ArchiMate is a comprehensive framework for enterprise architecture that provides a structured way to describe the architecture of business domains [58]. It consists of a strategy, business, application, and technology layers. Each layer of the ArchiMate framework will add value to the comprehensive design of our digital platform aimed at reducing food waste in Saudi Arabia. This strategy layer outlines the high-level vision, mission, strategic goals, key performance indicators, and required capabilities for the digital platform. The Business Layer aligns strategic goals with operational processes, ensuring stakeholder collaboration and efficient service delivery. The Application Layer translates these processes into functional software applications, providing necessary services to users. The Technology Layer supports these applications with a robust infrastructure, ensuring scalability, reliability, and security. By aligning our digital platform design with the ArchiMate framework, we ensure that every platform aspect is well-defined and systematically integrated.

Using ArchiMate for modeling and analyzing enterprise architecture offers a standardized notation and approach, enabling consistent communication and understanding among stakeholders [59]. Additionally, ArchiMate's layered structure and comprehensive frameworks facilitate a holistic perspective of enterprise architecture, allowing us to recognize connections and potential impacts across domains. With clear visual representations and a standardized language, ArchiMate will help us align our digital platform design with the main platform's objective of facilitating food waste reduction.

5.2 Strategy Layer

The strategy layer in the ArchiMate framework outlines the strategic direction, high-level goals, and capabilities required to achieve the business objectives [60]. It will include the platform's vision, mission, strategic goals, and key performance indicators (KPIs) to tackle food waste at the retail stage in the Eastern Province of Saudi Arabia.

5.2.1 Vision

The vision defines the long-term aspiration and guiding purpose of the digital platform. It summarizes the desired future state that the platform aims to achieve, serving as a beacon for all strategic initiatives and activities. Establishing a clear vision is essential because it aligns stakeholders around a common goal, providing direction and motivation [61]. For this platform, the vision emphasizes creating a sustainable digital marketplace, which is critical for reducing food waste, promoting circular economy principles, and ensuring environmental and economic sustainability in the Eastern Province of Saudi Arabia.

Our vision is to create a sustainable digital platform that reduces food waste, promotes circular economy principles, and supports environmental and sustainability efforts in the Eastern Province of Saudi Arabia.

5.2.2 Mission

The mission outlines the platform's core purpose and its primary activities to achieve its vision. It describes what the platform does, who it serves, and how it operates to fulfill its goals. A well-defined mission is crucial as it

clarifies the platform's role and operational focus, ensuring that all efforts are aligned with the overarching vision [62]. For the digital platform, the mission emphasizes facilitating the redistribution and reuse of food waste through an efficient, user-friendly digital platform, thereby supporting sustainability and regulatory compliance.

Our mission is to facilitate the redistribution and reuse of food waste through an efficient, user-friendly digital platform that connects retailers, consumers, and logistics providers, ensuring compliance with regulatory standards and fostering a sustainable community.

5.2.3 Strategic goals

Strategic goals are specific, measurable objectives the platform aims to achieve to fulfill its mission and realize its vision. These goals provide a clear roadmap for the platform's development and growth. Strategic goals are essential because they translate the vision and mission into actionable and achievable targets [63].

Our strategic goals are to minimize food waste at the retail stage by facilitating its sale and redistribution, enable the reuse and recycling of food waste to support the principles of the circular economy, contribute to environmental sustainability by reducing food waste sent to landfills, and adhere to local regulations regarding food waste management and digital platform operation.

5.2.4 Key Performance Indicators (KPI)

Key Performance Indicators (KPIs) are quantifiable metrics used to evaluate business process performance in achieving its strategic goals. They provide insights into how well the process functions and where improvements are needed. [64]

KPIs are vital because they offer objective measurements of success, allowing the platform to track progress, identify areas for improvement, and make data-driven decisions [64]. For this digital platform, KPIs help measure the success of the main objective of facilitating the exchange of food waste between retailers and consumers. Thus, we need to measure the reduction in food waste, the number of transactions, user satisfaction, regulatory compliance, and economic impact, monitor effectiveness, and ensure that the platform delivers on its promises. Our proposed KPIs are as follows:

- Reduction in Food Waste: Measure the decrease in food waste at participating retailers.

This is the most direct and relevant KPI, as the platform's primary goal is to decrease the amount of food waste generated by participating retailers. By measuring the actual reduction in waste, this KPI provides clear evidence of the platform's effectiveness in fulfilling its core mission. It allows stakeholders to see tangible results, which is essential for demonstrating the platform's value and justifying its continued use and expansion. Additionally, a significant reduction in food waste would contribute to Saudi Arabia's broader sustainability goals under Vision 2030, making this KPI particularly relevant.

- Number of Transactions: Track the number of successful transactions on the platform.

The number of Transactions serves as a critical indicator of the platform's adoption and usage. Tracking the number of successful transactions helps gauge the platform's reach and its ability to facilitate food waste redistribution. A higher number of transactions indicates that retailers and consumers are actively using the platform, thereby directly contributing to reducing food waste. Furthermore, this KPI can help identify patterns and trends in platform usage, which can inform future enhancements and marketing strategies to boost engagement further.

- User Satisfaction: Gauge satisfaction levels among retailers and consumers.

User Satisfaction is another essential KPI because the success of any digital platform is heavily dependent on the satisfaction of its users [64]. By gauging the satisfaction levels of both retailers and consumers, this KPI helps ensure that the platform meets the needs and expectations of its stakeholders. It also provides insights into potential areas for improvement, helping the platform remain user-centric and effective in the long term.

- Regulatory Compliance: Monitor adherence to food waste management and environmental regulations.

Monitoring compliance ensures that the platform operates within the legal framework and supports retailers in meeting their regulatory obligations. This mitigates the risk of legal penalties and enhances the platform's credibility and attractiveness to users who prioritize regulatory adherence

- Economic Impact: Assess the financial benefits to participating retailers, including return on investment.

Economic Impact is a vital KPI that assesses the financial benefits of the platform for participating retailers, including return on investment (ROI). This KPI is important because the platform's primary goal is to reduce food waste, but it must also be economically viable for retailers to adopt and continue using. By tracking the economic impact, this KPI demonstrates the platform's ability to provide financial value, making it more appealing to businesses. A positive economic impact ensures the platform's sustainability and encourages broader participation, which is crucial for achieving long-term food waste reduction goals.

These KPIs are applicable and critical for evaluating the platform's success from multiple angles, including environmental, operational, user-centric, regulatory, and economic. Together, they provide a comprehensive method for assessing the platform's performance and guiding its ongoing development.

5.3 Business Layer

The Business Layer describes the business actors, roles, core functions, and business processes. It defines the interactions between the enterprise's strategic goals and the operational processes required to achieve them. [60]

5.3.1 Business Actors

Business actors are the entities that participate in the system and interact with each other to achieve the goals of the digital platform. They are the key stakeholders whose needs and contributions drive the platform's functionality and success.

- Retailers: Businesses, including restaurants, cafes, and bakeries, that generate food waste and want to sell or donate it.
- Consumer: Entities or individuals who purchase/use food waste.
- Platform Operator: The organization that develops and maintains the digital platform.
- Logistics Provider: A delivery partner that manages the transportation of food waste.

5.3.2 Business Roles

Business roles define the specific responsibilities and activities of the platform's actors. Each role focuses on distinct aspects of the platform's operation to ensure seamless interactions and processes.

- Retailer Role: Responsible for listing food waste on the platform and managing orders.
- Consumer Role: Responsible for purchasing food waste.
- Platform Administrator: Manages platform operations and user support.
- Logistics Partner: Facilitate the delivery of food waste.

5.3.3 Business Core Functions

Core functions refer to the essential features a digital platform must have to fulfill its primary objectives and meet user needs. These functions form the platform's backbone, enabling it to deliver value to its users and achieve its intended purpose. [65]

We have developed the core functions based on identified stakeholder requirements. During the design phase, these functions will be defined and detailed to ensure they address the key challenges and needs identified during the requirement-gathering process. Each core function is designed to operate seamlessly within the platform, often involving the development of specific modules, APIs, and user interfaces that facilitate smooth and efficient interactions. By focusing on core functions, we aim to design a robust and scalable system that meets stakeholders' expectations, supports business processes, and delivers consistent performance. Additionally, well-defined core functions help streamline the design and development process, making it easier to maintain and enhance the

platform over time. Based on the identified functional requirements in Table 12 under Chapter Four, Table 13 displays the main platform functions, executor, and objective. We have also developed Table 21 under Appendix E, which presents the connection between the requirements, challenges, and design components.

Table 13: Core Functions

ID	Function	By	Objective
1	Selected Preferred Language	Consumer/Retail	Enable employees unfamiliar with the Arabic language to use the platform
2	User Registration	Consumer/Retail	Allow users to use the platform and provide the necessary information and requirements.
3	User Verification	Platform	Validates the authenticity of the users to prevent fake accounts and ensure a secure environment.
4	Onboarding	Platform	Ensures that all users can effectively use the platform regardless of technical proficiency.
5	Item listing	Retail	Enable retailers to connect to consumers who are interested in the item.
6	Item Search	Consumer	Helps users find specific food items quickly and efficiently.
7	Initiating Request	Consumer	Facilitates the transfer of food waste or nearly expired items to consumers.
8	Transaction Processing	Platform	Ensures that the requested items are available.
9	Secure Payment Processing	Platform	Provides a secure and reliable method for financial transactions
10	Delivery Service	Platform/Delivery Partner	Ensures that food items are delivered.

5.3.4 Business Processes

Business processes are the sequences of activities that actors perform to achieve specific objectives [66].They ensure that the platform operates efficiently and meets its users' needs [67]. In this section, we will present the main platform business processes and support them with use case scenarios and a sequence diagram to clarify the business processes further. In the following sections, platform users refer to retailers and consumers.

5.3.4.1 Main Business Processes

We have developed the main business processes based on the main functions listed in Table 13. We used whimsical.com, an online software, to create the business processes listed in Figures 7, 8, and 9.

Platform User Registration:

The user registration process is the same for retailers and consumers. The difference will be the terms and conditions (T&C) and the onboarding. The T&C that will appear for retailers is different from that for consumers. Furthermore, the onboarding for retailers will focus on the functionalities needed by retailers to list items and manage inventory, while for consumers, it will be related to searching for items and submitting requests.

- Users provide their requested information
- Platform process the data and accept or deny platform access.

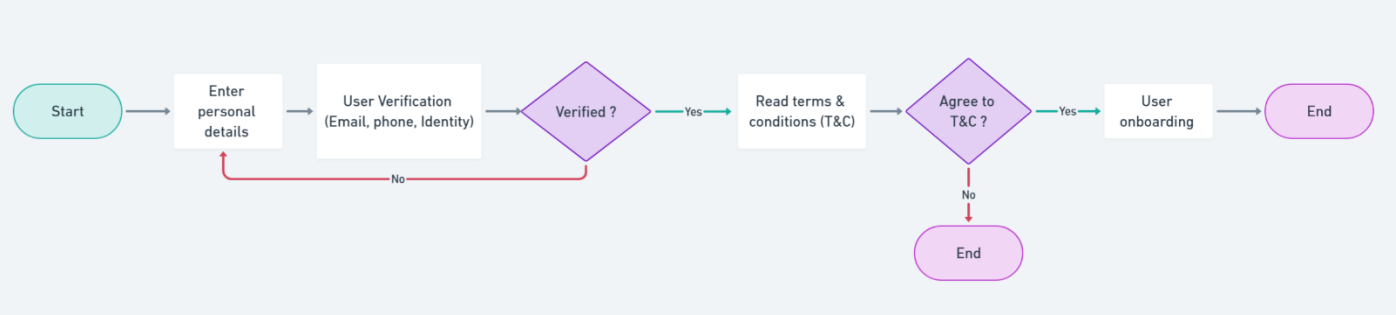

Figure 7: User Registration

Food Waste Request Process:

- Consumer browses listings.
- Consumer filter listings per type, location, potential use, and quantity.
- Consumer adds selected items to the cart.
- Consumer shares payment and location details.
- Platform facilitates secure payment.
- Platform facilitates delivery if requested.
- Consumer receives order.
- Rate order and share feedback (Optional)

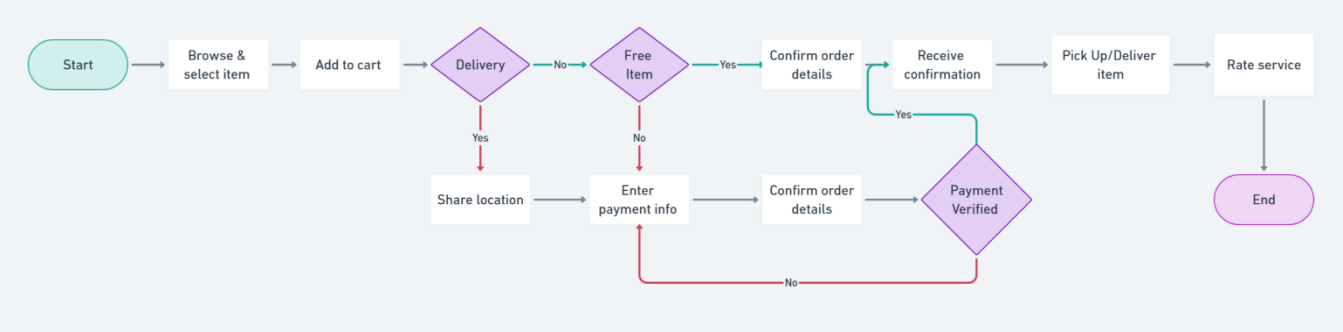

Figure 8: Item Request by Consumer

Food Waste Listing Process:

- Retailers log into the platform.
- Retailers list the food waste items with details like type, quantity, picture, description, and expiry date.
- If the retailer wants to list an item which is not available in the platform, a request has to be made and approved by the platform. This is needed to insure only applicable food waste items can be listed and insures the segregation of food waste items.

