**System Dynamics of Food Waste in Dutch Gastronomy -
Exploring Mitigation Practices**

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ABSTRACT

Food waste continues to challenge the Dutch gastronomy sector, driven by inefficiencies, consumer behaviour, and logistical hurdles. This research adopts a systemic approach, using qualitative insights and a causal loop diagram (CLD) to analyse the interconnected dynamics of food waste. By exploring the potential of digital innovations and other collaborative approaches, it offers practical solutions rooted in circular economy principles. The study addresses key research gaps and delivers actionable recommendations for restaurant owners, policymakers and sustainability advocates, aiming to promote resource-efficient practices and supporting a more sustainable gastronomy sector in the Netherlands.

Keywords

System Dynamics, Food Waste, Gastronomy Sector, Sustainability Practices, Causal Loop Diagram

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1. INTRODUCTION

1.1 Problem Statement

Food waste is a major global issue, with an estimated one billion tons discarded worldwide in 2022 (UNEP, 2024). The urgency of this problem is highlighted by projections that the global population will reach nine billion by 2050, requiring a significant increase in food production. The Food and Agriculture Organization (FAO, 2015) defines food waste as the disposal or repurposing of food that is intended for human consumption. Although private households are the primary contributors, the food service sector - which includes businesses that serve food outside the home - accounts for 28% of food waste globally (Sigala *et al.*, 2025). In the Netherlands alone, approximately 2.5 million tons of food are wasted annually, underlining the need to address the current inefficiencies (Bos-Brouwers *et al.*, 2024). This thesis focuses specifically on food waste within the Dutch gastronomy sector, encompassing restaurants across various formats, from fast food to fine dining.

Beyond its direct impact, food waste has broader systemic effects. Environmentally, it contributes to greenhouse gas emissions associated with production, transport, and waste management (Babbitt *et al.*, 2022). It is responsible for approximately 8-10% of total global emissions, making it a critical driver of climate change (UNEP, 2024). From an economic perspective, it adds further pressure on businesses operating in a competitive sector (Talukder *et al.*, 2024). The social consequences are concerning, reflecting deeper issues of inequality. The FAO (2019) points out that the global volume of wasted food could feed the estimated 800 million hungry people four times over, a situation which is difficult, if not impossible, to morally justify.

Despite growing academic attention, literature often treats food waste as a linear problem, focusing on isolated causes or solutions. For instance, while digital solutions have shown promise and become popular among the current generation, their implementation often overlooks barriers such as user adoption resistance, technological integration issues, and regulatory alignment (Kanwal *et al.*, 2024). Additionally, the logistical and operational challenges unique to the gastronomy sector, such as storage constraints and food safety concerns highlighted by Gurrala & Hariga (2022), are not adequately addressed in current studies. A spatial gap is also

evident, as there is relatively little focus on food waste in gastronomy in the Netherlands, despite its prominent interest in sustainability, consumer behaviours, and culinary practices (Filimonau *et al.*, 2020).

Most notably, current studies rarely adopt systemic methodologies that address food waste as an interconnected issue. This thesis addresses this gap by employing System Dynamics (SD), a methodological approach designed to analyse the behaviour of complex systems over time. By adopting a systems-based perspective, SD allows researchers to visualise the interactions and dependencies between different system components (Naugle *et al.*, 2023). When applied to food waste, this perspective goes beyond identifying isolated drivers; it reveals how elements such as consumer awareness, supply chain logistics, and regulatory policies are interconnected, collectively influencing waste generation.

Tackling food waste is not only about addressing environmental, economic and ethical concerns; it also offers an opportunity for sustainable entrepreneurship. Positioned within this context, this research focuses on understanding how food waste is generated within the Dutch gastronomy sector and explores effective strategies to minimise it. Sustainable entrepreneurship emphasises the integration of environmental, social, and economic values into business practices (Avelar *et al.*, 2023). A holistic perspective of waste generation in Dutch restaurants fits well within this framework, offering potential to reduce environmental impact, boost economic resilience, and encourage more responsible consumption.

1.2 Research Objectives and Contributions

This thesis aims to develop a systemic understanding of food waste in the Dutch gastronomy sector by identifying key drivers, evaluating current mitigation practices, and examining the role of digital technologies. Using a SD perspective, the study aims to explore how different factors are interconnected in driving waste generation, with the goal of identifying practical insights and tackling existing inefficiencies. By visualising these dynamics, the research highlights key areas where effective changes can make a real impact and reduce waste sustainably.

The target audience consists of three main stakeholder groups. For restaurant owners, it provides practical suggestions to improve operations, reduce food waste, and lower related costs, helping

to build more efficient and sustainable businesses. For policymakers, it provides evidence-based recommendations that can support adaptive regulations. For sustainability advocates and researchers, the study contributes a systems-based framework that links empirical insights with theoretical advancement in circular gastronomy. Essentially, this thesis will provide valuable insights for changemakers within the sustainability realm.

This research explores three objectives. Firstly, it examines the interconnected drivers of food waste, focusing on how operational, behavioural, and institutional factors shape waste generation within restaurants and food service settings. Building on existing research, including Thyberg and Tonjes (2015) and Filimonau *et al.* (2020), it identifies these drivers as critical points of intervention. Secondly, it investigates how stakeholders - including restaurant owners and kitchen staff - engage with certain waste reduction practices, highlighting the complexities of adoption, behavioural shifts, and logistical barriers.

Thirdly, to deepen this understanding, the study aims to create a CLD that illustrates how various factors interact and contribute to waste generation in gastronomy. These diagrams, an important tool in SD, help visualise the connections between elements, highlighting how changes in one area can influence others (Barbrook-Johnson *et al.,* 2022). The goal is to provide a clear representation of these relationships, making it easier to identify key areas for targeted waste reduction strategies.

