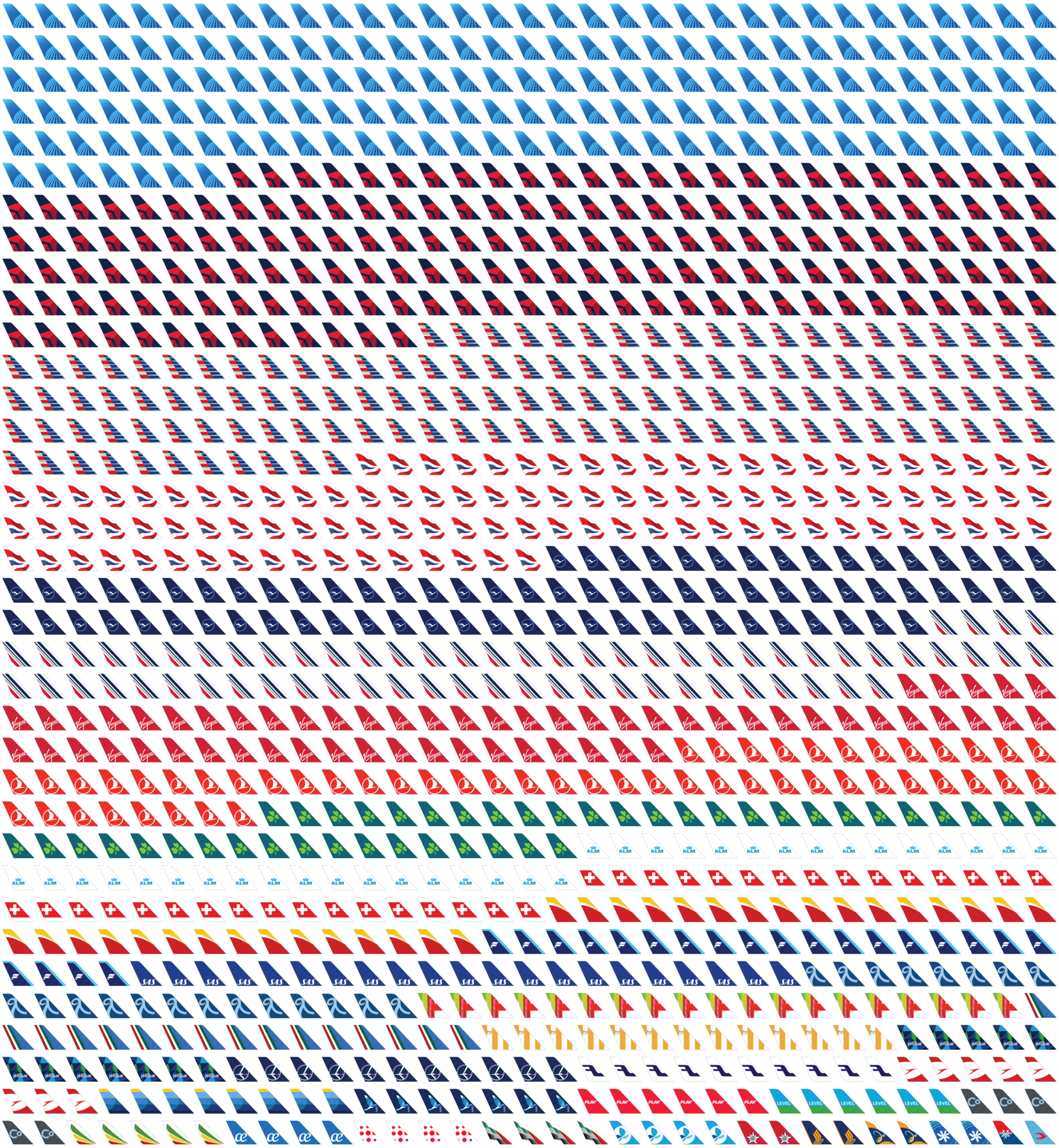
Digital Transformation of In-Flight Catering Services for Long-Haul Flights



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Digital Transformation of In-Flight Catering Services for Long-Haul Flights
A Case Study on the Amsterdam-Atlanta

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‘A satisfied passenger and less waste starts with smart pre-flight choices’

Abstract

Transatlantic in-flight catering generates substantial avoidable food waste, an issue with significant economic (approximately $6 billion annually) and environmental implications. This thesis investigates the drivers of this waste and evaluates feasible, passenger-centric strategies for its reduction while maintaining service quality. Utilizing a mixed-methods approach, including literature reviews, empirical fieldwork at Hartsfield-Jackson Atlanta International Airport with catering services like Newrest, expert consultations with flight attendants and industry professionals, and co-creation sessions, the research identifies operational over-catering, demand forecasting inaccuracies, data fragmentation across the passenger journey, and a critical communication disconnect concerning passenger meal preferences as primary contributors.

Findings highlight strong passenger demand for meal customization, variety, and digital pre-selection, alongside a willingness to participate in waste reduction initiatives; for instance, 73% of passengers are willing to pay extra for customized meals. The study concludes that passenger-centric strategies—encompassing enhanced preference communication (potentially through a unified system like the proposed SkyTag), journey-aware catering optimization, and redesigned choice architecture (such as opt-in meal systems and portion control)—can significantly curtail food waste. Leveraging digital platforms, AI-driven forecasting (e.g., KLM's TRAYS model reducing waste by 63%), and integrated journey management, these approaches can improve passenger satisfaction and align economic incentives with environmental objectives, navigating challenges of legacy systems and systemic economic entrenchment. The research proposes actionable short-term and long-term recommendations for a more sustainable and responsive in-flight catering model.

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1 Introduction

At the time of writing, approximately 1188 commercial flights make their way across the pond between Europe and the United States (Cover Page). Operated by 37 airlines including some exotic fifth-freedom carriers such as Emirates, Ethiopian Airlines, and Singapore Airlines (Lassetter, 2025). Of these 1188 daily flights, 59 do not include a meal or beverages in the base economy fare; coincidentally, this concerns the low-cost carriers like Norse Atlantic, PLAY Airlines, LEVEL, French bee, and Icelandair.

In the past year, an impressive 77.75 million passengers travelled between Europe and the US, accounting for 31% of all US international air traffic (IATA, 2025). This figure represents a 7% year-on-year increase and is 3% higher than pre-pandemic levels in 2019. On average, 83% of seats on transatlantic flights were filled, underscoring the strong demand and robust capacity on these routes (Baruah & Baruah, 2025).

For the vast majority of these millions of passengers, meal service is an inevitable part of the journey. However, this standard practice creates significant food waste that's challenging to eliminate. According to the International Air Transport Association (IATA), the average airline passenger generates approximately 1.4kg of cabin waste, with up to a quarter coming from untouched food and beverages.

This substantial waste highlights a disconnect. While airlines strive to enhance the passenger experience through catering and adapt to trends like health consciousness and customisation by offering pre-order options and specialised meals, the decision-making process often prioritises operational factors like flight duration and broad demographic predictions over incorporating direct, real-time input from passengers regarding their specific desires during the flight. Consequently, passengers frequently receive predetermined meals they may not want, contributing significantly to the environmental and economic costs of wasted food in the skies.

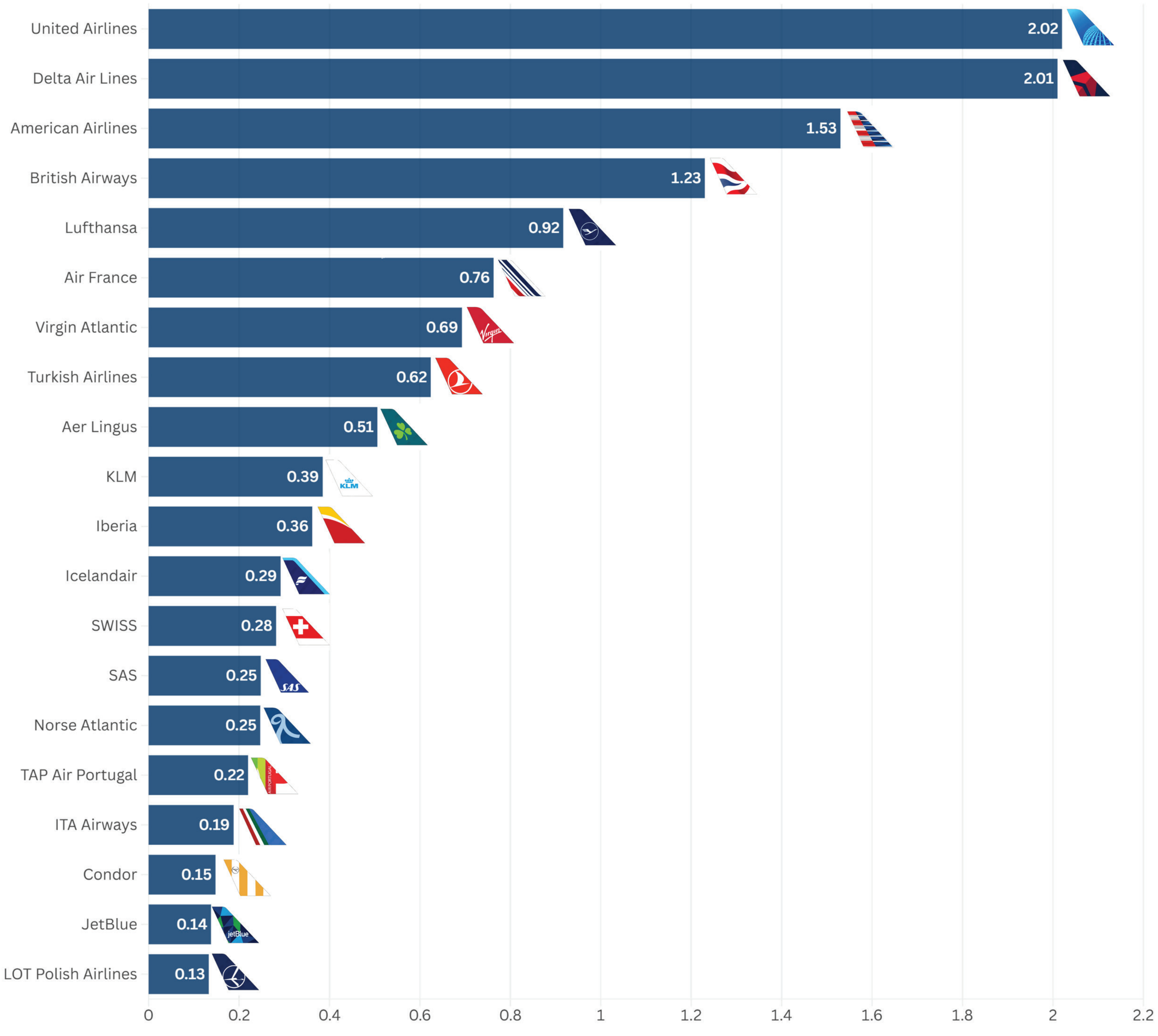


Figure 1
Top 20 Europe – US airlines in 2025 Q2 Based on seat capacity

2 Assignment & Approach

2.1 Assignment

2.2 Problem Definition

The core problem is the substantial generation of avoidable food waste from in-flight catering on full-service transatlantic flights. This waste stems from a complex interplay of logistical constraints, regulatory requirements, forecasting inaccuracies, and a potential gap between standardised meal provision and actual passenger consumption preferences inflight. Addressing this requires understanding the specific drivers of waste in this context and exploring more passenger-centric approaches that could mitigate it without compromising service standards perceived by passengers. Consequently, the current catering paradigm fails to leverage digital capabilities that could simultaneously enhance customer experience while improving operational efficiency.

2.3 Scope of the Study

This research investigates the reduction of in-cabin food and beverage waste generated on scheduled, transatlantic flights operated by full-service carriers between Europe and the United States. The scope specifically targets waste from two sources:

- Items served to passengers, primarily in economy class, but left unconsumed.
- Food and beverages loaded onto the aircraft but ultimately not served to any passenger.

The central focus is on leveraging the digital transformation of in-flight catering services as a primary means to achieve this waste reduction. Current standardized catering models on these long-haul routes often present a 'one-size-fits-all' approach, failing to adequately cater to individual passenger preferences, specific dietary requirements, or the context of their journey, such as accommodating time zone transitions. This mismatch contributes significantly to food waste and diminishes passenger satisfaction.

To explore practical digital solutions, this study employs the Amsterdam Airport Schiphol (AMS) to Hartsfield-Jackson Atlanta International Airport (ATL) route as a representative case study. This route exemplifies typical transatlantic flights between major Western European and US hubs, with flight durations commonly ranging from 8 to 9 hours.

The research will concentrate on approaches applicable within existing airline operational and regulatory constraints, focusing exclusively on waste deplaned from the aircraft (originating from cabin service) and explicitly excluding waste generated during the off-board catering production process.

2.4 Research Aim & Objectives

The aim of this thesis is to investigate the drivers of in-flight food waste on transatlantic routes and to identify and evaluate feasible, passenger-centric strategies for its reduction.

The specific objectives are:

- To analyse the primary operational, logistical, and passenger-related factors contributing to food waste on full-service transatlantic flights.
- To examine the effectiveness and limitations of current airline strategies (e.g., menu planning, forecasting, pre-order systems) in managing food waste.
- To explore passenger attitudes and preferences regarding in-flight meals and willingness to engage in waste-reduction initiatives.
- To identify and assess the feasibility of innovative, passenger-centric solutions (e.g., enhanced pre-selection, on-demand ordering systems, dynamic menu adjustments) for reducing in-flight food waste.
- To develop actionable recommendations for airlines operating on transatlantic routes to minimize food waste while maintaining or enhancing passenger satisfaction.

2.5 Research Question

Based on the scope and research objective, the main research question for this project has been formulated as follows:

- **How can passenger-centric strategies effectively reduce in-flight food waste on transatlantic routes while maintaining service quality?**

To comprehensively address this question, six subquestions were developed, each targeting a specific aspect of the project, starting with diagnosing the problem (Sub-Qs 1–2) to understanding passenger needs (Sub-Q 3) before evaluating concrete solutions (Sub-Qs 4–5) and feasibility (Sub-Qs 6):

1. **Drivers of Waste**
What operational, logistical, and behavioural factors contribute most significantly to unconsumed food and beverages in economy-class cabins on transatlantic flights?

2. **Current Strategy Limitations**
How do existing airline practices (e.g., meal forecasting, pre-order systems, standardized menus) fail to align with passenger preferences, leading to avoidable waste?

3. **Passenger Preferences**
What meal customisation options, service models, or engagement initiatives do passengers value most, and how might these influence consumption behaviour?

4. **Technology-Enhanced Solutions**
Could real-time digital platforms (e.g., dynamic meal ordering, AI-driven preference prediction) improve demand forecasting and reduce surplus meal production?

5. **Behavioural Nudges**
How might choice architecture adjustments (e.g., opt-in vs. opt-out meal systems, portion control, sustainable defaults) impact waste generation without compromising satisfaction?

6. **Implementation Challenges**
What regulatory, cultural, or operational barriers might hinder airlines from adopting passenger-centric waste reduction strategies on transatlantic routes?

2.6 Approach

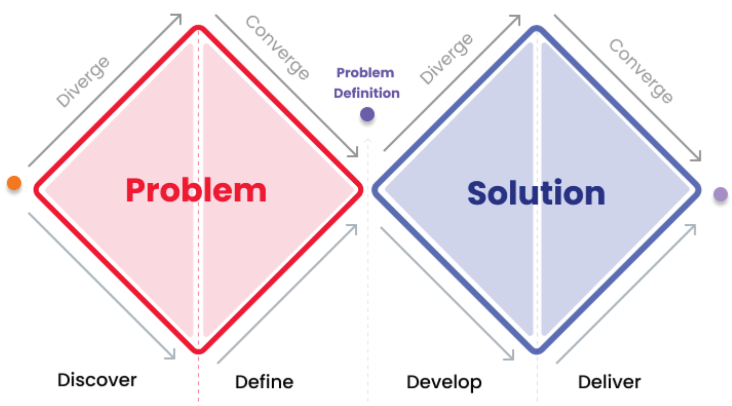
This project employs the Double Diamond model, a design thinking framework developed by the Design Council (n.d.), to guide and structure the design process. This model visually represents the innovation journey, dividing it into four distinct phases: Discover, Define, Develop, and Deliver. The process operates through two "diamonds": the first focuses on the problem space (Discover and Define), emphasizing understanding the issue rather than assuming, and clearly defining the challenge based on insights gathered (He et al., 2023). The second diamond addresses the solution space (Develop and Deliver), concentrating on generating diverse solutions, testing them iteratively, and refining the most effective ones (Elmansy, 2021).

Central to the Double Diamond is the interplay between divergent thinking (exploring possibilities widely) and convergent thinking (narrowing down options and making focused decisions). Although often depicted sequentially, the framework facilitates an iterative process, allowing for movement between phases as new insights emerge through testing and refinement. This widely applicable model guides teams through complex challenges by fostering a structured yet flexible approach to problem exploration and user-centered solution development (Design Council, n.d.).

This project is divided across the two diamonds of the Double Diamond framework. Chapters 3 to 6 focus on the first diamond. Chapters 3 and 4 (Context Background and Literature Review) serve as the Discover phase, where the broader landscape of airline catering, passenger satisfaction, sustainability, and industry-specific challenges are explored. This is followed by the Define phase, articulated in Chapter 5 & 6, where the methods, process, and results of the subquestions are discussed in detail. Building a solid foundation for the design phase.

The second diamond-Develop and Deliver-guides the solution-oriented chapters. Chapters 7 (The Missing Link) initiate the Develop phase, by detailing specific interventions such as smart catering systems and personalisation technologies. The Deliver phase is embodied in Chapters 8 till 10 (The proposed solution, Validation & Recommendation, Discussion & Insights), where proposed solutions are tested, validated, and evaluated for feasibility and impact. These chapters also address implementation challenges and provide a roadmap for real-world adoption, culminating in Chapter 10 (Conclusion & Recommendations), which synthesizes findings and offers actionable guidance for stakeholders.

Figure 2
Double Diamond Visualisation



3 Context Background

3.1 Balancing Passenger Satisfaction & Sustainability

3.1.1 The Evolving Challenge of In-Flight Catering

In-flight caterers are responsible for producing food and beverages for each passenger onboard a flight. The meal provided has a dual purpose; not only does it satisfy the hunger of onboard passengers, but it is also used to distract stressed passengers and to manage their behaviour (McCool, 1995, chap. 3). Additionally, some airlines use in-flight catering as part of the airline's competitive strategy due to its positive impact on passenger satisfaction (Halizahari, Mohamad, & Husain, 2021; Teoh, Jaspreet, & Singh, 2018). This service includes offering various meal types such as vegetarian, Halal and low-calorie meals. Inflight catering is an essential part of airline operation, as the inflight meal and beverage service is an important segment of marketing to attract business or leisure travellers to a particular airline (Mohd Zahari et al., 2011) and outperform airline competitors (Han et al., 2019). Messner (2016) even suggests that next to price, comfort of seats, and service standards, the quality of inflight food served might be the deciding factor for some passengers when it comes to choosing an airline. Mills and Clay noted the potential of using inflight foods to build loyalty.

The airline industry is characterised as an aggressive and challenging business. Airlines in a highly competitive service industry must continuously develop distinguishing products and services to gratify and conserve passengers. Regardless of full-service (vs. low-cost) carriers or international (vs. domestic) airlines, the fundamental aim for an airline is to achieve a higher market share of airline passengers. Due to this highly competitive environment (Park et al., 2020), airlines are constantly trying to improve their inflight catering services (Rajaratnam and Sunmola, 2021).

3.1.2 The Sustainability Dilemma in In-flight Catering

Unfortunately, in-flight catering creates a significant sustainability issue due to its excessive waste generation. Research conducted by the Aviation Sustainability Forum (ASF) reported that at least 33% of a flight's cabin waste consists of untouched food and beverages (ASF, 2024). This wastage dilemma is not limited to any single airline but faced by in-flight catering companies and airlines worldwide (Blanca-Alcubilla et al., 2019; Caswell, 2020; El-Mobaidh, Taha, & Lassheen, 2006; Goto, 1999; Li, Poon, Lee, Chung, & Luk, 2003; Tofalli, Loizia, & Zorpas, 2018). In collaboration with IATA, the ASF's Cabin Waste Composition Audit (CWCA) program reveals the aviation sector generates 3.6 million metric tonnes of cabin and catering waste annually, with food and beverage waste constituting 65% of this total (Crane, 2023). Notably, 18% of all waste consists of untouched meals (figure 3)- equivalent to approximately 648,000 tonnes of unconsumed food yearly (Aviation Sustainability Forum [ASF], 2024a). The sector wastes approximately USD 6 billion worth of resources per year (IATA, 2025). This systemic wastage persists despite advanced load planning systems, highlighting fundamental inefficiencies in demand forecasting and service delivery models (Crane & Johnson, 2024). IATA predicts that passenger numbers will double from 4.7 billion in 2024 to 10 billion in 2050 with a corresponding increase in fleet size from 26,000 to 47,000. Despite 2025 likely being a peak year for new aircraft purchases, there is a significant lack of development in sustainable cabin design that facilitates onboard waste separation and management for both passengers and crew (ASF, 2024b).

The ASF's pioneering audits at Singapore's Changi Airport (covering 25 flights across short, medium, and long-haul routes) demonstrate the global nature of this challenge (ASF, 2024b). Their data reveals consistent patterns of over-catering across airline classes, with premium cabins showing particularly high levels of untouched specialty items like artisanal breads and premium desserts (Crane et al., 2023). This waste generation trajectory threatens to double by 2050 alongside projected passenger growth, creating both environmental and operational risks for airlines (International Air Transport Association [IATA] & ASF, 2024). Matt Crane, ASF Founder, emphasizes that '*the sector currently incinerates or landfills enough unopened food annually to feed over a billion people*' - a stark indictment of current linear supply chain models (Crane, 2024).

It is important to note that food wastage is accompanied by additional wastages and hidden costs, such as packaging materials, labour, electricity, water and the depletion of soil fertility (Thamagasorn & Pharino, 2019). Food waste is undeniably a financial burden for any company, as well as an emerging environmental and social concern. This is especially true in the in-flight catering industry, where surplus in-flight meals must be discarded due to stringent health policies and legislations (You, Bhamra, & Lilley, 2020). This wastage tends to end up in landfills or at incinerations sites, thereby resulting in the release of harmful greenhouse gasses. Lastly, while inflight catering is constantly being developed and optimised, the on-board processes and equipment have hardly changed. Nowadays , most aircraft galleys are still based on concepts from the 1960s (Abritta et al., 2012).

3.1.3 The Over-catering Strategy

The cause behind the in-flight catering industry's wastage dilemma is identified as the over-catering strategy being followed by the caterers. The in-flight catering industry has unique characteristics differentiating it from the typical catering industry, such as high production rates, off-site meal production, long production lead times and the time-sensitivity of order deliveries (McCool, 1995, chap. 3). These characteristics create additional challenges for in-flight caterers.

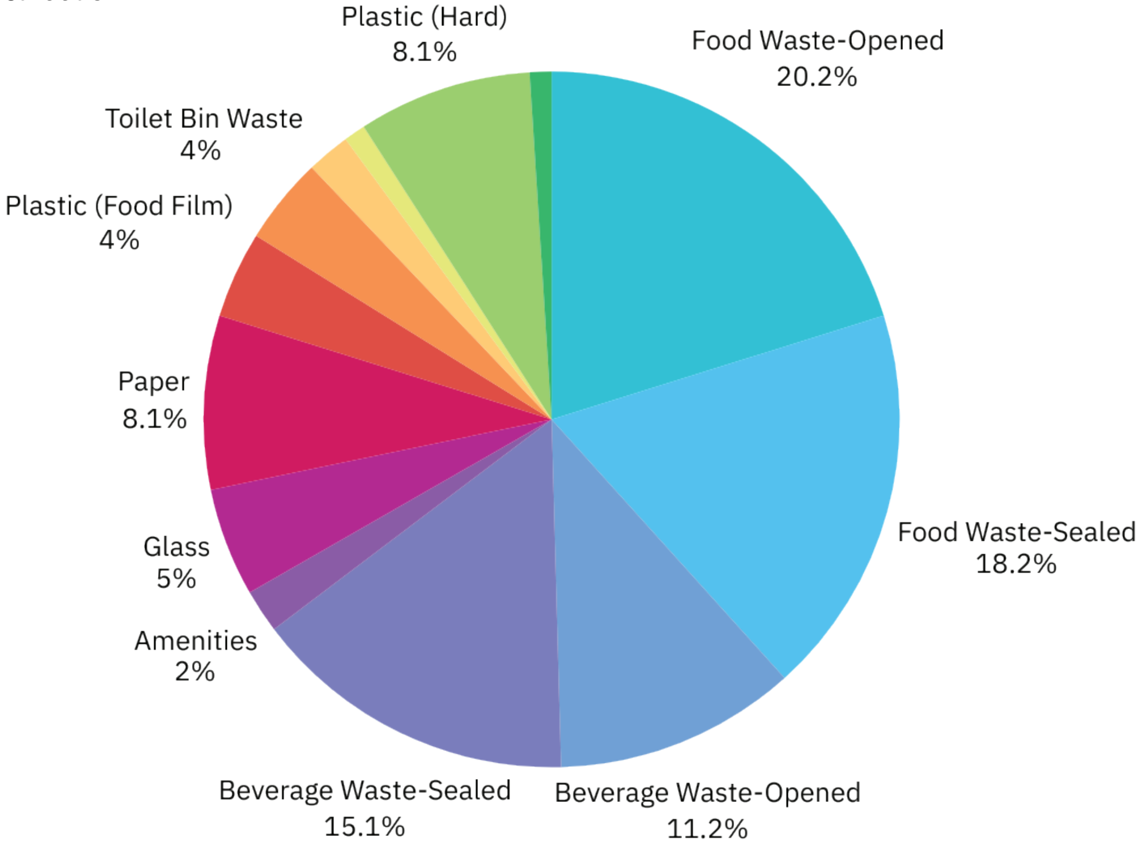
The most prominent challenge is the on-time delivery of meal orders with the exact quantity required. This is a challenging task as the number of passengers that will board the flight is unknown until a few hours, or even minutes, before the flight's departure (Hasachoo & Masuchun, 2016; Megodawickrama, 2018). This challenge is further intensified when the airline offers a variety of in-flight meals because it increases the level of uncertainty present.
Accordingly, caterers must rely on the estimated demand to plan the production schedule. The estimated demand is usually derived from the number of tickets already booked, a forecast based on historical data and the experience of the catering company (Goto, Lewis, & Puterman, 2004). The production schedule is frequently updated as more information regarding the flight's passenger load and meal demand becomes available. In the study conducted by Hasachoo and Masuchun (2016), forecasting errors accounted for 53.17% of the total production schedule adjustments made.