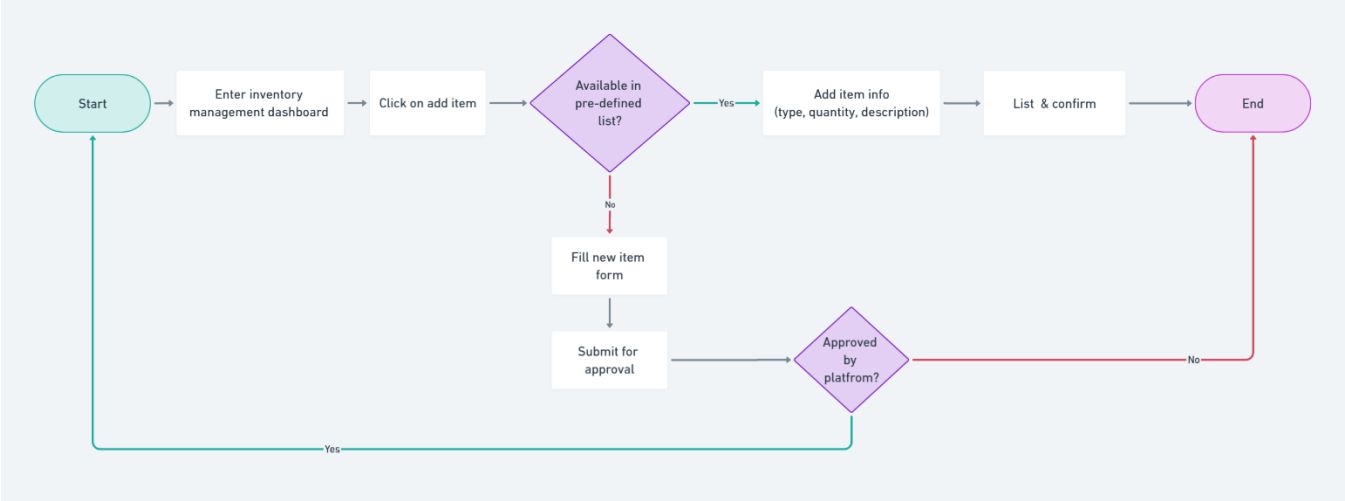

Figure 9: Food Waste Listing by Retail Business

5.3.4.2 Use Case Scenarios

Use case scenarios describe how users interact within the digital platform to achieve specific goals. Each scenario outlines the steps involved in a particular task or process, the interactions between the user and the system, and the expected outcomes. For us, the purpose of the scenarios is to draw a high level of understanding of the digital platform by illustrating user interactions. Use case scenarios are essential for ensuring that the platform meets the practical needs of its users [68]. By detailing user and system interactions, use case scenarios help developers and designers anticipate potential issues, improve user experience, and ensure that the final product delivers value to its stakeholders [68]. We have developed two different scenarios to clarify the platform's interaction.

5.3.4.3 Retailer Listing Food Waste

1. The retailer logs into the platform using their credentials.
2. The retailer navigates to the "Inventory Management" section, which includes adding and deleting items.
3. The retailer clicks on "List New Item."
4. The retailer enters the details of the food waste item, including type, description, and quantity.
5. The retailer uploads a photo of the food item (optional).
6. The retailer clicks "Submit" to list the item on the platform.
7. The platform system validates the entered data and stores the information in the database.
8. The platform sends a confirmation notification to the retailer.

5.3.4.4 Consumer Searching for and Requesting Food Wate

1. The consumer logs into the platform using their credentials.
2. The consumer navigates to the "Search" section.
3. The consumer enters search criteria, such as location and type of food.
4. The platform displays a list of matching food waste items.
5. The consumer selects an item from the list to view more details.
6. The consumer clicks on "Request Item."
7. The consumer selects the pickup or delivery option.
8. The consumer reviews the request details and confirms the request.
9. The retail business reviews and accepts the request.
10. The platform processes the request and sends a notification to the retailer and the consumer.

5.3.4.5 Sequence Diagram

A sequence diagram is an interaction diagram showing how processes operate with one another and in what order. It is a detailed graphical representation of the sequential flow of messages between objects in a system [69]. Each sequence diagram captures the dynamic behavior of a system by illustrating the objects involved in a particular interaction and the sequence of messages exchanged between them to achieve a specific functionality [70].

Sequence diagrams clearly and visually represent the interaction between various system components. This clarity helps stakeholders understand the system's behavior and information flow, facilitating better communication and collaboration [70]. Moreover, Sequence diagrams help validate the system design by illustrating how different system parts work together to perform a function [69]. We developed the sequence diagram based on the main functions in Table 13 using whimsical.com, an online software. Figure 10 presents the actors involved in facilitating a transaction of food waste items along with the functions executed by each stakeholder.

Figure 10: Sequence Diagram

5.4 Application Layer

The Application Layer describes the application services that support business processes, provide functionality, and enable data exchange. It focuses on the software applications and components that deliver business services to users and other applications. This layer includes application components, services, interfaces, and their interactions. [60]

The Application Layer is important because it operationalizes the business processes defined in the Business Layer. It ensures that the platform provides the necessary functionalities efficiently and securely. By focusing on this layer, designers can create a seamless user experience and ensure that robust and reliable software solutions meet all business requirements. [66]

5.4.1 User Interface (UI)

The User Interface (UI) aims to provide an intuitive and seamless experience for all platform users, including retailers and consumers. The UI should facilitate easy navigation, efficient interaction, and quick access to all platform functionalities. It aims to minimize the learning curve for new users and ensure that tasks such as listing food waste, searching for food waste, and managing transactions can be performed effortlessly. A key focus is creating a visually appealing and responsive design, ensuring accessibility and usability for all users. Additionally, the UI should support multiple languages, including Arabic and English, to cater to the diverse user base in Saudi Arabia.

When developing a user interface (UI) for a digital platform, there are several options, each with its own advantages. The main options include **web-based** interfaces, **desktop applications**, and **mobile applications**. A web-based interface offers the advantage of being accessible from any device with an internet connection and is generally easier to update and maintain since changes can be made server-side without requiring user intervention [71]. On the other hand, desktop applications can offer more powerful features and better performance by leveraging the full capabilities of a user's hardware [71]. However, these often require specific installations and are limited to the devices they are installed on [72].

A mobile application stands out as a better option, particularly for a digital platform aimed at a wide user base, due to several key factors. Mobile apps provide superior accessibility and convenience as users increasingly rely on smartphones for their daily tasks [72]. This ensures that the platform is always within reach, allowing for more frequent interaction and engagement. Mobile apps can also leverage the built-in capabilities of smartphones, such as location services, cameras, and push notifications, to enhance the user experience and offer features that are difficult or impossible to implement on other platforms [72].

Furthermore, mobile applications typically offer a more optimized and responsive user experience, as they are designed specifically for mobile devices, ensuring faster performance and smoother interactions [72]. Mobile applications are ideal for regions like Saudi Arabia, where mobile phone penetration is extremely high [73]. Opting for a mobile application aligns with user preferences and technological trends [74]. This approach also supports the development of features such as integration with mobile payment systems. Furthermore, consumers prefer mobile applications, as mentioned by a consumer in interview #8 and by a subject matter expert in interview #6. Therefore, a mobile application is the optimal choice for delivering a user-friendly, feature-rich, and widely accessible interface that meets the needs of a diverse and mobile-centric user base. The UI consist of several key modules covering the core functions, each designed to meet specific user needs:

- User Management: This module allows users to create accounts, log in securely, and manage their profiles. It includes password recovery, two-factor authentication, and user authentication.
- Dashboard: The dashboard provides an overview of available functionalities and relevant metrics, such as the number of food items listed, transactions completed, and user feedback. It includes interactive charts, graphs, and notification panels to inform users.

- Inventory Management: This module enables retailers to list food waste items, including details such as type, description, quantity, and expiration dates if needed.
- Search and Filter: Users can search for food items based on various criteria, such as location, type, and quantity.
- Request and Transaction Management: This module facilitates the submission and management of requests for food items, including approval workflows, payment processing, and tracking. It integrates with third-party payment gateways and logistics providers to ensure smooth transactions.
- Feedback and Rating System: Users can provide feedback and ratings for transactions and food items. This module includes features for submitting reviews, rating transactions, and viewing aggregated feedback scores.

5.4.2 Required Integrations

Third-party integrations aim to enhance the platform's functionality by connecting it with external services and APIs [13]. These integrations allow the platform to leverage existing technologies and services, providing users with a seamless and comprehensive experience [14]. By integrating with third-party services, the platform can offer features such as secure payment processing, efficient logistics management, and location mapping without developing these capabilities in-house. This approach reduces development time and costs and ensures that the platform can offer best-in-class services to its users. It also keeps the platform modular and allows for better scalability. Key integrations include:

Identity authentication: Authentication systems are processes and technologies used to verify the identity of users accessing a platform [75]. This integration ensures that platform users are authenticated, which increases security and improves trust among platform users. This can be done by integrating with Nafath, a government authentication service for individuals or businesses.

User verification: User verification confirms the email addresses and phone numbers to ensure the user is who they claim to be. It is a crucial security measure to prevent unauthorized access and ensure the integrity and trustworthiness of the platform [76]. This can be done by integrating with authentication services such as Auth0, OneLogin, or Google Identity Platform.

Payment gateways: A payment gateway is a service that authorizes and processes payments for online transactions. It is an intermediary between the platform and financial institutions, enabling secure and efficient fund transfers. This integration ensures that users can make payments conveniently and securely, enhancing their overall experience [77]. This can be done by integrating with an approved payment gateway in Saudi Arabia, such as Moyasar, Payfort, Paytabs, or Hyperpay.

Location mapping: Location mapping refers to the technology and processes used to identify, display, and analyze geographical locations on a digital map [78]. This is needed to enable users to identify nearby retailers and execute delivery requests. It can be done by integrating with a provider such as Google Maps, Mapbox, Here Technologies, or OpenStreetMap.

Translation system: A translation system enables a digital platform to support multiple languages by translating content into different languages. It involves using translation tools to convert text and other content into the desired languages [79]. By supporting multiple languages, the platform can reach users of different languages, expanding its potential user base and market reach. This capability enhances user experience by allowing individuals to interact with the platform in their preferred language, making it more comfortable and intuitive. This can be done by integrating with providers such as Google Cloud Translate, Microsoft Translate, Amazon Translate, or DeepL Translate.

Delivery service: Connect the platform with a delivery partner who will facilitate the delivery of food waste orders. This can be done by integrating with locally approved delivery providers such as Locate, Hunger Station, or Marsool.

Embedded Communication System: Embedded communication refers to the integration of communication tools directly within the platform, allowing users to interact seamlessly without switching to external applications. These tools can include chat functions, messaging systems, video conferencing, and email integrations. This can be done by integrating with providers such as Twilio, Firebase, or Send Bird.

Data Analytics System: Data analytics tools are software applications that collect, process, and analyze data to provide actionable insights [80]These tools can help visualize trends, track performance metrics, and support data-driven decision-making. They can integrate with providers such as Google Analytics, Tableau, or Mix Panel.

Notification System: This integration will focus on collecting items' expired dates, allowing the platform to send notifications and alerts regarding nearly expired items. This will help retail businesses manage their inventory better, enhance inventory forecasting, and support the effort to reduce food waste. This can be done by integrating with providers such as Twilio Notify, Amazon SNS, or Pusher.

The platform will use RESTful APIs to connect with third-party services. RESTful APIs provide a standardized way to communicate with external services, ensuring interoperability and flexibility. The selection of RESTful API is due to the requirements provided through interview #6 by the technology/digital platform provider and expert, who already serves retailers in the eastern province of Saudi Arabia.

5.4.3 Additional Integrations

The additional integrations section outlines potential external systems, services, and technologies that can be integrated with the digital platform to enhance its functionality and provide extra value to users. These integrations are not mandatory for the platform's basic operations but offer significant benefits that can improve efficiency, user experience, and overall effectiveness. Additional integrations include:

Social Media Integration: Social media integration involves connecting the platform with various social media networks to enable sharing, engagement, and interaction through social channels. This can include sharing achievements regarding food waste management, showcasing retail sustainability efforts, and generating awareness, which supports the retail business brand image. This can be done by integrating widely used social media platforms in Saudi Arabia such as Instagram, LinkedIn, or X.

Engagement mechanism (Gamification): Gamification Tools refer to the application of game-design elements and principles in non-game contexts to engage and motivate individuals to achieve their goals [81]. Gamification can be used in the digital platform to encourage user participation and commitment to sustainable practices. The platform can make interactive and enjoyable activities like sharing or requesting food waste by incorporating techniques such as points, badges, leaderboards, challenges, and rewards. This approach enhances user engagement and drives behavior change toward reducing food waste, supporting the platform's mission and objectives. This can be done by integrating with providers such as Badgeville or Bunchball Nitro.

5.4.4 Recommender Systems

A recommender system is a software application that provides personalized suggestions to users based on their preferences, location, behaviors, and interactions with the platform. By leveraging data analytics and machine learning algorithms, recommender systems analyze user data to predict items or services that may interest the user. In our digital platform, a recommender system will be essential in matching food waste items with potential consumers. By analyzing user behavior and preferences, the system can suggest relevant items to consumers, ensuring that food waste is utilized efficiently and waste is minimized. Benefits include enhanced user engagement, improved user retention, and increased sales and transactions. [82] The components required are:

- Data Collection Module: Essential for gathering the necessary user data to make informed recommendations [82].
- Data Processing Module: This module ensures that the data is accurate and usable for analysis, improving the quality of recommendations [82].
- Machine Learning Algorithms: Provide the computational power to analyze large datasets and generate accurate predictions [82].
- Recommendation Engine: A central component that combines data processing and machine learning outputs to deliver recommendations [82].