Ultimately, the study is guided by the following research question:

What are the system dynamics of food waste in the Dutch gastronomy sector, and which mitigation practices could help reduce it?

2. THEORY
2.1 Literature Review on Food Waste Drivers

Food waste in the gastronomy sector is a complex and multifaceted issue, shaped by a combination of operational, regulatory, cultural, and technological factors (Heikkilä *et al.,* 2016). While existing research offers valuable insights into these dimensions, many studies approach

the topic through a linear lens, focusing on individual drivers rather than exploring how they interact within the broader food system.

At a systemic level, poor forecasting and a lack of coordination across supply chains are frequently highlighted as root causes. Thyberg and Tonjes (2015) argue that inefficiencies in planning and distribution often lead to overproduction and spoilage, particularly in environments where demand fluctuates. Canali *et al.* (2016) add that cultural and institutional norms - such as consumer expectations around abundance and aesthetic food standards - also contribute significantly to waste by reinforcing practices that undervalue surplus food.

Understanding the primary drivers of food waste in the gastronomy sector requires looking at both supply and demand dynamics. On the supply side, issues such as overproduction, inefficient inventory management and limited internal coordination significantly contribute to waste generation (Filimonau *et al.*, 2020). Operational inefficiencies, such as incorrect portioning and inadequate forecasting, affect these issues. On the demand side, consumer behaviour such as excessive ordering and low awareness of food waste intensifies the problem (Canali *et al.*, 2016).

Within the gastronomy sector itself, day-to-day operational practices play a central role. Research by Filimonau *et al.* (2020) highlights portion sizing, complex menus, and poor stock rotation as key contributors to food waste in restaurants across European countries, including the Netherlands. Inadequate waste tracking systems, limited staff training, and a lack of managerial oversight further exacerbate the problem. These issues are often embedded in organisational routines that prioritise efficiency and speed over sustainability, making structural change more difficult (Sakaguchi *et al.,* 2018).

Although these studies highlight important challenges, much of the literature treats food waste as a series of isolated behaviours or outcomes. This fragmented perspective can obscure the broader, interconnected dynamics that shape waste generation. For example, Garske *et al.* (2020) explore regulatory barriers to food redistribution but do not examine how these intersect with logistical limitations such as storage or transportation gaps. Similarly, Bolwig *et al.* (2021)

emphasise the potential of digital solutions - such as inventory monitoring and food-sharing platforms - but provide limited insight into how such tools could be successfully implemented into the everyday realities of restaurant operations.

2.2 Foundations of System Dynamics

System dynamics (SD) is a theoretical and methodological approach for understanding complex systems. It focuses on how elements within a system influence each other over time through feedback loops, delays, and accumulations (Morecroft, 2020). Originally developed by Jay W. Forrester in the 1950s, SD was designed to help managers and policymakers understand how structural relationships within systems give rise to dynamic behaviour (Forrester, 1994).

At its core, SD views systems not as static collections of parts, but as evolving structures of interconnections. A central concept is the feedback loop: a closed chain of cause-and-effect relationships where a change in one variable eventually influences itself. These loops can be reinforcing, when change amplifies over time, or balancing, when the system seeks stability (Sterman, 2001). These feedback structures often give rise to patterns of growth, collapse or resistance that cannot be understood by examining individual events in isolation.

Another key feature of SD is its ability to represent non-linear, time-dependent behaviour (Gudlaugsson *et al.,* 2022). Unlike linear models that assume straightforward, proportional responses, SD accounts for delays and indirect effects (e.g. food waste levels, refrigerated stock) that influence future decisions. This makes it particularly suitable for complex, real-world challenges such as food systems, climate change, and organisational management (Tzachor, 2022).

Causal loop diagrams are a core tool within system dynamics, used to visualise how different factors in a system influence each other through feedback loops. Figure 1 illustrates how these loops operate in practice. This is an example from Barbrook *et al.* (2022), which shows the interplay between revenue generation, social action and organisational legitimacy. The arrows indicate causal relationships, while a "+" or "–" sign shows whether the effect moves in the same

or opposite direction. Loops with reinforcing feedback (R) amplify change, while balancing loops (B) seek stability.
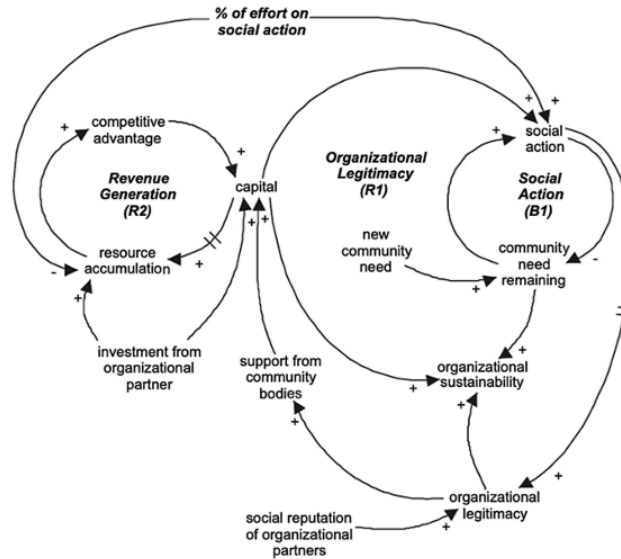

Figure 1: Example of a Causal Loop Diagram (Barbrook-Johnsen et al, 2022)

2.3 Application to the Gastronomy Sector

Although SD has increasingly been applied to food systems research, only a limited number of studies have employed it to explore food waste within food service environments. This section reviews two relevant system dynamics models that focus on food waste in hospitality contexts, and positions the thesis in relation to them.