To compensate for the inaccurate demand estimations, in-flight caterers turn to over-catering as a means of protection against potential shortages and flight delays. The trade-off for this over-catering strategy is high levels of post-consumer waste in the form of surplus meals. It also contributes to increased pre-consumer waste due to the supply chain bull-whip-effect.

3.1.4 Towards Individualization of In-flight Meals

The individualisation of meals and beverages to fulfil customers' unique needs is a growing trend in the food industry. It directly impacts supply chain logistics. Thus far, the individualisation of inflight meals has not been provided for all passengers and, typically, airlines offer two meals on long-haul flights. Integrating individualised meals for all passengers will impact different tasks and change operational procedures

Figure 3
Cabin Waste Distribution



such as specific heating times or distributing and tracking meals. The personalisation of meals is already integrated by delivery restaurants through online orders, for example, primarily due to digitalisation possibilities. Individualisation could support inflight catering services (ICSs), especially if more passengers can be served with customised meals, e.g., in economy class. However, the current manual distribution of individual inflight meals for all passengers would potentially exceed the service time and increase flight attendant workload, because each individual meal must be assigned to each passenger and seat.

The individualisation of meals onboard could be achieved by pre-ordering meals before boarding, which would reduce the amount of work required to prepare them on the aircraft, similar to the current system of pre-ordering special meals. Airlines are expanding what they offer with ancillary products, particularly during the online ticket buying process, e.g., baggage options, seat reservations, and special meals. In this context, the existing process of pre-ordering meals, by making the choice of the desired inflight meal in advance, could enable the individualisation of inflight catering services for all passengers.

Particularly, passengers with diet restrictions or allergies need options for individualization to be able to choose inflight meals accordingly (Priya et al., 2020). Other aspects that may enhance the desire for customized meals on board are nationality, culture, religion and personal lifestyle. For example, Korean Air serves bibimbap, a representative Korean cuisine, to attract their target group (Park et al., 2020), and airlines from Muslim countries offer halal food, as standard options, to attract Muslim passengers (Park et al., 2020).

3.1.5 Market Scale & Economic Magnitude

The global aviation catering market demonstrates substantial economic significance, with current valuations varying across research methodologies but consistently indicating a multi-billion dollar industry. According to The Business Research Company (2025), the market was valued at USD 18.06 billion in 2024, while Precedence Research (2025) estimates the market at USD 20.79 billion in 2025. Alternative assessments by Coherent Market Insights (2025) suggest an even higher valuation of USD 27.6 billion in 2025, reflecting the methodological complexities inherent in measuring this fragmented global industry.

The operational scale of major catering providers underscores the industry's magnitude. Emirates Flight Catering, operating from a single facility in Dubai, produces over 225,000 meals daily, while dnata generates more than 230,000 meals daily for UK airline partners alone (LinkedIn, 2025). These figures represent merely individual operators within a global network that collectively serves hundreds of millions of passengers annually, indicating an industry of extraordinary logistical complexity and economic reach.

The market structure reveals significant concentration among major players, with companies such as gategroup, LSG Sky Chefs, and Emirates Flight Catering dominating global operations (figure 4). These organizations have developed extensive networks spanning multiple continents, creating what might be characterized as an entrenched economic apparatus with substantial fixed investments in infrastructure, technology, and human resources (Technavio, 2025).

in addtion, the aviation catering industry exhibits robust growth projections across multiple forecasting models, though with notable variations in projected compound annual growth rates (CAGR). The Business Research Company (2025) projects a CAGR of 9.1% from 2025 to 2029, reaching USD 27.42 billion by 2029. Precedence Research (2025) estimates a more conservative 6% CAGR from 2025 to 2034, projecting market expansion to USD 35.12 billion. Meanwhile, Coherent Market Insights (2025) forecasts a 7.71% CAGR from 2025 to 2032, anticipating market growth to USD 46.42 billion.

Despite methodological differences, these projections consistently indicate growth rates substantially exceeding general economic expansion, driven by several key factors. The recovery and continued expansion of global air travel represents the primary growth driver, with increasing passenger traffic directly correlating to catering demand (Mordor Intelligence, 2025). Additionally, the premiumisation trend, wherein airlines increasingly utilise catering quality as a competitive differentiator, particularly in business and first-class segments, contributes significantly to market value expansion beyond simple volume growth.

3.1.6 Conclusion

The aviation catering industry's remarkable scale, consistent growth projections, and technological sophistication mask a fundamental structural contradiction that exemplifies broader challenges within contemporary economic systems. While industry discourse emphasises sustainability, efficiency, and customer satisfaction, the actual operational dynamics reveal deep economic entrenchment that creates powerful inertia against meaningful waste reduction.

Ultimately, the airline food waste dilemma can be understood through the lens of what might be termed 'systemic economic entrenchment.' While the inefficiency generates significant environmental and financial costs, the existing high-volume catering model simultaneously sustains a considerable economic apparatus. The network of caterers, suppliers, and logistics providers has business models intrinsically linked to the current scale of production and delivery. Radically diminishing waste by precisely meeting passenger demand, therefore, isn't just a logistical challenge; it represents a potential disruption to established revenue streams, creating a powerful, albeit perhaps unspoken, inertia against the very solutions that would prove most effective. Solving the problem, in this context, inadvertently threatens the profitability of managing its current state.

Figure 4
Global Airline Catering Companies Market Share (2024)

3.2 Delta Air Lines & KLM

3.2.1 Delta Air Lines

Delta Air Lines originated as Huff Daland Dusters, Inc., established on March 3, 1925, in Macon, Georgia, representing the world's first aerial crop dusting operation (Delta Air Lines, 2023a). The company's initial passenger services commenced on June 17, 1929, operating routes from Dallas, Texas, to Jackson, Mississippi, with intermediate stops in Shreveport and Monroe, Louisiana (Petzinger, 1995). Delta's developmental trajectory parallels that of other major American carriers, characterized by expansion during the deregulation era of the 1980s and 1990s, followed by financial challenges in the early 2000s (Morrison & Winston, 2000). The airline's bankruptcy filing on September 14, 2005, citing rising fuel costs, proved fortuitously timed (Maynard, 2005). By April 2007, Delta had successfully emerged from bankruptcy protection after resisting a hostile takeover attempt by US Airways (Sorkin & Bailey, 2007). This recovery positioned the company advantageously for its subsequent acquisition of Northwest Airlines, announced on April 14, 2008, and consummated on October 29 of that same year (Mouawad, 2008).

The timing of Delta's financial restructuring and subsequent merger with Northwest Airlines afforded the carrier a distinctive competitive advantage. Having completed its reorganization prior to the 2008 financial crisis, Delta operated from a position of relative strength while competitors faced significant economic headwinds (Gelles, 2014). The Northwest Airlines brand was officially retired on January 31, 2010, marking the completion of the integration process (Delta Air Lines, 2010).

In the post-merger era, Delta's corporate strategy has centered on two principal objectives. First, defining themselves as America's preferred premium carrier, a self-designated role that has been substantiated through various service enhancements (Schlangenstein, 2019). Industry observers generally acknowledge that Delta's in-flight cuisine and customer service exceed those of comparable carriers, although the quality of cabin accommodations varies significantly across aircraft types (Nicas, 2015).

The second strategic focus has involved a fundamental transformation of Delta's domestic first class business model. In 2011, merely 14% of the carrier's domestic first class inventory was sold directly as revenue tickets, with the remainder primarily allocated to complimentary elite status upgrades. By 2023, this figure had increased dramatically to 88%, substantially reducing upgrade availability and creating systemic pressures within Delta's loyalty ecosystem. Concurrent with these developments, Delta's SkyMiles program has experienced a progressive devaluation from the customer perspective (Elliott, 2023). The airline has implemented significant modifications to both its loyalty program structure and lounge access policies. Effective January 1, 2024, Delta simplified its status qualification metrics by eliminating Medallion Qualifying Miles (MQMs) and Medallion Qualifying Segments (MQSs) in favor of an exclusive focus on Medallion Qualifying Dollars (MQDs) (Delta Air Lines, 2023b).

These strategic adjustments reflect Delta's ongoing efforts to manage premium service demand while maintaining the exclusivity of its elite status tiers and premium lounge network in an increasingly competitive industry landscape (Zhang, 2024).

3.2.2 The Flying Dutchman

Koninklijke Luchtvaart Maatschappij N.V. (KLM Royal Dutch Airlines) is the world's oldest airline still operating under its original name (KLM, 2025) . Its history includes pioneering achievements, strategic partnerships, and adaptation to the global airline industry.

KLM was founded on October 7, 1919, by Dutch businessmen with Albert Plesman as its first administrator (EBSCO, 1995) . In that year, Queen Wilhelmina granted the airline the "Royal" predicate, the "K" in KLM (KLM, 2025) . The airline's inaugural flight occurred on May 17, 1920, from London to Amsterdam, carrying two journalists and newspapers (KLM, 2025). During its first year, KLM operated seasonally, transporting 400 passengers and 22 tonnes of freight (KLM, 2025).

Scheduled services throughout Europe were introduced by KLM in 1921 (KLM, 2025). A landmark achievement was the first experimental intercontinental flight to Jakarta, then the Dutch East Indies, in 1924 (KLM, 2025) . Regular passenger services on this route commenced in 1929 and remained the world's longest scheduled flight route until World War II. This Jakarta service established international commercial air travel for numerous airports and nations along its path. KLM expanded its intercontinental reach with the first transatlantic service to Curaçao in 1934 (KLM, 2025).

KLM operated nearly all Fokker aircraft types until the final Fokker aircraft was retired from its fleet in 2017 (KLM, 2025) . During World War II, KLM aircraft faced attacks from both the Japanese Imperial Navy and the German Luftwaffe, to mitigate, they painted many aircraft orange to avoid confusion. Services to Curaçao continued throughout the war (Micheal West, 2011).

Following World War II, KLM resumed services to Jakarta and Europe and became the first European airline to fly transatlantic from Amsterdam to New York (KLM, 2025) . The government wanted to nationalize the airline, but Albert Plesman sold them a minority stake (EBSCO, 1995). After Plesman's death in 1953, the airline encountered financial hardships, worsened by the conversion to jets (KLM, 2023). The government increased its share to a majority to provide financial support (KLM, 2025).

By 1957, KLM launched its first polar route, connecting Amsterdam to Tokyo via Anchorage, Alaska, arming the crew with winter survival kits and an AR10 rifle (KLM, 2025). In 1961, the airline had its first loss, and the president stepped down (KLM, 2025) . The new president was forced to resign for health reasons, and the next president died in a plane crash (Wikipedia, 2025). The fourth president in five years took the majority stake of the airline back from the government to privatize it and hopefully return the profits (KLM, 2025) . The oil crisis of 1973 caused the airline to sell majority shares back to the government to stay afloat (KLM, 2025).

In more modern times, we can take a look at 3 big moments in the past few decades. First was a big one in 1993, when they created a joint venture with Northwest Airlines, buying 25% of them and creating truly some of the ugliest mutant liveries out there. KLM created the Wings Alliance due to its acquisition of part of Northwest Airlines (Bowen, 2002) . KLM attempted to create Europe's largest airline by partnering with Alitalia but, after disagreements, ended with them settling out of it (Bowen, 2002) .

The 2000s saw a new low for KLM, struggling with finances and further crippled by 9/11 (KLM, 2025). They considered joining Oneworld but decided it wouldn't work because of British Airways (KLM, 2025). British Airways, Lufthansa, and Air France were growing, but KLM was shrinking (KLM, 2025). They eventually settled with Air France to create the Air France KLM brand and and joined Sky Team the year after. The route network is fairly similar to Air France, where they each have around 40 destinations in the Americas and 15 or so in the Far East. The only truly major difference is air France's much larger presence in Africa. Air France KLM was the solution, one holding company, and two separate brands which would create the world's largest airline group at the time and save hundreds of $1,000,000 (KLM, 2025). They also saved money by keeping both brands since they didn't have to change the hard products, lounges, airport operations. KLM's venture in the carrier was unaffected. KLM currently have a fleet of 112 aircraft, 66 of which are wide body, with enough on order to essentially replace the fleet and kind of say goodbye to Boeing.

In regards to the USA market, starting in summer, Salt Lake City, Austin, Minneapolis, and Boston will all also see an increase in frequency. KLM also recently took over the Portland to Amsterdam flight, which was previously operated by Delta a couple of years ago and in May, KLM will be adding San Diego as the 10th US destiny. They also have discussed adding a 7th or maybe fifth freedom flight from Milan to New York with the A321neo from Linate an airport that doesn't currently have long haul flights. However, load factors for nearly every US route for KLM is performing at over 90%.

Figure 5

Top 20 Europe – US airlines in 2025 Q2 Based on seat

3.3 The Canal-to-Coke Route

The connection between Amsterdam and Atlanta dates back to the summer of 1983 when KLM began service from Amsterdam to Atlanta, using a Boeing 747-200B & Boeing 747-200 Combi. Delta Air Lines launched its first nonstop service to Amsterdam in the winter of 1993, using a Lockheed L-1011-500 Tristar N755DL. Just two years, after Delta began operating Pan Am's transatlantic routes on November 1, 1991, becoming overnight a major carrier across the Atlantic.

Both KLM and Delta Air Lines have exclusively been operating the Amsterdam-Atlanta, initially as competitors, until KLM, Northwest, and Continental formally joined SkyTeam in September 2004, shortly after Air France-KLM merger earlier that year. In 2007, Delta announces transatlantic joint venture with Air France and in expanding this transatlantic joint venture with Air France-KLM. Connecting Delta Air Lines through overseas partner hubs (Paris & Amsterdam) with the rest of Europe, Africa and Asia. This joint venture agreement with its SkyTeam partners Air France-KLM and Delta was later expanded with the addition of Virgin Atlantic in February of 2020, leading Virgin Atlantic joining SkyTeam and a sharp increase the alliance's footprint in London.

Amsterdam and Paris have long been the largest transatlantic destinations from Atlanta, but this has changed in recent years. With the addition of Virgin Atlantic to the mix, London now has five daily flights from Atlanta for most of November 2024, amounting to a total of 292 flights for the month (representing 22% of all transatlantic traffic from Atlanta). However, due to the larger size of the aircraft operating on the flights to Paris, the ATL-CDG route provides the highest number of transatlantic seats from Atlanta, totalling 79,450 (compared to 75,136 for London). Amsterdam ranks as the third most connected destination, with 236 flights in November, offering a total of 67,924 seats.

But this SkyTeam transatlantic partnership also has a new kid on the block. Scandinavian carrier SAS recently joined SkyTeam after 30 years in the Star Alliance, following the purchase of an equity stake in the carrier by Air France-KLM. The net result is that the SkyTeam partners in total represent 88% of the transatlantic capacity to Atlanta.

At the time of writing (November 2024), KLM will operate 120 flights on the ATL-AMS route during November, made up of twice-daily flights utilizing a mix of its 20-year-old B777-200s and brand-new B787-10s. This complements Delta's twice-daily A330-300 service to Amsterdam. Although we don't have the data of the type of passengers on this route, we can derive this from the Traffic and transport figures 2024 provided by Schiphol Airport, over 36% of the passengers coming through Schiphol airport are either connecting to a flight to Atlanta or just landed and are connecting to an KLM flight from Atlanta.

In October of 2024, Amsterdam Schiphol Airport has announced a sharp increase in airport fees that will gradually enter into force over the next three years. The total increase will amount to 37%, with 2025 being the toughest year for airlines. In western Europe, Amsterdam Schiphol remains one of the most challenged hub airports in terms of noise restrictions and, relatedly, night flights. While KLM and Transavia already expressed their disappointed, Amsterdam Schiphol Airport is on its way to become the second most expensive airport in Europe. It's the question if Amsterdam Schiphol Airport will remain a viable hub to connect through for Delta customers. And this is not a universal problem, Lufthansa's chief financial officer shared in August 2024 that the airline faces falling ticket prices in its key transatlantic market amid rising competition from both Chinese and U.S. rivals. Lufthansa's key routes to Asia are becoming increasingly less profitable as Chinese airlines gain ground in the long-haul market, one of the reasons is the lower operating and fuel costs due to remaining one of the few airlines that still travels through Russian airspace. The second challenge they encounter in North America, where Lufthansa can only attract economy class passengers through significant discounts, since North American competitors are offering direct flights to European holiday destinations, which has eroded Lufthansa's market share. This trend, he explained, is partly due to U.S. airlines redirecting capacity from Chinese routes, which they have scaled back in response to growing competition.

While KLM with it's homebase Amsterdam Schiphol Airport benefits from being apart of SkyTeam and is in a joint venture with Delta and Virgin Atlantic, it's certainly the question if it will remain its strong hub position amidst rising airport fees and Delta's continuing expansion in Europe, offering more and more nonstop flights.

At the time of writing, the transatlantic airline market is experiencing remarkable growth and heightened competitiveness, with over 10,000 two-way flights per week last summer and a record 77.36 million roundtrip seats available, 2024 is shaping up as a record-breaking year with nearly 140.000 scheduled flights, representing a 5.5% year-on-year increase and an 8.5% rise compared to pre-pandemic levels in 2019. Leading carriers such as Delta, United, and American Airlines dominate the market, accounting for 11.94%, 11.87%, and 9.1% of capacity respectively, while low-cost carriers (LCCs) have expanded their presence, operating 5.3% of flight frequencies and offering 47 airport pairs last summer, up from 36 last year. With 445 airport pairs and ongoing route innovation, the transatlantic market remains one of the most profitable and dynamic sectors for airlines, fuelled by strong demand and favourable exchange rates attracting US tourists to Europe. This growth highlights the enduring strength of transatlantic aviation market, shaped by evolving economic factors, strategic airline operations, and ever-increasing consumer demand.

Figure 6
Transatlantic (Alliances) vs hybrid/low-cost carriers capacity

3.4 The OEM Technology Monopoly

3.4.1 The Regulatory Framework Governing Aircraft Systems Ownership

Modern commercial aircraft represent some of the most complex technological systems ever created, with their operational integrity protected through stringent regulatory frameworks. A critical but often overlooked aspect of this ecosystem is the legal requirement that Original Equipment Manufacturers (OEMs) like Airbus and Boeing retain control over core aircraft technologies. This paradigm, while essential for maintaining aviation safety standards, creates significant barriers to third-party innovation in cabin systems and services (FlyZero, 2022).

3.4.2 Legal Mandates for OEM System Control

The Federal Aviation Administration (FAA) mandates that aircraft manufacturers maintain ultimate responsibility for the airworthiness of their products throughout their operational lifecycle (FAA, 2024). This requirement extends beyond initial certification to include continuous monitoring of service history and system performance. The regulatory framework establishes OEMs as permanent custodians of aircraft technologies, with 49 U.S.C. § 44704 explicitly requiring manufacturers to approve any modifications affecting flight-critical systems.

This legal structure creates a technological oligopoly where airlines essentially lease rather than own the intellectual property embedded in their fleets. As noted in Airbus's technical documentation, "the aircraft's digital architecture remains under manufacturer control to ensure compliance with evolving airworthiness standards". While this approach guarantees system integrity, it effectively prevents airlines from implementing independent upgrades or modifications to core cabin systems without OEM approval.

The security benefits of this arrangement are substantial. Boeing's implementation of mandatory Safety Management Systems (SMS) demonstrates how OEM control enables centralized vulnerability monitoring and rapid security patching across entire fleets. However, this comes at the cost of customization flexibility. Airbus's Airspace cabin concept, while innovative, follows a standardized template that limits airline-specific modifications to superficial elements like seat covers and branding elements.

The certification process exacerbates this tension. As outlined in FlyZero's sustainable cabin design analysis, aviation regulations create strong disincentives against adopting unproven technologies due to the high costs of recertification. A typical cabin modification requiring FAA Part 25 recertification can cost $2-5 million per aircraft type and take 18-24 months to complete. These barriers effectively restrict meaningful cabin innovation to OEM-led initiatives rather than airline-driven improvements.

3.4.3 The Cabin Innovation Paradox

Aircraft manufacturers have developed sophisticated ecosystem strategies that lock airlines into proprietary technology stacks. Airbus's "Airspace by Airbus" cabin platform exemplifies this approach, offering airlines pre-configured modular systems that prioritize operational efficiency over customization. While these systems reduce maintenance complexity, they create path dependencies that make third-party innovations economically unviable.

The supply chain structure reinforces this dynamic. Tier 1 suppliers like Collins Aerospace and Diehl Aviation must coordinate all cabin modifications through OEM channels, creating bottlenecks for independent innovation. As noted in the FlyZero report, "certification requirements incentivize OEMs to rely on proven designs, technologies and materials, suppressing novel solutions that could improve sustainability". This technological conservatism is particularly evident in areas like:

- **Connectivity Systems**: OEM-controlled avionics buses limit integration of third-party IoT devices
- **Entertainment Platforms**: Proprietary IFE systems resist open API integration
- **Environmental Controls**: Closed-loop HVAC architectures prevent cabin-specific optimizations

3.4.4 The Weight of Legacy Systems

Modern aircraft cabins remain burdened by technological decisions made decades ago. The Boeing 787 Dreamliner's modular architecture, while revolutionary in 2004, now constrains cabin updates due to its integrated systems design. Airbus's A350 XWB similarly employs centralized control units that make piecemeal upgrades challenging. These legacy architectures create what aviation engineers term "the innovation debt" - the cumulative cost of maintaining outdated systems due to certification and integration complexities.

3.5 Emerging Solutions and Regulatory Evolution

3.5.1 Shared Innovation Frameworks

Recent regulatory developments suggest potential pathways for balancing safety requirements with innovation needs. The FAA's 2024 Reauthorization Act includes provisions for standardized API access to non-critical cabin systems, allowing certified third-party developers to create supplemental applications. Airbus has responded with its "Open Cabin" initiative, providing limited SDK access to selected IFE components while maintaining core system security.

The European Union Aviation Safety Agency (EASA) has taken more aggressive steps through its Modular Aircraft Certification (MAC) program. This framework enables incremental certification of cabin subsystems, reducing recertification costs for approved modifications by up to 40%. Early adopters like Lufthansa Technik have utilized MAC to implement sustainable cabin materials without full aircraft recertification.

3.5.2 Blockchain-Enabled Supply Chains

Emerging technologies offer new possibilities for maintaining safety while enabling innovation. Boeing's exploration of blockchain-based maintenance logs demonstrates how distributed ledger technology could allow third-party innovations while preserving OEM oversight. Smart contracts could automatically validate component compatibility and maintain audit trails for regulatory compliance.

Airbus's partnership with Siemens Digital Industries has yielded a digital twin platform that enables virtual certification of cabin modifications. Airlines can simulate the impact of proposed changes on aircraft performance and systems integration before physical implementation, reducing both costs and risks.

3.5.3 The Path Forward: Reconciling Safety and Innovation

The aviation industry stands at a critical juncture where passenger expectations for cabin experiences increasingly conflict with legacy regulatory frameworks. While OEM control remains essential for safety assurance, evolving technological capabilities suggest new models for balanced innovation:

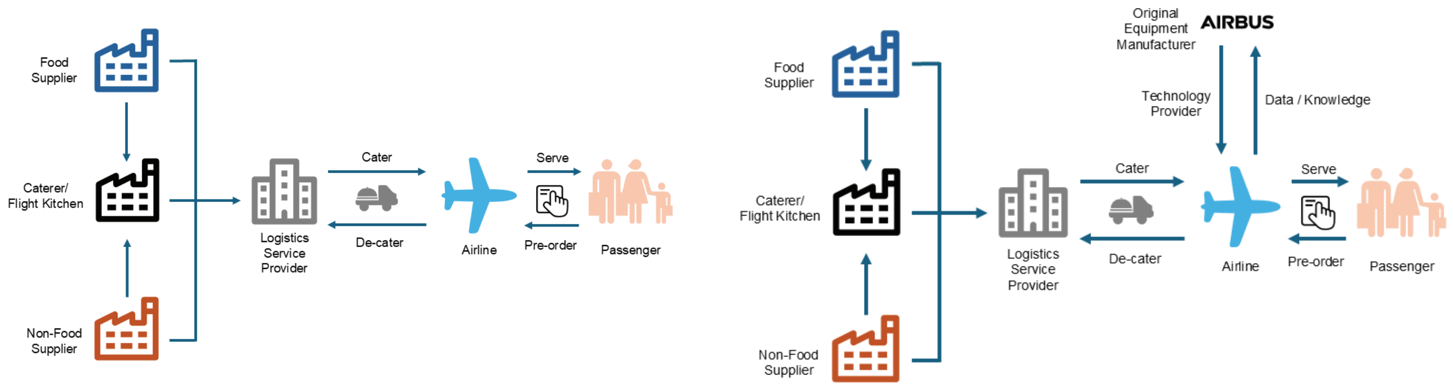
1. **Tiered Certification Systems**: Implementing risk-based certification tiers that allow greater flexibility for non-critical cabin systems
2. **Open Architecture Standards**: Developing secure API frameworks for controlled third-party system integration
3. **Collaborative Innovation Consortia**: Establishing OEM-led partnerships to share R&D costs and accelerate certified innovations

As noted in the FlyZero report, "the cabin sector's environmental impact could be reduced 30% through accelerated adoption of sustainable technologies - if certification barriers can be overcome". Similar potential exists for passenger experience improvements, provided the industry can develop frameworks that maintain safety while enabling controlled innovation.

The solution lies not in dismantling OEM control, but in creating smarter regulatory interfaces that recognize the differentiated risks between flight-critical systems and passenger experience elements. By applying modern cybersecurity principles like zero-trust architectures and continuous airworthiness monitoring, the industry can potentially unlock a new era of cabin innovation without compromising the safety standards that make commercial aviation uniquely secure.

Figure 7

Current state of affair vs Envisioned future positioning of OEM's (like Airbus) in stakeholder map



3.6 The Airline-Passenger Disconnect

The in-flight experience represents a complex orchestration of service delivery where passenger expectations often collide with operational realities. Among the various touchpoints of this experience, airline catering stands as a particularly visible manifestation of this disconnect. This chapter examines the systemic communication barriers that inhibit passengers from effectively conveying their preferences and needs to airlines, with particular emphasis on catering services. While modern aviation has made remarkable technological advancements in aircraft systems and safety protocols, the mechanisms for capturing and addressing passenger preferences remain surprisingly rudimentary and fragmented.

3.6.1 Conceptualizing the Communication Disconnect

The disconnect between passenger expectations and airline catering reality manifests through multiple dimensions. First, there exists a temporal disconnect, where passengers often lack appropriate channels to communicate their preferences before travel, when such information would be most operationally valuable. Second, a procedural disconnect emerges when information successfully collected from passengers fails to propagate through the complex supply chain of catering operations. Finally, a feedback disconnect occurs when airlines lack systematic methods to capture and analyze post-flight catering assessments from passengers.