It is essential to mention that integrating the recommender system is not critical at the beginning as it is not part of the platform's core functions.

5.5 Technology Layer

The Technology Layer in the ArchiMate framework describes the technological infrastructure that supports the application services, including hardware, software, and network components [67]. This layer focuses on the physical and technical infrastructure needed to support the application and business layers, ensuring they operate effectively and efficiently [66]. It involves selecting and implementing the technological components, including storage solutions.

The Technology Layer is critical because it provides the foundation for the entire platform [83]. A robust and scalable technological infrastructure ensures that the platform can handle high volumes of data, support large numbers of users, and maintain high performance and availability[84]. By focusing on this layer, the platform can achieve reliability, security, and compliance, essential for gaining user trust and ensuring long-term success [85].

5.5.1 Data Management

The database objective is to securely store all platform data, ensuring data integrity, availability, and security [85]. The database must handle a wide range of data types, including user information, food item details, transaction records, feedback, and analytics. It must be designed to support high read and write operations, provide fast data retrieval, and scale efficiently as the amount of data grows.

In alignment with Saudi Arabia’s personal data protection laws, the user interface will include privacy notices displayed at all data collection points. These notices clearly explain what data is being collected, the purposes for its collection, and how it will be used. Also**,** before collecting any personal data, the platform seeks explicit consent from users through opt-in and opt-out options.

The database will use a hybrid approach to meet the scalability and reliability requirements, combining relational databases such as PostgreSQL for structured data and NoSQL databases such as MongoDB for unstructured data. This combination allows the platform to leverage the strengths of both database types, providing flexibility and scalability [86]. The relational database will store structured data, including user profiles, transaction records, and inventory details, while the NoSQL database stores unstructured data, including user feedback. PostgreSQL offers robust ACID compliance, ensuring transactional integrity and reliability [85].

ACID is an acronym that stands for Atomicity, Consistency, Isolation, and Durability. These are the key properties that ensure reliable processing of database transactions [85].

Atomicity ensures that each transaction is treated as a single unit, which either completely succeeds or completely fails[85]. If any part of the transaction fails, the entire transaction is rolled back, leaving the database in its previous state. This is vital for maintaining the integrity of the platform, especially during critical operations like financial transactions, inventory updates, or order processing. For instance, if a consumer purchases food waste for repurposing or donation, atomicity guarantees that all related processes—deducting inventory, updating the

payment status, and confirming the order—either fully complete or do not occur at all. If any step in this transaction fails, atomicity will roll back the entire transaction, preventing any partial updates that could leave the database in an inconsistent state. This is crucial to avoid scenarios where inventory might be reduced without a corresponding financial transaction, leading to discrepancies and potential losses for retailers or dissatisfaction among consumers.

Consistency ensures that a transaction brings the database from one valid state to another valid state, maintaining database invariants [85]. Consistency ensures that the database remains in a valid state before and after any transaction. Maintaining consistency is critical for the digital platform, which handles various operations like inventory management, user authentication, and transaction processing. Each transaction must uphold the defined rules and constraints of the database—such as ensuring that inventory quantities do not drop below zero or that payment amounts are correctly recorded. Consistency is particularly important in enforcing business rules and maintaining the platform's integrity, as any violation could lead to data corruption or errors in order fulfillment. For example, if a retailer lists a food item for sale, the platform must ensure that all associated data (e.g., item availability and pricing) meets the defined criteria, thereby preventing invalid or conflicting data from being entered into the system.

Isolation ensures that the concurrent execution of transactions results in a system state that would be obtained if transactions were executed serially, one after the other. This property prevents transactions from interfering with each other, which helps maintain data integrity in a multi-user environment [85]. Multiple transactions on the digital platform can occur concurrently, such as multiple consumers placing orders or retailers updating inventory. Isolation ensures that these concurrent transactions do not compromise data integrity. For example, if two consumers attempt to purchase the last available unit of a food waste item simultaneously, isolation guarantees that only one transaction will proceed to completion, preventing the platform from overselling or double-booking items. This is essential for maintaining trust and reliability, as it prevents inconsistencies like duplicate transactions or incorrect inventory levels from arising, which could otherwise lead to operational issues or customer dissatisfaction.

Durability ensures that once a transaction has been committed, it will remain so, even in the event of a system failure. This means that the results of the transaction are permanently recorded in the database and will not be lost [85]. For the digital platform, which deals with sensitive operations such as financial transactions and user data management, durability is critical for ensuring that no data is lost after a transaction is confirmed. For instance, once a payment is processed and an order is placed, durability guarantees that this information is securely recorded in the database, protecting against data loss due to power outages, hardware failures, or software crashes. This is vital for maintaining user trust and platform reliability, as any loss of data could lead to significant disruptions, financial discrepancies, and loss of user confidence in the platform's ability to manage food waste transactions securely and effectively.

The ACID properties are foundational to the digital platform's integrity, reliability, and trustworthiness. They ensure that the platform can handle complex transactions in a multi-user environment while maintaining data accuracy, consistency, and availability, which are essential for achieving the platform’s goal of reducing food waste through efficient and secure digital operations.

MongoDB's horizontal scaling capabilities enable seamless handling of large volumes of unstructured data, ensuring the system can grow with increasing demand [87]. Moreover, both databases incorporate advanced security features, such as encryption at rest and in transit, role-based access control, and audit logging, to safeguard sensitive information and maintain high standards of data protection [84]. The database structure for the core functions includes:

- User Data: Stores user information, including name, email, contact number, location, and food waste item preferences.

- Food Item Data: Stores details about food items, including type, descriptions, quantities, and expiration dates (optional).
- Transaction Data: Records all transactions, including requests, approvals, payments, and deliveries.

5.5.1.1 Entity Relation Diagram

In the subsection, we present the Entity-relationship diagrams (ERDs) to clarify the data requirements and relationship among actors. ERDs are visual representations of data and relationships within a system. ERDs are essential in the design and development of databases, as they help define data requirements, how data is interconnected, and the system's entities and their attributes and relationships. They help stakeholders understand the data model and its components, promoting better communication and collaboration. [88]

We have developed the Entity-Relationship Diagram (ERD) presented in Figure 11 by analyzing the key components and interactions within the digital platform. To create the ERD, we first identified the primary entities involved in the platform, including users (such as retailers and consumers), food waste items, transactions, and logistics providers. Each entity was defined based on the data attributes necessary to support the platform's functionalities.

Data used to develop the ERD included user profiles, which encompass attributes such as names, contact information, and user roles; food waste item details, including type, description, quantity, and expiration dates; transaction records, which include details of food waste requests, approvals, payments, and deliveries. These data points were collected and organized to illustrate how the entities relate to one another within the platform's ecosystem. The ERD visually maps out these relationships, ensuring a clear understanding of how data flows through the system and how different entities interact to facilitate the platform's core functions, such as food waste listing, searching, and transaction processing.

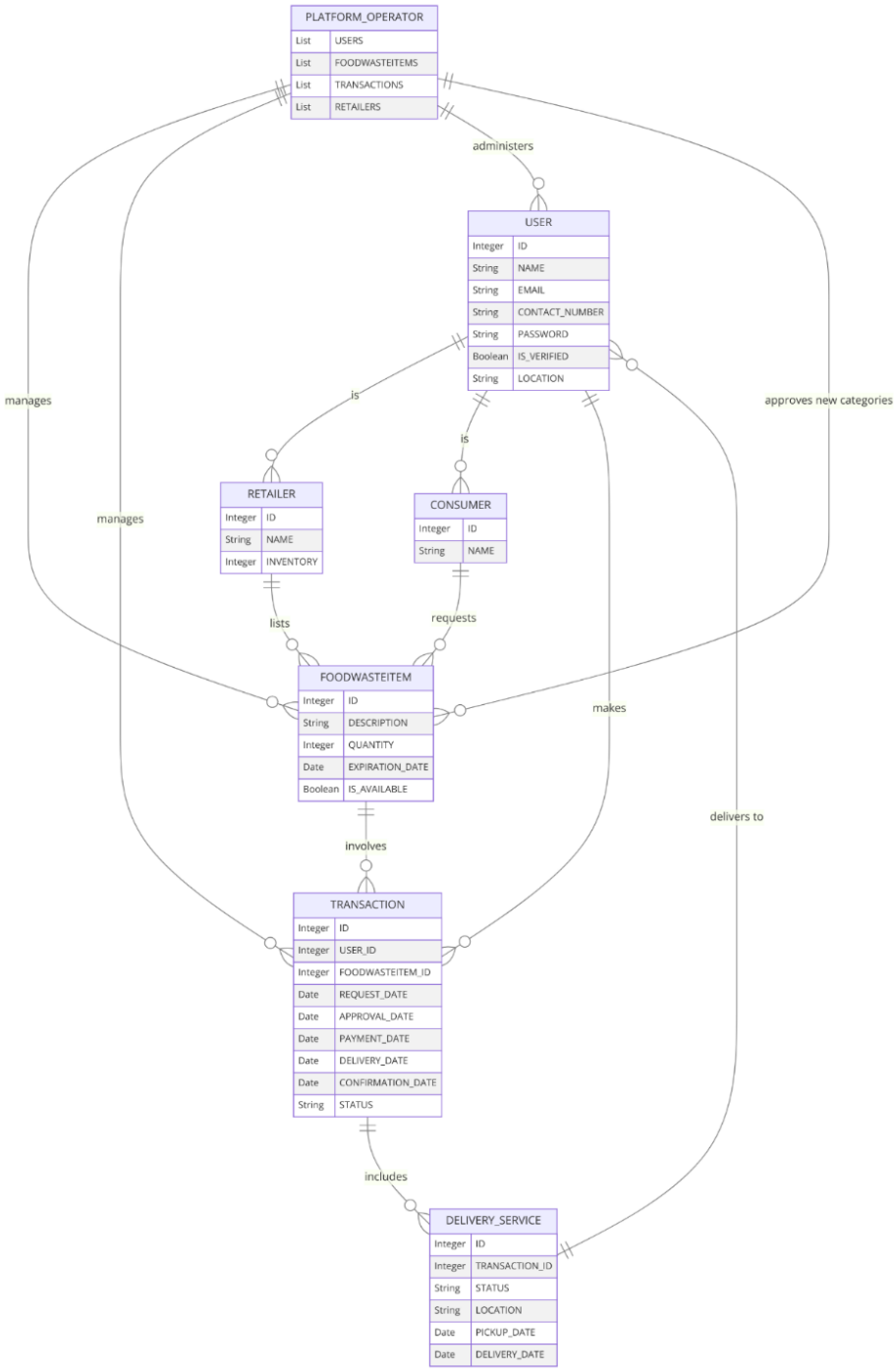

Figure 11: Entity Relationship Diagram

5.5.2 Infrastructure

For the technological infrastructure, there are two options that meet the governmental requirement of utilizing local data centers. The first option is an on-premise infrastructure, while the second option is a **cloud-based** solution with a provider with data centers in Saudi Arabia.

On-premises data centers, while offering certain advantages such as greater control over physical hardware and data storage, present several significant disadvantages, particularly when compared to cloud-based solutions. One of the primary drawbacks is the high initial cost involved in setting up the infrastructure, including purchasing hardware, software, and networking equipment. These expenses are compounded by ongoing costs related to maintenance, upgrades, and eventual hardware replacements. Moreover, maintaining an on-premises data center demands a dedicated IT team to manage all aspects of the infrastructure, including security, which increases the operational burden and the risk of human error [84]. Implementing robust disaster recovery solutions is also more complex and expensive on-premises, requiring duplicate systems and offsite backups to ensure continuity[89].

The lack of flexibility and agility in adapting to new technologies and changing business needs further hampers on-premises solutions, as implementing upgrades or new software often involves significant downtime and effort [90]. Additionally, the physical space required for on-premises data centers can be a constraint for organizations with limited real estate, making it difficult to accommodate growing data storage and processing needs.

On the other hand, choosing a cloud-based solution offers significant advantages, particularly in scalability, security, privacy, and reliability [91]. Scalability is a crucial benefit of cloud solutions, as they provide elastic resource management, allowing the platform to automatically scale up or down based on demand [87]. This is crucial for handling varying user activity levels, such as surges in users listing food waste after a marketing campaign, without service disruption. Additionally, the pay-as-you-go model ensures cost efficiency, as resources can be adjusted in real-time based on actual usage [92].

Security is another major advantage of cloud solutions. Leading cloud providers offer a range of advanced security features, including encryption, identity and access management, and threat detection, which can be challenging and costly to implement in a traditional on-premises setup [86]. Cloud providers also comply with industry standards and regulations, offering certifications ensuring the platform meets stringent security and privacy requirements [91]. Cloud providers ' continuous monitoring and automated security updates help protect the platform from emerging threats without requiring manual intervention by the platform's IT team [89].

Cloud solutions enhance privacy by providing robust data protection mechanisms that ensure personal data is stored securely and access is strictly controlled [93]. Features like multi-factor authentication and role-based access control can limit access to sensitive data to authorized personnel only, enhancing privacy[86]. Additionally, cloud solutions can give users control over their data, including options to manage consent, access, and deletion of personal information[85]. This helps build trust and ensures compliance with Saudi Arabia's personal data protection laws.

Reliability is another crucial advantage of cloud solutions. Cloud providers typically offer high availability and redundancy features that ensure the platform remains operational even during failures or maintenance periods [84]. For example, data replication across multiple servers and automated failover mechanisms help maintain continuous service, reducing downtime and ensuring that users can always access the platform [90].