Purwanto and Ardi (2023) present a causal loop model of food waste in the food service sector in Jakarta. Their diagram maps ten interconnected feedback loops, covering waste that occurs during storage, preparation, service, and after consumption. The model incorporates variables such as pricing strategies, consumer behaviour and donation systems in an effort to simulate the effects of different intervention scenarios. This approach provides a valuable view of food waste as a complex system shaped by both organisational practices and external influences. However, the model is designed primarily for simulation and scenario testing, rather than for understanding how internal decision-making within restaurants contributes to waste generation. Also, it is not

grounded in qualitative research, and its variables remain relatively generalised, offering limited insight into the routines and constraints of gastronomy businesses.

A broader, sustainability-focused causal loop model is presented by Buczacki *et al.* (2021), who develop a conceptual diagram to examine food waste within the Horeca sector through the lens of the UN Sustainable Development Goals. The Horeca sector refers to hotels, restaurants, and café/catering services (Di Pierro *et al*, 2022). The authors' model maps feedback structures related to procurement, menu planning, food preparation, consumer behaviour, technological adoption, and sustainability performance. While the model is not based on a single case study, it integrates systemic insights relevant to hospitality operations and highlights how food waste outcomes are shaped by both internal practices and external sustainability pressures. Unlike simulation models, it remains conceptual and primarily serves to identify high-level leverage points for reducing waste.

In contrast to simulation-focused frameworks (e.g. Purwanto & Ardi, 2023) or sectoral mappings such as Buczacki et al. (2021), the model developed in this thesis offers a grounded conceptualisation based on empirical data from Dutch restaurant practitioners. While prior models remain close to the operational level - detailing variables such as procurement, preparation, or consumer behaviour - they offer limited insight into the underlying structures or strategic opportunities for intervention. By contrast, this thesis takes a broader systems perspective that captures both routine practices and the reinforcing dynamics behind them. As such, it contributes a deeper understanding of how food waste is generated and where systemic leverage points for change may exist within gastronomy operations.

3. METHODS

3.1 Research Design

This research follows a qualitative design grounded in a constructivist epistemology, which assumes that reality is shaped by social interactions, cultural norms, and individual experiences (Cresswell, 2009). Rather than seeking universally applicable conclusions, the study aims to

understand how food waste is generated and managed within restaurants, by exploring how practitioners experience and navigate this issue in their everyday work. This approach is especially suited to studying food waste - a challenge shaped not only by operational choices but also customer behaviour, organisational routines, and broader societal expectations.

An exploratory and flexible approach was adopted, in the form of semi-structured interviews with restaurant staff and owners across the northern Netherlands. The open-ended format allowed participants to share their perspectives in their own words, while still guiding the discussion toward relevant themes. Thematic coding was applied to identify recurring patterns and practices. These were then interpreted from a systems-based perspective, drawing on concepts from SD. This analytical lens enabled a dynamic understanding of food waste, not as a fixed outcome, but as emergent properties from interconnected feedback processes within restaurants.

Overall, this design supported an in-depth investigation of not only what types of waste exist, but how and why they arise within the broader operational and societal systems of gastronomy. Figure 2 provides a visual overview of the research process, outlining the key steps from data collection and analysis to the final outcome.
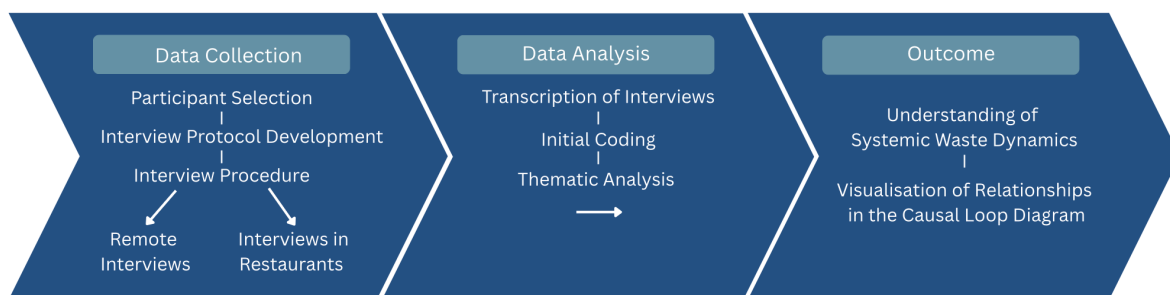

Figure 2: Visual Overview of the Research Design

3.2 Data Collection

3.2.1 Participant Selection

Semi-structured interviews were conducted with eleven participants, purposefully selected to represent diverse roles within food service environments. The selection process targeted two

main stakeholder groups: restaurant owners and managers, responsible for strategic decision-making and procurement, and kitchen and service staff, directly involved in food preparation, portioning, and waste disposal. It was ensured that various types of establishments were represented - fine dining, casual dining, and hybrid kitchens - to capture differences in food waste practices influenced by scale, menu design, and operational models. Hybrid kitchens, also known as "ghost" or "dark" kitchens, operate delivery-only concepts without having a traditional dine-in space (da Cunha *et al*., 2024).

Participants were recruited through initial outreach to restaurants in the northern Netherlands, supported by a strategic connection with an account manager at Thuisbezorgd, a leading Dutch food delivery platform. This collaboration provided access to a range of restaurants across the region. Invitations were sent via e-mail and telephone, accompanied by an information sheet outlining the study's purpose, the voluntary nature of participation, and assurances of confidentiality. To broaden the participant pool, snowball sampling was applied, relying on referrals from initial interviewees to connect with others who met the study criteria. Table 1 provides an overview of the anonymised interview participants, including their roles, restaurant types, and locations.