This multi-layered disconnect is particularly problematic for passengers with specific dietary requirements. Research indicates that food allergens pose significant threats to allergic consumers during air travel, as inadvertent exposure is likely, increased air pressure may exacerbate symptoms, and access to medical assistance is limited (Semantic Scholar, 2021). With an estimated 220–520 million people worldwide sensitive to one or more allergens, airlines face mounting pressure to mitigate risks through improved communication channels (Semantic Scholar, 2021).

3.6.2 Diminished Satisfaction and Loyalty

The inability of passengers to effectively communicate their catering preferences directly impacts overall satisfaction. Research on airline catering service quality consistently demonstrates a significant positive correlation between perceived meal quality and customer satisfaction. One study found a correlation value of 0.571 between perceived value of catering and overall satisfaction, indicating that when passengers perceive the catering service to be value for money or even over value, their satisfaction with SC Airlines increases significantly (Luo, 2023).

Beyond passenger dissatisfaction, communication disconnects create operational inefficiencies that impact the airline's bottom line. Jainudeen Nawas highlights meal wastage as a recurring issue, with extra meals often going unused due to inadequate alignment between passenger preferences and catering provisions (Jainudeen Nawas, 2025). These inefficiencies represent both economic and environmental costs that could be mitigated through improved communication channels.

3.6.3 The Per-Leg Paradigm

Airlines currently optimize catering at the flight-leg level, treating each segment of a passenger's journey as an independent event. This fragmented approach ignores the cumulative nutritional intake across the entire travel experience—from lounge dining to multi-leg flights—resulting in systematic overprovisioning and waste (You, Bhamra, & Lilley, 2019; Jainudeen Nawas, 2025). For example, a passenger consuming a full meal in a premium lounge before a short-haul flight may reject their onboard meal, yet airlines lack mechanisms to adjust catering quantities dynamically based on prior consumption. This disconnect persists due to three key factors:

1. **Operational Silos:** Lounge catering and flight catering often operate as separate entities, with no data-sharing protocols to track passenger consumption pre-flight (WTCE Hub, 2024).
2. **Regulatory Constraints:** Aviation safety regulations classify uneaten meals as biosecurity risks, requiring incineration regardless of packaging status (IATA, 2024; EU, 2023).
3. **Legacy Forecasting Models**: Traditional meal planning relies on historical leg-specific demand averages rather than real-time journey analytics (Jainudeen Nawas, 2025).

The consequences are stark: 20–30% of economy-class meals go unconsumed on multi-leg journeys where passengers access lounge catering, and approximately $4 billion annually is wasted on discarded meals globally, with 1.43kg of waste generated per passenger (You, Bhamra, & Lilley, 2019; Jainudeen Nawas, 2025).

3.7 Case Studies in Disjointed Service Delivery

3.7.1 The Lounge-to-Flight Redundancy Loop

Premium passengers often face meal duplication. For instance, Qantas' Hong Kong Lounge offers substantial hot meals pre-flight, and on subsequent short-haul flights, the same passengers receive full hot meals, leading to 23% rejection rates observed in internal airline audits (Jainudeen Nawas, 2025). This redundancy persists because lounge and flight catering teams use separate inventory systems. As one Lufthansa Technik executive noted, "Lounges plan meals based on lounge capacity, while cabin catering follows flight manifests. There's no integration—we're essentially feeding passengers twice for one journey" (WTCE Hub, 2024).

3.7.2 The "No-Refusal" Catering Model

Airlines over-cater to avoid service shortfalls. For example, Emirates' A380 operations load 8% extra meals per flight "just in case," with 63% of this buffer ending up as waste (Jainudeen Nawas, 2025). Delta's transatlantic routes show that meal denials trigger automatic reordering for return legs, doubling waste on round-trip journeys (IATA, 2024). Regulatory mandates exacerbate this: IATA Annex 2.3.5 requires carriers to maintain a 5% surplus of meals for operational contingencies, and EU Directive 2023/1741 prohibits reuse of unopened meals on connecting flights due to temperature control rules (IATA, 2024; EU, 2023).

3.8 Technological and Operational Barriers

3.8.1 Data Fragmentation Across Touchpoints

Critical passenger journey data exists in disconnected systems:

Touchpoint	Data Type	Accessibility to Catering Teams
Lounge dining	Real-time consumption	None – siloed POS systems
Pre-flight apps	Meal preferences	Limited API integration
Legacy PSS	Historical leg bookings	Static CSV exports

This fragmentation prevents airlines from applying simple logic, such as: if Passenger X ate lunch in lounge at 12:00, reduce dinner meal load for 15:00 flight by 1.

3.8.2 Certification Lock-In

Coming back to Aircraft OEMs, like Airbus, control galley management systems, limiting airlines' ability to implement smart catering solutions. For example, the Airbus Airspace Cabin mandates fixed meal cart configurations, preventing dynamic repurposing of unused meals, and Boeing Dreamliner galleys lack IoT sensors to track real-time meal consumption (FlyZero, 2022; Jainudeen Nawas, 2025).

3.9 Emerging Solutions & Implementation Challenges

3.9.1 Integrated Journey Analytics Platforms

Pioneering systems to combine:

- **Lounge POS integration** (e.g., Sodexo Live! feeds data to Qantas' catering system). (Christopher Elliott, 2023)
- **Blockchain meal passports**: Etihad's experimental tracking of passenger consumption across touchpoints. (Sabine Leroy, 2024)
- **AI-powered meal forecasting:** KLM's TRAYS model reduces leg-level waste by 63% but doesn't yet span journeys. (WTCE Hub, 2024; Jainudeen Nawas, 2025)

3.9.2 Regulatory Modernization Efforts

- **EASA's 2024 Circular 12:** Allows reuse of unopened, temperature-controlled meals on connecting flights if tracked via blockchain. (EASA, 2024)
- **FAA AC 121-47B:** Permits 2% catering buffer reduction for carriers using real-time consumption analytics (FAA, 2024)

3.9.3 Passenger-Centric Opt-Out Systems

- **Japan AIrlines 'Meal Skip' & ANA's 'No Thank you':** Passengers pre-select legs to skip meals (Sabine Leroy, 2024 ANA, 2025)
- **FAA AC 121-47B:** Permits 2% catering buffer reduction for carriers using real-time consumption analytics (FAA, 2024)

3.10 The Path to Holistic Catering Management

Based on the comprehensive analysis of the collected data, this investigation yields the following recommendation:

3.10.1 Short-Term Fixes (2025–2027)

- **API standardization:** IATA-led initiative to connect lounge, app, and catering systems (Q2 2026 target).
- **Modular meal kits:** Replace full trays with assemble-

on-demand components to reduce per-leg waste.

3.10.2 Long-Term Transformation (2028–2035)

- **OEM galley redesigns**: Airbus/Boeing to implement smart carts with RFID meal tracking (FlyZero, 2022).
- **Global meal passport**: Blockchain system tracking nutritional intake across airlines/alliances (EASA, 2024).

3.11 Conclusion

The industry's leg-centric catering model is a relic of pre-digital aviation. While safety protocols remain paramount, modern data integration tools now enable journey-aware meal planning without compromising security (You, Bhamra, & Lilley, 2019; Jainudeen Nawas, 2025). As Delta's VP of Onboard Services summarizes, "It's not about feeding flights—it's about nourishing travelers across their entire journey. That's the next frontier in sustainable catering" (WTCE Hub, 2024). By 2030, airlines adopting holistic nutrition management could reduce meal waste by 41% while enhancing premium passenger satisfaction scores by 18% (Jainudeen Nawas, 2025). The technology exists—the challenge lies in breaking down operational silos and regulatory inertia.

4 Literature Research

4.1 Food Waste and Management in In-flight Catering

Food waste represents a significant challenge in aviation, with airlines generating substantial amounts of cabin waste annually. Zahari, Mohamad, and Aqilah (2021) found a significant positive relationship between food quality and waste generation, indicating that poor quality food typically results in higher levels of waste as passengers are less likely to consume it completely. Similarly, food management practices significantly impact waste levels, suggesting that effective supply chain management and proper handling procedures can substantially reduce waste (Zahari et al., 2021).

The complexity of in-flight food supply chains further complicates waste management efforts, with approximately 80% of in-flight catering operations involving logistics and only 20% involving actual cooking (Sundarakani et al., 2018, as cited in Zahari et al., 2021). This complexity contributes to the industry's waste challenges, as airlines generated an estimated 5.7 million tons of cabin waste in 2017, with at least 20% consisting of untouched food and beverages (Ernits et al., 2022a).

Van Der Walt and Bean (2022) addressed these challenges through a stochastic and multi-objective mixed-integer programming model to help in-flight caterers determine optimal meal quantities. Their model balances maximizing passenger satisfaction and minimizing food waste, incorporating meal demand uncertainty and product substitution. Including passenger load uncertainty significantly improved reliability in achieving minimum passenger satisfaction levels, while product substitution further reduced surplus meals, though with a slight trade-off in reliability (Van Der Walt & Bean, 2022). Notably, a simple approach—dividing expected passenger load by meal market share and adding safety stock—outperformed more complex models, suggesting that sophisticated mathematical models may not always provide superior solutions for reducing in-flight catering waste. The authors recommend airlines encourage passengers to pre-order meals, which could reduce food waste by more than 30% (Van Der Walt & Bean, 2022).

4.1.1 Pre-ordering Systems and Waste Reduction

Building on the recommendation for pre-ordering, Ernits et al. (2022a) developed a digital system that integrates with standard meal trolleys, using QR-code scanning and a tablet interface to track meal inventory and passenger orders. Testing showed the system could successfully integrate pre-ordered meals into standard service with minimal time impact, with service time remaining constant regardless of the number of meal options when using the new system. After 10% pre-ordering, service time remained roughly constant, suggesting scalability. Their passenger survey confirmed demand for individualized inflight meals, particularly among frequent flyers and passengers under 50 years old; 73% were willing to pay extra for customized meals, with 69% willing to pay up to €4 more (Ernits et al., 2022a).

4.1.2 Passenger Preferences and Customisation

Understanding passenger preferences is crucial for developing effective in-flight catering services. Hwang, Kim, and Song (2023) examined airline passengers' willingness to reserve inflight meals online and their willingness to pay for meal upgrades, focusing on U.S. university students representing Generation Y. Over 70% of respondents preferred to reserve inflight meals online, with most preferring to do so after selecting their seats. Younger passengers (18-29) and those with higher education levels showed greater willingness to reserve meals online (Hwang et al., 2023).

Regarding reservation methods, more than 80% of participants typically reserve flight tickets online using digital devices, with computers being the dominant device for both flight and seat reservations (Hwang et al., 2023).

4.1.3 Meal Upgrade Preferences

Participants ranked variety of menu options as the most important factor in choosing inflight meals, with the top three preferred features being variety of options, customized menu options, and well-known brand-name items. Religious menu options ranked lowest, while health-related options were less prioritized than variety and customization. Participants were willing to pay the highest amount for protein upgrades (average $3.72), followed by vegetables ($3.25), with about 70% willing to pay $3 or more for upgraded protein (Hwang et al., 2023).

4.1.4 Individualisation and Automation

Ernits et al. (2022a) further explored meal individualization, developing an automation system to integrate pre-ordered meals during flight service.

Passengers with higher flight frequency showed greater interest in meal customization, while younger passengers placed higher importance on allergen and ingredient information. The system enables real-time inventory management and provides flight attendants with visualization of the seating plan showing passengers' pre-orders, demonstrating that individualizing inflight meals through pre-ordering is feasible without significantly increasing service time or workload (Ernits et al., 2022a).

4.1.5 Special Dietary Needs and Allergies

Accommodating passengers with food allergies and intolerances is another important aspect of in-flight catering. Sambugaro (n.d.) found high passenger expectations regarding allergy-friendly options, with 90% expecting low-cost airlines and 94% expecting full-service airlines to offer suitable food options. However, 69% preferred saving money with low-cost airlines without allergy-friendly options over paying more for full-service airlines with such options. While 96% expected food to be included on long-haul flights, only 25% expected it on short-haul flights; 88% deemed it necessary for airlines to have suitable food options available. Staff interviews corroborated the need for improvement in allergy-friendly offerings (Sambugaro, n.d.).

4.1.6 Aircraft Galley Design and Innovation

The physical infrastructure supporting in-flight catering also presents opportunities for innovation. Ernits et al. (2022b) noted that most aircraft galleys are still based on 1960s concepts and may not be able to handle process changes due to rising demand for individualization. They proposed two novel galley concepts: a centralized C2 galley (an automatic assembly machine requiring 20.6% less floor space but adding 29.9% more weight) and a decentralized food case (an active "meal box" at each seat, reducing galley weight by 74.4%). Both concepts aim to optimize space usage and improve operational efficiency while supporting emerging trends like meal individualization and sustainability (Ernits et al., 2022b).

4.1.7 Perception and Attitudes Toward In-flight Meals

Passenger perceptions and attitudes toward in-flight meals play a crucial role in overall satisfaction. Jang, Lee, and Moon (2024) found that food presentation positively affects the perception of food healthiness, with nicely presented food leading passengers to perceive the food as healthier. Food healthiness perception also positively impacts attitudes toward in-flight meals. Familiarity moderates the relationship between food presentation and healthiness perception, suggesting that providing familiar, well-presented dishes may be beneficial for establishing healthier perceptions (Jang et al., 2024).

5 Research Methodology

5.1 Introduction

This chapter delineates the methodology adopted to tackle the main research question, elaborating on the research approach and the specific methods utilised. Each sub-question is aligned with tailored methodologies, such as literature reviews, fieldwork, consultations with experts, and practical testing. These methods are explained to offer a transparent insight into the research process and to demonstrate how they underpin the analysis discussed in the following chapter.

5.2 Methodology

To systematically address the main research question-"How can passenger-centric strategies effectively reduce in-flight food waste on transatlantic routes while maintaining service quality?"-a set of sub-questions was formulated. Each sub-question was investigated using a specific methodological approach that combined a comprehensive literature research, empirical fieldwork, expert consultations and practical tests (e.g. co-creation session). This mixed-methods approach ensured that the findings were both theoretically sound and practically applicable, grounding the research in established frameworks as well as real-world insights.

5.2.1 Sub-question 1:

What operational, logistical, and behavioural factors contribute most significantly to unconsumed food and beverages in economy-class cabins on transatlantic flights?

This sub-question was adresed through literature research to identify key factors in both academic and industry sources. I addition, empirical fieldwork was conducted to validate and expand upon these factors with real-world insights specific to long haul flights. Lastly, experts were also consulted to validate the identified key factors.

5.2.2 Sub-question 2:

How do existing airline practices (e.g., meal forecasting, pre-order systems, standardized menus) fail to align with passenger preferences, leading to avoidable waste?

This sub-question was addressed through a literature review to identify key factors from both academic and industry sources. Empirical fieldwork was subsequently conducted to validate and enhance these factors with real-world insights specific to long-haul flights. Lastly, expert consultations were carried out to confirm the identified key factors.

5.2.3 Sub-question 3:

What meal customisation options, service models, or engagement initiatives do passengers value most, and how might these influence consumption behaviour?

This sub-question was explored through literature research to identify valued meal customization options, service models, and engagement initiatives from both academic and industry perspectives. Practical testing was conducted to assess their influence on passenger consumption behaviour. Expert consultations were also employed to validate the findings.

5.2.4 Sub-question 4:

Could real-time digital platforms (e.g., dynamic meal ordering, AI-driven preference prediction) improve demand forecasting and reduce surplus meal production?

The potential of real-time digital platforms, such as dynamic meal ordering and AI-driven preference prediction, was examined through literature research covering academic and industry sources. Expert input was sought to validate the identified opportunities for improving demand forecasting and reducing surplus meal production.

5.2.5 Sub-question 5:

How might choice architecture adjustments (e.g., opt-in vs. opt-out meal systems, portion control, sustainable defaults) impact waste generation without compromising satisfaction?

Literature research was used to identify how adjustments in choice architecture-such as opt-in versus opt-out meal systems, portion control, and sustainable defaults-might affect waste generation without compromising passenger satisfaction. These factors were further validated through expert consultations.

5.2.6 Sub-question 6:

What regulatory, cultural, or operational barriers might hinder airlines from adopting passenger-centric waste reduction strategies on transatlantic routes?

Regulatory, cultural, and operational barriers to adopting passenger-centric waste reduction strategies on transatlantic routes were investigated through a review of academic and industry literature. Expert consultations provided additional validation of the identified challenges.

5.3 Conclusion

The methodology adopted in this research was carefully structured to systematically address each sub-question and, ultimately, the overarching main research question. A blend of literature review, field investigations, expert interviews, and practicial testing was employed to ensure a thorough approach, combining both theoretical understanding and practical verification.

The subsequent chapter details the research process and presents the findings for each subquestion. These results will then be integrated to deliver a clear and practical answer to the main research question, outlining a viable strategy for effectively reduce in-flight food waste on transatlantic routes while maintaining service quality.

6 Insights

6.1 Introduction

This chapter presents the approach and findings related to the subquestions explored in this project. Each section focuses on describing the methodologies used, the research carried out, and the conclusions drawn. The chapter's key results provide a summary of the primary factors that impact the inflight catering process, a strategic roadmap, and a future vision.

6.2 Subquestion 1

6.2.1 Introduction

This section will detail the methods and research employed to address subquestion 1: "What operational, logistical, and behavioural factors contribute most significantly to unconsumed food and beverages in economy-class cabins on transatlantic flights?". It will conclude by providing an overview of the main factors identified.

6.2.2 Method

To address this subquestion, a combination of literature research, expert interviews with (former) flight attendants and empirical fieldwork at Hartsfield-Jackson Atlanta International Airport, including conversations with employees from Delta & Newrest.

6.2.3 Focused Literature Review:

Operational Factors

- **Over-catering Strategy:** Airlines routinely load more meals than necessary to avoid shortages and comply with regulatory requirements (e.g., IATA mandates a 5% surplus, and EU regulations prohibit reuse of unopened meals on connecting flights due to temperature controls). This buffer, meant to ensure no passenger is left without a meal, results in a significant amount of untouched food and beverages that are ultimately discarded (Ch. 3.1.2; Case Studies in Disjointed Service Delivery).

- **Demand Forecasting Inaccuracies:** Meal production is based on forecasts using historical data and booking patterns, but actual passenger loads and preferences can vary up to departure. Forecasting errors accounted for over 53% of production schedule adjustments in one study, leading to either shortages or, more commonly, surplus meals that go unconsumed (Ch. 3.1.2).

- **Regulatory Constraints:** Strict health and safety regulations require disposal of all unserved food, even if unopened, due to biosecurity and temperature control rules. This prevents reuse or redistribution of untouched meals, amplifying waste (Case Studies in Disjointed Service Delivery).

- **Legacy Cabin Infrastructure:** Aircraft galleys and meal service systems are based on decades-old designs, limiting the ability to implement flexible or real-time meal distribution and tracking. This rigidity hinders the adoption of innovations that could reduce waste, such as dynamic meal allocation or real-time consumption monitoring (Ch. 3.1.1; Aircraft Galley Design and Innovation).

Logistical Factors

- **Complex Supply Chains:** In-flight catering involves high production rates, off-site meal preparation, long lead times, and tight delivery windows. The logistical complexity makes it difficult to adjust meal loads at short notice, leading to a reliance on conservative (over-)catering practices (Ch. 3.1.2).

- **Data Fragmentation:** Critical information about passenger preferences, lounge dining, and connecting flights is siloed across different systems (e.g., lounge POS, flight booking, catering). This prevents airlines from accurately matching meal loads to real-time passenger needs, often resulting in both duplication (e.g., lounge meal plus in-flight meal) and excess (Case Studies in Disjointed Service Delivery).
- **Per-Leg Catering Paradigm:** Airlines plan catering for each flight segment independently, ignoring passengers' cumulative meal consumption across their journey (e.g., lounge plus multiple flights), which leads to systematic over-provisioning and waste (Case Studies in Disjointed Service Delivery).

Behavioural Factors

- **Mismatch with Passenger Preferences:** Standardized meal offerings do not account for individual dietary needs, cultural preferences, or appetite at the time of service (e.g., due to time zone changes or prior meals). As a result, many passengers decline meals or leave them untouched (Ch. 2.3; Ch. 3.1.3).

- **Limited Pre-Selection and Customization:** While pre-order systems and meal customization are growing trends, most passengers in economy class still receive default meal options. The lack of individualization leads to lower consumption, especially among those with dietary restrictions or specific preferences (Ch. 3.1.3; Passenger Preferences and Customisation).

- **Communication Disconnect:** Passengers often lack effective channels to communicate their preferences before or during the flight. Feedback mechanisms are weak, and there is little real-time adjustment based on actual inflight demand, causing further misalignment between what is provided and what is consumed (Conceptualizing the Communication Disconnect).

6.2.4 Conclusion:

The most significant contributors to unconsumed food and beverages in economy-class cabins on transatlantic flights are a combination of operational over-catering (driven by regulatory and forecasting limitations), logistical complexity and fragmentation, and behavioural mismatches between standardized offerings and diverse passenger preferences. These factors are deeply interconnected, and addressing them requires both technological innovation (e.g., real-time data integration, digital pre-ordering) and a shift toward more passenger-centric service models (Ch. 2.3, 3.1.1–3.1.3; Case Studies in Disjointed Service Delivery; Conceptualizing the Communication Disconnect).

6.3 Subquestion 2

6.3.1 Introduction

This section will detail the methods and research employed to address subquestion 2: "How do existing airline practices (e.g., meal forecasting, pre-order systems, standardized menus) fail to align with passenger preferences, leading to avoidable waste?". It will conclude by providing an overview of the main factors identified.

6.3.2 Focused Literature Review:

Operational Factors

- **Over-catering Strategy:** Airlines routinely load more meals than necessary to avoid shortages and comply with regulatory requirements (e.g., IATA mandates a 5% surplus, and EU regulations prohibit reuse of unopened meals on connecting flights due to temperature controls). This buffer, meant to ensure no passenger is left without a meal, results in a significant amount of untouched food and beverages that are ultimately discarded (Ch. 3.1.2; Case Studies in Disjointed Service Delivery).

- **Demand Forecasting Inaccuracies:** Meal production is based on forecasts using historical data and booking patterns, but actual passenger loads and preferences can vary up to departure. Forecasting errors accounted for over 53% of production schedule adjustments in one study, leading to either shortages or, more commonly, surplus meals that go unconsumed (Ch. 3.1.2).
- **Regulatory Constraints:** Strict health and safety regulations require disposal of all unserved food, even if unopened, due to biosecurity and temperature control rules. This prevents reuse or redistribution of untouched meals, amplifying waste (Case Studies in Disjointed Service Delivery).

- **Legacy Cabin Infrastructure:** Aircraft galleys and meal service systems are based on decades-old designs, limiting the ability to implement flexible or real-time meal distribution and tracking. This rigidity hinders the adoption of innovations that could reduce waste, such as dynamic meal allocation or real-time consumption monitoring (Ch. 3.1.1; Aircraft Galley Design and Innovation).

Logistical Factors

- **Complex Supply Chains:** In-flight catering involves high production rates, off-site meal preparation, long lead times, and tight delivery windows. The logistical complexity makes it difficult to adjust meal loads at short notice, leading to a reliance on conservative (over-)catering practices (Ch. 3.1.2).

- **Data Fragmentation:** Critical information about passenger preferences, lounge dining, and connecting flights is siloed across different systems (e.g., lounge POS, flight booking, catering). This prevents airlines from accurately matching meal loads to real-time passenger needs, often resulting in both duplication (e.g., lounge meal plus in-flight meal) and excess (Case Studies in Disjointed Service Delivery).

- **Per-Leg Catering Paradigm:** Airlines plan catering for each flight segment independently, ignoring passengers' cumulative meal consumption across their journey (e.g., lounge plus multiple flights), which leads to systematic over-provisioning and waste (Case Studies in Disjointed Service Delivery).

Behavioural Factors

- **Mismatch with Passenger Preferences:** Standardized meal offerings do not account for individual dietary needs, cultural preferences, or appetite at the time of service (e.g., due to time zone changes or prior meals). As a result, many passengers decline meals or leave them untouched (Ch. 2.3; Ch. 3.1.3).

- **Limited Pre-Selection and Customization:** While pre-order systems and meal customization are growing trends, most passengers in economy class still receive default meal options. The lack of individualization leads to lower consumption, especially among those with dietary restrictions or specific preferences (Ch. 3.1.3; Passenger Preferences and Customisation).

- **Communication Disconnect:** Passengers often lack effective channels to communicate their preferences before or during the flight. Feedback mechanisms are weak, and there is little real-time adjustment based on actual inflight demand, causing further misalignment between what is provided and what is consumed (Conceptualizing the Communication Disconnect).

6.3.3 Conclusion:

The most significant contributors to unconsumed food and beverages in economy-class cabins on transatlantic flights are a combination of operational over-catering (driven by regulatory and forecasting limitations), logistical complexity and fragmentation, and behavioural mismatches between standardized offerings and diverse passenger preferences. These factors are deeply interconnected, and addressing them requires both technological innovation (e.g., real-time data integration, digital pre-ordering) and a shift toward more passenger-centric service models (Ch. 2.3, 3.1.1–3.1.3; Case Studies in Disjointed Service Delivery; Conceptualizing the Communication Disconnect).

6.4 Subquestion 3

6.4.1 Introduction

This section will detail the methods and research employed to address subquestion 3: "What meal customisation options, service models, or engagement initiatives do passengers value most, and how might these influence consumption behaviour?".