Overall, using a cloud solution provides substantial benefits in scalability, security, privacy, and reliability [93]. These advantages make cloud solutions ideal for supporting the digital platform's infrastructure and meeting stakeholders' requirements.

5.6 Conclusion

In this chapter, we have detailed the design activities in alignment with the third phase of the DSR approach, the design phase. We have answered this chapter's sub-research question: "What digital platform design fulfills the identified requirements?" We have utilized the ArchiMate framework to answer this question, which consists of strategy, business, application, and technology layers. We have looked at academic and grey literature to identify best practices, which helped us finalize the ArchiMate's layers. The ArchiMate model summarizing the layers is presented in Appendix D.

The ArchiMate framework contributed to the design of the digital platform by providing a structured description of the architecture across its strategy, business, application, and technology layers. Through this framework, we ensured that the platform design aligns with the platform's strategic goals and the stakeholders' requirements,

enabling a purposeful and goal-oriented design process. By systematically integrating all components, the ArchiMate framework ensures that the digital platform design is coherent, efficient, and capable of meeting the intended objectives.

Key components and functionalities are outlined across the business, application, and technical layers. In the Business Layer, business actors, roles, core functions, and processes were defined to facilitate interactions and achieve strategic goals. This layer focuses on stakeholders driving platform functionality and success. Moving to the Application Layer, application services supporting business processes, functionalities, and data exchange were detailed, ensuring efficient delivery of services to users. Components like the User Interface (UI) aim to provide a seamless experience for all platform users, enhancing usability and accessibility. The Technology Layer highlights the infrastructure choice between on-premise or cloud-based solutions, emphasizing cloud solutions' scalability, security, and reliability advantages. Data management aspects, including database design for storing various data types securely and efficiently, are crucial for ensuring data integrity and compliance with privacy laws.

To ensure cost-effectiveness, the design incorporates scalable architecture to efficiently handle a growing user base while utilizing RESTful APIs for seamless integration and performance. User authentication is implemented to secure platform access, aligning with data regulation and cybersecurity standards in Saudi Arabia. The platform facilitates the process of food waste sharing by enabling food waste listing, purchasing, payment, and delivery. Location and product filtration options enhance user experience, while multilingual support in Arabic and English caters to diverse user needs. Data security and privacy measures are implemented to safeguard user information, and location data collection ensures efficient service delivery. The onboarding process assists users in platform usage, and delivery service options are available for convenience. Integration with the current retail management system streamlines operations, while performance analytics features offer valuable insights for optimization. Alerts and notifications for products nearing expiry dates enhance food waste management, and gamification tools encourage user participation and engagement. Including a mobile application extends platform accessibility, while integration with social media platforms enables generating awareness. Engagement mechanisms and embedded chatting services foster user interaction and collaboration, enhancing the overall platform experience.

In terms of scalability, the platform's architecture, cloud-based infrastructure, RESTful APIs, and mobile application development all play key roles in ensuring that the platform can grow and adapt to accommodate a more extensive user base and increasing data volume. By prioritizing these long-term scalability considerations, the digital platform is equipped to address expansion needs and remain practical and relevant in the future landscape of sustainability efforts in Saudi Arabia.

This design serves as a foundation for the evaluation chapter. The design is evaluated against the platform’s objective, stakeholders' requirements, and challenges.

6 Evaluation

The evaluation phase is a critical component of the design science research (DSR) methodology, ensuring that the developed artifacts effectively address the identified problems and meet stakeholder needs. This chapter's sub-research question is, “To what extent does the digital platform address the identified problem and requirements?”. We have conducted an alignment analysis between the identified requirements and challenges against the final design to answer this question. The envisaged result at the end of the chapter is a comprehensive design evaluation highlighting the extent to which the design addresses the objective, challenges, and requirements.

This chapter starts by evaluating the design components against requirements. Then, we present the evaluation of the design against challenges. Lastly, we conclude the chapter by answering the sub-research question.

6.1 Evaluation Against Requirements

Evaluating the design against the identified requirements is essential in design science research (DSR). This process ensures that the digital platform meets the needs of the stakeholders. We can verify that each platform aspect has been addressed by comparing the platform's design components to the pre-defined requirements. This evaluation highlights the platform's strengths and identifies any gaps or areas for improvement.

The digital platform meets the retailer’s business requirements by providing a user-friendly interface for seamless interaction, which includes a multilanguage user interface, onboarding for new users, and an embedded communication mechanism for technical support. Additionally, integrating with existing business management systems, including supplier and delivery systems, through RESTful API ensures security, scalability, and efficiency. Addressing the process of facilitating the sharing of food waste through a safe and reliable environment that adheres to government privacy and security requirements enables the retailers to shift from throwing food waste unsegregated into municipality bins, which end up in landfills, to sharing it with consumers. Consumers, such as farm owners, will use it mainly for animal feeding and composting, enabling circularity. Furthermore, the main features include generating analytics, delivery service, and notification of nearly expired items, assuring alignment with retail business requirements.

The digital platform aligns with governmental requirements by prioritizing data regulation and cybersecurity standards in Saudi Arabia. The platform ensures compliance with personal data protection laws by implementing privacy notices, explicit consent mechanisms, safeguarding user information and transaction records. Furthermore, integration with approved payment gateways and utilizing locally based cloud-based solutions promote secure data handling practices in line with Saudi Arabia's cybersecurity regulations. The platform's choice of a cloud-based infrastructure offers significant scalability advantages. Cloud solutions provide elastic resource management, automatically allowing the platform to scale up or down based on demand. This capability is crucial for handling varying user activity levels without service interruptions, ensuring consistent performance and reliability.

The digital platform is tailored to meet the requirements of technology providers, including suppliers, delivery partners, and subject matter experts. This is done by offering a secure and scalable architecture, and supporting RESTful APIs for seamless integration. Furthermore, It ensures data security and privacy and utilizes hybrid database approaches for efficient data storage, catering to the technical functionalities and security needs. The platform's integration with approved payment gateways, including performance analytics features, and incorporation of engagement mechanisms further enhance its appeal to technology providers, promoting a safe environment for collaboration. The design ensures data integrity and availability by utilizing a hybrid database approach, combining relational databases like PostgreSQL and NoSQL databases like MongoDB to efficiently store structured and unstructured data. This choice allows for flexibility, scalability, and optimal handling of various data types, including user information, food item details, transaction records, feedback, and analytics.

The digital platform addresses consumers' requirements by providing a user-friendly interface, supporting online payment functionality, and offering reliable delivery service options for convenience and accessibility. Furthermore,

enabling food waste search and filter per location, category, quantity, and possible use provides a user-friendly and convincing process for processing food requests.

Table 14 cross-checks each requirement with the design component detailed in the design chapter. It is important to note that requirement ID # 3, "must be cost-effective," is excluded as it is addressed in the following Business Model chapter.

Table 14: Requirement and Design Traceability

ID	Requirement	Design Component
1	Must provide a user-friendly interface.	User Interface (UI)
2	Should integrate with the current retail management system.	RESTful API Integration
4	Must authenticate users before granting access.	User Registration
5	Must facilitate the process of food waste.	The collective features of the platform
6	Must offer training and support for platform usage.	User Restoration & Onboarding
7	Should enable generating analytics.	User Interface integration with analytics system
8	Should send alerts for products approaching their expiry dates.	Integration with notification/ alerts system
9	Should include incentive programs to encourage user participation.	Integration with a gamification system
10	Must enable waste categorization listing.	Inventory Management dashboard
11	Must align with data regulation and cybersecurity in Saudi Arabia.	Data Management and Infrastructure
12	Must support approved payment gateways.	Approved payment gateway integration
13	Should provide a mobile application.	Mobile App
14	Must allow filtration by location and product.	Search & Filter Module
15	Should offer delivery service options.	Delivery Integration
16	Should support the segregation of food waste.	Inventory Management dashboard
17	Must support online payment functionality.	Secure and approved payment gateway
18	Must have a scalable architecture to handle a growing user base.	Cloud infrastructure
19	Must provide multilingual support, including Arabic and English.	Integration with a translation system
20	Must ensure data security and privacy.	Data Management
21	Should generate awareness about food waste.	Gamification and social media integration
22	Should incorporate engagement mechanisms.	Gamification & recommender system
23	Must collect location information for users.	Integration with location mapping system
24	Should include an embedded chatting service.	Integration with a chat system
25	Must utilize RESTful APIs for integration.	RESTful API design and integration

6.2 Evaluation Against Challenges

In this subsection, we aim to evaluate how well the digital platform design addresses the challenges identified during the problem identification phase. This evaluation is crucial to ensure the platform meets its intended objectives and provides practical solutions to real-world issues associated with food waste management in Saudi Arabia. By analyzing the platform's design against the identified challenges, we can verify the alignment of the proposed solution. This process helps identify gaps or areas needing improvement, ensuring that the final platform is well-equipped to tackle the complexities of food waste reduction within the circular economy framework.

We address the evaluation of each challenge in Table 15 by listing the evaluation status through (Met, Partially Met, or Out of Scope). We also list the design components associated with addressing each challenge. It is important to mention that we are evaluating the design for the scope and the context of the retail stage in the eastern province of Saudi Arabia. Also, challenge # 4, economic concern, is not addressed in Table 14, as it is addressed in the following

Business Model chapter. Furthermore, as mentioned and detailed at the conclusion of the problem identification chapter, challenges related to establishing policies and regulations are out of the scope of our research. Developing the necessary infrastructure for efficient waste management involves significant governmental investment and coordination, and establishing food waste management policies and regulations is also within the purview of government authorities.

Table 15: Design Against Challenges

#	Challenge	Status	Design Component/ Remarks
1	Awareness	Partially Met	While awareness generation for citizens is mainly a governmental action, the platform's design will generate awareness through integration with social media channels, which is mentioned under optional integration in the design chapter. This integration is not listed under the ArchiMate's model as we only included the required integrations.
2	Policies & Regulations	Out of Scope	As mentioned in the problem identification chapter, this challenge is out of scope as the design of new policies is beyond the scope of the digital platform design and is to be addressed by the government.
3	Inventory Control	Met	Met through the inventory management dashboard and the integration with supplier and notification/ alert system to enable alerts for nearly expired items. This can be done by connecting the platform to a food supplier system.
5	Efficient Technologies	Partially Met	As there is no single solution or technology to address all the technological challenges associated with food waste management. This challenge is partially met through the collective technologies, systems, and tools discussed during the design phase to facilitate the sharing of food waste to be utilized/ recycled by consumers and to reduce waste through the inventory management module.
6	Cultural Practices	Partially Met	While multiple cultural practices are highlighted in the problem identification phase, this challenge is partially met as the platform will assist in changing retailers' practices of throwing food waste unsegregated into the municipality bin to segregating and sharing it with potential consumers, which will enable building new habits.
7	Waste Categorization	Met	This is met through the inventory management module, where retailers can list their food waste in pre-identified food waste categories. Consumers feedback will enable the platform operator to check if the retailers are not compliment with what is listed and shared.
8	Waste Processing	Partially Met	While the main objective of facilitating and sharing food waste between retailers and consumers (individuals and businesses) is fully met, the design could still be improved by integrating the platform directly with the companies in the eastern province of Saudi Arabia that process food waste through composting equipment.
9	Infrastructure	Partially Met	While multiple challenges related to infrastructure and logistics, the challenges of facilitating delivery are met through integration with a locally approved delivery partner.

10	Waste Measurement	Met	This is met as the platform will collect and analyze the data on the food waste listed on the platform. In the long term, this will assist in measuring food waste for all retailers using the platform. Furthermore, it will enable us to identify trends and highlight major food waste items. To enable accurate measurement of food waste, platform operator should know if the retailers are sharing the food waste through other channels or not. This can be simply done as part of the registration process.
11	Stakeholders Collaboration	Met	This is met through the stakeholders' involvement in the platform's design and the ecosystem it will have by enabling active collaboration between retailers, suppliers, consumers, and technology providers. Furthermore, the integration of engagement mechanisms (gamification), listed under the optional integrations under the design chapter will pave the way for municipality involvement in issuing incentives.

6.3 Conclusion

In conclusion, this chapter's sub-research question is, “To what extent does the digital platform address the identified problem and requirements?” To answer this question, we conducted an alignment analysis between the identified requirements and challenges and the final design.

The evaluation against requirements demonstrated that the digital platform effectively meets most of the specified requirements. The platform provides a user-friendly mobile interface, food waste listing, searching, and reusing functionalities, and it ensures data security and privacy in compliance with Saudi regulations. Additionally, it supports scalable architecture, multilingual capabilities, and various features such as analytics, notifications, and gamification to enhance user engagement and operational efficiency. The cross-checking of requirements against design components confirmed that the platform addresses the key needs of retailers, government, technology providers, and consumers.

An area for improvement is finding an innovative way to connect the platform with food waste processing machines through companies specializing in food waste composting machines. Integrating such a process will help facilitate food waste more efficiently and enhance the current design to facilitate the R9:Recover, R7:Repurpose, and R3: Reuse, and R2: Reduce, which we detailed in Chapter One and presented in Figure 1.

The evaluation against challenges highlighted the platform's strengths and areas for improvement in addressing the identified issues. The platform successfully meets the challenges related to inventory control, waste categorization, waste measurement, and stakeholder collaboration. It partially addresses challenges such as awareness generation, efficient technologies, cultural practices, and waste processing. The platform's design effectively facilitates the sharing of food waste, enabling the reuse and repurposing of food waste. However, certain challenges, such as policy formulation and infrastructure development, are beyond the platform's scope and require governmental intervention.

This evaluation confirms that the digital platform design aligns with its objectives and stakeholder requirements. It provides a robust, secure, and scalable solution to reduce food waste in the eastern province of Saudi Arabia. The insights gained from this evaluation can guide further refinements and enhancements to ensure the platform's long-term success and sustainability.