#	Interview	Role	Type of Restaurant	Location
1	A	Owner	Casual Mexican	Leeuwarden
2	B	Kitchen Staff	Gourmet Burgers	Groningen
3	C	Owner	Asian-European Fusion	Leeuwarden
4	D	Owner	Poké and Fusion Bowls	Leeuwarden
5	E	Kitchen Staff	Café with Seasonal Menu	Leeuwarden
6	F	Manager	Nikkei Fine Dining	Groningen
7	G	Kitchen Staff	French Fine Dining	Groningen
8	H	Owner	Fast Food Chain	Leeuwarden
9	I	Co-owner	Smashed Burgers & Ghost Kitchen	Leeuwarden
10	J	Co-owner	Pizza & Hybrid Ghost Kitchen	Leeuwarden
11	K	Owner	Carribbean Ghost Kitchen	Leeuwarden

Table 1: Overview of Interview Participants

3.2.2 Interview Procedure

The interviews were held between March and May 2025, with each session lasting approximately 30 to 45 minutes. Despite efforts to contact a wide range of restaurants, the response rate was lower than anticipated, extending the interview period. They were primarily held in person, however several took place via online platforms such as Zoom or by phone, depending on participants' availability and geographical accessibility. An interview guide was structured around three primary themes: operational drivers of food waste, current mitigation practices, and perceptions of barriers to reduction efforts. This multi-angle approach was chosen to explore not only how and where waste occurs, but also how it is currently managed and what prevents further reduction - enabling a more comprehensive view of food waste dynamics within gastronomy settings. Questions were open-ended to allow participants the freedom to elaborate on their experiences and to introduce new themes that may not have been initially anticipated. The flexibility of this semi-structured format facilitated deeper exploration into how food waste is generated and managed, and how these processes are influenced by both internal and external factors.

3.3 Data Analysis

To analyse the qualitative data collected through semi-structured interviews, a thematic analysis was conducted following Braun and Clarke (2006). This method includes familiarisation with the data, generation of initial codes, searching for themes, both reviewing and defining them, and producing the final report. It was chosen for its flexibility in interpreting experience-based insights while remaining grounded in the raw data. This made it especially suitable for exploring systemic dynamics within a complex organisational context such as the gastronomy sector.

Interviews were first transcribed using Otter.ai and then reviewed manually to become familiar with the content and context of participants' responses. Initial codes were generated inductively using Atlas.ti, with attention to recurring patterns, behaviours, and practices related to food waste. These codes were not predefined but emerged through iterative reading and reflection. The final codebook, which guided the development of themes, is included in the Appendix.

Once the main themes had been developed, the coded data were explored to identify potential causal relationships between different elements. For instance, several interviewees mentioned that when suppliers were flexible with deliveries, restaurants could order more accurately and reduce waste. Guided by the principles of SD (Sterman, 2001), the direction of influence was interpreted based on the described order of cause and effect, while the valence (positive or negative) referred to whether the influence contributed to an overall increase or decrease in food waste. These relationships were then grouped into broader patterns and served as the basis for constructing the CLD.

3.4 Ethical Considerations

Ethical considerations were essential to this research, ensuring participants' rights and privacy were protected throughout the study. All participants provided informed consent after receiving clear information about the study's purpose, data usage, and their right to withdraw at any time. Personal details were anonymised, and data is stored in a password-protected digital system, accessible only to the researcher. Participants could skip any questions they felt uncomfortable with. Efforts were made to include diverse stakeholder perspectives to promote fairness and balance. Transparency was ensured by communicating the study's goals and offering participants a summary of the results. The research plan, including consent forms and data management procedures, was approved by the Ethical Committee.

4. FINDINGS

4.1 Overview of the Findings

Interviews with restaurant staff and owners across the northern Netherlands revealed patterns in how food waste is created, managed, and reduced in practice. Although operations varied by restaurant, recurring themes became apparent - noticeable in areas such as inventory and forecasting management, as well as customer behaviour and perception.

Key thematic groups were developed through inductive coding: *Menu and Kitchen Design Strategies*, *Inventory and Forecasting Practices*, *Supplier and Delivery Relationships*, *Staff Engagement and Internal Routines*, Redistribution and *End-of-life Management*, and *Customer Behaviour and Perceptions*. Each theme included codes that reflected practical actions and systemic patterns discussed by participants. These themes form the analytical basis for the system model presented in the next section.

These themes shaped two systemic categories of food loss discussed across contexts: *shelf waste* and *plate waste*. Shelf waste refers to food discarded before reaching the customer, typically caused by poor inventory management or constraints in the supply chain. Plate waste, in contrast, arises after meals are served, often due to portion sizes, customer preferences, or mismatches between supply and demand. Attempts to reduce waste in one area - such as downsizing portions or limiting ingredients - can unintentionally increase it elsewhere. This interconnectedness highlights the need for a systems perspective. The next section explores these dynamics in more detail, using a CLD and interview insights to trace the structures, drivers, and dynamics of food waste generation.

4.2 Key Dynamics of Food Waste Generation in Dutch Gastronomy

Figure 3 illustrates the core system dynamics that emerged from the analysis, visualised through a CLD. The diagram is organised around the two primary food waste streams identified in this study: shelf waste and plate waste.

For visual clarity, blue arrows represent shelf waste dynamics and green arrows indicate plate waste. Some variables, such as *Policies and Regulation*, clearly contribute to both dynamics and are reflected accordingly.

Figure 3: Developed CLD

4.2.1 Shelf Waste Dynamics

A key dynamic that emerged from the data is the influence of *prior experience* on the internal processes that shape food waste reduction. Although prior experience is not a feedback variable within the system itself, it acts as a critical external driver that initiates a balancing loop involving *forecasting accuracy*, *inventory management*, and *shelf waste*.