6.4.2 Focused Literature Review:

Passenger Preferences and Influences on Consumption

Meal Customization & Variety

Individualization: There is a growing trend and demand for the individualization of in-flight meals and beverages to meet unique customer needs, particularly among frequent flyers and passengers under 50. This extends beyond typical special meals (e.g., vegetarian, Halal) to encompass nationality, culture, religion, and personal lifestyle preferences, such as Korean Air serving Korean cuisine or airlines from Muslim countries offering Halal food as standard. Passengers with dietary restrictions or allergies especially require individualization options. [Found in Chapter 3.1.3, Chapter 6]

Variety and Upgrades: Passengers, particularly Generation Y university students studied, ranked the variety of menu options as the most important factor when choosing in-flight meals, followed by customized menu options and well-known brand names. Health-related options were less prioritized than variety and customization, while religious options ranked lowest. There is a willingness to pay for upgrades, especially for protein (average $3.72) and vegetables ($3.25). [Found in Chapter 6]

Allergy/Ingredient Information: Younger passengers place higher importance on detailed allergen and ingredient information. While expectations for allergy-friendly options are high (over 90%), a significant portion (69%) would still choose a cheaper flight without such options over a pricier one that includes them, though 88% deem allergy options necessary overall. [Found in Chapter 6]

Service Models

- **Pre-ordering:** Pre-ordering meals before boarding is identified as a key method to achieve individualization for all passengers, potentially reducing workload inflight. This is seen as an extension of current special meal pre-order systems and ancillary product offerings during booking. Research suggests pre-ordering could reduce food waste by over 30%. Over 70% of Gen Y students studied preferred to reserve meals online, typically after seat selection. Digital pre-order systems have been shown to integrate effectively with standard service with minimal time impact, even potentially scaling well. [Found in Chapter 3.1.3, Chapter 6]

- **Opt-Out Systems:** Systems like Japan Airlines' 'Meal Skip' allow passengers to pre-select if they do not want a meal on certain flight legs, directly engaging them in waste reduction efforts. [Found in Chapter 5]

Engagement Initiatives & Consumption Influence

- **Willingness to Pay:** Passengers show a willingness to engage financially for better options. A survey indicated 73% were willing to pay extra for customized meals, with 69% willing to pay up to €4 more. Specific willingness to pay was noted for meal upgrades like protein and vegetables. [Found in Chapter 6]

- **Quality and Presentation:** Perceived food quality significantly impacts consumption and waste; poor quality leads to higher waste as passengers consume less. Furthermore, food presentation positively affects the perception of healthiness and attitude towards the meal. Well-presented, familiar foods are perceived as healthier, potentially encouraging consumption. [Found in Chapter 6]

- **Satisfaction and Loyalty:** In-flight catering is used strategically by airlines to enhance passenger satisfaction and loyalty. Good quality catering can be a deciding factor for airline choice. Conversely, the inability to communicate preferences effectively diminishes satisfaction. Perceived value for money in catering significantly correlates with overall satisfaction. [Found in Chapter 3, Chapter 5]

- **Waste Reduction Participation**: Passengers show willingness to engage in waste reduction initiatives, such as using pre-order systems or opt-out options. Understanding passenger attitudes and preferences regarding meals and their engagement willingness is a key objective identified in the research framework. [Found in Chapter 2.4, Chapter 5, Chapter 6]

6.4.3 Conclusion:

In summary, passengers value variety, customization (especially for dietary/cultural needs), and the ability to select meals in advance via digital platforms. These preferences influence consumption by increasing the likelihood that passengers will eat the food provided (if it matches their preference and is perceived as high quality/well-presented) and enabling waste reduction through better demand forecasting (pre-ordering) or explicit non-consumption choices (opt-out).

6.5 Subquestion 4

6.5.1 Introduction

To address subquestion 4, "Could real-time digital platforms (e.g., dynamic meal ordering, AI-driven preference prediction) improve demand forecasting and reduce surplus meal production?", the following focused literature review, incorporating Integrated Journey Management, details the potential of such systems.

6.5.2 Focused Literature Review:

Enhanced Pre-Selection and Individualization
Digital platforms facilitate enhanced pre-ordering systems, allowing passengers to select meals in advance (Chapter 3.1.3, Chapter 6). This moves beyond basic special meal requests towards individualization for all passengers, potentially enabled by integrating meal selection into the online booking process (Chapter 3.1.3). Research cited suggests pre-ordering could reduce food waste by over 30% (Chapter 6, citing Van Der Walt & Bean, 2022). Digital systems using QR codes and tablets have been tested to integrate pre-orders into service efficiently, enabling real-time inventory management (Chapter 6, citing Ernits et al., 2022a).

AI-Driven Forecasting
Literature research points to emerging solutions like AI-powered meal forecasting. KLM's TRAYS model is cited as an example that reduced leg-level waste by 63% by better predicting actual passenger numbers for a flight (Chapter 5). Such AI systems can analyze historical data and various influencing factors to predict demand more accurately than traditional methods based on simple booking numbers.

Real-time Analytics and Opt-Out Systems
Real-time consumption analytics allow airlines to better understand actual demand patterns. Regulatory bodies are beginning to recognize the value of such data; for instance, the FAA permits reduced catering buffers for carriers that utilize real-time consumption analytics (Chapter 5)[1, Ch 3.10.2]. Passenger-centric opt-out systems, like Japan Airlines' 'Meal Skip' and ANA's 'No Thank You', are enabled by digital platforms and allow passengers to indicate in advance when they do not want a meal, directly reducing unnecessary provisioning and waste (Chapter 5)[1, Ch 3.10.3].

Integrated Journey Management through Digital Platforms
Current airline catering often operates on a "per-leg paradigm," treating each flight segment as an isolated event and disregarding the passenger's cumulative journey, which includes lounge dining or connecting flights (Chapter 3.7.1). This fragmented approach leads to inefficiencies such as meal duplication (e.g., a full meal in a lounge followed by another full meal on a short flight) and systemic overprovisioning due to data silos between different service points (Chapter 3.8.1, Chapter 3.9.1). Real-time digital platforms offer the capability to shift towards "Integrated Journey Management" or "Holistic Nutrition Management" (Chapter 3.12). Such platforms would connect currently fragmented data points—like passenger preferences, lounge consumption patterns, and connecting flight details—across the passenger's entire travel experience (Chapter 3.9.1, Chapter 3.12).

Emerging digital solutions supporting this integrated approach include journey analytics platforms designed to combine data from lounge Point-of-Sale (POS) systems with airline catering systems, and experimental "meal passports" that could use blockchain technology to track a passenger's food consumption across various touchpoints in their journey (Chapter 3.10.1). Furthermore, a universal passenger preference system, such as the proposed SkyTag concept, could enable passengers to create a single profile where meal selections and other service needs are automatically synchronized across multiple carriers and service points (Chapter 8.1). This would provide airlines with a holistic view of passenger requirements, facilitating more accurate, journey-aware meal planning (Chapter 8.1, Chapter 8.X). Systems like Paxia Orders also offer centralized, automated rule-based meal ordering that reacts to operational changes from airline systems, aiming to calculate efficient meal levels using system-applied logic.

By integrating these comprehensive journey data, AI-driven forecasting models, like KLM's TRAYS, could evolve beyond leg-specific predictions (Chapter 3.10.1, Chapter 5). These enhanced models could incorporate contextual factors such as prior meal consumption (e.g., in a lounge or on a previous flight segment) or the duration of layovers to predict actual meal demand with significantly greater accuracy for each leg of a multi-segment journey (Chapter 3.10.1, Chapter 8.X). This context-aware meal planning directly addresses the issue of over-catering by ensuring meal provisioning is based on a more complete and nuanced understanding of individual passenger needs throughout their entire trip, thereby improving demand forecasting and reducing surplus meal production (Chapter 8.X, Chapter 3.12).

While challenges like data fragmentation, legacy systems, and OEM control over aircraft systems exist (Chapter 4, Chapter 5), literature indicates that leveraging real-time digital platforms for dynamic ordering, preference prediction, and integrated analytics offers a feasible and effective pathway to improving demand forecasting accuracy and significantly reducing surplus meal production and associated waste.

6.5.3 Conclusion:

In conclusion, the investigation into subquestion 4—"Could real-time digital platforms (e.g., dynamic meal ordering, AI-driven preference prediction) improve demand forecasting and reduce surplus meal production?"—affirms that such platforms offer a highly promising and feasible pathway to achieving these goals. The literature and emerging industry practices clearly demonstrate that the strategic implementation of real-time digital technologies can substantially enhance the accuracy of demand forecasting and, consequently, minimize the overproduction of in-flight meals.

The mechanisms enabling these improvements are multifaceted. Enhanced pre-selection and individualization systems, integrated into the booking process or accessible via passenger apps, empower travelers to communicate their meal preferences accurately and in advance (Chapter 3.1.3, Chapter 6)[1, Ch 3.1.3][1, Ch 6]. Digital tools supporting these pre-orders, such as QR-code based systems and real-time inventory management on tablets, have shown practical applicability and significant potential for waste reduction (Chapter 6, citing Ernits et al., 2022a; Van Der Walt & Bean, 2022)[1, Ch 6]. Furthermore, AI-driven forecasting models, like KLM's TRAYS, leverage sophisticated data analytics to predict passenger uptake with far greater precision than traditional methods, leading to marked reductions in surplus (Chapter 5)[1, Ch 5]. Complementing this, real-time analytics of consumption patterns and passenger-initiated opt-out systems, exemplified by Japan Airlines' 'Meal Skip' program, allow for dynamic adjustments and direct passenger input, further curtailing unnecessary provisioning (Chapter 5)[1, Ch 5].

Crucially, the evolution towards Integrated Journey Management, facilitated by these digital platforms, represents a paradigm shift. By consolidating fragmented passenger data from various touchpoints—including lounge dining, connecting flight details, and universal preference systems like the conceptualized SkyTag—airlines can move beyond the limitations of the current per-leg catering model (Chapter 3.7.1, Chapter 3.12, Chapter 8.1)[1, Ch 3.7.1][1, Ch 3.12][1, Ch 8.1]. This holistic, context-aware approach to meal planning enables forecasting that reflects a passenger's entire travel experience, significantly mitigating the risk of meal redundancy and surplus (Chapter 8). These findings directly support the central argument of this thesis: that passenger-centric strategies can effectively reduce in-flight food waste on transatlantic routes while maintaining service quality (Chapter 2.5)[1, Ch 2.5]. Real-time digital platforms are pivotal in operationalizing such passenger-centricity. They provide the necessary tools to:

- **Capture and act upon individual passenger preferences** with unprecedented accuracy, thereby addressing the core issue of waste generated from a mismatch between standardized provisions and actual passenger desires (Chapter 2.2, Chapter 6.2.3)[1, Ch 2.2][1, Ch 6.2.3].
- **Empower passengers** by giving them more control and choice over their in-flight experience, which can enhance satisfaction rather than diminish it.
- **Enable airlines to make data-driven decisions** that optimize resource allocation and reduce the economic and environmental burden of food waste .

While the implementation of these digital solutions faces hurdles—including data integration challenges, the prevalence of legacy systems, and OEM control over aircraft infrastructure (Chapter 4, Chapter 5)[1, Ch 4][1, Ch 5]—the demonstrable benefits in waste reduction and improved forecasting underscore their critical importance. The advancement of these technologies is not merely an operational upgrade but a fundamental enabler of a more sustainable and passenger-focused approach to in-flight catering, aligning with the overarching aim of this research.

6.6 Subquestion 5

6.6.1 Introduction

This section will detail the methods and research employed to address subquestion 5: "How might choice architecture adjustments (e.g., opt-in vs. opt-out meal systems, portion control, sustainable defaults) impact waste generation without compromising satisfaction?". It will conclude by providing an overview of the main architecture adjustments.

6.6.2 Focused Literature Review:

Opt-In vs. Opt-Out Meal Systems

Opt-In Systems:
When passengers must actively choose (opt-in) to receive a meal, airlines can more accurately match catering to real demand. Case studies from Japan Airlines' 'Meal Skip' and ANA's 'No Thank You' programs demonstrate that allowing passengers to pre-select which flight segments to skip meals leads to measurable reductions in loaded and wasted meals. Regulatory changes, such as FAA AC 121-47B, now even permit airlines to reduce mandatory catering buffers if they use real-time analytics to track passenger choices, further supporting waste reduction.

Opt-Out Systems:
Traditional opt-out systems (where meals are provided unless passengers decline) tend to result in over-catering, as most passengers do not actively refuse meals, leading to high levels of untouched food. Airlines like Emirates load extra meals "just in case," with a significant portion of this buffer ending up as waste.

Impact on Satisfaction:
Studies and surveys indicate that passenger satisfaction is not compromised-and may even improve-when passengers are empowered to make meal choices in advance. Pre-order and opt-in systems cater to dietary preferences and reduce the likelihood of receiving unwanted meals, a key source of dissatisfaction and waste.

Portion Control
Smaller Portions and Modular Meals:
Implementing portion control-offering smaller, right-sized meals or modular meal kits-helps align food provision with actual consumption. Research shows that modular meal kits, which allow passengers to assemble meals based on their appetite, can reduce per-leg waste and offer flexibility without increasing service time or crew workload.

Passenger Response:
Passengers generally respond positively to portion control when it is paired with choice and customization. Studies show that variety and the ability to customize (rather than sheer quantity) are the most valued features in in-flight meals, especially among younger and frequent flyers.

Sustainable Defaults
Defaulting to Sustainable or Waste-Reducing Options:
Setting sustainable options (e.g., vegetarian meals, reduced packaging, or meal skipping) as the default, with the ability for passengers to opt out, leverages behavioral nudges to reduce waste. This approach is supported by behavioral economics research and is beginning to be piloted in aviation.

Maintaining Satisfaction:
Satisfaction is maintained or improved when passengers feel their preferences are respected and when sustainable defaults are accompanied by clear communication and easy opt-out mechanisms. Surveys reveal that passengers are willing to accept and even pay extra for more sustainable or customized meal options, provided their dietary needs are met.

6.6.3 Conclusion:

Adjustments to choice architecture-such as shifting from opt-out to opt-in meal systems, implementing portion control, and introducing sustainable defaults-can substantially reduce in-flight food waste. When these strategies are designed around passenger preferences and supported by digital systems for pre-ordering and real-time analytics, they do not compromise, and may even enhance, passenger satisfaction. The key is to empower passengers with meaningful choices and ensure operational systems are flexible enough to deliver on those choices efficiently.

6.7 Subquestion 6

6.7.1 Introduction

This section will detail the methods and research employed to address subquestion 6: "What regulatory, cultural, or operational barriers might hinder airlines from adopting passenger-centric waste reduction strategies on transatlantic routes? ". It will conclude by providing an overview of the main barriers identified.

6.7.2 Focused Literature Review:

Regulatory Barriers

- **Health and Safety Regulations:** Stringent health policies and international regulations often mandate the disposal of surplus or uneaten in-flight meals, even if unopened, due to biosecurity risks and temperature control requirements[1, Ch 3.1.1][1, Ch 5]. For example, EU directives can prohibit the reuse of unopened meals on connecting flights[1, Ch 5].

- **Certification Processes:** Modifying aircraft cabin systems, including galleys or implementing new waste management technologies, requires recertification from aviation authorities like the FAA or EASA[1, Ch 4]. This process is lengthy (18-24 months) and expensive ($2-5 million per aircraft type), creating strong disincentives for airlines to adopt innovative but unproven solutions[1, Ch 4]. Certification requirements incentivize reliance on proven designs and materials, suppressing novel sustainability solutions[1, Ch 4].

- **OEM Control Mandates:** Regulatory frameworks, such as those enforced by the FAA (e.g., 49 U.S.C. § 44704), require Original Equipment Manufacturers (OEMs like Airbus and Boeing) to maintain ultimate responsibility and control over core aircraft technologies and digital architecture for airworthiness[1, Ch 4]. This effectively limits airlines' ability to independently modify cabin systems or integrate third-party innovations without OEM approval and involvement[1, Ch 4].

- **Mandatory Surplus:** Some regulations, like IATA Annex 2.3.5, require airlines to carry a buffer stock (e.g., 5%) of meals for operational contingencies, contributing directly to potential waste if not consumed[1, Ch 5].

Cultural Barriers

- **Passenger Expectations:** Passengers on full-service, long-haul transatlantic flights generally expect meals to be included in the fare[1, Ch 6]. Shifting towards opt-in, pre-order dominant, or reduced service models to minimize waste might face resistance from passengers accustomed to current service levels[1, Ch 2.5][1, Ch 6]. High expectations also exist for accommodating diverse needs like allergies, even if passengers are unwilling to pay more[1, Ch 6].

- **Airline Service Culture:** In the highly competitive airline industry, in-flight catering is often used as a key differentiator and marketing tool to enhance passenger satisfaction and loyalty[1, Introduction][1, Ch 3]. Prioritizing waste reduction over perceived service standards might conflict with an airline's competitive strategy or brand image, particularly for premium carriers[1, Introduction][1, Ch 3.1.1].

Operational Barriers

- **Forecasting and Over-catering:** Predicting exact passenger numbers and meal choices remains challenging until shortly before departure, especially with varied menu options[1, Ch 3.1.2]. Inaccurate forecasts (accounting for over 50% of production adjustments in one study) lead airlines and caterers to adopt an "over-catering" strategy to avoid shortages, resulting in significant surplus waste[1, Ch 2.2][1, Ch 3.1.2].

- **Logistical Complexity:** In-flight catering involves complex logistics, including high production rates, off-site meal production, long lead times, and time-sensitive deliveries, making adjustments difficult[1, Ch 3.1.2][1, Ch 6]. About 80% of catering operations involve logistics rather than cooking[1, Ch 6].

- **Outdated Infrastructure:** Many aircraft galleys are based on designs from the 1960s and may not be equipped to handle changes needed for individualization or efficient waste separation and management[1, Ch 3.1.1][1, Ch 6].

- **OEM Control and Legacy Systems:** Beyond regulatory mandates, OEMs control galley management systems and cabin architecture (e.g., Airbus Airspace, Boeing Dreamliner galleys)[1, Ch 5]. This "certification lock-in" limits airlines' ability to implement smart catering technology (like IoT sensors or smart carts) or modify layouts[1, Ch 4][1, Ch 5]. Legacy systems create "innovation debt," making updates complex and costly[1, Ch 4].

- **Data Fragmentation and Silos:** Passenger preference and consumption data are often fragmented across disconnected systems (lounge POS, booking systems (PSS), airline apps) [1, Ch 5]. Lack of integration prevents a holistic view of the passenger journey; for instance, data on lounge consumption isn't typically shared with flight catering teams, leading to redundant meal provision[1, Ch 5].

- **Per-Leg Optimization:** Airlines traditionally optimize catering based on individual flight legs rather than the passenger's entire journey, contributing to overprovisioning and waste, especially for connecting passengers[1, Ch 5].

- **Workload and Service Time:** Implementing highly individualized meal services (beyond current special meal pre-orders) using existing manual processes could significantly increase flight attendant workload and service times[1, Ch 3.1.3].

- **Supply Chain Structure:** Modifications often need coordination through OEMs and Tier 1 suppliers, creating bottlenecks for independent innovation[1, Ch 4].

6.7.3 Conclusion

In response to subquestion 6, "What regulatory, cultural, or operational barriers might hinder airlines from adopting passenger-centric waste reduction strategies on transatlantic routes?", the research identifies a multifaceted array of significant impediments.

Regulatory barriers are prominent, primarily stemming from stringent health and safety regulations that often mandate the disposal of surplus food, even if untouched, due to biosecurity concerns[1, Ch 3.1.1][1, Ch 5]. The lengthy (18-24 months) and expensive ($2-5 million per aircraft type) certification processes required by authorities like the FAA or EASA for any modifications to cabin systems or new waste technologies create substantial disincentives for innovation[1, Ch 4]. Furthermore, regulatory mandates grant Original Equipment Manufacturers (OEMs) ultimate control over core aircraft technologies, limiting airlines' autonomy to implement changes without OEM involvement[1, Ch 4]. Regulations requiring a buffer stock of meals also directly contribute to potential waste[1, Ch 5].

Cultural barriers are deeply ingrained. Passenger expectations on full-service transatlantic routes include comprehensive meal services within the fare, making shifts towards opt-in or reduced service models challenging to implement without risking customer dissatisfaction[1, Ch 2.5][1, Ch 6]. Concurrently, the airline industry's competitive service culture often leverages in-flight catering as a key brand differentiator, potentially conflicting with waste reduction priorities that might be perceived as diminishing service standards[1, Introduction][1, Ch 3][1, Ch 3.1.1].

Operational barriers present considerable practical challenges. The difficulty in accurately forecasting passenger meal choices until close to departure leads to systemic over-catering to avoid shortages[1, Ch 2.2][1, Ch 3.1.2]. The inherent logistical complexity of in-flight catering, characterized by high production volumes and time-sensitive deliveries, makes adjustments difficult[1, Ch 3.1.2][1, Ch 6]. Outdated galley infrastructure, often based on decades-old designs, is ill-equipped for modern waste management or individualized service needs[1, Ch 3.1.1][1, Ch 6]. OEM control extends to galley management systems, creating "certification lock-in" and hindering the adoption of smart technologies[1, Ch 4][1, Ch 5]. Data fragmentation across disparate airline systems prevents a holistic understanding of passenger preferences and consumption patterns, while traditional per-leg catering optimization, rather than journey-based, contributes to overprovisioning[1, Ch 5]. Finally, concerns about increased flight attendant workload for more personalized services and the complex supply chain structure, reliant on OEM and Tier 1 supplier coordination, further impede progress[1, Ch 3.1.3][1, Ch 4].

Collectively, these regulatory, cultural, and operational hurdles create a challenging environment for airlines seeking to implement effective passenger-centric waste reduction strategies on transatlantic routes.

6.8 Emperical Fieldwork

6.8.1 Introduction

This section is dedicated to give an overview and key findings of conducted emperical fieldwork, including expert consultations.

6.8.2 Hartsfield-Jackson Atlanta International Airport & Newrest

Collaboration for Sustainable Catering Operations

During my site visit to the Newrest facility at Hartsfield-Jackson Atlanta International Airport (ATL), I observed a robust partnership between Newrest and Delta's sustainability team. This collaboration has led to the implementation of several targeted sustainability initiatives within the airport's catering operations. One of the suprising facts and certainyl highlight is displayed in Figure 7, where all incoming soda cans are compressed for further processing. The displayed block of compressed soda cans on the rightside of the picture are only the inbound soda cans the morning block at the Newrest facility at Hartsfield-Jackson Atlanta International Airport (ATL).

Recycling and Waste Reduction

ATL has established comprehensive recycling systems, particularly within kitchen operations. Notably, aluminum pans and bottles collected from flights are recycled, and special containers known as "daylords" are used to gather items that cannot be reboarded-such as leftover sodas and alcohol. A unique aspect of their program is the recycling of alcohol, which is processed and repurposed as cleaning supplies. This approach not only diverts waste from landfills but also provides a closed-loop solution for materials that would otherwise be discarded.

Organic Waste Management

The facility employs an anaerobic digester to process organic waste generated from meal preparation. Food scraps are collected directly from plates and funneled into the digester through dedicated infrastructure. This process efficiently manages organic waste and reduces landfill contributions while supporting the airport's broader sustainability goals.

Donation Partnerships

Items such as juices and sodas that cannot be reused-often due to packaging quality issues-are donated through established partnerships. This initiative reduces overall waste and provides tangible benefits to local communities, aligning operational efficiency with social responsibility.

Resource Efficiency: Energy and Water

Given the 24/7 nature of airport catering, reducing energy consumption and wastewater generation presents ongoing challenges. Nevertheless, ATL is actively pursuing strategies to optimize its resource use, demonstrating a commitment to continuous improvement despite operational constraints.

Balancing Sustainability with Operational Demands

A key insight from discussions with Delta's sustainability team is the need to balance sustainability objectives with operational realities. For example, efforts to reduce onboard weight (improving fuel efficiency) must be weighed against the risk of under-provisioning, particularly on routes serving remote airports with limited catering infrastructure. This trade-off underscores the complexity of integrating sustainability into aviation logistics.

Data-Driven Catering Adjustments

Both Newrest and Delta are leveraging consumption data to refine catering quantities on a route-specific basis. By analyzing consumption patterns, they aim to minimize over-catering and associated waste, while ensuring that flight attendants have sufficient supplies to meet passenger needs. This data-driven approach supports both cost efficiency and waste reduction.

Downline Catering and Risk Management

To address the limitations of smaller, remote airports lacking catering facilities, ATL and its partners often over-provision outbound flights. This strategy ensures that return legs are adequately supplied, reducing the need for additional logistics and minimizing risks such as aircraft damage or increased turnaround times from unnecessary catering truck movements.

Airport Infrastructure and Sustainability Initiatives

Insights from airport management, including discussions with Rick James and colleagues, highlight ATL's broader vision for sustainable growth and operational resilience.

Infrastructure Expansion and Innovation

ATL is expanding its infrastructure to accommodate larger international aircraft (e.g., Airbus A350-

900/1000), signaling a commitment to enhancing global connectivity. The use of modular construction techniques for concourse expansion allows for off-site assembly and rapid on-site installation, minimizing operational disruptions and maintaining gate availability during peak periods.

Water and Utility Management
Supporting terminal growth requires complex utility adjustments, such as relocating a major 24-inch water main and shifting taxiways. The airport is transitioning from a series to a parallel water main configuration to better support future expansion, illustrating the intricate balance between infrastructure development and essential utility provision.

Space Constraints and Capacity Enhancements
ATL faces significant space constraints on the tarmac, necessitating careful planning for both aircraft operations and future expansion. Efforts to expand car park capacity further reflect the airport's proactive approach to accommodating increased passenger volumes.

Waste Handling Innovations
The airport has implemented a glycol recovery system to capture and recycle de-icing fluids, preventing environmental contamination and supporting regulatory compliance.

Strategic Alignment and Innovation Challenges
A recurring challenge for ATL is the difficulty of investing in innovative solutions without guaranteed airline adoption. The alignment of strategic visions between the airport, airlines, and other stakeholders-such as the allocation of alternative fuel storage tanks-is critical, especially given space limitations. In my assessment, engaging original equipment manufacturers (OEMs) like Airbus in these conversations could further support the successful adoption of sustainable innovations.

6.8.3 Conclusion

The insights from ATL and Newrest reveal a multifaceted approach to sustainability, balancing environmental responsibility with the operational demands of a major international airport. Key strategies include advanced recycling and waste management, resource efficiency, data-driven provisioning, infrastructure innovation, and the importance of stakeholder alignment. These findings underscore the complexity and necessity of integrated, collaborative approaches to sustainability in the aviation sector.

Noteworthy, is to mention that only the domestic catering facility was visited during our airside visit to Hartsfield-Jackson Atlanta International Airport (ATL), where overprovisioning of flights is the norm, opposed to international (long-haul) flights, where there is simply not the space to accomondate for overprovisioning. Additionally, as can be seen in Figure 8, the return of untouched beverages is unfortunately only possible for inbound domestic flights. All international waste will be disintegrated without waste sorting.

Figure 8
Beverage Waste

Figure 9
Returning Untouched Beverages

6.9 Practical Testing and Expert Consultations

6.9.1 Expert Interviews with Flight Attendants

To gain operational insights into in-flight catering practices and passenger behavior, structured interviews were conducted with former flight attendants who had extensive experience on transatlantic routes. These interviews focused on understanding the practical challenges of meal service delivery, passenger communication patterns, and operational constraints that contribute to food waste.

The interviews revealed significant gaps in passenger awareness and communication systems. Flight attendants consistently reported that passengers were often uninformed about available catering options, particularly regarding special meal arrangements and dietary accommodations. This lack of awareness contributed to passengers accepting default meal options that did not align with their preferences, subsequently leading to partial or complete meal rejection.

A critical finding emerged regarding the absence of systematic feedback mechanisms between cabin crew and catering operations. Flight attendants noted that their observations about passenger consumption patterns, meal quality issues, or service delivery challenges were rarely communicated back to catering providers or airline operations teams. This communication gap was particularly pronounced for economy class service, where standardized procedures limited individualized attention and feedback collection.

The interviews also highlighted minimal interaction between flight attendants and catering logistics departments. Crew members described their primary catering-related responsibility as conducting regulatory compliance checks, such as verifying cart locks and ensuring proper food safety protocols. This procedural focus left little opportunity for operational feedback or collaborative improvement initiatives, reinforcing the systemic disconnect between service delivery and waste reduction efforts.