7 Business Model

The business model chapter focuses on the strategic and economic aspects that support the operation and sustainability of the digital platform. This chapter addresses the sub-research question: "What business models fit a digital platform aimed at reducing food waste at the retail stage in the Eastern Province of Saudi Arabia?". We utilized a Business Model Canvas and conducted a SWOT analysis to address the sub-question. This helped us identify and evaluate revenue streams, key activities, resources, and partnerships necessary to support the platform's long-term viability and effectiveness. By examining for-profit and non-profit models, we aim to provide a balanced view of the potential pathways for achieving financial sustainability and social impact.

This chapter starts with an overview of the Business Model Canvas, followed by an introduction to the SWOT analysis, its objective, and its components. We then analyze both models, discussing each approach's strengths, weaknesses, opportunities, and challenges. Lastly, we present a conclusion summarizing the key findings. The envisaged result at the end of this chapter is detailed and substantiated business models that align with the platform's objectives.

A business model serves as a comprehensive framework outlining how a company creates, delivers, and captures value[94]. It encompasses a business's entire operational and strategic architecture, detailing the resources, partnerships, and market interactions that drive its success [95]. Business models are essential for businesses as they provide a clear blueprint for achieving financial sustainability, competitive advantage, and growth [96]. They guide decision-making, align organizational efforts, and ensure that all aspects of the business are integrated and focused on delivering value to customers [97].

A well-defined business model is essential for the creation of digital platforms [96], [98]. Digital platforms often operate in complex and dynamic environments, requiring robust strategies to manage interactions between multiple stakeholders, such as users, partners, and service providers [98]. A robust business model helps digital platforms navigate these complexities by clearly defining how they will attract and retain users, generate revenue, and leverage technology to enhance their value proposition [99]. It also ensures the platform can scale effectively and adapt to changing market conditions, providing a sustainable path to long-term success [98].

7.1 Business Model Canvas

The Business Model Canvas is a strategic management tool that offers a visual framework for formulating, describing, and evaluating business models. It deconstructs the business model into nine essential building blocks, providing a comprehensive overview of how a business generates, delivers, and captures value. The nine building blocks, as per Figure 11, include Key Partners, Key Activities, Key Resources, Value Propositions, Customer Relationships, Channels, Customer Segments, Cost Structure, and Revenue Streams.[100]

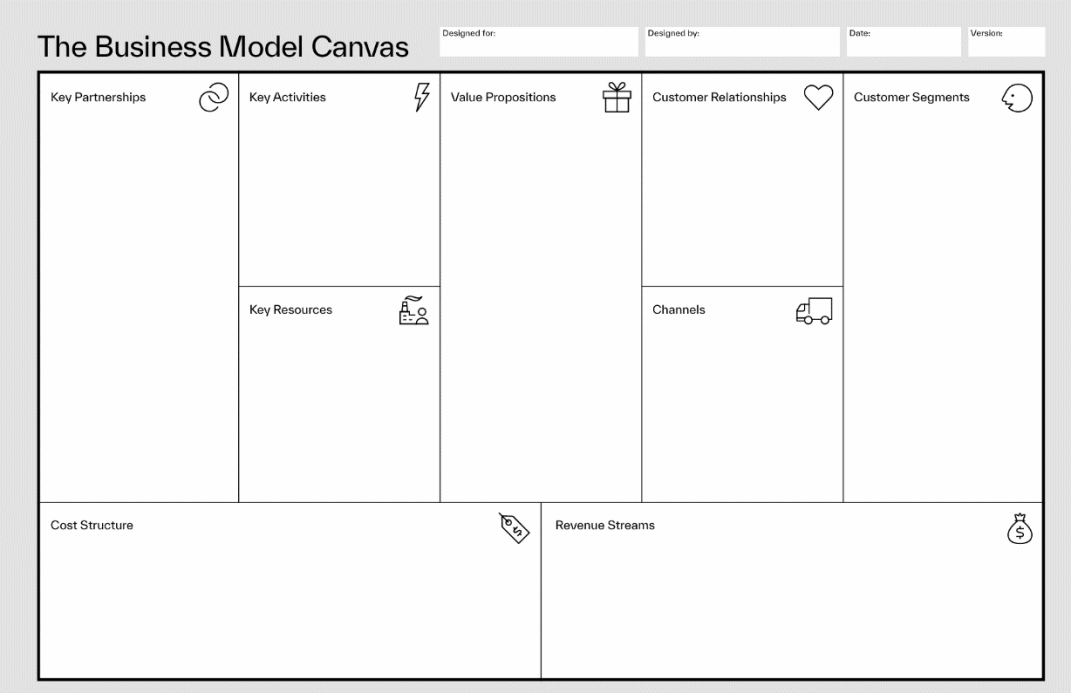

Figure 12: Business Model Canvas, [100]

The Business Model Canvas is used because it simplifies the complexity of developing a business strategy. It allows stakeholders to see the entire business model on a single page, facilitating better understanding and communication [100]. Visual mapping out the components of the business model helps identify gaps, dependencies, and opportunities for innovation [99]. For our research, using the Business Model Canvas will help align the design with operational and strategic goals, address the economic concern identified as a challenge, and address the cost-effective requirement. We will fill in each of the nine buildings to use the Business Model Canvas. Table 16 presents the activities along with the method related to each one.

Table 16: Business Model Canvas Activities, [100]

Activity	Method
Key Partners	Identify the organizations and stakeholders to help achieve the business objectives.
Key Activities	Determine the activities that need to be performed to deliver the value proposition.
Key Resources	Identify the assets required to create and deliver the value proposition.
Value Propositions	Define the platform's unique value to its customers.
Customer Relationships	Describe the relationships we will establish with different customer segments.
Channels	Identify how the platform will reach and interact with customers.
Customer Segments	Define the different groups of people or organizations the platform aims to serve.
Cost Structure	Outline the costs involved in operating the business model.
Revenue Streams	Identify how the business will generate income.

We will address these components to build a detailed and cohesive business model for the digital platform. The resulting business model will serve as a guide for implementing the platform, ensuring all necessary elements are in place to support its success in reducing food waste at the retail stage in the eastern province of Saudi Arabia.

7.2 SWOT Analysis

SWOT analysis is a strategic planning tool used to identify and analyze the Strengths, Weaknesses, Opportunities, and Threats associated with a business, project, or initiative. It helps in understanding both internal factors (strengths and weaknesses) and external factors (opportunities and threats) that can influence the success of an endeavor. The purpose of SWOT analysis is to provide a comprehensive framework for strategic planning, decision-making, risk management, and resource allocation. By identifying these factors, organizations can develop strategies to leverage their strengths, mitigate weaknesses, exploit opportunities, and defend against potential threats. [101]

SWOT analysis provides a structured approach to evaluating the business model options, helping stakeholders make informed decisions about the most viable path forward [102]. This ensures that the platform's design aligns with its long-term objectives and the socio-economic context of the eastern province of Saudi Arabia, promoting sustainability and effectiveness in reducing food waste.

In the upcoming sections, we have used the SWOT analysis to evaluate the for-profit and non-profit business models. We have evaluated the strengths, weaknesses, opportunities, and threats associated with the proposed business models for the digital platform. By examining these four dimensions, we gain a comprehensive understanding of each business model's internal capabilities and external environment.

7.3 Business Model Canvas: For-Profit

This business model aims to create a financially sustainable digital platform by connecting retailers with consumers. Operating as a for-profit entity, the platform can leverage various revenue streams to ensure long-term viability and scalability while promoting sustainability and social responsibility. Figure 12 presents the components of the business model.

<table>
<tr>
<td rowspan="2">Key Partnerships

- Retailers
- Logistics providers
- Technology providers
- Ministry of Environment and Agriculture</td>
<td>Key Activities

- Platform operation and maintenance
- User acquisition and engagement
- Marketing and promotion
- Data analytics and reporting
- Customer support and training</td>
<td rowspan="2">Value Proposition

For Retailers: Reduced food waste, enhanced corporate social responsibility, and potential revenue from selling food waste.

For Consumers: Access to affordable or free food waste and contributing to sustainability efforts.</td>
<td>Customer Relationships

- Online customer support
- Training and onboarding for retailers
- Community building through social media and forums</td>
<td rowspan="2">Customer Segments

- Retailers (Restaurants, cafes, and Bakeries)
- Consumers such as farm owners looking for food waste</td>
</tr>
<tr>
<td>Key Resources

- Software development and customer support teams
- API
- Cloud infrastructure</td>
<td>Channels

- Online platform</td>
</tr>
<tr>
<td colspan="3">Cost Structure

- Platform development and maintenance costs
- Marketing and promotion expenses
- Salaries for staff (developers, customer support, marketing)
- Cloud infrastructure and hosting costs
- Technology integrations costs
- Compliance and regulatory costs</td>
<td colspan="2">Revenue Stream

- Transaction fees on food sales
- Subscription fees from consumers
- Advertising revenue from partners</td>
</tr>
</table>

Figure 13: For-profit Business Model Canvas

7.3.1 For-Profit Business Model: SWOT Analysis

The for-profit business model has several strengths. It can generate consistent revenue through subscription fees, transaction fees, and partnerships, ensuring financial stability. Access to venture capital, private equity, and other investment opportunities can support growth and expansion. Saudi Arabia provides many channels to access such opportunities. The model offers greater flexibility in resource allocation, enabling quick adaptation to market demands and technological advancements. It is also better positioned to attract and retain skilled professionals with competitive salaries and benefits.

However, the for-profit model has its weaknesses. The perception of prioritizing profit over social impact may affect public trust and engagement, particularly in a mission-driven initiative like food waste reduction. The model is subject to corporate taxes, reducing the revenue that can be reinvested into the platform. Compliance with business regulations and reporting requirements adds to operational complexity. Additionally, higher operating costs are associated with marketing, technology development, and customer acquisition. Furthermore, one significant weakness is the challenge of generating enough income from food waste transactions to make the business model profitable, as it typically represents a low-income revenue stream. This is especially relevant at the beginning when there is only a limited number of participating retailers. This weakness must be carefully addressed by focusing on the other mentioned revenue streams to ensure the platform's financial sustainability. Reliance on one revenue stream of commission generated from food waste only will lead to a very minimal revenue, which will make the for-profit model not a feasible option.

The for-profit model offers substantial opportunities. It can scale the platform faster, tapping into larger markets. Diverse revenue streams through ads, partnerships, and expanded services can enhance financial sustainability. The model can leverage resources for continuous innovation, development, and technological advancements. Partnerships with brands and corporations interested in sustainability offer further growth potential.

Nevertheless, the for-profit model faces threats such as market competition from other entities offering similar services, which can affect market share. Economic fluctuations can impact revenue and profitability. Increased public scrutiny and potential backlash may arise if the platform is perceived as prioritizing profits over sustainability. Regulatory risks, including changes in business operations, data privacy, and financial practices, pose additional challenges.

7.4 Business Model Canvas: Non-Profit

This business model focuses on creating a digital platform as a non-profit organization. The non-profit model emphasizes social impact and community engagement, leveraging grants, donations, and partnerships to sustain operations.

<table>
<tr>
<td rowspan="2">Key Partnerships

- Retailers
- Logistics providers
- Technology providers
- Ministry of Environment and Agriculture - Volunteers and community groups
- Educational institutions
- Non-profit organization focuses on food waste management
- Business and organization with a focus on social responsibility and sustainability</td>
<td>Key Activities

- Platform operation and maintenance
- Awareness campaigns and education programs
- Fundraising and grant applications
- Data collection and reporting
- Volunteer recruitment and coordination</td>
<td rowspan="2">Value Proposition

For Retailers: Helping reduce food waste and enhance brand image without additional costs.
For Consumers: Access to free food waste, contributing to sustainability.
For Organizations providing sponsorships and donations:
Enhanced social responsibility image.</td>
<td>Customer Relationships

- Community engagement through events and workshops
- Volunteer programs and opportunities
- Personalized support for retailers and charities</td>
<td rowspan="2">Customer Segments
- Retailers (Restaurants, cafes, and Bakeries)
- Consumers such as farm owners looking for food waste
- Organizations looking to enhance their social responsibility</td>
</tr>
<tr>
<td>Key Resources

- Software development and customer support teams
- API
- Cloud infrastructure
- Partnerships with local organizations focusing on sustainability and social responsibility
- Volunteers</td>
<td>Channels

- Online platform
- Social media
- Partnerships with educational institutions and community groups</td>
</tr>
<tr>
<td colspan="3">Cost Structure

- Platform development and maintenance costs
- Marketing and promotion expenses
- Salaries for staff and stipends for volunteers
- Cloud infrastructure and hosting costs
- Fundraising events costs
- Compliance and regulatory costs
- Technology integrations costs</td>
<td colspan="2">Revenue Stream

- Grants and donations from government and private entities
- Fundraising events and campaigns
- Sponsorships from corporate partners
- In-kind donations (e.g., technology, services)
- Membership fees from participating organizations</td>
</tr>
</table>

Figure 14: Non-profit Business Model Canvas

7.4.1 Non-profit Business Model: SWOT Analysis

The non-profit business model for the digital platform offers several strengths. Primarily, it is mission-driven, attracting support and funding based on its social mission of reducing food waste and promoting sustainability. This alignment with circular economy principles will likely attract grants and donations from government entities, public and private organizations, and private donors interested in sustainability initiatives. Additionally, non-profit organizations benefit from tax exemptions, allowing more resources to be directed toward platform development and operations. The higher public trust associated with the non-profit nature can drive user engagement and stakeholder participation.