Participants with extensive professional experience in gastronomy consistently demonstrated a stronger ability to anticipate customer demand. This link between professional experience and the ability to anticipate customer demand - coded as forecasting accuracy - was consistently described as an intuitive skill developed through time and repetition. In Interview A, the respondent explained: *"Over time, we got a feel for customer demand patterns. Sundays were our busiest days, so we prepped the most. Mondays and Tuesdays were typically slower, so we prepped less."* This intuitive forecasting was supported by Interview J, who emphasised

consistency developed over the years: *"And after four years of running restaurants, I have a pretty good idea of what's needed. That means we can order quite specifically."*

These examples suggest that forecasting accuracy can be shaped by various factors, with professional experience emerging as a particularly important contributor in this context. Participants frequently described it as a form of practical knowledge developed through routine and repetition. Once forecasting becomes more accurate, it enables tighter and more controlled *inventory management* - another core theme coded across interviews. With better forecasts, restaurants can order only what is needed, reducing overstocking and limiting the chances of food spoiling before use.

In Interview J, this was made explicit: *"That means we can order quite specifically. It almost never happens that we end up with leftovers."* Interview C also confirmed the same relationship, describing a system of demand estimation tied to specific delivery days: *"They deliver three times a week. They prefer two, but I insist on three, so I can keep things fresher. That's one of the main causes of waste—if deliveries are too far apart."* Inventory management, when well-executed, directly reduces *shelf waste*. This was confirmed across multiple interviews, such as Interview D: *"We can place orders up until late. That way, we can check how busy the day was and adjust the order for the next day accordingly. This helps us avoid waste."*

Together, these relationships form a balancing feedback loop. Accurate forecasting supports better inventory decisions, which leads to less food being wasted before it is served. This reduction in shelf waste alleviates pressure on inventory levels, reinforcing the loop. As long as forecasting and inventory routines remain effective, the system maintains a stable and efficient balance. A second dynamic involves how operational flexibility enables responsive supplier relationships. This flexibility - linked to establishment size, autonomy, and decision-making speed - was more prevalent in smaller restaurants. Interview H explained: *"We're small enough that we can change things fast. If I see one product isn't selling as well, I just don't prep as much the next day. Bigger places can't really do that."* Interview I added: *" If we ever run short on something, it's just a 15-minute drive to get more."*

Such supplier relationships, grounded in trust, enable short-term adjustments in ordering. Interviewees reported that frequent, demand-based ordering reduced overstocking and shelf waste. This dynamic - though not a loop - represents a vital pathway: Operational flexibility enables strong supplier relationships, which in turn support precise ordering and ultimately lead to less spoilage.

A third key dynamic within the system is the way in which *financial pressure* caused by shelf waste drives changes in *menu design*. When unsold or expired ingredients accumulate, restaurants face not only food loss but also direct financial loss. Several interviewees described this financial strain as a critical motivator for simplifying their menus and improving the way ingredients are used. This response results in higher *ingredient utilisation*, which helps reduce *shelf waste* - forming a balancing loop.

The first step in this dynamic is the experience of *financial pressure*, a code that surfaced in multiple interviews. As Interview I explained: *"...and food waste is a big topic for us -especially now. Food in general has gotten really expensive."* Interview E added: *"We call it "dead money." If you have a lot of stock sitting around, it's just money that's tied up."* This comment reflected a broader concern that emerged: shelf waste does not just represent a sustainability failure, but a direct financial threat. Interview K stated: *"In the first year, I tried to put some different dishes on the menu, but they didn't sell as well as I hoped. So I removed them from the menu because there was too much waste and it wasn't profitable."* This kind of pressure often led to conscious *changes in menu design*. The owner further described his experience related to these adjustments: *"Don't try to offer too many things. Simplicity helps reduce waste."* Interview E contributed: *"I'd say it all starts with your menu – how you design it".*

This act of *menu simplification* - a key code that emerged under operational strategies - wasn't always about limiting creativity, but about creating alignment between what was sold and what could be used efficiently. For many participants, simplified menus enabled more strategic use of ingredients across multiple dishes. Interview A provided a particularly clear link between simplification and *cross-use of ingredients*: *"But overall, because we had such a small selection of ingredients—lettuce, tomatoes, corn, cheese, carrots, white cabbage, and red peppers—we could rotate everything efficiently and avoid waste."* This approach was echoed in Interview I as

well: *"For example, we have a spicy hamburger we call "The Hot Butter," which uses jalapeños, red onions, lettuce, and so on. We use nearly the same ingredients to create a spicy chicken burger as well. The taste experience is different, but it comes from the same core items."*

By increasing the *cross-use of ingredients*, restaurants were able to improve overall *ingredient utilisation*, a code strongly related to how perishable products are used before expiry. This ensured that ingredients were consumed across dishes before going bad. As a result, *shelf waste* decreased. Together, these interconnections form a balancing loop. Shelf waste creates *financial pressure*, which pushes restaurants to adapt their *menu structure*. This leads to more streamlined offerings and greater *cross-use of ingredients*, which improves *utilisation* and reduces shelf waste - thereby relieving the original financial strain.

A fourth dynamic centres on shelf life management, which mediates operational control and creative freedom. Practices such as labeling, rotation and preservation were widely cited. Interview A noted: *"We used stickers to label prep dates. For example, if something was prepped on Monday, it would be discarded by the end of Wednesday."* Interview B described creative use of products: *"Some ingredients are also pickled or fermented, which helps extend their shelf life."* Ingredient cross-use strengthens shelf life control. Interview I emphasised: *"And from those eight, we use core ingredients like potatoes, chicken, etc.—and prepare them in different ways for various portions."* Cross-use ensures products are used across multiple dishes, reducing the risk of spoilage and stabilising inventory. The interviewee continues: *"It's a win-win. You get creative with the menu, you minimize food waste, and the customer gets variety."*

However, food safety policies impose constraints. Interview K noted: *"But we only use a maximum of 48 hours. So if I cook something today, it has to be gone by tomorrow."* Regulations create tension between flexibility and safety, yet most participants managed this through labelling and routines rather than digital tools.

In sum, shelf life management - when paired with cross-use and strong routines - extends product usability and reduces shelf waste. It supports adaptive menu planning without compromising food safety, reinforcing a low-waste operating environment.