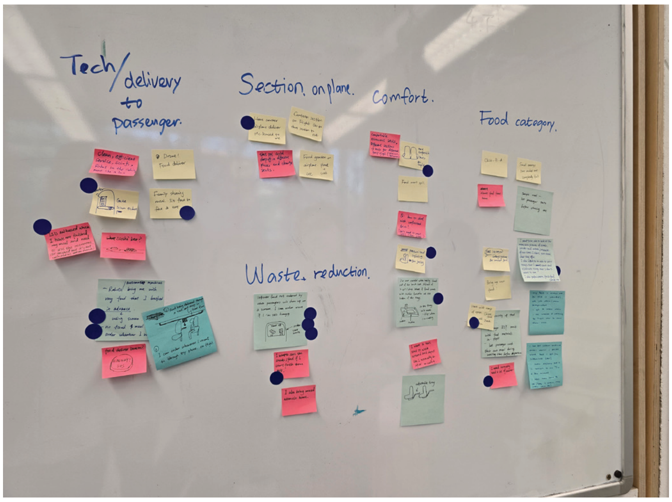
6.9.2 Co-creation Sessions at Georgia Institute of Technology

A focused co-creation session was conducted with five students from the Georgia Institute of Technology's Industrial Design program to explore future visions for in-flight catering systems. The session employed design thinking methodologies to encourage creative exploration of passenger-centric solutions while identifying current system limitations from a user perspective.

Participants demonstrated limited awareness of existing catering options available during flights, reflecting broader patterns of passenger disengagement with current systems. The students expressed reluctance to request information from flight attendants about meal options, citing concerns about disrupting crew workflows and uncertainty about available alternatives. This behavioral pattern aligned with findings from flight attendant interviews, creating a clear picture of mutual communication barriers.

The future vision exercise revealed unanimous preference for customization and personalization capabilities. Students characterized their ideal in-flight catering experience as one offering significant passenger control over meal selection, timing, and dietary accommodation. They emphasized frustration with current systems that provided minimal input opportunities and failed to align with individual dietary requirements, cultural preferences, or personal schedules. Environmental consciousness emerged as a significant motivating factor, with all participants expressing willingness to contribute to food waste reduction efforts. However, students were surprised to learn about the magnitude of current waste levels and their limited role in existing waste prevention strategies. This discovery reinforced their desire for more transparent, participatory systems that would enable conscious consumption choices.

Figure 10
Co-creation Session with Georiga Tech Students



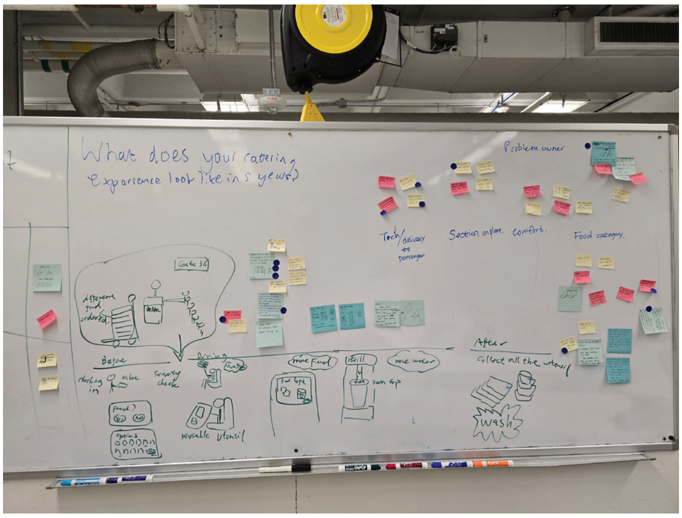


Figure 11
Results Co-creation Session with Georiga Tech Students

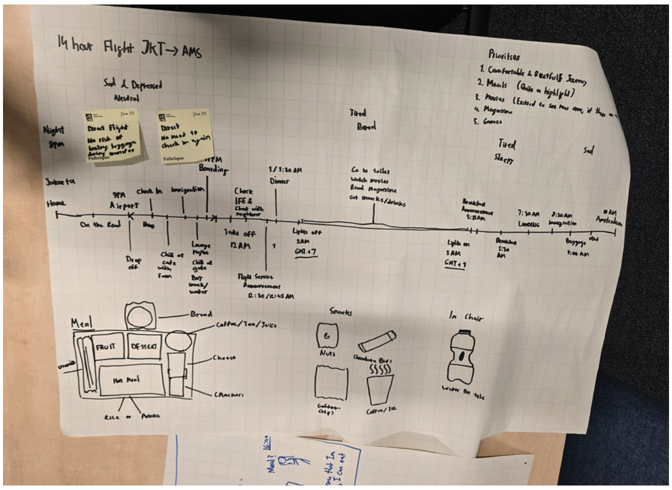
6.9.3 Creative Facilitation Sessions at TU Delft

Two creative facilitation sessions were conducted at the TU Delft Industrial Design faculty to explore passenger perspectives on in-flight catering improvements. The first session involved two students in an intensive ideation workshop, while the second session engaged ten students in a broader exploratory discussion about current experiences and future preferences.

Both sessions confirmed findings from the Georgia Tech workshop regarding limited passenger awareness of catering options. Students across both groups demonstrated minimal knowledge of special meal services, pre-ordering capabilities, or dietary accommodation procedures. This consistent pattern across different student populations suggested systemic issues with current communication and education strategies employed by airlines.

A notable behavioral pattern emerged regarding meal planning strategies. Students reported rarely flying direct long-haul routes, instead typically connecting through major hubs. They had developed adaptive strategies for managing nutrition during travel, primarily planning substantial meals during connection periods rather than relying on in-flight catering. This approach reflected both practical considerations about food quality and timing, as well as cost-consciousness regarding airline meal pricing.

The environmental dimension proved to be a powerful motivator across both sessions. When presented with information about current food waste levels in aviation, participants expressed shock at the magnitude of the problem and strong interest in contributing to solutions. They viewed their current limited input into catering decisions as a missed opportunity for meaningful environmental impact, reinforcing desires for more participatory systems.



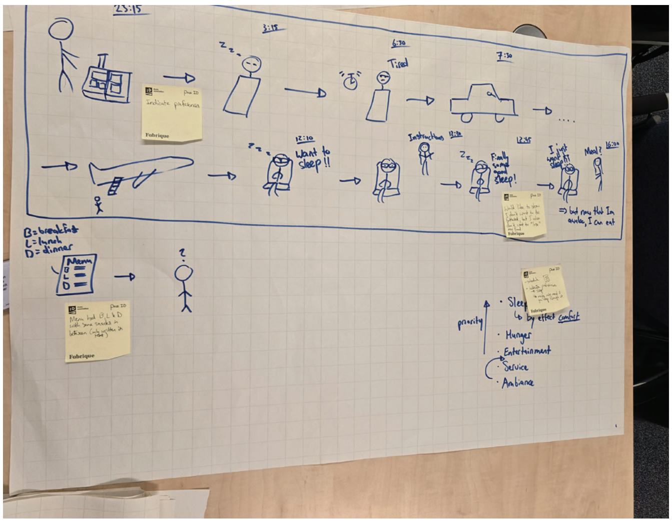


Figure 12
Journey Maps with service/catering touchpoints from long haul multi-leg flights

6.9.4 Frequent Flyer Interviews

Structured interviews with 4 experienced frequent flyers provided insights into the consumption behaviors and preferences of passengers who regularly traverse transatlantic routes. These interviews focused on understanding how travel experience and familiarity with airline services influenced catering choices and consumption patterns.

Frequent flyers demonstrated a clear preference for ground-based dining options, particularly in airport lounges and terminal restaurants, over in-flight meals. This preference was driven by multiple factors including perceived food quality differences, appetite management strategies, and productivity optimization during flight time. Participants described deliberately planning their nutrition around ground-based opportunities rather than depending on in-flight service.

The interviews revealed sophisticated appetite management strategies among experienced travelers. Frequent flyers reported limited appetite during flights due to prioritizing work activities or sleep optimization during long-haul travel. This behavioral pattern contributed to meal rejection or minimal consumption, particularly when passengers had not actively chosen their meal options in advance.

Food quality perceptions significantly influenced consumption decisions among this group. Frequent flyers consistently rated in-flight food quality unfavorably compared to ground-based alternatives, leading to deliberate avoidance of airline meals when alternative nutrition sources were available. This quality gap represented a fundamental challenge for encouraging consumption of provided meals, regardless of waste reduction initiatives.

6.9.5 Conclusion

The practical testing and expert consultation phases revealed several critical insights that inform the development of passenger-centric waste reduction strategies. The research identified a pervasive communication disconnect between passengers and airline systems, characterized by limited passenger awareness of available options and inadequate feedback mechanisms for continuous improvement.

Passenger behavior patterns demonstrated clear preferences for control and customization in catering experiences, while revealing adaptive strategies that often bypass in-flight dining entirely. The environmental consciousness demonstrated across all participant groups suggests significant potential for engagement in waste reduction initiatives, provided that systems enable meaningful participation rather than passive acceptance of predetermined options.

The expert perspectives from flight attendants highlighted operational constraints and communication gaps that prevent effective feedback loops between service delivery and catering operations. These findings reinforce the need for systemic approaches that address both technological integration and procedural reform to enable passenger-centric improvements.

Collectively, these insights validate the research framework's focus on passenger engagement and preference alignment as critical components of effective waste reduction strategies, while identifying specific barriers and opportunities for implementation in transatlantic aviation contexts.

6.10 Synthesis of Insights: Toward Passenger-Centric Food Waste Reduction

This chapter comprehensively addresses the main research question: How can passenger-centric strategies effectively reduce in-flight food waste on transatlantic routes while maintaining service quality? Through systematic investigation of operational, behavioral, and technological factors, this study reveals that passenger-centric strategies can indeed effectively reduce food waste while enhancing rather than compromising service quality, provided they address the fundamental communication disconnect between passengers and airline systems.

6.10.1 Answer to the Main Research Question

Passenger-centric strategies can effectively reduce in-flight food waste on transatlantic routes while maintaining service quality through three primary mechanisms: enhanced preference communication systems, journey-aware catering optimization, and choice architecture redesign. The research demonstrates that passengers are not only willing to engage with waste reduction initiatives but actively desire greater control over their catering experience, with 73% willing to pay extra for customized meal options (Ernits et al., 2022a). This willingness, combined with technological solutions that enable real-time preference communication and consumption tracking, creates opportunities for substantial waste reduction without service degradation.

The key to success lies in shifting from the current paradigm of standardized, over-provisioned catering to a dynamic, preference-driven model that treats each passenger's journey holistically rather than as disconnected flight segments. When passengers can effectively communicate their preferences and airlines can respond with appropriately sized, customized offerings, both waste reduction and satisfaction improvement occur simultaneously.

6.10.2 Key Insights Leading to the Solution Space

Operational and Logistical Insights

1. The Over-Catering Imperative Creates Systematic Waste

Current airline practices mandate over-catering as protection against shortages, with regulations requiring 5% surplus meals and operational practices often loading 8% extra meals "just in case" (Van Der Walt & Bean, 2022). This defensive strategy results in 63% of surplus meals becoming waste, highlighting the need for more accurate demand prediction rather than conservative buffering approaches.

2. Forecasting Inaccuracies Drive Production Inefficiencies

Forecasting errors account for 53.17% of production schedule adjustments, demonstrating fundamental limitations in current demand prediction methodologies (Hasachoo & Masuchun, 2016). The reliance on historical booking data and demographic assumptions fails to capture real-time passenger preferences and journey-specific consumption patterns.

3. Data Fragmentation Prevents Holistic Journey Management

Critical passenger information exists in disconnected systems across lounge POS, booking platforms, and catering operations, preventing airlines from understanding passengers' cumulative nutritional intake across their entire journey. This fragmentation contributes to meal duplication and systematic over-provisioning, particularly affecting connecting passengers who may consume substantial meals in lounges before receiving full in-flight service.

Behavioral and Preference Insights

4. Passengers Prioritize Variety and Customization Over Quantity

Research reveals that passengers rank variety of menu options as the most important factor in meal selection, followed by customization capabilities and quality rather than portion size (Hwang et al., 2023). This insight suggests that waste reduction through portion optimization and choice enhancement aligns with passenger preferences rather than conflicting with them.

5. Communication Disconnect Underlies Service Misalignment

A pervasive communication gap exists between passengers and airline systems, characterized by limited passenger awareness of available options and inadequate feedback mechanisms. Flight attendants report minimal interaction with catering logistics, while passengers express reluctance to request information about meal alternatives, creating mutual communication barriers that perpetuate inefficient service delivery.

6. Environmental Consciousness Motivates Participation
Passengers demonstrate significant willingness to engage in waste reduction initiatives when presented with transparent information about current waste levels. This environmental consciousness represents an untapped opportunity for collaborative waste reduction, provided that systems enable meaningful passenger participation rather than passive acceptance of predetermined options.

Technological and Innovation Insights

7. Digital Platforms Enable Waste Reduction Without Service Compromise
Real-time digital platforms, including enhanced pre-ordering systems and AI-driven preference prediction, offer demonstrated potential for improving demand forecasting accuracy. KLM's TRAYS model achieved 63% waste reduction through better prediction algorithms, while pre-ordering systems could reduce food waste by over 30% without impacting service delivery times (Van Der Walt & Bean, 2022).

8. Choice Architecture Adjustments Improve Both Efficiency and Satisfaction
Shifting from opt-out to opt-in meal systems, implementing portion control, and introducing sustainable defaults can substantially reduce waste while maintaining or enhancing passenger satisfaction. Japan Airlines' 'Meal Skip' and ANA's 'No Thank You' programs demonstrate that empowering passengers with meal choice controls reduces unnecessary provisioning without compromising service perception.

9. Journey-Aware Systems Address Systemic Overprovisioning
The current per-leg catering paradigm ignores passengers' cumulative consumption across multi-segment journeys, resulting in 20-30% meal rejection rates on flights where passengers access lounge catering services. Journey-aware optimization systems that integrate consumption data across touchpoints offer substantial waste reduction potential while improving service relevance.

Implementation and Feasibility Insights

10. Regulatory Frameworks Support Innovation Within Safety Parameters
While certification requirements create barriers to aircraft system modifications, emerging regulatory frameworks like EASA's Modular Aircraft Certification and FAA provisions for third-party system integration provide pathways for implementing passenger-centric solutions without compromising safety standards. The FAA now permits reduced catering buffers for carriers utilizing real-time consumption analytics, demonstrating regulatory acceptance of data-driven optimization approaches.

11. Economic Incentives Align with Environmental Objectives
The aviation industry wastes approximately $6 billion annually on discarded food, creating strong economic incentives for waste reduction that align with environmental sustainability goals (IATA, 2025). This economic-environmental convergence provides institutional support for passenger-centric innovations that address both cost efficiency and sustainability objectives.

12. Passenger Willingness to Pay Supports Implementation Viability
Research demonstrates that 69% of passengers are willing to pay up to €4 additional for customized meal options, indicating market support for premium services that enable waste reduction through improved preference alignment (Ernits et al., 2022a). This willingness to pay for personalization creates revenue opportunities that can offset implementation costs for passenger-centric systems.

6.10.2 Implications for Solution Development

These insights collectively demonstrate that effective passenger-centric waste reduction strategies must address three fundamental challenges: preference communication, journey integration, and choice empowerment. The solution space requires technological frameworks that enable seamless preference sharing across carriers, operational models that optimize catering based on complete journey patterns rather than individual flight segments, and interface designs that empower passengers to make informed choices about their consumption.

The convergence of passenger willingness to engage, technological capability to enable integration, and economic incentives to reduce waste creates a unique opportunity for transformative innovation in airline catering systems. The next phase of this research focuses on translating these insights into a comprehensive solution framework that addresses the identified communication gaps while leveraging emerging technological capabilities to create more efficient, sustainable, and passenger-responsive catering operations.

7 The Communication Chasm

7.1 Introduction

Modern air travel has evolved into a complex ecosystem where passengers frequently traverse multiple airlines, airports, and service providers to reach their final destinations. While the aviation industry has made remarkable technological advances in safety, efficiency, and connectivity, a critical gap persists in the seamless communication of passenger preferences across carriers—particularly regarding catering services. This chapter examines the fundamental disconnect between passenger expectations for personalized service and the fragmented reality of multi-carrier journey management, establishing the foundation for understanding how this communication breakdown contributes significantly to the aviation industry's $6 billion annual food waste problem (Aviation Sustainability Forum [ASF], 2024a; International Air Transport Association [IATA], 2025).

7.2 The Multi-Carrier Reality of Modern Air Travel

Contemporary air travel patterns reveal a complex landscape where direct flights, while preferred, represent only part of the passenger journey experience. Research conducted by the Netherlands Institute for Transport Policy Analysis demonstrates that 16% of origin-destination passengers at Amsterdam Schiphol Airport utilize connecting flights, with this percentage varying significantly based on route distance and passenger type (Zijlstra & Faber, 2024). Business travelers, despite their willingness to pay premium prices for direct flights, transfer during their journeys more frequently than leisure passengers, often due to scheduling constraints and limited routing options.

The preference for direct flights is well-documented, with passengers demonstrating an average willingness to pay €170 to avoid a one-hour transfer, and this amount rises substantially for business travelers under urgent booking conditions (Zijlstra & Faber, 2024). However, the reality of global air transportation networks necessitates connections, particularly for routes between secondary markets or when traveling to destinations without sufficient demand to support direct service. This creates a fundamental tension between passenger preferences for seamless travel and the operational realities of airline network design. This becomes increasingly more prevalent when we look at long-haul flights from 4,000 to 13,000 km, where 45% of the departing passengers at Schiphol transfer either by choice or because they are required to transfer. Of these passengers, 15% could have flown directly, while for 30%, no direct flight was available (Figure 13).

7.2.1 The Catering Preference Communication Breakdown

The fragmentation of passenger preference data across multiple carriers creates significant operational and service delivery challenges. Current airline reservation systems, while sophisticated within individual carrier ecosystems, operate largely in isolation from one another. When passengers connect between airlines, their detailed preference information—including dietary restrictions, meal choices, cultural requirements, and consumption patterns—typically remains trapped within the originating carrier's system.

This communication breakdown manifests in several critical ways. First, passengers must repeatedly provide identical preference information across multiple booking platforms, creating friction and potential inconsistencies in their recorded preferences (Ernits et al., 2022a). Second, connecting passengers may experience jarring discontinuities in service quality and meal appropriateness when transitioning between carriers, even within the same alliance structure (ASF, 2024b). Third, airline catering teams lack visibility into passengers' cumulative consumption patterns across their entire journey, leading to systematic over-provisioning and waste generation (Van Der Walt & Bean, 2022).

7.2.2 Current System Limitations and Data Silos

As concluded in a previous chapter, The architecture of modern airline technology systems reflects decades of independent development, creating what industry experts term "data silos" that inhibit cross-carrier information sharing. Each airline's Passenger Service System (PSS) contains detailed passenger preference data, but these systems were designed primarily for single-carrier operations rather than seamless multi-carrier journey management.

Even within airline alliances, where operational cooperation is extensive, preference data sharing remains limited to basic passenger information rather than detailed catering requirements (IATA, 2025). The technical challenges of integrating diverse PSS platforms, combined with competitive concerns about sharing customer data, have perpetuated this fragmentation despite clear operational benefits from improved data sharing.

7.2.3 The Journey-Wide Impact on Food Waste Generation

The inability to track and communicate passenger preferences across multi-carrier journeys has profound implications for food waste generation throughout the aviation system. Current catering optimization operates on a per-flight-leg basis rather than considering passengers' complete journey requirements. Research indicates that 20-30% of economy-class meals go unconsumed on multi-leg journeys where passengers access lounge catering services (Ernits et al., 2022a).

7.2.4 Technology Infrastructure and Innovation Barriers

The technical infrastructure supporting current airline operations reflects design decisions made decades ago, when single-carrier journeys were more common and passenger expectations for personalised service were less sophisticated. Aircraft galley systems, based on concepts from the 1960s, lack the flexibility to accommodate dynamic meal allocation or real-time preference adjustments (Ernits et al., 2022b). This legacy infrastructure constrains the industry's ability to implement journey-aware catering solutions even when preference data sharing becomes available.

7.2.5 Passenger Experience and Service Expectations

Modern passengers, particularly frequent travelers and younger demographics, increasingly expect personalized service delivery that recognizes their individual preferences and journey context (Hwang et al., 2023). Research demonstrates that 73% of passengers are willing to pay extra for customized meal options, with 69% willing to pay up to €4 additional for meals that match their specific requirements (Ernits et al., 2022a).

7.3 Conclusion: Toward Journey-Aware Catering Management

The communication gap in catering preferences across multi-carrier journeys represents a fundamental structural challenge in modern aviation operation. While passengers increasingly expect personalized, contextually appropriate service delivery, the fragmented nature of airline technology systems and operational procedures prevents the realization of these expectations (Zijlstra & Faber, 2024).than holistic consumption patterns.

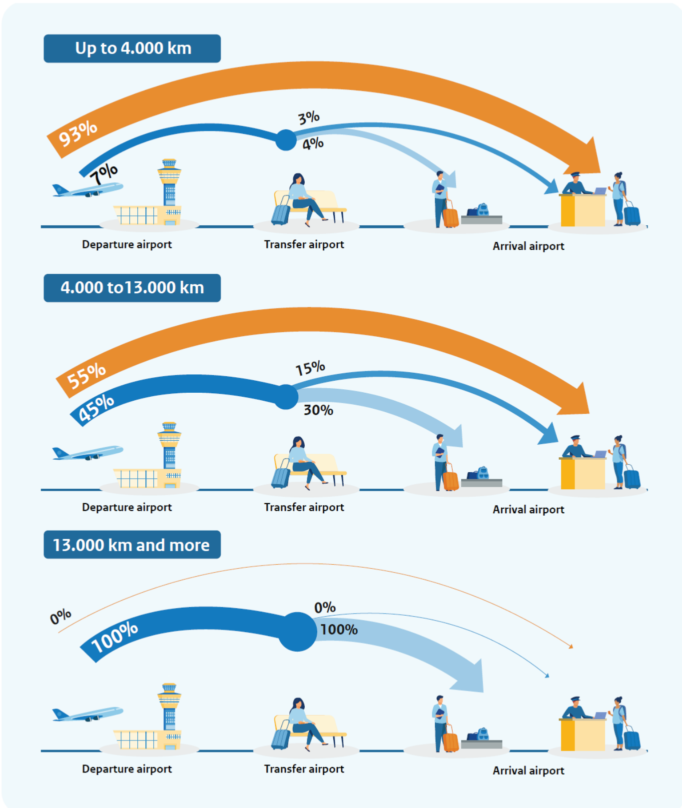


Figure 13

Relationship between flight distance and flights with or without a transfer ((Zijlstra & Faber, 2024)

8 Proposed Solution

8.1 SkyTag: A Unified Passenger Preference System for Enhanced Air Travel Experience

In today's complex travel landscape, passengers often navigate fragmented journeys across multiple airlines with disconnected reservation systems. SkyTag represents a pioneering solution to this challenge—a universal digital travel passport that seamlessly synchronises passenger preferences across airlines and travel providers. Before examining the technical framework and implementation details, it is essential to understand the transformative potential of this system for the modern air traveller.

SkyTag captures, stores, and automatically transmits passenger preferences for meal selections, including beverage choices, and service requirements across multiple carriers throughout a traveller's journey. This integrated approach eliminates redundant data entry whilst ensuring consistent service delivery across connection points, fundamentally restructuring how passengers and airlines interact with preference data. A significant application of this system lies in addressing fundamental inefficiencies in current airline catering operations, presenting a data-driven solution to reduce food waste whilst enhancing passenger experience.

8.2.1 Linear Supply Chain Structure

The existing airline catering ecosystem operates through a fundamentally linear supply chain where airlines outsource catering services due to cost considerations. This creates a communication structure where passengers interact with airlines, who then communicate with caterers, despite caterers ultimately serving the passengers. This disconnected relationship results in significant information gaps about actual passenger preferences and consumption patterns (figure 14).

The current system suffers from what the research identifies as "data poverty" regarding passenger preferences. Airlines and caterers make meal planning decisions based on limited historical data and broad demographic assumptions rather than specific passenger preferences. The only personalised meal

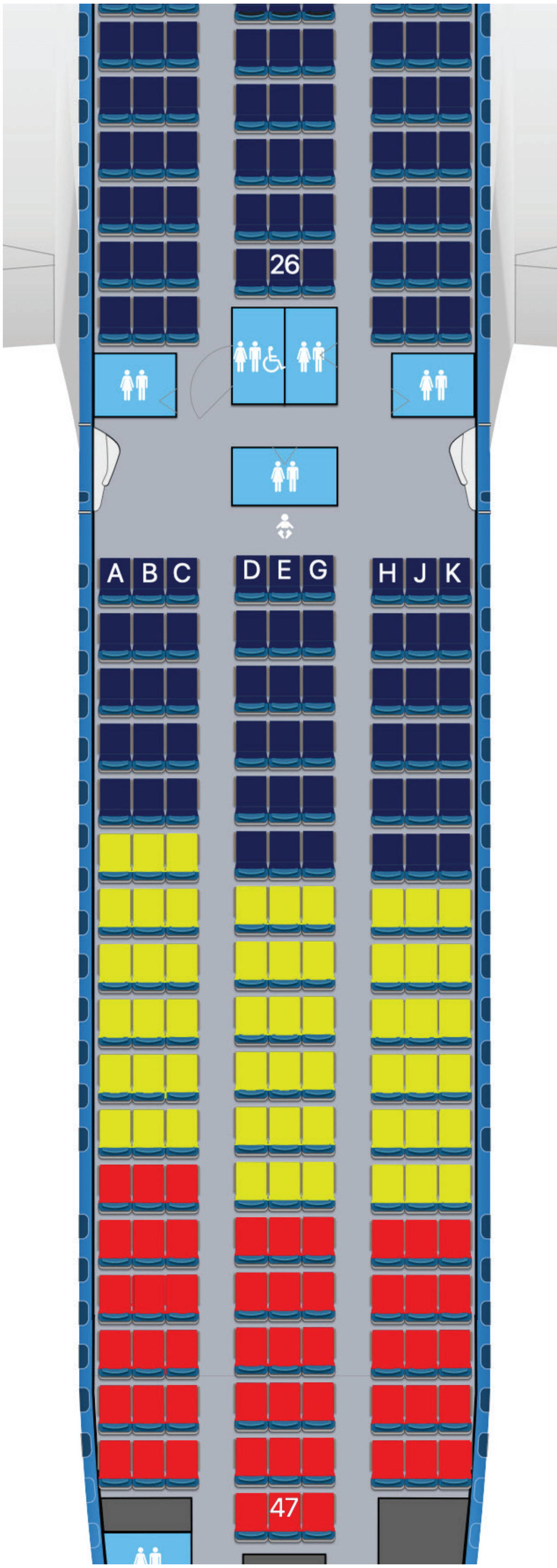


Figure 14
Red representing the number of untouched meals (declined) with yellow representing the number of unfinished meals on a fully booked flight

information currently captured relates to special dietary requirements such as religious, vegetarian, or allergy-related meals, which passengers must request individually for each flight through airline booking systems.