However, this model has its weaknesses. It heavily relies on donations and grants, which may be inconsistent and limited, leading to financial instability. The revenue streams are fewer than for-profit models, potentially affecting the platform's scalability and sustainability. Operational constraints also arise due to restrictions on how funds can

be used, limiting flexibility in operations and innovation. Attracting and retaining skilled professionals can be challenging due to potentially lower salaries and benefits than for-profit organizations.

Opportunities for the non-profit model are significant, especially in the Eastern Province of Saudi Arabia, which is known for its strong community ties and charitable activities. Collaborating with government agencies, educational institutions, and other non-profits focused on sustainability can enhance the platform's impact and reach. Community engagement through volunteer involvement can further strengthen the platform's initiatives. The model can also influence public policies on food waste management and sustainability, potentially gaining recognition and support from environmental and sustainability organizations.

Despite these opportunities, the non-profit model faces threats such as economic downturns that can reduce donations and grants, affecting financial stability. There is also competition for funding from other non-profit organizations. Regulatory changes in non-profit regulations and tax laws can impact funding and operations. Ensuring long-term sustainability without consistent revenue streams remains a challenge.

7.5 Conclusion

This chapter's sub-research question is, "What business models fit a digital platform aimed at reducing food waste at the retail stage in the Eastern Province of Saudi Arabia?" To answer this question, we have utilized a business model canvas and conducted a SWOT analysis. We have completed two business models, for-profit and non-profit.

Both the for-profit and non-profit business models offer feasible approaches to operating a digital platform for reducing food waste. The for-profit model focuses on financial sustainability and scalability, leveraging multiple revenue streams to support its growth. In contrast, the non-profit model emphasizes social impact and community engagement, relying on grants and donations to fund its operations.

The for-profit model must use multiple revenue streams, such as subscription fees, transaction fees, advertising, and data monetization, to ensure the platform's sustainability. These funds are reinvested into platform development and marketing to attract more users. Key partnerships with retailers, logistics providers, and technology companies are crucial for delivering reliable food listing, delivery, and transaction processes, enhancing user satisfaction. The platform effectively addresses the needs of retailers, consumers, and charities, making it an attractive solution for reducing food waste while generating profit.

On the other hand, the non-profit model focuses on social impact and community engagement. It relies on grants, donations, and sponsorships to fund its operations, which can be less predictable than revenue from business activities. Building strong partnerships with retailers, charities, and community groups is crucial for maximizing the platform's reach and impact. Awareness campaigns and educational programs are essential for raising public awareness about food waste and encouraging community involvement. The non-profit model benefits from a strong volunteer base and collaborations with academic institutions, helping to maintain low operational costs while maximizing social impact.

Choosing between these models depends on the organization's goals and the preferences of its stakeholders. The for-profit model may attract investors and scale more rapidly, while the non-profit model can build stronger community ties and emphasize social good. Ultimately, both models can effectively reduce food waste and promote sustainability, contributing to a more circular economy in Saudi Arabia. However, we lean into the non-profit model to ease the value proposition for both retail and consumers through offering free services, at least for core functionalities.

8 Conclusion

In conclusion, this research aimed to answer the main research question (MRQ): ***(What digital platform design can contribute to reducing food waste in the retail sector in the Eastern Province of Saudi Arabia in alignment with circular economy principles?)***. We have adapted the design science research (DSR) methodology to address this question. Initially, the food waste problem in Saudi Arabia was thoroughly analyzed, highlighting key challenges such as lack of awareness, inadequate policies, logistical issues, and cultural practices. These challenges made the foundation for defining the requirements for the digital platform. We have then collected stakeholders' requirements through interviews. Besides segregating the collected requirements into functional and non-functional, we have divided them into must and should address. The design phase then involved creating a comprehensive digital platform architecture using the ArchiMate framework, encompassing strategy, business, application, and technology layers. Each layer was designed to meet stakeholders' functional and non-functional requirements. The platform's key components included a seamless user interface, robust security measures that adhere to governmental requirements, and scalable cloud infrastructure. We have also created an ArchiMate model, which is available in Appendix D. This ArchiMate model summarizes the digital platform architecture design. The evaluation phase confirmed that the digital platform addresses the identified requirements and challenges to varying degrees.

In the conclusion chapter, we provide a comprehensive response to the main research question. We also detailed the social and scientific contributions, highlighting how they close the knowledge gap, specifically within the context of food waste management in Saudi Arabia. Additionally, we critically assessed the research limitations, acknowledging areas where further investigation is needed, and proposed future research topics to extend the findings and address gaps that emerged during the study.

Moreover, we offered practical recommendations for the implementation of the digital platform, emphasizing the importance of stakeholder collaboration, technology integration, and scalability to ensure its success. Finally, we detailed the alignment of our research with the MSc CoSEM program, demonstrating how the study meets the program's objectives by combining engineering principles, system design, and stakeholder management strategies to solve a complex socio-technical problem.

To answer the main research question, we have worked on answering five sub-research questions, each related to one of the design science research (DSR) phases.

The sub-research question that guided the **problem identification** phase is: (*What are the critical challenges for reducing food waste in the retail stage in the eastern province of Saudi Arabia?).* To answer that, we have employed qualitative analysis. We have conducted a literature review on food waste management challenges in Saudi Arabia, contributing to identifying current challenges. Additionally, we have conducted interviews with retail business owners, which provided qualitative insights into the challenges faced in tackling food waste, specifically in the Eastern Province of Saudi Arabia. While the literature review highlighted challenges in food waste in Saudi Arabia, the expert interviews helped us identify challenges specifically related to the retail stage in the eastern province of Saudi Arabia and aid in confirming the literature review findings.

Through the literature review, we have identified that addressing food waste challenges in Saudi Arabia requires an approach that considers the interplay of technological, regulatory, behavioral, and socioeconomic factors. The identified challenges are presented in Table 9. The interviews with restaurant and cafe owners confirmed the challenges identified in the literature regarding food waste management in Saudi Arabia's retail sector. Low awareness levels, inventory control issues, lack of government policies, minimal technology integration, logistical challenges, and cultural practices contribute to the problem. Participants expressed a willingness to engage in food waste reduction efforts but emphasized the need for systematic approaches that do not disrupt daily operations, a

safe environment, and possible incentives. The findings underscore the importance of government intervention, incentives, and user-friendly technology solutions to address these challenges effectively.

Despite the challenges, there are several opportunities for reducing food waste in the retail stage in Saudi Arabia. The country has been actively embracing digital technologies and innovation as part of its Vision 2030 initiative [6], which aims to diversify the economy, promote sustainable development, and enhance the quality of life for its citizens [40], [52]. With a growing emphasis on digital transformation and e-commerce, the country is well-positioned to leverage digital platforms and intelligent technologies to address food waste challenges in the retail sector.

The identified challenges have steered the development of the digital platform's requirements. By deriving the requirements from the identified challenges, we ensured that the final platform design was directly aligned with the core issues, which enhanced the final product's relevance and effectiveness. The sub-research question that guided the **requirement** collection phase is: *(What are the stakeholders' requirements for a digital platform to reduce food waste at the retail stage in Saudi Arabia in alignment with circular economy principles).* To answer this question, we interviewed relevant stakeholders, providing insights into expected outcomes based on their experiences and needs. Based on the interviews, we have generated the requirements in Table 12, which revolve around user experience, technical functionalities and security, and regularity compliance.

In the Design Science Research (DSR) methodology, the requirements collected serve as the foundation for the design phase [32] The identified requirements guided the digital platform's design and supported the overall design evaluation. While the identified requirements help us select applicable design features and functionalities, they have also helped us evaluate the degree to which these requirements were met.

The sub-research question that guided the **design** phase is: *(What digital platform design fulfills the identified requirements?).* We have utilized the ArchiMate framework to answer this question. We have looked at academic and grey literature to identify best practices, which helped us finalize the ArchiMate's layers. The ArchiMate model summarizing the layers is presented in Appendix D.

The ArchiMate framework contributed to the design of the digital platform by providing a structured description of the architecture across its strategy, business, application, and technology layers. Through this framework, we ensured that the platform design aligned with its strategic goals and the stakeholders' requirements, enabling a purposeful and goal-oriented design process.

Key components and functionalities are outlined across the business, application, and technical layers. In the Business Layer, business actors, roles, core functions, and processes were defined to facilitate interactions and achieve strategic goals. This layer focuses on stakeholders driving platform functionality and success. Moving to the Application Layer, application services supporting business processes, functionalities, and data exchange were detailed, ensuring efficient delivery of services to users. Components like the User Interface (UI) aim to provide a seamless experience for all platform users, enhancing usability and accessibility. The Technology Layer highlights the infrastructure choice between on-premise or cloud-based solutions, emphasizing cloud solutions' scalability, security, and reliability advantages. Data management aspects, including database design for storing various data types securely and efficiently, are crucial for ensuring data integrity and compliance with privacy laws.

To ensure cost-effectiveness, the design incorporates scalable architecture to efficiently handle a growing user base while utilizing RESTful APIs for seamless integration and performance. User authentication is implemented to secure platform access, aligning with data regulation and cybersecurity standards in Saudi Arabia. The platform facilitates the process of food waste sharing by enabling food waste listing, purchasing, payment, and delivery. Location and product filtration options enhance user experience, while multilingual support in Arabic and English caters to diverse user needs. Data security and privacy measures are implemented to safeguard user information,

and location data collection ensures efficient service delivery. The onboarding process assists users in platform usage, and delivery service options are available for convenience. Integration with the current retail management system streamlines operations, while performance analytics features offer valuable insights for optimization. Alerts and notifications for products nearing expiry dates enhance food waste management, and gamification tools encourage user participation and engagement. Including a mobile application extends platform accessibility, while integration with social media platforms enables generating awareness. Engagement mechanisms and embedded chatting services foster user interaction and collaboration, enhancing the overall platform experience.

In terms of scalability, the platform's architecture, cloud-based infrastructure, RESTful APIs, and mobile application development all play key roles in ensuring that the platform can grow and adapt to accommodate a more extensive user base and increasing data volume. By prioritizing these long-term scalability considerations, the digital platform is equipped to address expansion needs and remain practical and relevant in the future landscape of sustainability efforts in Saudi Arabia.

The identified problems, requirements, and design served as a foundation for the evaluation phase. The sub-research question that guided the **evaluation** phase is: *(To what extent does the digital platform address the identified problem and requirements).* To answer this question, we conducted an alignment analysis between the identified requirements and challenges and the final design.

The evaluation against requirements, under Table 14, demonstrated that the digital platform effectively meets most of the specified requirements. The platform provides a user-friendly mobile interface, food waste listing, searching, and reusing functionalities, and it ensures data security and privacy in compliance with Saudi regulations. Additionally, it supports scalable architecture, multilingual capabilities, and various features such as analytics, notifications, and gamification to enhance user engagement and operational efficiency. The cross-checking of requirements against design components confirmed that the platform addresses the key needs of retailers, government, technology providers, and consumers.

An area for improvement is finding an innovative way to connect the platform with food waste processing machines through companies specializing in food waste composting machines. Integrating such a process will help facilitate food waste more efficiently and enhance the current design to facilitate the R9:Recover, R7:Repurpose, and R3: Reuse, which we detailed in Chapter One and presented in Figure 1.

The evaluation against challenges, under Table 15, highlighted the platform's strengths and areas for improvement in addressing the identified issues. The platform successfully meets the challenges related to inventory control, waste categorization, waste measurement, and stakeholder collaboration. It partially addresses challenges such as awareness generation, efficient technologies, cultural practices, and waste processing. The platform's design effectively facilitates the sharing of food waste, enabling the reuse and repurposing of food waste. However, certain challenges, such as policy formulation and infrastructure development, are beyond the platform's scope and require governmental intervention.

This evaluation confirmed that the digital platform design aligns with its objectives and stakeholder requirements. It provided a robust, secure, and scalable digital platform that can contribute to reducing food waste in the eastern province of Saudi Arabia. The insights gained from this evaluation can guide further refinements and enhancements to ensure the platform's long-term success and sustainability.

We have developed two **business models** to ensure that the proposed digital platform design is feasible to implement and address the cost-effective requirement. The sub-research question that guided this is: *(What business models fit a digital platform aimed at reducing food waste at the retail stage in the Eastern Province of Saudi Arabia?).* We have utilized a business model canvas and conducted a SWOT analysis to answer this question. We have completed two business models, for-profit and non-profit, available under chapter seven.

The for-profit model uses multiple revenue streams, such as subscription fees, transaction fees, advertising, and data monetization, to ensure the platform's sustainability. These funds are reinvested into platform development and

marketing to attract more users. Key partnerships with retailers, logistics providers, and technology companies are crucial for delivering reliable food listing, delivery, and transaction processes, enhancing user satisfaction. The platform effectively addresses the needs of retailers, consumers, and charities, making it a viable solution for reducing food waste while generating profit. The for-profit model may struggle with prioritizing profit over social impact, corporate taxes reducing potential reinvestment, meeting regulations, and generating enough income from food waste transactions. It's important to address these weaknesses for financial sustainability.

On the other hand, the non-profit model focuses on social impact and community engagement. It relies on grants, donations, and sponsorships to fund its operations, which can be less predictable than revenue from business activities. Building strong partnerships with retailers, charities, and community groups is crucial for maximizing the platform's reach and impact. Awareness campaigns and educational programs are essential for raising public awareness about food waste and encouraging community involvement. The non-profit model benefits from a strong volunteer base and collaborations with academic institutions, helping to maintain low operational costs while maximizing social impact. However, this model has its weaknesses. It heavily relies on donations and grants, which may be inconsistent and limited, leading to financial instability. The revenue streams are fewer than for-profit models, potentially affecting the platform's scalability and sustainability. Operational constraints also arise due to restrictions on how funds can be used, limiting flexibility in operations and innovation. Attracting and retaining skilled professionals can be challenging due to potentially lower salaries and benefits than for-profit organizations.