Collectively, these dynamics reveal how day-to-day decisions interact in self-regulating systems. Forecasting, operational agility, financial pressures, and safety routines all feed into loops and pathways that shape food waste outcomes in Dutch gastronomy. Each dynamic contributes to a broader systemic understanding of how shelf waste can be effectively minimised.

4.2.2 Plate Waste Dynamics

Leaning on the mentioned food safety policies and regulations, which are often viewed as external constraints, plate waste dynamics contribute to an environment in which the use of *digital tools* becomes more likely. For instance, the presence of frameworks like HACCP (Hazard Analysis and Critical Control Point), which require traceability and accountability, can increase the appeal and uptake of digital tracking systems such as Horeca. One interviewee explained how these systems became part of daily operations: *"We always work with a system called Horeca. It allows us to manage everything precisely."* This integration of technology into kitchen routines represents the code *digital tools*. Once in place, these systems increased *awareness and visibility* of what was being used - not just in terms of ingredients, but also at the plate level. Interviewee F continued: *"And Horeca helps a lot with managing all of this - it's a lifesaver. We use it for staff scheduling, tracking hours, and also food tracking".* This *food waste visibility* enabled staff to make more informed decisions about *portion monitoring*. When restaurants could see patterns in what was being left uneaten, they adapted portion sizes or components accordingly. The interviewee added: *"We pay attention to what people leave behind. If they stop eating the rice, for example, and everything else on the plate is empty - we know the rice isn't as exciting, and they were full. But if the rice is also finished, that's a sign people were still hungry. We ask for feedback after the meal, especially during the first week of a new menu. Then we fine-tune the portion sizes."* These actions - adjusting portion sizes based on observation or data - contributed to a reduction in *plate waste*. As waste decreased, the benefits of using such tools became more visible, increasing the willingness of restaurant owners and staff to continue using or investing in them.

These dynamics form a balancing loop: *digital tools* enhance *food waste visibility*, which leads to improved *portion monitoring*, reducing *plate waste*. The reduction in plate waste reinforces the perceived value of digital tools, encouraging their continued or expanded use. While *policies and*

regulations are not a causal factor in this loop, they increase the likelihood that such systems are adopted by incentivising accountability and structure - outcomes that digital solutions can support effectively.

The adoption of *digital tools* was described by participants not only as a means of monitoring kitchen performance and portion control, but also as a potential enabler for *redistributing surplus food*. While tools like Horeca are used to weigh and track portions internally, other systems - such as apps like Too Good To Go - serve a different yet complementary function. They help restaurants manage uneaten, but still edible, food by diverting it from the waste stream. In Interview D, the restaurant owner recalled: *"In that case, I can totally see the benefit. But for us, maybe once a week we have something - and then I'd forget to list it on Too Good To Go anyway. But I do think it's a great concept."*

Although not every business adopted these tools, their existence reflects a broader trend toward *diverting surplus food*. This diversion - the act of redistributing rather than discarding - was viewed as a more sustainable and socially responsible approach. When restaurants have a system in place to send surplus food to secondary use, whether through digital platforms or informal means, this directly contributes to minimizing *food waste*. In this way, digital tools can be understood not only as internal management systems but also as bridges to external redistribution networks.

In parallel, *food waste awareness* - whether raised through digital insights, team culture, or even customer conversations - emerged as a key factor influencing how restaurants approached *takeaway culture*. Several interviewees shared that heightened attention to waste encouraged them to offer or even promote packaging as a way to prevent unfinished food from being discarded. A key finding here is that the type of establishment has potential to influence the packaging culture. Interview G shared: *"I feel like in fine dining, it's just not the vibe to take a to-go box. It's almost like, "I don't care about the money I'm wasting," or something. So they just throw it out."*

This links to the code *takeaway incentives*, which appeared in the form of informal reminders, packaging availability, or even environmental nudges. Some restaurants offered compostable packaging by default; others left the decision to the customer, but always had it available.

The ability and willingness to offer takeaway options - particularly for frequently wasted plate components - formed a type of *packaging culture*. Where such a culture existed, plate waste tended to be lower, especially in dine-in settings where portions were fixed. As Interview B noted: *"I'd say the primary source of food waste is customers not finishing their meals. We do offer takeaway boxes and encourage guests to take leftovers home,…"* Interview J adds: *"We always try to minimise waste and encourage people to take their food home — they paid for it, after all."*

Together, these relationships show how both technological and cultural shifts around *awareness* can influence tangible actions that reduce waste. On one side, *digital tools* enhance redistribution by connecting surplus food to external users. On the other, *awareness* - among both staff and guests - encourages *takeaway behaviour*, which supports a packaging culture and minimises plate waste.

Though these may seem like small steps, they represent a shift in how food is valued across its entire lifecycle - from portioning, to redistribution, to what happens after a meal is left unfinished. These dynamics play a crucial role in the everyday decisions that determine whether food becomes waste or remains part of the system.

A final key dynamic identified in the CLD involves the influence of *regional customer expectations* on *plate waste*, particularly in the context of portion size. In the northern Netherlands - the focal region of this research - several interviewees described how customer perceptions of value shaped decisions about how much food to serve, especially in smaller cities like Leeuwarden compared to places like Amsterdam.

These expectations directly shape *portion size control*, another key theme across interviews. Restaurants that frequently noticed specific components being left uneaten began adjusting their standard portioning - either informally or through measurement. One frequently cited example was the wastage of side dishes or vegetables. This awareness of what gets left behind links closely with the code *frequently wasted ingredients*, which often included garnishes, bread, fries, or secondary components. These insights pushed restaurants toward *offering adjustments*, both to reduce waste and to better align with what customers wanted.