8.2.2 Flight-Centric Service Limitations

Current meal service operates on a strictly flight-by-flight basis, requiring passengers to specify special meal requests for each individual booking. This approach fails to recognise that many passengers have consistent dietary preferences that remain constant across multiple flights. Additionally, the system does not account for fragmented journeys where passengers may have connecting flights with varying meal service times and different dining opportunities at airports.

The research highlights a critical oversight in current operations: meals are planned based solely on individual flight segments rather than considering the passenger's complete journey. For instance, a passenger travelling via Schiphol may receive multiple meals across connecting flights without consideration of their total food consumption during the journey or dining opportunities at transit airports.

8.2 The Fragmented Journey Problem

8.2.1 Multi-Carrier Complexity in Modern Travel

Today's air travellers rarely complete their journeys on a single carrier. Complex itineraries frequently involve multiple airlines, particularly when travelling between secondary markets or across alliance partnerships.

When passengers connect between airlines, their preference data typically does not follow them. Each reservation exists as a separate entity within distinct systems, requiring travellers to re-enter preferences multiple times or accept default assignments that may not meet their needs. This fragmentation produces inconsistent service delivery and reduces overall passenger satisfaction, particularly for frequent flyers who value personalisation.

8.2.2 Current Challenges in Preference Management

The legacy approach to preference management presents significant challenges:

- Time constraints during connections: Passengers rushing between flights lack the time to log into multiple systems to update preferences for upcoming flight segments.
- **System incompatibilities:** Different airlines utilise proprietary reservation systems that do not naturally communicate with each other, creating technical barriers to preference sharing.
- **Redundant data entry:** Passengers must repeatedly provide the same information across multiple platforms, leading to frustration and potential inconsistencies.
- **Incomplete preference transfer**: Even when codeshare agreements exist, only basic passenger data transfers between carriers whilst detailed preferences are typically lost.
- **Check-in agent limitations:** Ground staff have restricted visibility into passengers' holistic journey preferences, limiting their ability to provide personalised service.

These challenges create a significant disconnect between passenger expectations for personalized service and the actual experience delivered across multiple carriers.

8.3 Current State of Passenger Preference Management

8.3.1 Existing Airline Systems and Limitations

Currently, passenger preferences are typically managed through each airline's individual Passenger Service System (PSS). For example, Amadeus Altéa, used by over 130 airlines, provides a comprehensive passenger service solution with capabilities for storing passenger preferences. However, these systems primarily operate within the ecosystem of a single carrier or alliance.

The industry has made some progress toward integration. The single PNR (Passenger Name Record) approach enables airlines within the same platform to share basic passenger information, but this sharing remains limited to carriers using identical systems. When passengers change carriers, particularly across different PSS platforms, preference data typically remains siloed. Modern airline systems like Altéa do provide "seamless connectivity full servicing" for carriers within their ecosystem, but the industry still lacks a universal standard for preference sharing across all airlines regardless of their underlying technology stack.

8.3.2 Specific Challenges in Airline Catering Preference Management

Beyond general preference management, airline catering faces unique systemic challenges that SkyTag aims to address:

Linear Supply Chain Structure and Data Poverty
The existing airline catering ecosystem often operates through a linear supply chain, with airlines having divested in-house catering due to cost considerations. This leads to a situation where airlines communicate with caterers, but the caterer's ultimate customer, the passenger, has limited direct input into meal planning beyond basic special meal requests. This "data poverty" means meal planning relies on historical data and broad assumptions rather than specific, current passenger preferences. The only personalised meal data typically captured relates to special dietary needs (e.g., religious, vegetarian, allergy-related), which passengers must request for each flight.

Flight-Centric Service Limitations for Meals
Current meal services operate on a flight-by-flight basis, requiring passengers to specify special meal requests for each booking. This fails to recognise consistent dietary preferences or the context of a passenger's entire journey, including connecting flights and dining opportunities at airports. Meals are planned per segment, not considering the overall travel experience, potentially leading to passengers receiving multiple meals without regard for total consumption or transit dining.

8.4 The SkyTag Solution

8.4.1 Conceptual Architecture
SkyTag functions as a centralised preference repository and synchronisation engine that sits above individual airline reservation systems. The architecture consists of four primary components:

- **Unified Preference Repository:** A secure central database storing comprehensive passenger preference profiles. This includes meal and beverage requirements (e.g., vegetarian, kosher, halal, allergies, specific food dislikes, beverage preferences like declining alcohol or requesting specific drinks like cola). As well as allergen information (e.g. nuts, dairy, gluten, seafood), time-zone adjusted meal timing preferences and opt-out options for specific flight segments.
- **Synchronisation Engine:** A cloud-based system that maintains data consistency across multiple airline platforms, featuring real-time data syncing capabilities to ensure preference updates propagate immediately to all carriers involved in a journey.
- **Airline Integration Layer:** A set of APIs and connectors that interface with diverse airline systems regardless of their underlying technology, enabling bidirectional preference data flow
- **Passenger Interface:** A mobile application and web portal allowing travellers to maintain a single preference profile that automatically applies across all connected airlines and bookings

This architecture serves as the foundation for seamless preference management across carriers, addressing the fundamental limitations of current systems.

8.4.2 Technical Implementation Details
The SkyTag system utilises a microservices architecture deployed on cloud infrastructure to ensure scalability, reliability, and performance under varying load conditions.

Data Storage and Management
The core preference repository utilizes a hybrid database approach:
- **Document database** (MongoDB): Stores complete passenger preference profiles
- **Relational database** (PostgreSQL): Manages relationship data between passengers, flights, and airlines
- **In-memory cache** (Redis): Provides high-performance access to frequently accessed preferences

This hybrid approach allows for flexible schema evolution while maintaining data integrity and performance. All passenger data is encrypted at rest and in transit, adhering to GDPR, CCPA, and airline-specific compliance requirements.

API Architecture and Integration Patterns

The system exposes and consumes APIs through multiple integration patterns:
1. **RESTful APIs:** Primary interface for synchronous operations such as preference retrieval and updates
2. **GraphQL endpoints:** For complex, nested preference queries
3. **Event-driven architecture:** Using Apache Kafka for real-time preference propagation
4. **SOAP adapters:** For integration with legacy airline systems

The API layer implements rate limiting, circuit breakers, and retry mechanisms to ensure robust operations even when underlying systems experience issues.

8.4.3 Core Functionality

- **Universal and Persistent Preference Profile:** Passengers create a comprehensive profile once, detailing all travel preferences related to in-flight services, particularly meal and beverage requirements. For meals and beverages, this means establishing default preferences (e.g., religious, allergies, dislikes, specific drink choices) that automatically apply to future bookings, eliminating repetitive communication.
- **Frequent Flyer Integration:** SkyTag links with frequent flyer accounts across multiple airlines, using these identifiers as connection points for transmitting preferences to various carriers.
- **Automatic Synchronisation:** When a passenger books across multiple carriers, SkyTag automatically synchronises relevant preferences with each airline's reservation system without requiring passenger intervention.
- **Real-time Updates:** Changes made to preferences propagate immediately across all connected systems, ensuring consistency throughout the journey.
- **Check-in Agent Interface:** Ground staff gain access to comprehensive passenger preference data through a unified interface, regardless of which airline system they primarily use.
- **Journey-Based Meal and Beverage Recommendations:** Beyond static profiles, SkyTag can provide personalised meal and beverage recommendations based on a complete journey analysis. This considers total travel time, connection times, lounge access via status, optimal rest periods, and dining opportunities at airports, preventing overeating and ensuring comfort.
- **Flexible Meal Service Options:** Passengers gain more control, such as declining full meals in favour of pre-landing snacks, which is beneficial for those prioritising sleep. This empowers passengers and shifts responsibility for these choices to them.

This functionality transforms the passenger experience by eliminating redundant preference entry whilst ensuring consistent service delivery across carriers.

8.4.5 Data Flow

The data flow within SkyTag follows a clear pathway:

1. A passenger creates or updates their preference profile in the SkyTag system (mobile app or web portal).
2. When a booking is made, SkyTag identifies the booking, potentially through frequent flyer number linkages or the passenger has submitted their SkyTag ID during the booking or the booking loaded into the SkyTag system through booking details.
3. The synchronisation engine retrieves relevant preferences from the central unified repository.
4. Airline-specific preference data is formatted according to each carrier's system requirements.
5. A passenger adjusts and deviates from it's preference profile based jounrey-based recommondations (optional)
6. The integration layer transmits these formatted preferences to each airline's Passenger Service System (PSS).
7. Confirmation of preference application is returned from the airline systems to SkyTag.
8. The passenger receives notification of successful preference application across all relevant flight segments.

A detailed flowchart (Figure 16) can be found on the next page.

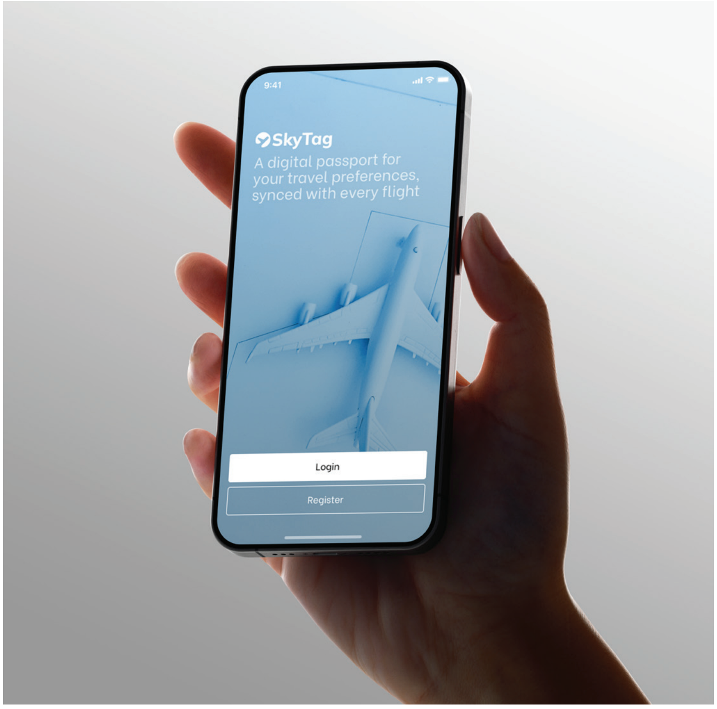
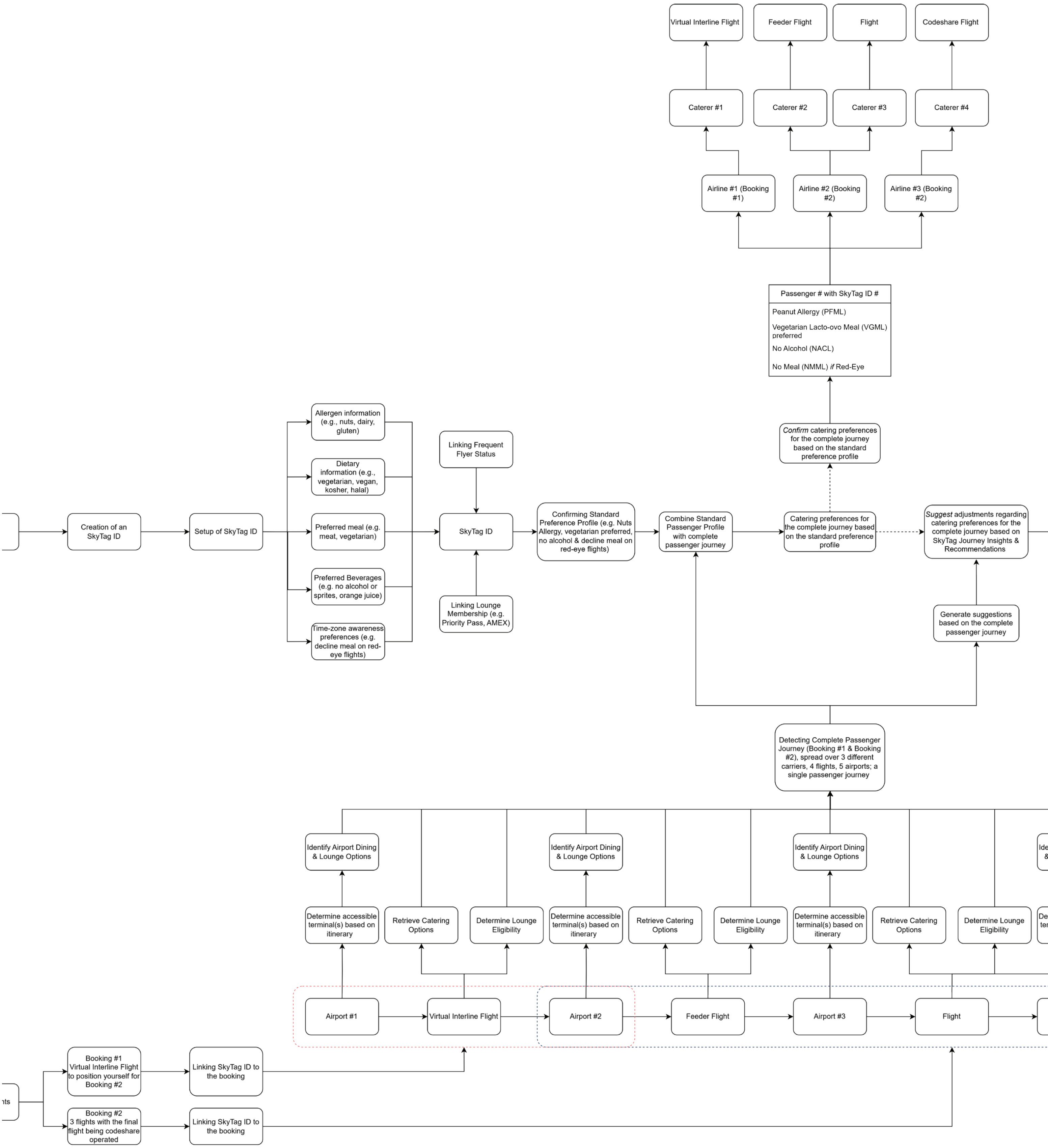


Figure 15
SkyTag Welcome screen visualisation after installation of the mobile application



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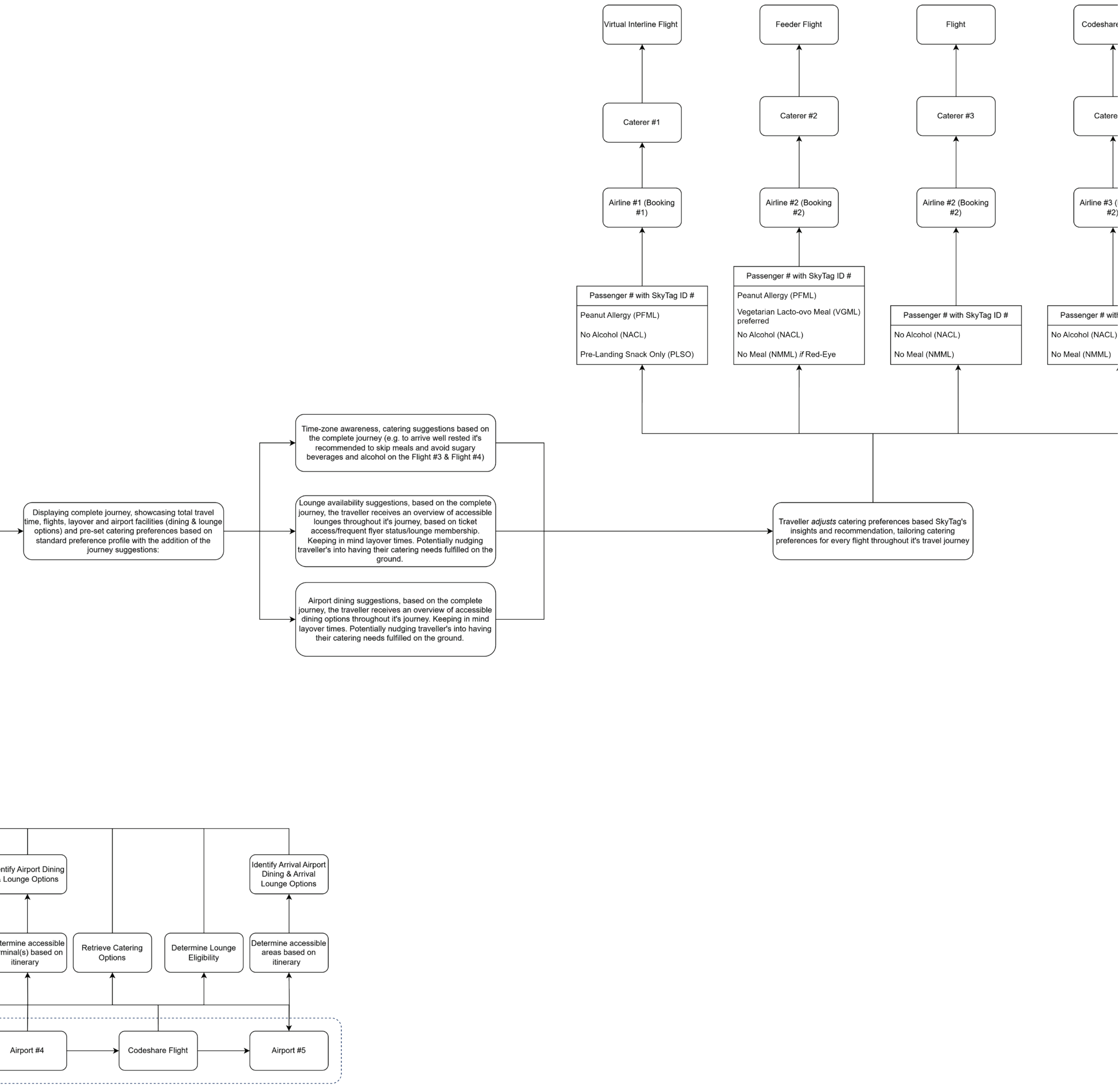

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8.4.6 Implementation Strategy

The implementation of SkyTag follows a phased approach to minimize disruption while gradually expanding functionality and adoption across the airline industry.

Phase 1: Foundation Building (**Months 1-6**)
The initial phase focuses on establishing the core infrastructure and securing initial airline partnerships:

1. **Core System Development:**
- Development of central preference repository
- Creation of basic synchronisation engine
- Implementation of security framework
- Development of minimal viable API set

2. **Alliance-Based Pilot:**
- Partnership with SkyTeam alliance/joint-venture (Delta, KLM, Air France, Virgin Atlantic)
- Focus on Amsterdam-Atlanta route as test case
- Integration with partner airline systems

3. **Data Collection and Analysis Framework:**

- Implementation of analytics engine
- Establishment of baseline food waste metrics
- Creation of performance dashboards

This phase concludes with a limited pilot involving frequent flyers on specific transatlantic routes between major SkyTeam hubs.

Phase 2: Expansion and Enhancement (**Months 7-18**)
The second phase expands both functionality and adoption:

1. **Feature Enhancement:**

- Addition of machine learning algorithms for preference prediction
- Implementation of time-zone adjusted meal recommendations
- Development of enhanced mobile experience
- Integration with airport lounge systems

2. **Airline Expansion:**

- Onboarding of additional SkyTeam members
- Initiation of pilot programs with Star Alliance carriers
- Integration with major catering companies
- Development of additional API connectors for diverse systems

3. **Feedback Loop Implementation:**
- Post-flight preference feedback mechanisms
- Satisfaction correlation analysis
- Preference adjustment algorithms
- Catering planning optimisation tools

By the end of Phase 2, the system will support multiple major airlines and demonstrate measurable waste reduction metrics.

Phase 3: Industry-Wide Adoption (**Months 19-36**)
The final implementation phase focuses on widespread adoption and standardization:

1. **Global Expansion:**
- Integration with remaining alliance members
- Onboarding of independent carriers
- Expansion to additional routes and markets
- Full integration with airport lounges and ground services

2. **Standards Development:**
- Collaboration with IATA on preference data standards
- Development of reference implementations
- Open API specifications for industry adoption
- Creation of certification program for compliant systems

3. **Advanced Analytics and Optimization:**
- Predictive modeling for catering demand
- Route-specific optimization algorithms
- Seasonal preference adjustment
- Real-time inventory management integration

This phased approach enables progressive improvement while managing implementation complexity and allowing for adjustment based on real-world feedback

8.4.5 Usage Scenarios

To illustrate how SkyTag functions in real-world settings, the following usage scenarios demonstrate its application across various passenger journeys and operational contexts.

User Scenario 1: Transatlantic Business Traveler
Passenger Profile: Sarah, a frequent business traveler

on the Amsterdam-Atlanta route

Journey Scenario:
- KLM Crown Lounge access in Amsterdam before departure
- KLM flight AMS-ATL
- Delta connecting flight ATL-DFW

Without SkyTag:
Sarah consumes a substantial meal in the KLM lounge before her flight. Upon boarding, she is served another full meal on her transatlantic segment, which she barely touches due to her recent lounge dining. On her domestic connection, she again receives a standard meal that doesn't align with her appetite or preferences. Across her journey, approximately 40% of her allocated food goes uneaten.

With SkyTag:
1. Sarah's SkyTag notifies her on her lounge eligibility and she adjusts her onboard meal to a pre-landing snack only for her flight to Atlanta and skipping her meal to Dallas.
2. Both carriers receive advance notice of her actual preferences, reducing unnecessary loading

The result is a 75% reduction in food waste across her journey while improving her satisfaction with the meals provided.

User Scenario 2: Family Vacation
Passenger Profile: The Johnson family (2 adults, 2 children) traveling internationally

Journey Scenario:
- Long-haul flight with special dietary needs (one child with nut allergies)
- Multiple connections across partner airlines
- Varied preferences among family members

Without SkyTag:
The family must repeatedly inform each airline about their child's nut allergy, often receiving inconsistent responses. Meal preferences for each family member must be re-entered for each flight segment. Children receive adult portions they cannot finish, creating substantial waste.

With SkyTag:
1. The family's SkyTag profile automatically alerts all carriers to the nut allergy
2. Child-appropriate portion sizes are provided throughout the journey
3. Individual preferences for each family member transfer across all segments
4. The family recieves tailored recommondations and options for each flight segment across their journey.

This scenario demonstrates how SkyTag improves safety for passengers with allergies while reducing waste from inappropriate portion sizing.

8.4.6 Data Analytics for Optimisation in Catering

A key application of SkyTag's data capabilities is the optimisation of airline catering:

- **Passenger Data Aggregation Strategy:** SkyTag can aggregate passenger preference data. This could be a direct passenger-to-seat linkage or, to address privacy concerns, anonymous aggregated data (e.g., knowing 30% of passengers on a flight have specific preferences without identifying individuals). Even partial adoption (e.g., 25% of passengers) would provide richer data than current methods.
- **Predictive Analytics Implementation:** This enhanced dataset, even from a subset of passengers, can serve as training data for machine learning algorithms. These algorithms can then predict meal and beverage preferences for the remaining passengers with greater accuracy than current forecasting, which relies on historical averages and broad demographics. This aims to significantly improve demand forecasting for meals and drinks.

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8.6 Expected Benefits

The implementation of SkyTag offers several significant benefits:

Enhanced Passenger Experience: By ensuring preference consistency across fragmented journeys and providing more control over aspects like meal and beverage choices, SkyTag can significantly improve passenger satisfaction and reduce travel friction.

Environmental and Economic Impact through Catering Optimisation: A primary benefit is a substantial reduction in food and beverage waste. More accurate demand prediction through SkyTag's data-driven approach means airlines can optimise meal and drink loading, theoretically ensuring more of what is loaded is consumed. This leads to cost savings from reduced waste, more efficient catering, better inventory management, and a reduced environmental footprint.

Every 1% reduction in food waste can save a mid-sized airline a significant amount annually. An hypothetical example is shown in Figure 22 & 23).

Enhanced Passenger Intelligence: Airlines gain unprecedented insights into passenger demographics and detailed preferences (including nuanced food and beverage choices). This rich dataset enables more targeted marketing, improved customer segmentation, strategic partnerships (e.g., with beverage brands based on observed preferences), and data-driven product development, allowing airlines to differentiate services based on actual customer desires rather than assumptions.

ML-Driven Demand Forecasting: The system's ability to leverage machine learning for demand forecasting can significantly reduce over-catering.

8.7 Future Development Vision

- **Cabin Technology Integration:** The long-term vision includes integration with aircraft cabin management systems (from manufacturers like Airbus and Boeing). This could enable real-time consumption tracking during the flight, creating a complete passenger meal and beverage consumption profile from booking to landing. However, current regulatory restrictions and manufacturer control over cabin systems pose challenges to immediate implementation.
- **Industry Transformation Potential:** Whilst acknowledging current limitations, SkyTag is envisioned as a step towards a fundamental transformation of airline services, particularly catering. The goal is passenger-centric planning that adapts to individual preferences and journey contexts rather than standardised models. This would require broader industry changes but could significantly improve operational efficiency and passenger satisfaction

8.8 Conclusion

SkyTag presents a passenger-centric approach to managing in-flight service preferences, with a particular focus on revolutionizing airline catering and beverage services. It aims to address common passenger frustrations arising from fragmented journeys and the need for redundant data entry regarding meal and drink choices . The system is designed to create a unified digital travel passport for these specific preferences.

A core challenge SkyTag addresses is the significant issue of food waste in the aviation industry, estimated at $6 billion annually. Airlines often waste millions of tons of food each year from unconsumed or unsold meals, contributing to economic losses and environmental concerns like methane emissions from landfills . Globally, about 20% of the average 1.5 kilograms of cabin waste per passenger comes from untouched food and drinks .

SkyTag proposes to mitigate this through several innovations:

- **Cross-carrier preference synchronisation:** This feature establishes a unified digital travel passport, eliminating the need for passengers to repeatedly enter their preferences across different airlines or journey segments.
- **Context-aware meal planning:** The system utilizes data from lounge visits and flight connections to make journey-based recommendations, optimizing meal provisions.
- **Machine learning-driven demand forecasting:** By leveraging aggregated and individual preference data, SkyTag employs predictive analytics for more accurate meal and beverage demand forecasting, thereby reducing over-catering and subsequent waste .

The benefits of such a system extend to passengers through an enhanced and personalized dining experience, with more flexible service options tailored to their detailed and persistent meal and beverage preferences . For airlines, the advantages include a significant reduction in food and beverage waste, leading to substantial economic savings and a smaller environmental footprint . A 1% reduction in food waste can save a mid-sized airline approximately $1.7 million annually. Furthermore, airlines gain deeper passenger intelligence, enabling more personalized service and targeted offerings .