Choosing between these models depends on the organization's goals and the preferences of its stakeholders. The for-profit model may attract investors and scale more rapidly, while the non-profit model can build stronger community ties and emphasize social good. Ultimately, both models can effectively reduce food waste and promote sustainability, contributing to a more circular economy in Saudi Arabia. However, we lean into the non-profit model to ease the value proposition for both retail and consumers through offering free services, at least for core functionalities.

8.1 Answering Main Research Question

We have developed a digital platform design that integrates key components and functionalities tailored to address the specific challenges of food waste management within the retail sector of the Eastern Province of Saudi Arabia. The design was developed using the ArchiMate framework, which organizes the platform architecture into strategic, business, application, and technology layers, ensuring a comprehensive and systematic approach.

The **strategic layer** of the platform is grounded in the principles of the circular economy and the objectives of Saudi Arabia’s Vision 2030. The platform is designed with a clear vision and mission focused on reducing food waste by facilitating its redistribution and repurposing. Strategic goals such as minimizing food waste at the retail stage, enabling the reuse and recycling of food waste, and contributing to environmental sustainability are central to the platform’s design. The platform also includes Key Performance Indicators (KPIs) that measure success in areas like food waste reduction, user satisfaction, and regulatory compliance.

The **business layer** outlined the roles and interactions of key stakeholders, including retailers, consumers, platform operators, and logistics providers. It defined core functions such as food waste listing, search, transaction management, and delivery coordination, all of which are essential for the platform’s operation. The business processes are designed to be user-centric and efficient, allowing retailers to easily list surplus food items and consumers to access these items for purchase or donation.

The **application layer** focused on delivering the platform’s functionalities through a user-friendly interface (UI) that supports multiple languages, including Arabic and English, to cater to the diverse population of the Eastern Province. The platform incorporates essential features such as secure user authentication, food waste categorization, search and filter options, payment processing, and transaction management. The platform also integrates performance analytics, notifications for products nearing expiration dates, and gamification elements to enhance

user engagement and promote sustainable practices. RESTful APIs ensure seamless integration with external services, including payment gateways and logistics providers.

The **technology layer** provided the necessary infrastructure to support the platform's scalability, security, and reliability. A cloud-based solution is employed, offering elastic resource management and cost efficiency, which are crucial for handling varying levels of user activity. The hybrid database approach, combining relational and NoSQL databases, ensures that the platform can effectively manage both structured and unstructured data, maintaining data integrity and availability while complying with Saudi Arabia's data protection regulations.

In conclusion, the proposed digital platform design aligns closely with the circular economy strategies by enabling the R9:Recover, R7:Repurpose, R3: Reuse, and R2: Reduce of food waste in the retail sector. It addresses the specific challenges identified in the Eastern Province of Saudi Arabia by providing a secure, scalable, and user-friendly solution that integrates seamlessly with existing retail systems. By facilitating the efficient management and redistribution of food waste, the platform contributes to the broader goals of environmental sustainability and resource efficiency outlined in Saudi Arabia's Vision 2030. This design is a practical and innovative model for leveraging digital technology to tackle food waste, offering a replicable solution that can be adapted to similar contexts within and beyond the region.

8.2 Societal Contribution

The societal contributions of this research are profound, particularly in the context of Saudi Arabia's growing emphasis on sustainability and waste reduction. The digital platform developed through this research provides a practical solution to the problem of food waste in the retail sector, supporting national goals related to food security and environmental sustainability. By enabling the redistribution of food waste to consumers, including farmers, the platform promotes circular economy principles, facilitating the repurposing of food waste for animal feed and composting. This reduces the amount of waste sent to landfills and supports local agricultural practices. The platform's user-friendly mobile interface and multilingual support enhance accessibility for a diverse user base. At the same time, the integration of educational and awareness-generating features helps shift cultural attitudes towards more sustainable practices. The platform strengthens community involvement in sustainability initiatives by fostering collaboration among stakeholders, including retailers, consumers, technology providers, and government entities.

The digital platform developed through this research aligned with Saudi Arabia's Vision 2030, which emphasized sustainable development and resource efficiency. By facilitating the recover, reduction, reuse, and repurposing of food waste, the platform supported the nation's goals of fostering a circular economy and enhancing environmental sustainability. Additionally, the platform's integration with digital technologies aligns with Saudi Arabia's digitalization efforts, a core component of the Vision 2030 initiative. The platform exemplified how digital innovation could be harnessed to solve pressing environmental issues by leveraging cloud infrastructure, RESTful APIs, and data analytics. This enhances the country's technological landscape and demonstrates a scalable model that could be adapted and implemented in other regions facing similar challenges.

8.3 Scientific Contribution

This research made scientific contributions by addressing the knowledge gap identified in the literature review under chapter one, which highlighted the insufficient understanding of diverse stakeholder perspectives and requirements, the limited exploration of technological integration, and the lack of new business models to support food waste initiatives. By employing this, we have designed a digital platform tailored to the specific needs and challenges of relevant stakeholders aiming at reducing food waste in the Eastern Province of Saudi Arabia.

The research closed the knowledge gap by incorporating a detailed problem analysis, design approach, and design science research (DSR). We also integrated stakeholder perspectives and requirements through eight interviews. Summaries are available under Appendix B. The digital platform's functions and the integration of multiple

technologies throughout the design demonstrated the potential for innovative technological solutions in food waste management that are in alignment with the identified circular economy strategies. Additionally, the study explored and proposed new business models, including both non-profit and for-profit frameworks, to ensure the platform's sustainability and effectiveness.

8.4 Limitations

Despite its contributions, the research has several limitations that must be acknowledged. The first limitation is the small number of interviews conducted for each stakeholder, which might lead to bias. Even though the number we used for the interviews was small, we ensured that we conducted the interviews with retail owners and digital platform subject matter experts who have extensive experience within the eastern province of Saudi Arabia. While stakeholder interviews provided valuable insights, the platform's practical implementation and real-world testing are necessary to fully validate its effectiveness. Additionally, the scope of the research was limited to the Eastern Province of Saudi Arabia, which may limit the generalizability of the findings to other regions with different socio-economic contexts.

8.5 Future Research Topics

Future research should focus on the digital platform's practical implementation and real-world testing to validate its effectiveness and identify areas for further improvement. Studies assessing the platform’s impact on food waste reduction and sustainability practices over time would provide valuable insights. Expanding the scope of research to include different regions and cultural contexts would help generalize the findings and refine the platform for broader applicability. Furthermore, addressing the out-of-scope aspects of this research includes tackling the challenges related to policies, regulations, and infrastructure by designing effective policies and infrastructure networks. Finally, Investigating the long-term sustainability of both non-profit and for-profit business models in varying economic climates would provide a more comprehensive understanding of the most viable approach for scaling the platform.

8.6 Recommendation for Implementation

For the implementation, it is important to transition from theoretical frameworks to practical applications. This involves conducting pilot tests and real-world deployments to gather valuable feedback from users and stakeholders. Engaging in continuous refinement and iteration based on this feedback will ensure the platform's functionality aligns with user needs and market conditions. Expanding the scope of implementation beyond the Eastern Province to other regions will help assess the platform's adaptability and effectiveness in diverse socio-economic contexts.

Collaborating closely with retailers and consumers is essential to ensuring the platform's functions meet their needs. Regular engagement with these key stakeholders through workshops, surveys, and focus groups will provide insights into areas for improvement. This collaborative approach will help customize the platform’s features, such as user interface design, to better serve the needs of retailers and consumers.

For the non-profit model, exploring hybrid funding strategies, such as partnerships with private sector entities or grant opportunities, can enhance sustainability and reduce dependency on singular funding sources. Implementing compliance measures and maintaining transparent communication with stakeholders in the for-profit model will help navigate public perception and regulatory challenges. Additionally, incorporating real-time data analytics and performance monitoring will facilitate proactive adjustments, ensuring the platform remains responsive to evolving market dynamics and stakeholder expectations.

By focusing on these implementation aspects, including close collaboration with retailers and consumers, the digital platform can be better positioned to achieve its objective of reducing food waste while fostering a sustainable circular economy.

8.7 Alignment with COSEM

The MSc CoSEM (Complex Systems Engineering & Management) tackles large and intricate socio-technical problems. This involves blending technical, institutional, economic, and social knowledge to develop comprehensive solutions. This requires using various methods and tools to creatively design and evaluate the impact of technical solutions within organizations. The approach combines effective management strategies with system engineering methods, allowing us to navigate the complexities of technology and manage stakeholders with diverse interests. The I&C (Information & Communication) track tacks I&C-related issues, such as the digital platform proposed in this report. The research objective aligns seamlessly with the objectives of the COSEM program, integrating design and engineering components to address complex challenges in the food sector's circular economy. With a clear emphasis on technology, the research delves into the technical intricacies of designing a digital platform to reduce food waste. The selected systematic (DSR) approach focuses on dealing with complex design and engineering issues and resonates with COSEM's focus on addressing such challenges methodically. By utilizing COSEM methods, tools, and techniques, the research ensures that the design aligns with the program's goal of designing and assessing the impact of technical solutions in an integrated approach. Furthermore, diverse stakeholders' values and requirements in public and private domains align with addressing broader societal concerns within the COSEM program.

8.8 Personal Reflection

Reflecting on the journey of writing this report, I find myself considering the complexity and depth of the research process. Undertaking this project has been both a challenging and rewarding experience, demanding rigorous analysis, critical thinking, creativity, and perseverance. The subject of food waste reduction within the context of the circular economy in Saudi Arabia posed a unique challenge, requiring a multidisciplinary approach that spanned technology, sustainability, business models, and societal impact.

Throughout the research and writing process, I was continually reminded of the importance of a structured and methodical approach to problem-solving. Applying the Design Science Research (DSR) methodology provided a robust framework, guiding the project from the initial problem identification to the design and evaluation of the digital platform. This methodology helped organize my thoughts and efforts and ensured that the outcomes were rigorously tested and aligned with the identified requirements and objectives.

One key reflection from this experience is the value of stakeholder engagement. The insights gained from interviews with key stakeholders were invaluable in shaping the design of the digital platform. These interactions underscored the importance of considering diverse perspectives and the practical realities faced by those who would ultimately use the platform. It became clear that successful design is not just about technical excellence but also about understanding and addressing the needs and concerns of the end-users.

Another significant aspect of this journey was the constant need to balance theoretical research with practical application. While the literature review and theoretical frameworks provided a solid foundation, the real challenge lay in translating these into a functional and effective digital platform. This process highlighted the importance of adaptability and the willingness to iterate and refine ideas based on new information and feedback.

As I reflect on the completion of this report, I feel a sense of accomplishment in having navigated the complexities of the project and produced a comprehensive and well-rounded piece of research. The experience has deepened my understanding of the interplay between technology, business, and society.

In conclusion, this project has not only expanded my academic and professional knowledge but has also enriched my perspective on the role of research in driving positive change. It has been a transformative experience that has equipped me with new skills and insights, and I look forward to applying these in future challenges.

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Appendices

Appendix A: Interview Questions

Table 17: Problem Identification Interview Questions

#	Question
1	What do you know about food waste management and its impact?
2	Are you currently involved in any food waste reduction efforts or initiatives? And are you aware of any?
3	What are your main challenges in managing and reducing food waste in your business?
4	What existing policies or regulations are you aware of that hinder or facilitate efforts to reduce food waste in the retail sector?
5	What infrastructure and logistical limitations do you encounter or imagine encountering when participating in food waste management circularity initiatives in your retail operations?
6	Have you experienced any barriers or challenges in integrating technology to address food waste in your retail business?
7	How do cultural attitudes toward food waste influence behaviors and practices in the retail sector?
8	What incentives are you seeking to implement food waste reduction strategies in your retail business?

Table 18: Requirement Identification Interview Questions (Retail)

#	Questions: Retail Business Owner
1	What features or functionalities would you like to see in a digital platform? Make sure to include any governmental requirements if you are aware of any.
2	What are your expectations regarding the digital platform's user interface?
3	What integrations or compatibility requirements must the platform have to integrate with your system or other systems or technologies?
4	What specific data management & security requirements must we address?
5	How willing are you to pay for a subscription to the digital platform? Please elaborate.

Table 19: Requirement Identification Interview Questions (Technology Provider/ Subject Matter Expert)

#	Questions: Technology Provider/ Subject Matter Expert
1	What features or functionalities would you like to see in a digital platform? Make sure to include any governmental requirements if you are aware of any.
2	What are your expectations regarding the digital platform's user interface?
3	What integrations or compatibility requirements must the platform have to integrate with your system or other systems or technologies?
4	What specific data management & security requirements must we address?
5	Can you describe the services or functionalities requiring API integration?
6	Can you describe feasible business models?

Table 20: Requirement Identification Interview Questions (Consumer)

#	Questions: Consumer
1	What features or functionalities would you like to see in a digital platform? Make sure to include any governmental requirements if you are aware of any.
2	What are your expectations regarding the digital platform's user interface?
3	How willing are you to pay for a subscription to the digital platform? Please elaborate. ?

Appendix B: Interview Summaries

- Interview # 1: (Restaurant)

The interviewee is driven by the satisfaction of ensuring that food is not wasted and is either processed or shared, indicating a strong commitment to reducing food waste. While not primarily seeking monetary incentives, they want to cover at least the processing costs of managing food waste. Cultural attitudes, such as a culture of generosity leading to over-ordering in social settings and the religious prohibition against food waste, are highlighted as influential factors shaping behaviors and practices in the retail sector. The interviewee's current efforts to reduce food waste include collaborating with local farmers by sharing leftover bread for livestock feed. The challenges mentioned encompass the dynamic nature of customer volumes impacting forecasting accuracy and the potential for human errors like over-seasoning dishes, resulting in avoidable waste. Despite the absence of specific policies or regulations governing food waste management in the retail sector, the interviewee recognizes the importance of employee training and system integration to address food waste effectively. Moreover, they stress the need for seamless technology integration into existing systems to streamline food waste management processes within the restaurant, reflecting a forward-looking approach to sustainability practices.