Although not explicitly mentioned on the diagram, a strategic tool mentioned by some interviewees in making these adjustments was *psychological pricing*. This involves pricing dishes or components in ways that shift customer expectations or consumption behaviour. As explained in Interview C: *"Fries do get thrown out a lot. We decided to start charging separately for fries – as a side dish. No one asked why they had to pay for fries – because many restaurants do it that way. And now, people actually eat the fries. It's psychological. When consumers pay for something, they're more likely to eat it."* This subtle pricing strategy created space for restaurants to shape demand - leading to more selective ordering, better portion control, and ultimately less food being left uneaten. These *offering adjustments* fed back into the system by influencing what customers expected the next time they ordered. When a smaller salad or fewer fries became the new normal, expectations shifted accordingly.

This loop functions as a *balancing mechanism*: when plate waste increases due to oversized or mismatched portions, it signals the need for operational and psychological adaptation. Over time, *regional expectations* can shift in line with what is offered.

5. DISCUSSION
5.1 Theoretical Contribution and Reflection

This study confirms several established drivers of food waste in gastronomy while contributing a dynamic understanding of how these drivers interact over time. Prior research has identified operational factors such as forecasting inaccuracy and poor stock rotation as key sources of waste. However, these drivers are often treated as discrete variables. This thesis instead shows they are part of feedback loops that amplify or reduce food waste, depending on how they're managed.

Forecasting accuracy, for example, has long been recognised as a major operational challenge (Thyberg & Tonjes, 2015). This study supports that finding, but also shows that forecasting is often not a formal, data-driven process in smaller gastronomy businesses. Rather, it emerges from experience-based knowledge developed over time. Several interviewees described it as a "feeling" that helps predict demand. This insight deepens current understanding by showing how

intuitive forecasting supports better ordering practices and stabilises inventory - forming a balancing loop that directly reduces shelf waste. The CLD developed in this research makes this dynamic structure visible in a way that static process models cannot.

This contribution ties into the emerging theoretical application of SD within the context of sustainable gastronomy. While previous studies have explored food waste drivers and mitigation practices (Canali *et al.*, 2016), few have conceptualised these factors as part of a dynamic, feedback-driven system. By developing a CLD grounded in qualitative insights from Dutch restaurant practitioners, this thesis offers a novel framework that maps the interdependent relationships between forecasting, inventory, menu design, digital tools, and food safety practices. This model does not aim for simulation precision; rather it serves as a conceptual tool to understand how local decisions produce systemic effects over time. It extends existing literature by revealing the complexity and adaptability of waste-reduction practices within operational contexts. This approach aligns with SD theory, which emphasises the importance of feedback loops and emergent patterns in shaping system behaviour (Sterman, 2001).

Menu design and portion sizing, often flagged as waste contributors (Filimonau *et al.*, 2020), were also found to play an adaptive role. In this study, financial pressure caused by shelf waste led restaurants to simplify their menus and increase ingredient cross-use. These changes improved shelf life management and stock turnover, creating a balancing loop where cost-driven adaptation reduced waste over time. This reframing - seeing menu structures not only as causes of waste, but as responses to it - adds a dynamic dimension to existing findings.

Another unexpected finding was the limited reliance on digital solutions among some high-performing restaurants. While literature tends to position technology as central to food waste reduction (Cane & Parra, 2020; Ciulli *et al.*, 2019), this research found that knowledge and routine-based intuition often fulfilled a similar role. Most participants relied on analogue methods, including manual labelling and staff memory. This aligns with findings by Madanguli *et al.* (2021) that highlight integration barriers. However, this research goes further by showing how analogue routines themselves act as stabilising forces. Though not optimally efficient, these

routines form feedback structures that create consistency, even without digital support. This suggests that digital tools, while valuable, may not be essential in all contexts - particularly in smaller, tightly-managed operations.

Similarly, food safety policies were not always perceived as restrictive, but rather as structuring conditions that encouraged precision, creativity, and the uptake of certain technologies. The findings challenge prevailing assumptions that formal regulations and informal practices solely exist in tension. Regulatory and institutional factors more broadly also shaped food waste practices. Consistent with Canali *et al.* (2016), the study found that strict food safety norms and internal rules often limited operational flexibility. In some cases, ingredients were thrown away based on expiry dates alone, even if they still appeared usable. Institutional constraints, while intended well, can suppress adaptive behaviours and limit waste reduction potential.

From a transdisciplinary perspective, this research was strengthened by engagement with restaurant practitioners and a strategic link to Thuisbezorgd. These collaborations provided insight into the practical realities, constraints, and motivations that shape waste-related decision-making. They also revealed a gap between academic approaches to sustainability and the operational language of gastronomy. Bridging these perspectives required adapting interview questions and research framing to ensure mutual understanding. This process reinforced the value of transdisciplinary research in producing insights that are both theoretically meaningful and practically relevant. It also emphasised that sustainable entrepreneurship in food systems must account for the tacit knowledge and day-to-day rhythms of the sector - not just idealised solutions.

5.2 Practical Implications

Although grounded in theory, this thesis was ultimately aimed at producing practical insights that can inform change. The interviews revealed a strong commitment among restaurant owners and staff to avoid food waste, even in the absence of formal systems or technological tools. From a systems view, food waste is not confined to individual kitchens but shaped by supply chains,

regulations, and cultural norms in food service. Therefore, practical implications can be drawn not only for restaurant practices but also for broader actors and leverage points across the system.

Within restaurants, a key intervention lies in transforming forecasting from an intuitive individual skill into a collective practice. Regular end-of-day reviews and weekly planning discussions can foster shared learning, making demand estimation more resilient and reducing overproduction. Moreover, designing menus around a manageable set of core ingredients supports shelf-life extension and reduces the likelihood of spoilage. While financial pressure often drives such menu simplification, rethinking it through a sustainability lens opens opportunities for creative reuse and strategic cross-utilisation of ingredients.