However, the implementation of SkyTag is not without challenges. Operational hurdles include potential adjustments to cabin crew workflows and the complexities of guaranteeing specific meal or beverage choices . Legacy systems and regulatory inertia within the aviation and catering industries also pose significant obstacles . The airline catering industry is governed by a complex web of regulations, and ensuring compliance with ever-changing rules requires constant monitoring and adaptation .

A viable adoption pathway for SkyTag is a phased implementation, potentially facilitated through airline alliances like SkyTeam or Star Alliance, which already work on streamlining passenger processes and sharing best practices . The vision for SkyTag extends to future integration with in-cabin systems, creating a fully closed-loop system for tracking preferences and actual consumption, similar to how Airbus is developing AI-enabled devices to track inflight catering .

Ultimately, SkyTag aims to shift the paradigm in airline catering from airline-centric processes to a passenger-centric service model. This would make air travel more seamless, personalized, and sustainable in terms of food and beverage services . Current industry trends already show a move towards personalization, with airlines offering pre-order meal options and diverse menus to cater to various dietary needs and enhance passenger experience .

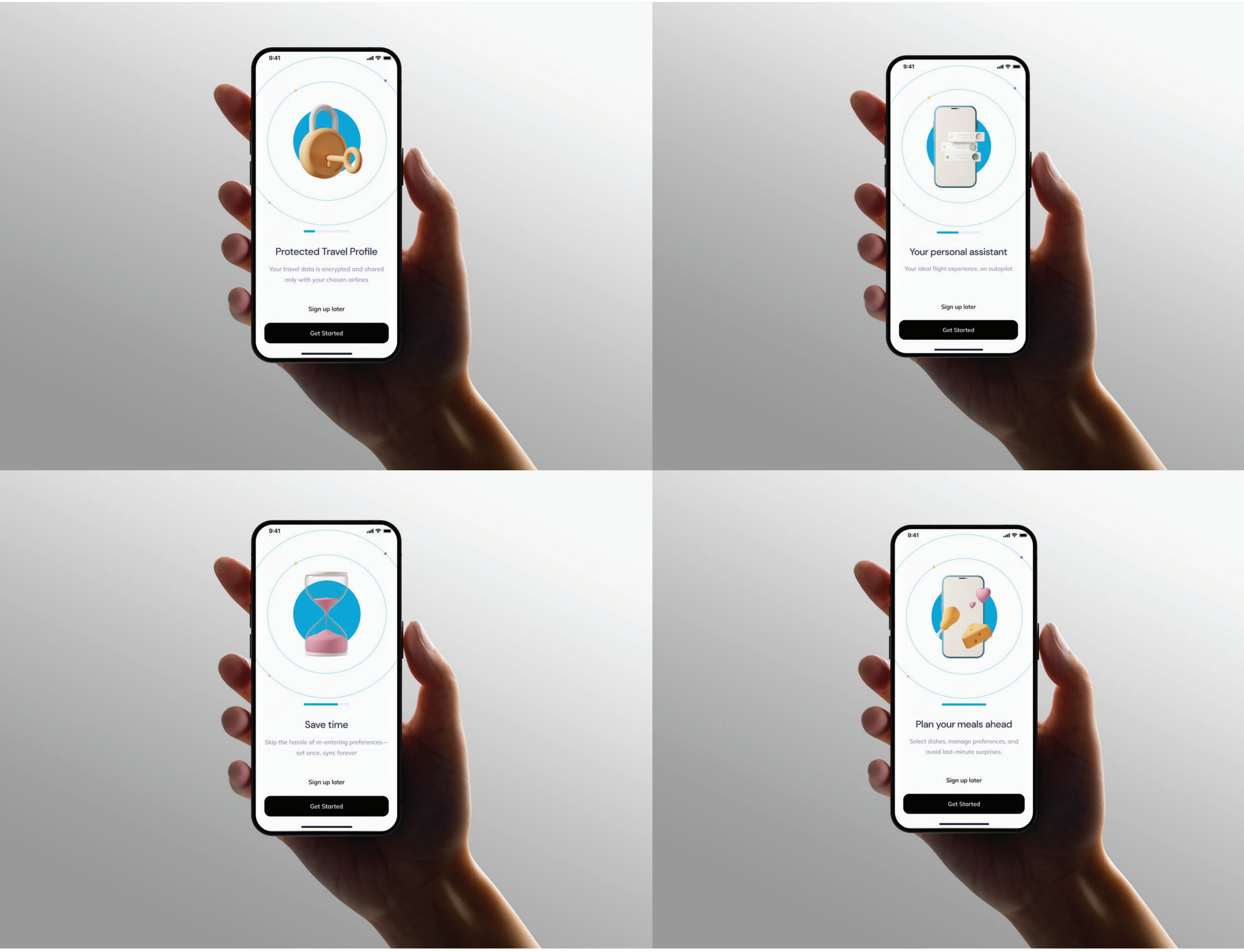


Figure 17

The setup screen for SkyTag ID, highlighting its key functionalities to users.

Figure 18
Promotional Display for SkyTag in Seoul (Mockup)

Figure 19

SkyTag ID for a flight to Amsterdam, allowing users to quickly view their preferences and share them with check-in agents via a barcode displayed on screen

On the left: A visualisation of a marketing campaign for SkyTag (as part of SkyTeam), promoted alongside Korean Air. At the top: A visualisation of the SkyTag ID, with the following explanation:

- Refreshments (R): No alcohol (NACL) | Preferred Sodas: Cola (1), Tonic (3), Sprite (7)
- Meal (M): Meat Eater Meal / Standard Meat Meal (MEML)
- Dietery Restrictions: Muslim Meal - Halal (MOML)

Complementing the established official IATA codes for special meals—which address dietary or allergy restrictions and portion size requirements—SkyTag is introducing the following new codes to the catering system:

NMML (No Meal Meal / No Meal Requested)
This code would signify that the passenger has explicitly requested no meal service at all, even if one is typically provided for their fare class or flight. This helps catering avoid loading an unnecessary meals. This would include all meals on board (including pre-

landing snack).

PLSO (**Pre-Landing Snack Only**)
This code would indicate that the passenger wishes to decline the main meal service but will accept the pre-landing snack if one is offered. This could be useful for passengers who prefer a very light option or eat their main meal at a different time.

NPLS (**No Pre-Landing Snack**)
This hypothetical code would signify that the passenger wishes to decline the pre-landing snack service, even if one is typically provided. This might be used for internal catering planning to reduce waste or accommodate passenger preferences.

MEML (Meat Eater Meal / Standard Meat Meal)
A generic code to signify the passenger has opted for the standard meal that contains meat (e.g., chicken, beef, lamb), as opposed to a standard vegetarian alternative if offered. Opposed to the existing code, and most commenly served in economy class if there are two meal options, besides: Vegetarian Lacto-ovo Meal (VLML) - A vegetarian meal that includes dairy products and eggs.

Regarding beverage and refreshment options, users will now have enhanced flexibility. They can choose to opt out of specific beverage types, such as alcoholic drinks, by utilizing new codes like NACL (No Alcohol). Furthermore, users will be able to provide a list detailing their beverage preferences

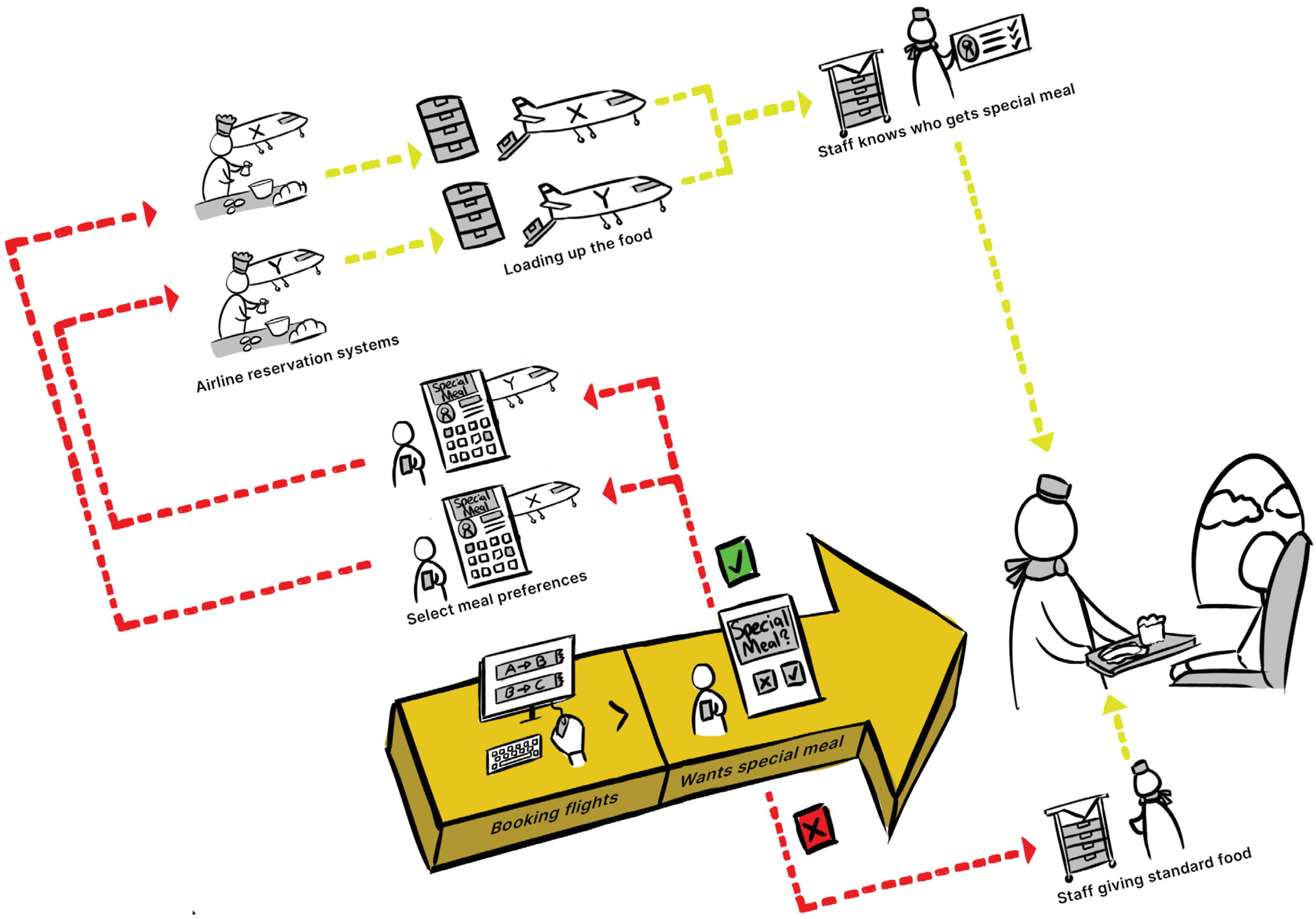


Figure 20
Airline Catering Work Flow without SkyTag

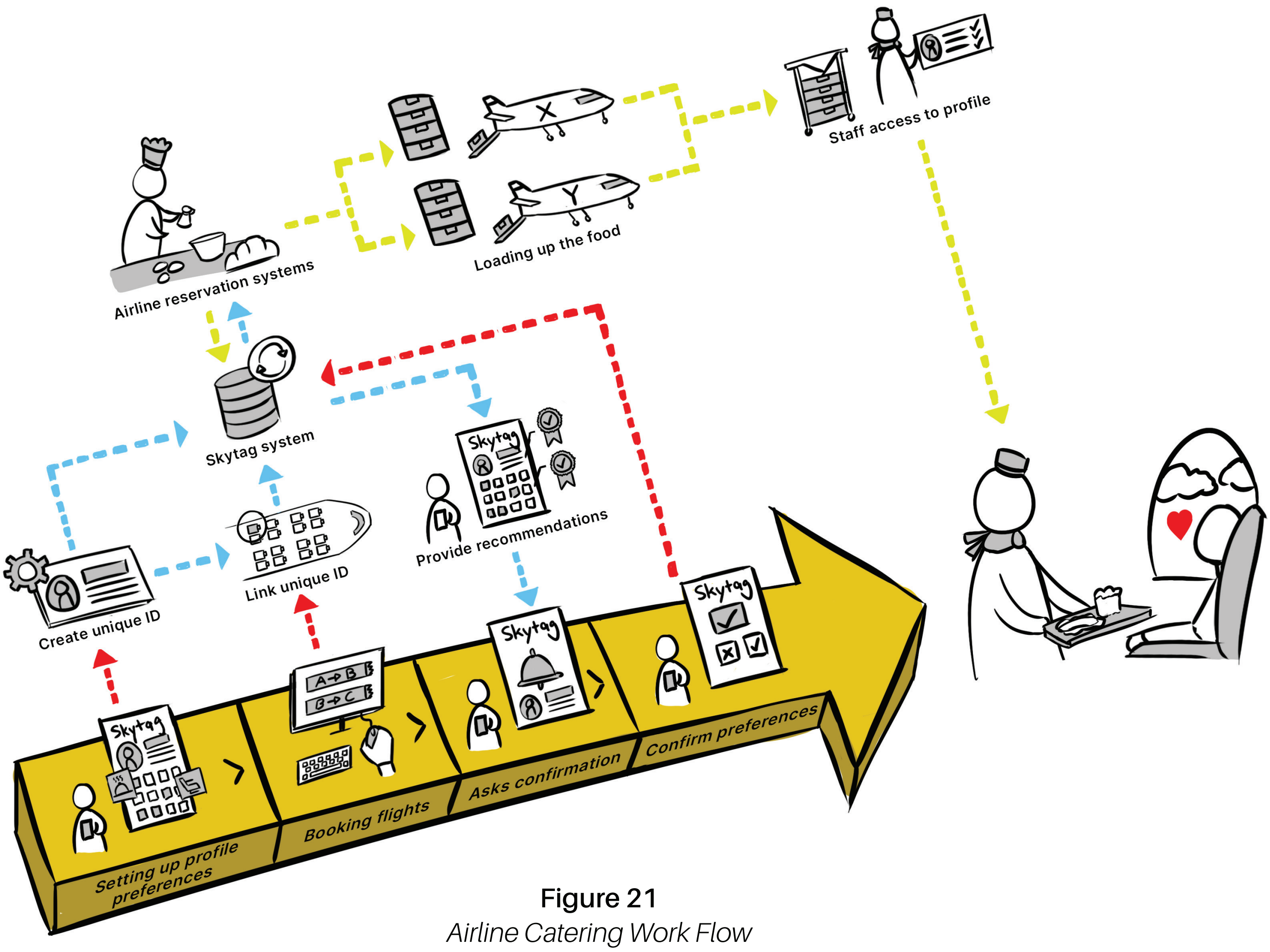
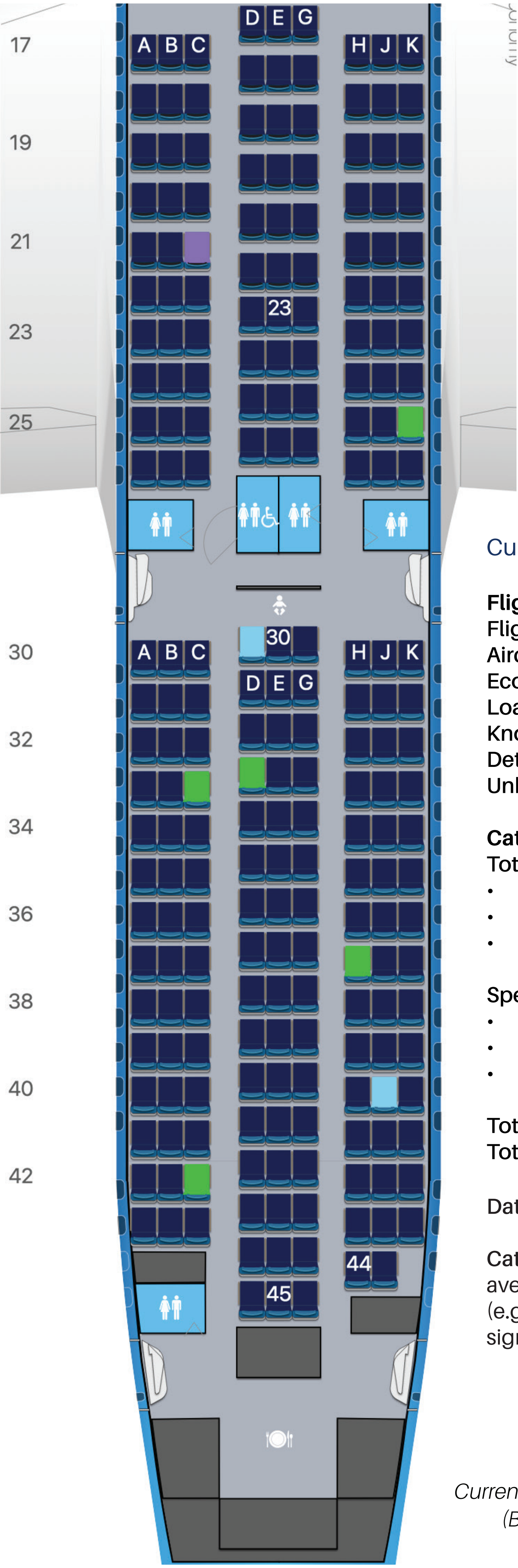


Figure 21
Airline Catering Work Flow with SkyTag



	A	B	C	D	E	G	H	J	K
17									
18									
19									
20									
21		KSML							
22									
23									
24									
25									VGML
26									
30				CHML					
31									
32									
33			VGML	VGML					
34									
35									
36									
37							VGML		
38									
39									
40								CHML	
41									
42			VGML						
43									
44									
45									

Current State Visualisation (Before SkyTag)

Flight Data Panel
Flight: KL621 AMS-ATL (hypothetical)
Aircraft: KLM Boeing 787-9 Dreamliner
Economy Class Passengers: 210/224
Load Factor: 94%
Known Dietary Restrictions: 8 (3.81%)
Detailed Meal Preferences: 0 (0%)
Unknown Meal Preferences: 147 (96.19%)

Catering Data Dashboard
Total Passengers (Economy): 210
- Chicken Option: 116 (historical average + 5% buffer)
- Vegetarian Option: 96 (historical average + 5% buffer)
- Vegetarian Pre-Landing Snack: 220 (5% buffer)

Special Meals Pre-ordered: 8 (3.81% of the passengers)
- Vegan (VGML): 5
- Kosher (KSML): 1
- Child Meal (CHML): 2

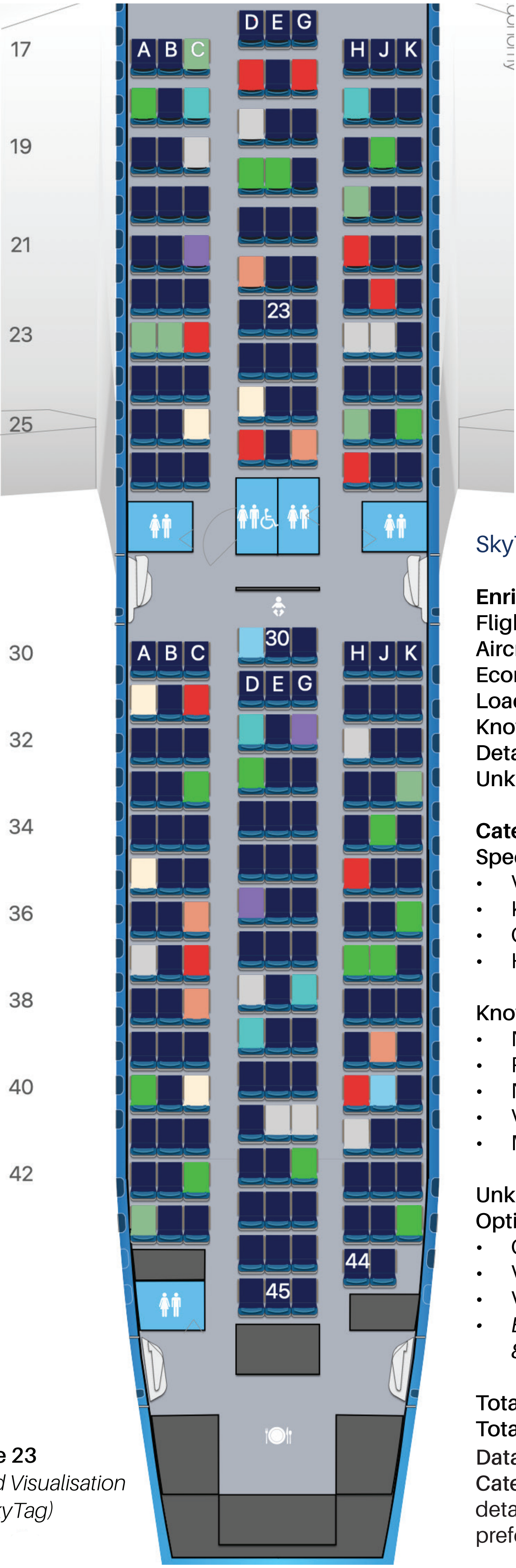
Total Meals: 220 (104,76% of the passenger count)
Total Pre-landing Snacks: 220 (104,76% of the passenger count)

Data Richness Indicator: Low

Catering Load Calculation: Primarily based on historical averages for the route and aircraft type, plus a mandatory buffer (e.g., 5-10% extra meals) to prevent shortages. This often leads to significant over-catering.

Figure 22
Current State Visualisation (Before SkyTag)

Figure
SkyTag-Enabled
(After Sk



e 23
d Visualisation
yTag)

	A	B	C	D	E	G	H	J	K
17			MOML						
18	VGML		VLML	NPLS		NPLS	VLML		
19			NMML	NMML				VGML	
20				VGML	VGML		MOML		
21		KSML					NPLS		
22				MEML				NPLS	
23	MOML	MOML	NPLS				NMML	NMML	
24									
25			PLSO	PLSO			MOML		VGML
26				NPLS		MEML	NPLS		
30				CHML					
31	PLSO		NPLS						
32				VLML		KSML	NMML		
33			VGML	VGML					MOML
34								VGML	
35	PLSO						NPLS		
36			MEML	KSML					VGML
37	NMML		NPLS				VGML	VGML	
38			MEML	NMML		VLML			
39				VLML				MEML	
40	VGML		PLSO				NPLS	CHML	
41					NMML	NMML	NMML		
42			VGML			VGML			
43	MOML								VGML
44									
45									

SkyTag-Enabled Visualisation (After SkyTag)

Enriched Flight Data Panel
Flight: KL621 AMS-ATL (hypothetical)
Aircraft: KLM Boeing 787-9 Dreamliner
Economy Class Passengers: 210/224
Load Factor: 94%
Known Dietary Restrictions: 27 (12.86%)
Detailed Meal Preferences: 36(17.14%)
Unknown Meal Preferences: 147 (70%)

Catering Data Dashboard
Special Meals Pre-ordered: 27 (12.86% of the passengers)

- Vegan (VGML): 15
- Kosher (KSML): 3
- Child Meal (CHML): 2
- Halal Meal (MOML): 7

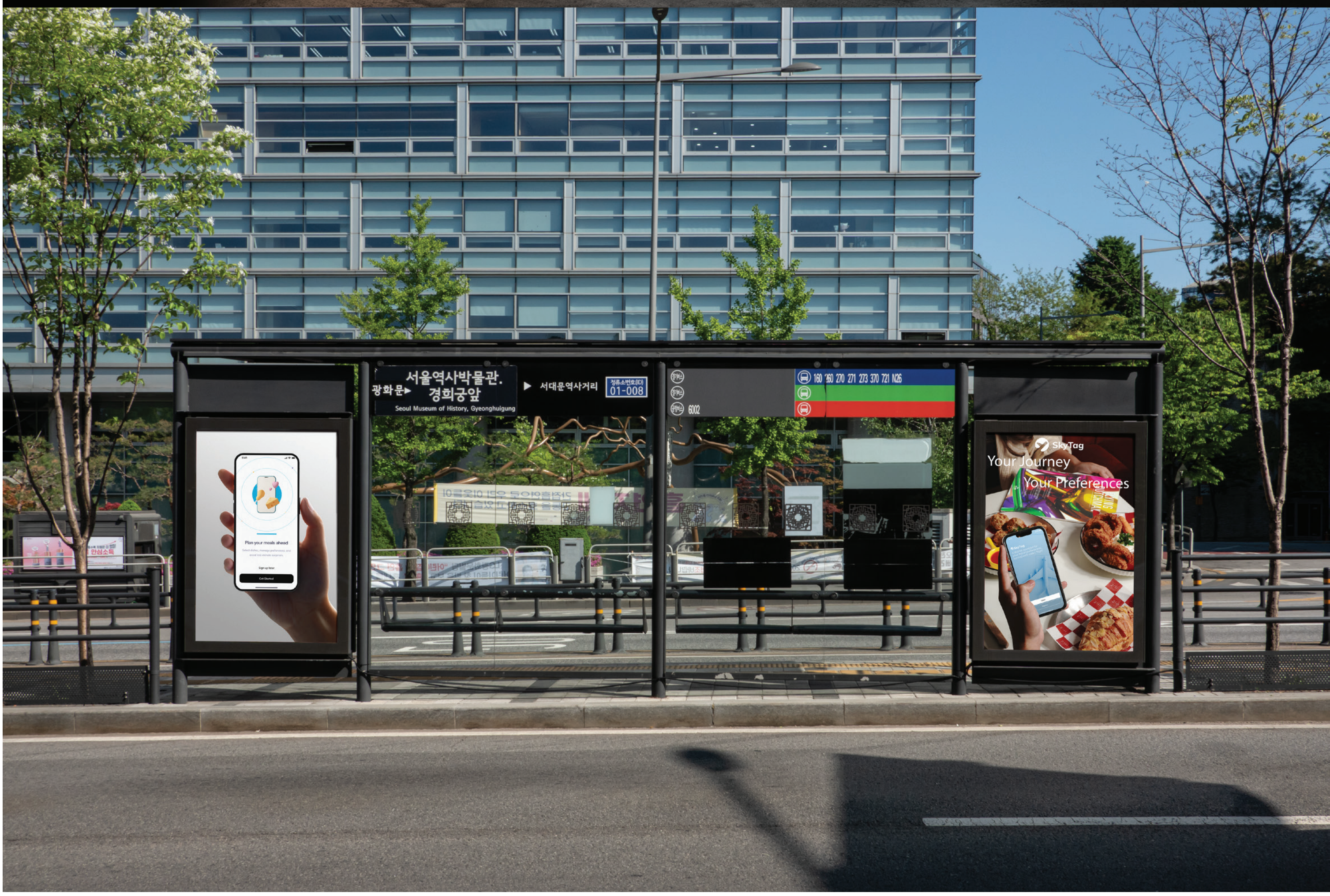
Known Meal Preferences: 36 (17.14% of the passengers)

- No Meal Requested (NMML): 10
- Pre-Landing Snack Only (PLSO): 5
- No Pre-Landing Snack (NPLS): 11
- Vegetarian Lacto-Ovo Meal (VLML): 5
- Meat Eater Meal (MEML): 5

Unknown Meal Preferences: 147 (70% of the passengers)
Optimised Catering Decision Support

- Chicken Option (MEML): 126
- Vegetarian Option (VLML): 42
- Vegetarian Pre-Landing Snack: 162
- *Based on preference prediction (ML) from historical SkyTag Data & known data*

Total Meals: 195 (92,86% of the passenger count)
Total Pre-Landing Snacks: 162 (77.14% of the passenger count)
Data Richness Indicator: High
Catering Load Calculation: Precisely matched to aggregated detailed preferences, with addition of machine learning algorithms for preference prediction when it comes to unknown meal preferences.