- Interview # 2: (Café)

The interview delved into the multifaceted landscape of food waste management in Saudi Arabia. The interviewee highlighted the challenges faced in integrating technology for recycling processes, citing logistical hurdles like distant garbage bins and the need for specialized devices for waste segregation. He also discussed the potential incentives for food waste reduction, including non-monetary rewards like municipal certifications for compliance with regulations, which could boost businesses' recycling-friendly image. The conversation delved into the cultural attitudes towards food waste in Saudi Arabia, noting the balance between religious reverence for food and the lack of financial impact on individuals, which may lead to less attention towards waste reduction. The interviewee also shared insights on existing initiatives like the Baraka app, which allows users to purchase leftover food from local bakeries at discounted prices, showcasing innovative solutions in the sector. Additionally, the interview touched upon the challenges faced in managing food waste within businesses, emphasizing the need for clear and efficient processes to streamline waste management practices. Lastly, the discussion highlighted the lack of awareness about existing policies and regulations related to food waste management, underscoring the necessity for clear guidelines and increased promotion to drive effective implementation and sustainability in the retail sector.

- Interview # 3: (Bakery)

The interview reveals a lack of clear guidelines and regulations regarding food waste management, with efforts to address the issue being voluntary as municipalities and government agencies do not enforce rules. Current initiatives include providing leftover food to employees, separating waste for animal feeding, and encouraging customers to take leftovers, with a critical challenge being allocating resources for waste management. The absence of policies and regulations in the retail sector hinders structured efforts to reduce food waste, emphasizing the necessity of enforced regulations. Infrastructure and logistical limitations, such as the lack of support from municipalities or third parties for waste collection, pose operational challenges. Integrating technology for food waste management is seen as beneficial but may require additional work, with the interviewee expressing a willingness to adapt to changes despite temporary disruptions. Incentives for implementing food waste reduction strategies include the potential for certification as a sustainable business, which could lead to further governmental incentives. Cultural attitudes towards food waste play a significant role in shaping behaviors and practices in the retail sector, with the availability of food sometimes leading to taking it for granted, balanced by ethical considerations that prompt self-initiated waste management efforts.

- Interview # 4 (Owner/ Operations Manager)

The interviewee highlighted the importance of integrating the digital platform with the current point of sales system, incorporating payment and delivery functions, generating analytics reports on food waste, and enabling alerts for nearly expired items. They emphasized the need for a simple interface that does not require extensive employee training. While specific technologies for value addition were not mentioned, data management and security were expected to comply with governmental requirements. The interviewee desired a business model for effective food waste management without additional costs, preferring a win/win situation. Subscription models were deemed challenging unless mandated by the government, emphasizing the significance of cost-effectiveness for the business.

- Interview # 5 (Digital Platform Owner/COO/SME)

The interview is conducted with the founder and COO of a digital platform company specializing in providing retail sectors with all their operation needs, including daily groceries. The interview outlines key requirements for the digital platform, emphasizing features, integrations, data management, security, and business models. The platform should prioritize user-friendliness, language flexibility, integration with existing systems to streamline processes, and automation to reduce manual tasks. Data management and security requirements include compliance with privacy regulations, clear privacy policies, and ethical practices to prevent data sharing across platforms. The platform should also focus on building Restful APIs compatible with the Laravel framework to add value. For the business model, a subscription-based SAS model is recommended for sustainability, ensuring value for retail and tech providers while addressing funding challenges for non-profit models.

- Interview # 6 (Digital Platform Owner/CEO/SME)

The interview is conducted with the founder and owner of a digital platform company specializing in connecting home business owners with consumers. The Integration requirements emphasize the need for compatibility with other systems, ensuring mutual data fields and encrypted connections, mainly using HTTPS for secure data transfer. Data management and security requirements include recommendations for obtaining ISO quality management and information security certifications to enhance trust and credibility. The document also highlights the importance of user-friendly features such as traceability of logistics and products, a rating and review system for user engagement, and compliance with governmental regulations, including data encryption and hosting servers within Saudi Arabia. Technological recommendations include React Native for mobile applications, React JS for web apps, API integrations for chat services, government data retrieval, two-factor authentication, push notifications, and map integration. Feasible business models are briefly touched upon, suggesting a subscription-based business model.

- Interview # 7 (Digital Platform Owner)

The interview was conducted with a cofounder and owner of a digital platform delivery app that serves retail businesses. The required key functionalities include a registration function, embedded communication for chatting, and user location data. This information will be needed to facilitate the integration of the delivery. Data management and security requirements emphasize compliance with delivery regulations if to operate as a delivery platform; however, since this is not the case, compliance with the server location in Saudi Arabia is the only requirement. API integration is necessary for live tracking services, and feasible business models include commission-based revenue from food waste, selling waste through the platform, and consumer subscription fees.

- Interview # 8 (Consumer/ Farm owner)

The farm owner expressed the need for a digital platform to better manage food waste and ensure good animal welfare by segregating food types for different animals to save time and prevent food damage. The desired functionalities include segregation of food, search options by location or category, and delivery service with drop-off timing selection. The user interface should be user-friendly, with a preference for a mobile application over a web-based platform. The owner mentioned a willingness to pay a reasonable amount for subscription fees.

Appendix C: Consent Form

We are starting an interview for my master's degree research study graduation project titled (Digital Platform for Sustainable Food Future: Designing a Digital Platform to Tackle Food Waste at Retail Stage in Saudi Arabia in alignment with Circular Economy Principles. We are conducting this study from the TU Delft in the Netherlands.

The purpose of this research study is to Design a Digital Platform to Tackle Food Waste at the Retail Stage in the Eastern Province of Saudi Arabia in alignment with Circular Economy Principles. It will take approximately 30 minutes to complete. The data will be used for the master's thesis graduation research project, which will include publication and teaching. We will ask you to answer questions regarding the current process of food waste management and design requirements for the digital platform.

The following questions are examples of what to expect during our interview:

- What do you know about food waste management and its impact?
- Are you currently involved in any (local/national) food waste reduction efforts or initiatives? And are you aware of any?

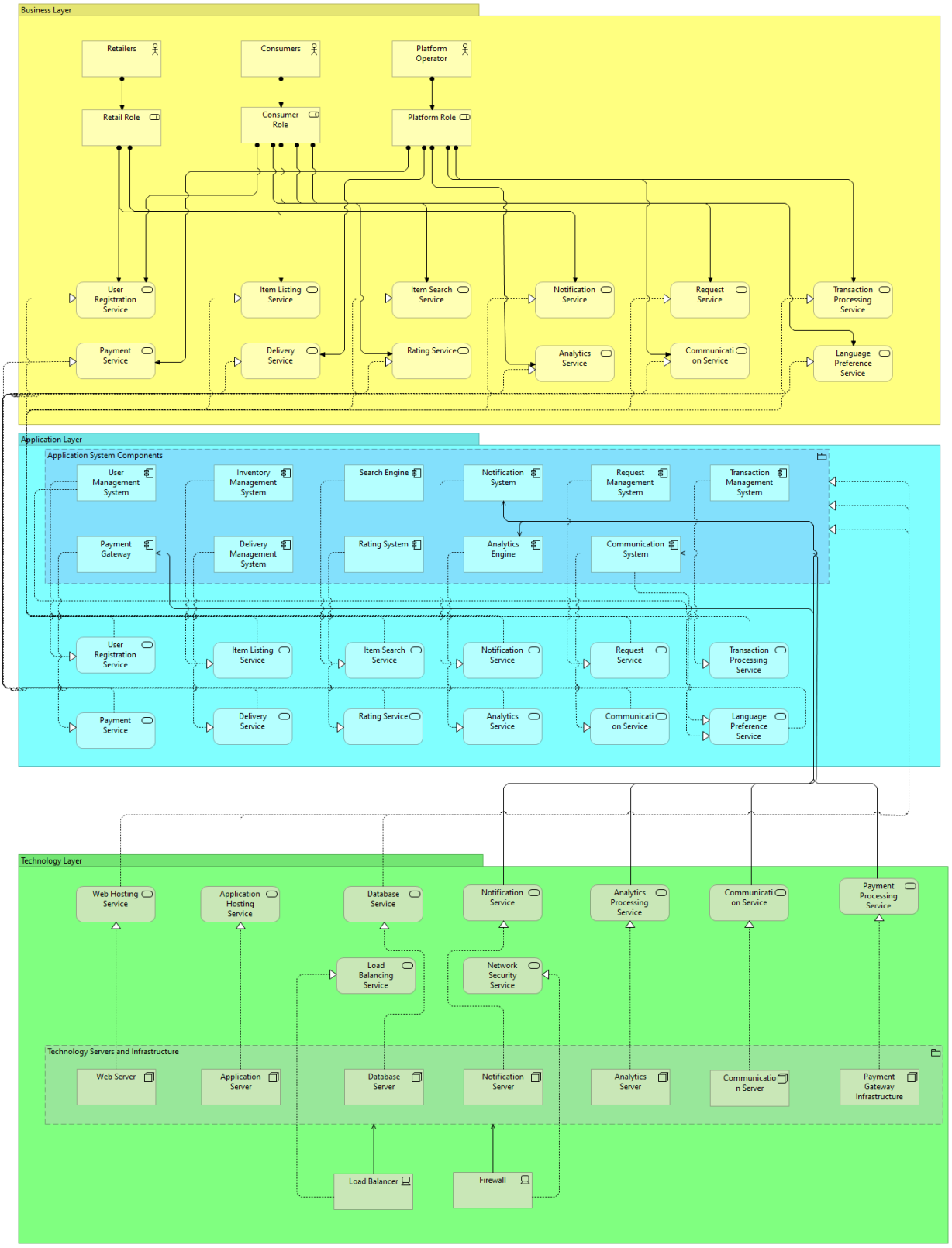
Your privacy and data security are our top priorities. As with any online activity, the risk of a breach is always possible. However, to the best of our ability, your answers in this study will remain confidential. We will minimize any risks by not collecting any personally identifiable information. Only job title, organization, and age range will be collected. All data will be stored in the TU delft database and only accessible to the research team. Data management will follow GDPR rules per the Netherlands' data management laws and comply with the Saudi Arabian data management laws. Survey data will be, at the latest, deleted two years after the project's completion. If you are interested, the research outcome will be shared with you upon completion of the research project.

We will produce an anonymous summary of this survey, which will be publicly available at the end of the MSc project. The personal data collected may be reused to support a scientific publication, and you will remain anonymous.

Your participation in this study is entirely voluntary. We respect your autonomy and understand that circumstances may change. You can withdraw at any time, and you are free to omit any questions that you do not feel comfortable answering. Your decision will not affect your relationship with us in any way.

By starting this interview, you agree to what we have mentioned above. Thank you for participating in our study, which will contribute to sustainability efforts.

Appendix D: The ArchiMate Model



Appendix E: Requirement, Challenges, and Design Connection

Table 21: Link Between Requirement, Challenges, and Design

Requirement	Challenges Addressed	Design Component
Provide a user-friendly interface	Efficient Technologies, Stakeholder Collaboration	User Interface (UI)
Be cost-effective	Economical Concerns, Efficient Technologies	Cloud Infrastructure, Business Model
Authenticate users before granting access	Efficient Technologies, Safe Environment	User Authentication
Facilitate the process of food waste	Waste Processing, waste Measurement, Stakeholder Collaboration	List & Request Module
Enable waste categorization listing	Waste Categorization, Waste Processing	Inventory Management Dashboard
Must align with data regulation and cybersecurity in Saudi Arabia	Efficient Technologies, Safe Environment	Data Management and Presented Required Integrations
Support approved payment gateways	Safe Environment, Efficient Technologies	Payment Gateway Integration
Allow filtration by location and product	Efficient Technologies	Search and Filter Module
Utilize RESTful APIs	Efficient Technologies, Stakeholder Collaboration	RESTful API Integration
Support online payment functionality	Efficient Technologies	Online Payment System
Have a scalable architecture to handle a growing user base	Efficient Technologies, Economical Concerns	Scalable Cloud Architecture
Provide multilingual support, including Arabic and English	N/A. Function needed for the utilization of the platform and increasing userbase	Multilingual Support System
Ensure data security and privacy	Efficient Technologies, Safe Environment	Data Security Measures
Collect location information for retail businesses and consumers	Efficient Technologies.	Location Mapping System
Offer training and support for platform usage	Efficient Technologies, Stakeholder Collaboration	Training and Support System
Offer delivery service options	Waste Processing, Efficient Technologies	Delivery Integration
Integrate with the current business management system	Efficient Technologies, Stakeholder Collaboration	Business Management System Integration

Include performance analytics features	Efficient Technologies, Stakeholder Collaboration, Waste Measurement	Performance Analytics Dashboard
Send alerts and notifications for products approaching expiry dates	Inventory Control, Efficient Technologies	Notification/Alert System
Include incentive programs to encourage user participation	Cultural Practices, Stakeholder Collaboration, Incentives	Gamification and Incentive System
Provide a mobile application	Efficient Technologies, Stakeholder Collaboration	Mobile Application
Support the segregation of food waste	Waste Categorization, Waste Processing, Waste Measurement	Waste Segregation Module
Generate awareness about food waste	Awareness, Cultural Practices	Awareness Campaign Integration
Incorporate engagement mechanisms	Awareness, Cultural Practices	Engagement and Collaboration Tools
Should include embedded chatting service	Stakeholder Collaboration, Efficient Technologies	Communication System (Embedded chatting)