Yet restaurants do not operate in isolation. Suppliers play a crucial role in shaping the food waste dynamics observed in this study. Restaurants that had strong, flexible relationships with small or local suppliers were better able to adapt their orders to real-time demand. This suggests that policies or programs encouraging flexible supply agreements - such as smaller minimum order quantities or more frequent deliveries - could significantly reduce food waste. Such leverage points operate early in the chain, but directly influence how restaurants manage stock.

Similarly, waste visibility emerged as a powerful - yet underused - feedback mechanism. In many kitchens, food waste was normalised and rarely discussed. Simple tracking tools, visual logs, or informal team reflections could disrupt this normalisation and reintroduce waste as an object of attention and learning. From a systems perspective, this represents a reinforcing loop: increased awareness feeds into behaviour change, which further reduces waste and strengthens the cultural norm of mindfulness. Here, municipalities or hospitality networks could play a role by supporting peer learning initiatives, recognition schemes, or accessible toolkits for waste tracking and team engagement.

Policy-makers, too, have a potential role to play - not necessarily through strict regulations, but by facilitating enabling conditions. For example, incentives for adopting waste-tracking technologies, or subsidies for local sourcing, could help accelerate the adoption of already

promising practices. Education and training programs for kitchen staff could further embed systemic awareness and offer new perspectives on sustainability beyond compliance.

Ultimately, the CLD developed in this thesis offers more than a retrospective explanation; it can act as a reflective tool to help restaurant teams and value-chain actors identify where interventions may yield the most systemic impact. By focusing on leverage points that influence multiple pathways - such as staff routines, supplier flexibility, and waste normalisation - interventions can generate ripple effects far beyond their immediate context. In this sense, the findings invite not only technical or operational changes but also deeper reflections on how collaboration, culture, and feedback loops shape the sustainability of gastronomy as a whole.

5.3 Limitations

As with any qualitative research, this study faces certain limitations. First, the sample was geographically limited to the northern Netherlands and focused primarily on small to medium-sized restaurants. While this provided rich, context-rich insights, it may limit the ability to generalise findings to larger or differently structured food service operations, such as chains, franchises or institutional kitchens.

Second, although the sample size of eleven interviews is above the required number, particularly for thematic saturation, it remains relatively small. Additional perspectives - such as those from suppliers, regulatory bodies, or even customers - could have further expanded the system boundaries and enriched the causal understanding of food waste. Similarly, including more kitchen and service staff could have also enriched the perspective on daily waste practices and internal dynamics.

Finally, the interpretation of interview data and the construction of the CLD were subject to researcher bias. While the codes and themes were grounded in participants' narratives, the causal relationships within the CLD remain interpretive. As these connections are based on subjective experiences rather than empirical testing, the diagram should be viewed as a reflective tool rather than a definitive causal model. Future research could enhance its robustness by involving

practitioners in co-constructing the model or by complementing it with observational or quantitative data.

6. CONCLUSION

This thesis explores the drivers and dynamics of food waste in Dutch gastronomy, aiming to understand how waste arises from interrelated decisions, routines, and constraints. Rather than treating food waste as the outcome of isolated missteps, the research adopts a systems perspective to highlight how waste is embedded in the very fabric of restaurant operations. Through qualitative interviews and the construction of a CLD, the study develops a conceptual model that illustrates the feedback structures behind shelf and plate waste, offering a more nuanced, systemic understanding of an evolving sustainability issue.

It finds that the system dynamics of food waste in Dutch gastronomy revolve around several interrelated factors. These components interact in feedback loops that either reinforce or counteract waste, depending on how they are managed. Food waste is not simply a matter of inefficient choices, but a symptom of how restaurants adapt to uncertainty, manage risk, and keep operations running smoothly. The study's methodological approach bridges the gap between theoretical analysis and practical relevance, making it easier for gastronomy professionals to reflect on the systems they operate within. The visual model developed serves as both an academic contribution and a reflective tool that could support learning and dialogue for changemakers. In doing so, the thesis contributes to the field of sustainable entrepreneurship by offering a practice-based, systems-oriented lens on waste mitigation in food service.

Importantly, the findings highlight several leverage points within the system that are particularly well-suited for intervention. Among these, the normalisation of waste emerged as a cultural dynamic that can be challenged through improved visibility and feedback. Forecasting practices represent another key node, connecting purchasing, menu planning, and storage decisions. Likewise, flexible supplier relationships act as a buffer against overstocking and enable real-time responsiveness, making them an essential part of the wider system architecture. These elements

are not only central in the CLD but also actionable in practice, making them valuable entry points for change initiatives.

The findings have implications beyond the restaurant floor. They suggest that policies aimed at reducing food waste should not only target consumer behavior or technological adoption but should also recognise the value of local supplier flexibility, embedded knowledge, and adaptive menu design. Future research could build on this work by testing the model in different contexts, developing versions of the diagram with practitioners, or exploring how digital tools like Horeca complement the intuitive routines that build everyday food operations. Further research could also examine how staff training, governmental incentives, or regulatory design can better align with the circular goals of the gastronomy sector.

In response to the initial research question, this thesis has shown that food waste in Dutch gastronomy is shaped by interconnected dynamics - particularly feedback loops between forecasting, inventory, and menu design - and that effective mitigation depends on leveraging practices such as shared forecasting routines and flexible supplier relationships. Tackling food waste, therefore, requires more than efficiency upgrades; it demands a systemic understanding of everyday decisions and constraints that shape restaurant operations.

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APPENDIX

Additional documents related to this research, including the anonymised interview transcripts, coding framework and consent forms, can be accessed by the supervisors via the following Google Drive link:

https://drive.google.com/drive/folders/1Jni5LYCXDsIzIuzMX4L6f0eIJ6-fU3Ag?usp=share_link