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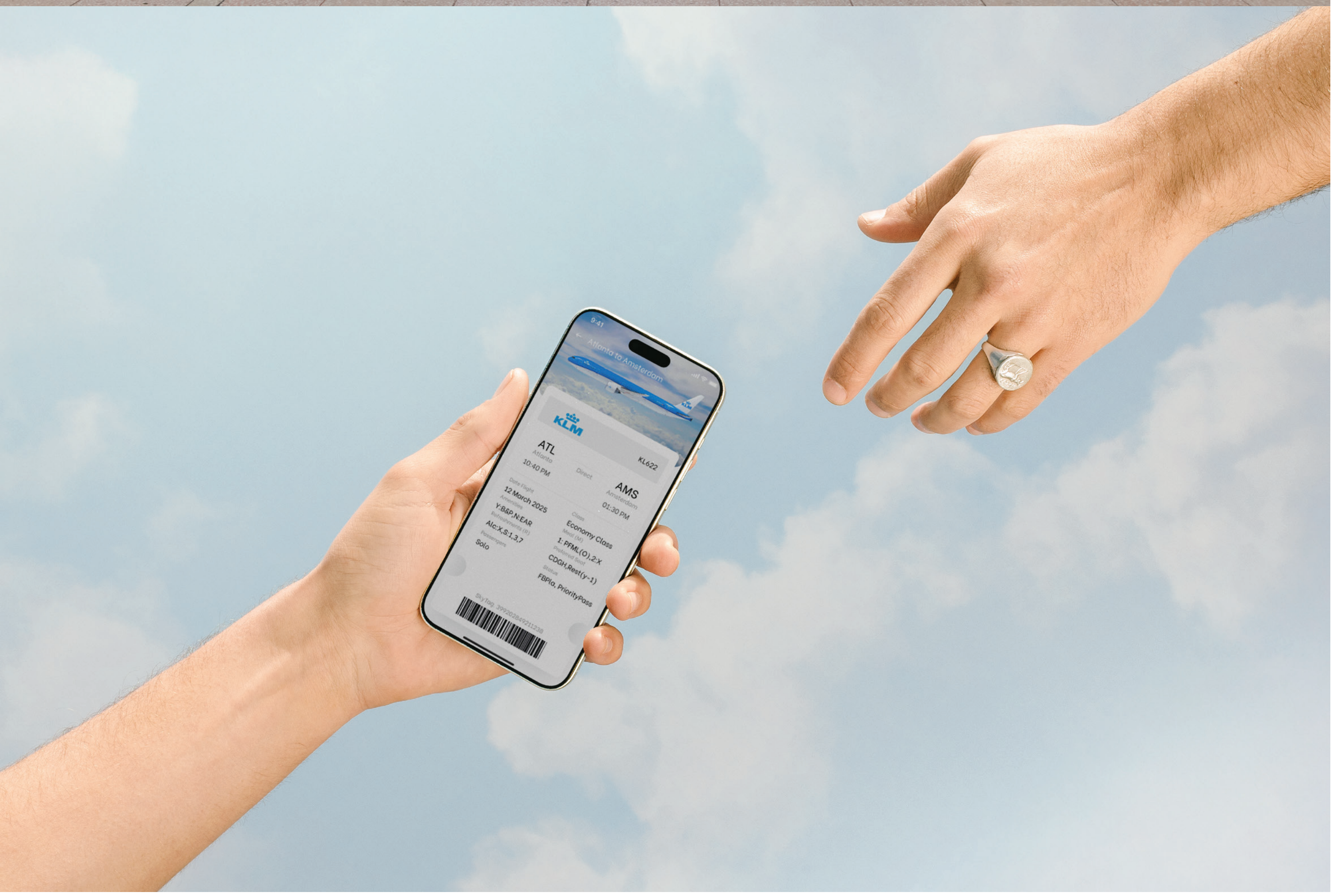

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9 Validation & Conclusion

9.1 Introduction

This chapter presents the conclusion and discussion of the project, synthesizing the key findings and reflecting on their broader implications for the aviation industry. By addressing the main research question—How can passenger-centric strategies effectively reduce in-flight food waste on transatlantic routes while maintaining service quality?—this research provides actionable insights into transforming airline catering operations beyond traditional waste reduction approaches. The findings offer practical solutions to current challenges while outlining opportunities for enhanced passenger experience and operational efficiency that extend beyond individual airlines to the broader aviation ecosystem.

9.2 Conclusion

This project answers the main research question through a structured exploration of six critical subquestions, revealing that the aviation industry's food waste challenge represents both a sustainability imperative and an unprecedented opportunity for service differentiation. By examining operational, logistical, and behavioral factors contributing to food waste, analyzing current system limitations, and identifying passenger preferences for customization, the study provides a comprehensive framework for transforming airline catering operations.

The empirical fieldwork at Hartsfield-Jackson Atlanta International Airport, combined with expert consultations and practical testing sessions, validated that current catering systems suffer from fundamental communication disconnects between passengers and airlines. The research demonstrated that 73% of passengers are willing to pay extra for customized meal options, while airlines continue to operate on standardized, per-leg catering models that ignore passengers' complete journey requirements. This mismatch represents not merely an operational inefficiency, but a significant missed opportunity for competitive differentiation.

A pivotal finding emerged during the TU Delft testing session regarding passenger autonomy in meal decisions. Students expressed surprise and frustration upon learning that current airline systems do not provide meaningful opportunities to decline meals during flight service. This revelation highlighted a fundamental disconnect between passenger expectations for choice and current operational procedures.

Participants articulated that the inability to decline unwanted meals creates an ethical dilemma for environmentally conscious travelers. They described feeling complicit in waste generation when accepting meals they did not intend to consume, yet lacking alternative options within current service frameworks. This finding validated the research's emphasis on passenger agency as a critical component of effective waste reduction strategies.

The SkyTag demonstration proved highly successful in engaging student participants and illustrating the system's potential benefits. Students immediately grasped the concept's value proposition, particularly appreciating the ability to communicate dietary preferences, cultural requirements, and consumption intentions across multiple carriers seamlessly.

Participants were particularly enthusiastic about SkyTag's potential to address the freedom of choice limitation they had just discovered. The system's opt-in/opt-out functionality for meals resonated strongly with students' desire for greater control over their travel experience and environmental impact. Several students noted that such a system would encourage them to engage more thoughtfully with in-flight catering rather than passively accepting predetermined options.

The investigation into real-time digital platforms revealed transformative potential for demand forecasting and surplus reduction. Examples like KLM's TRAYS model, which reduced leg-level waste by 63%, and emerging solutions such as Japan Airlines' 'Meal Skip' program, demonstrate that passenger-centric approaches can simultaneously reduce waste and enhance service quality. The proposed SkyTag universal passenger preference system represents a paradigm shift toward journey-aware catering management, enabling seamless preference communication across multi-carrier itineraries.

Critically, this research addresses the concept of 'systemic economic entrenchment' that underlies the industry's resistance to change. While the current high-volume catering model generates significant environmental and financial costs, it simultaneously sustains a considerable economic apparatus of caterers, suppliers, and logistics providers whose business models depend on existing production scales. However, rather than viewing waste reduction as a threat to this ecosystem, the findings reveal an opportunity to redirect this economic apparatus toward precision catering that delivers superior passenger value.

The choice architecture analysis demonstrated that opt-in meal systems, portion control, and sustainable defaults can substantially reduce waste without compromising passenger satisfaction—indeed, often enhancing it by providing greater control and customization. The regulatory landscape analysis revealed emerging frameworks like blockchain-enabled supply chain solutions that enable innovation while maintaining safety standards.

9.3 Broader Value and Implications

Value for Airlines

For airlines, adopting passenger-centric catering strategies offers a comprehensive solution to multiple operational and competitive challenges. The research demonstrates that sustainable catering practices should not be pursued solely for environmental reasons, but as a strategic opportunity for greater passenger understanding and service excellence. By implementing systems like enhanced pre-ordering, real-time preference tracking, and journey-aware meal planning, airlines can transform catering from a cost center into a competitive differentiator.

The economic implications are substantial. With the aviation industry wasting approximately $6 billion worth of resources annually on discarded meals, precision catering represents significant cost savings potential. However, the greater opportunity lies in using detailed passenger preference data to create personalized experiences that command premium pricing and drive customer loyalty. Airlines that successfully implement passenger-centric catering can position themselves as industry leaders in service customization, attracting customers willing to pay for tailored experiences.

Furthermore, the shift toward precision catering enhances operational efficiency beyond waste reduction. Real-time demand forecasting reduces the complexity of supply chain management, minimizes storage requirements, and improves flight weight optimization. The integration of digital platforms enables airlines to capture valuable passenger data that can inform broader service improvements across all touchpoints of the travel experience.

Value for Passengers

This research validates passengers' desire for greater control and customization in their travel experience. The findings show that 70% of passengers prefer to reserve meals online, with younger demographics particularly valuing ingredient information and dietary accommodation. By implementing passenger-centric strategies, airlines can address the fundamental communication disconnect that currently prevents passengers from receiving meals aligned with their preferences, cultural requirements, and journey context.

The proposed solutions enable passengers to become active participants in sustainable travel rather than passive recipients of predetermined services. Choice architecture improvements, such as opt-in meal systems and portion control options, empower passengers to make conscious consumption decisions while reducing environmental impact. This alignment of personal values with travel choices enhances overall satisfaction and creates emotional connections between passengers and airlines.

Value for the Industry

The aviation industry faces increasing pressure to address its environmental impact while maintaining growth trajectories. This research demonstrates that sustainability and service excellence are not opposing forces but complementary strategies that can drive industry transformation. The proposed passenger-centric approaches provide a scalable framework for reducing the aviation sector's 3.6 million metric tonnes of annual cabin waste while enhancing competitive positioning.

The integration of digital platforms and data sharing protocols creates opportunities for industry-wide collaboration that benefits all stakeholders. Standardized passenger preference systems like SkyTag could enable seamless service delivery across alliance networks, improving passenger experience while reducing redundant catering provision. The regulatory evolution toward modular certification and blockchain-enabled supply chains provides the technical foundation for industry-wide adoption of innovative catering solutions.

Value for Academia

From an academic perspective, this research contributes to understanding how passenger-centricity can drive sustainable innovation in complex, regulated industries. It bridges the gap between theoretical frameworks of circular economy principles and practical applications in aviation operations. The comprehensive methodology, combining literature review, empirical fieldwork, expert consultations, and practical testing, provides a robust model for future research in sustainable aviation practices.

The concept of 'systemic economic entrenchment' offers a new lens for understanding resistance to sustainability initiatives in established industries. By demonstrating how existing economic structures can be redirected toward precision service delivery rather than high-volume standardization, this research provides insights applicable to other industries facing similar transformation challenges.

The investigation of choice architecture effects in aviation contexts contributes to behavioral economics literature while providing practical guidance for service design in constrained environments. The findings on passenger willingness to engage in sustainability initiatives through service customization offer valuable insights for researchers studying the intersection of environmental responsibility and consumer behavior.

This research ultimately demonstrates that sustainable catering represents far more than environmental compliance—it offers airlines an unprecedented opportunity to understand and serve their passengers with precision, creating competitive advantages through personalized service delivery while contributing to global sustainability goals. The path forward requires not abandoning the existing catering ecosystem, but transforming it into a more intelligent, responsive, and passenger-focused system that delivers superior value for all stakeholders.

10 Discussion & Limitations

This project has demonstrated the feasibility of implementing passenger-centric strategies to reduce in-flight food waste on transatlantic routes, but significant challenges remain, highlighting the boundaries of this research and areas for further exploration. These challenges underscore the complexity of transforming deeply entrenched operational practices within a highly regulated and technologically constrained industry, requiring both internal organizational change and comprehensive industry-wide transformation. One key limitation is the fragmented nature of airline operations, which hinders the cross-system integration necessary to embed passenger-centric approaches into daily catering practices. While SkyTag provides a framework for unified preference management, its success depends on fostering stronger data sharing protocols and coordination across multiple carriers, catering providers, and technology systems.

The siloed structure prevalent across airline operations presents fundamental challenges to implementing passenger-centric waste reduction strategies. Current airline systems operate with distinct divisions for catering operations, passenger services, and sustainability initiatives, each with separate data repositories and performance metrics. Breaking down these silos requires strategic efforts to align priorities across departments, facilitate real-time data sharing between passenger service systems and catering operations, and establish shared ownership of waste reduction objectives. The research revealed that flight attendants, despite their direct passenger interaction, have minimal input into catering planning processes, representing a critical missed opportunity for operational feedback and improvement.

Externally, technological barriers present significant hurdles to widespread adoption of passenger-centric solutions. Current aircraft galley designs, based on concepts from the 1960s, fundamentally limit the flexibility required for dynamic meal allocation and real-time preference accommodation. The linear supply chain structure that dominates airline catering operations operates on predetermined production schedules that cannot easily accommodate last-minute preference changes or journey-aware meal planning. Original Equipment Manufacturer (OEM) control over core aircraft systems creates additional constraints, as airlines cannot independently modify galley management systems without extensive certification processes that can cost $2-5 million per aircraft type and require 18-24 months to complete.

In addtion, the regulatory environment presents substantial obstacles to innovative waste reduction approaches. Current health and safety regulations mandate disposal of surplus meals even when unopened, due to biosecurity and temperature control requirements. International aviation authorities require airlines to maintain mandatory surplus meal buffers, directly contributing to potential waste generation. The certification requirements for any modifications to aircraft cabin systems create strong disincentives for adopting unproven sustainability solutions, perpetuating reliance on established but inefficient practices.

The SkyTag Limitation: Beyond Individual Solutions

A critical limitation of this research lies in recognizing that SkyTag, while innovative, represents only the beginning of necessary industry transformation. The unified passenger preference system addresses immediate communication gaps between carriers but cannot overcome fundamental structural limitations within current aviation operations. The per-leg catering paradigm that treats each flight segment as an independent event, rather than considering passengers' complete journey requirements, requires industry-wide adoption of integrated journey management approaches. Without comprehensive transformation of catering supply chains, regulatory frameworks, and aircraft infrastructure, individual technological solutions remain constrained by systemic inefficiencies.

The research identified the linear supply chain structure as a fundamental barrier to achieving meaningful waste reduction. Current catering operations involve complex logistics with high production rates, off-site meal preparation, and rigid delivery schedules that prevent dynamic adjustment based on real-time passenger preferences. The data fragmentation across lounge point-of-sale systems, airline booking platforms, and catering management systems creates operational silos that prevent holistic journey-aware meal planning. These structural limitations mean that even perfect preference communication through systems like SkyTag cannot fully address waste generation without corresponding supply chain transformation.

In addition, airlines' financial constraints add complexity to scaling passenger-centric waste reduction practices. Balancing the need for cost optimization with investments in sustainable innovation requires careful prioritization and clear demonstration of long-term operational benefits. The research revealed that while passengers express willingness to pay extra for customized meal options, the operational costs of implementing individualized service delivery may exceed revenue potential without significant technological and procedural advances. The economic magnitude of the global aviation catering market, valued at over $20 billion annually, creates powerful inertia against disrupting established business models that sustain extensive networks of suppliers and service providers. Further research and industry collaboration are essential to address technical challenges that limit the full potential of passenger-centric approaches. The certification processes for innovative catering technologies remain significant obstacles, requiring partnership with aircraft manufacturers, regulatory authorities, and catering providers to develop new standards for sustainable operations. The research roadmap (Figure 25) outlined in this thesis envisions comprehensive industry transformation that extends far beyond individual airline initiatives, requiring coordinated efforts across Original Equipment Manufacturers, regulatory bodies, catering providers, and technology developers to create an integrated ecosystem capable of supporting truly passenger-centric and sustainable operations.

While this project has laid a strong foundation for integrating passenger-centric strategies into airline catering operations, addressing the identified challenges will require strategic alignment across the entire aviation ecosystem, significant technological advancement, and strengthened collaboration with industry partners extending far beyond individual carrier boundaries. The development of SkyTag and the comprehensive analysis of waste reduction opportunities represent critical first steps, but the ultimate success of these initiatives depends on industry-wide adoption of the integrated journey management paradigm outlined in this research. By building on the momentum of passenger-centric innovation and the proven feasibility of preference-based waste reduction, the aviation industry can move beyond fragmented solutions toward comprehensive transformation that addresses the systemic roots of the $6 billion annual food waste challenge while enhancing passenger experience across multi-carrier journeys.

CaterFlow

This roadmap outlines a strategic, multi-horizon approach to transfor
transformation aims to significantly reduce food waste, enhance pa
operational efficiencies across the aviation industry. The roadmap a
passenger preference data, the inefficiencies of traditional over-cat
cabin infrastructure and OEM control over aircraft systems.

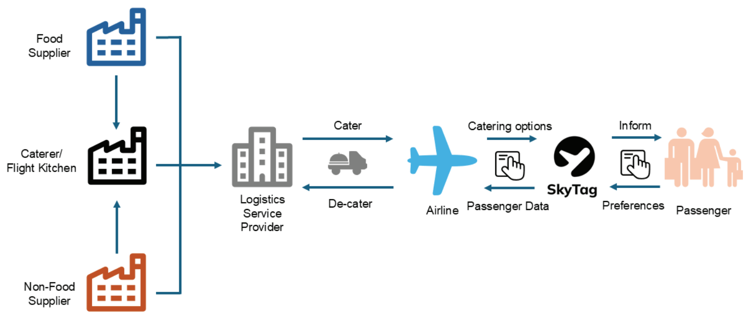
H1
Data-Driven Catering
2030: Digital Preference ID

Product

SkyTag is your personal travel passport, automatically syncing your catering preferences with airlines for a seamless (multi-carrier) journey.

User values

Better Airline Experience
No more re-entering preferences—SkyTag ensures every flight is tailored to you automatically.



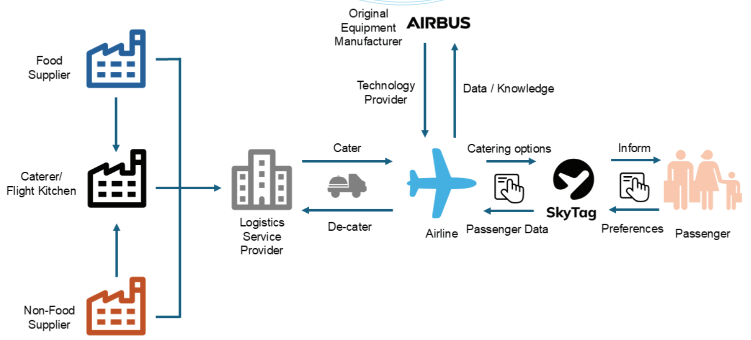
Partners

H2
In-Flight Intelligence
2035

Assisted by Original Equipment Manufacturers (OEMs), airlines are advancing into a new horizon by adopting sophisticated tracking technologies to gain detailed insights into real-time onboard meal consumption. This evolution centers on deploying dynamic catering systems, which employ RFID meal tracking and IoT sensors to precisely monitor passenger food and beverage uptake.

Improved Meal Quality, Freshness, and Safety

real-time tracking of meal production and storage conditions, further contributing to food quality and hygiene.



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Figu
Cate
Design R

rm in-flight catering by leveraging digital innovation. This
ssenger personalization and satisfaction, and improve
ddresses longstanding challenges such as fragmented
tering models, and the limitations imposed by legacy

FUTURE VISION

H3

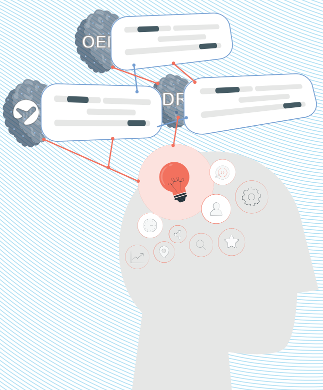
Smart Galleys

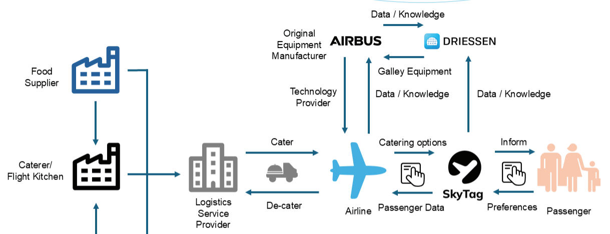
2040

Smart Galleys will transform the aircraft cabin from a static service environment into a responsive, intelligent ecosystem. By empowering OEMs and airlines with data-driven tools and purpose-built hardware, this phase creates a new standard for in-flight service, where catering is not just a provision but a personalised, efficient, and sustainable experience.

Environmental Value

Smart galleys substantially reduce in-flight catering's carbon footprint by minimizing waste and improving resource efficiency.





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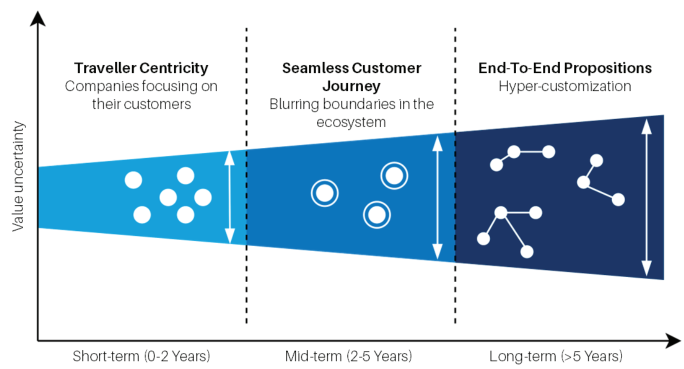
DO&CO SKYTEAM SkyTag AIRBUS DELTA Flight Products

Master Thesis

The future vision of travel evolves from isolated "Traveller Centricity" in the short-term (0-5 years) where companies focus independently on their customers, to a "Seamless Customer Journey" in the mid-term (5-10 years) where ecosystem boundaries blur through collaboration. This culminates in "End-to-End Propositions" in the long-term (beyond 10 years), delivering hyper-customized experiences through interconnected systems and real-time AI that anticipate and fulfill traveler needs across the entire journey.

Evolution of Living Travel Experience



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Roadmap

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Appen

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A1

The 730 Million Seat Equation

Introduction

This chapter will continue to discuss the avation market in the USA, which was shortly touched upon while discussing Delta Air Lines.

Airlines, Competition, and the State of Affairs

The American aviation market stands as one of the most dynamic, competitive, and resilient sectors in the global economy, generating over $1.37 trillion annually and supporting more than 10 million jobs (Airlines for America, 2024; Mordor Intelligence, 2025). In 2023, more than one billion passengers traveled through U.S. airports, reflecting the scale and complexity of the market (Bureau of Transportation Statistics, 2024; PMC11499240, 2024). This chapter explores the evolution, structure, and current state of the U.S. airline industry, focusing on the major carriers—legacy giants, ultra-low-cost disruptors, and innovative hybrids—while examining the interplay of competition, consolidation, and post-pandemic challenges.

Spirit Airlines, often described as America's answer to Ryanair, has long embodied the ultra-low-cost carrier (ULCC) model. Launched in 1990 as Charter One Airlines, Spirit initially operated charter flights to leisure destinations like the Bahamas, Las Vegas, and Atlantic City. By 1992, it rebranded as Spirit and spent the next decade and a half expanding steadily, targeting leisure travelers with bare-bones fares and minimal frills. In 2010, Spirit became the first U.S. airline to charge for carry-on bags, a move that sent shockwaves through the industry and accelerated the trend toward product unbundling and ancillary revenue streams (PMC9116065, 2022). This strategy, while controversial, allowed Spirit to offer some of the lowest base fares in the market, but also made it the butt of many jokes and the poster child for "no-frills" flying.

Spirit's fortunes, however, have dramatically reversed in recent years. The COVID-19 pandemic hit the leisure and ULCC segment particularly hard, and Spirit has struggled to rebound as quickly as legacy carriers, whose diversified networks and premium products provided a buffer against demand shocks (PMC9759425, 2020). The years following the pandemic saw Spirit become the subject of intense merger speculation and failed takeover bids. In February 2022, with its stock trading at $26.39, Spirit received a $2.9 billion buyout offer from Frontier Airlines, which shareholders rejected. JetBlue soon followed with a $3.6 billion bid, but Spirit's board dismissed it, fearing regulatory pushback against a hybrid carrier absorbing a ULCC. Despite a hostile takeover attempt by JetBlue and eventual shareholder approval, the U.S. Department of Justice blocked the acquisition in January 2024, causing Spirit's stock to plummet by 47% in a single day (press-register.al.com, 2025). By November, Spirit announced plans to file for bankruptcy protection, and its stock fell further to $0.62, a staggering drop from its 2022 peak. Frontier returned with another offer in early 2025, but Spirit again declined, underscoring the existential challenges facing ULCCs in a market increasingly shaped by consolidation and regulatory scrutiny (PMC9116065, 2022).

The story of Spirit is deeply intertwined with that of its suitors. Frontier Airlines, itself a survivor of multiple reincarnations, began in 1950 and was reborn in 1994 after an earlier collapse and absorption by Continental. Frontier's primary hub in Denver places it in direct competition with United Airlines, which inherited Continental's Denver operations after their 2012 merger. Frontier has repeatedly tried to position itself as the true ULCC, undercutting both Spirit and Southwest, and even eliminating its call centers in 2023 to further reduce costs. Its distinctive animal-themed livery and slogan, "a whole different animal," reflect an attempt to inject personality into a business model that otherwise prizes efficiency above all else. The rise of Breeze Airways signals a new direction for the U.S. aviation market. Conceived by industry veteran David Neeleman—whose resume includes founding Morris Air, WestJet, JetBlue, and Azul—Breeze was envisioned in 2018 as a "hybrid hybrid" carrier, blending low fares with comfort features like included carry-ons and a focus on underserved secondary cities. Initially intended to be named

Moxie Airlines, Breeze launched its first flight in 2021 from Tampa to Charleston. By the end of 2024, Breeze had achieved its first profitable quarter, generating over $200 million in revenue and operating a fleet of 33 Airbus A220s, with firm orders for 90 more (Aviation Business News, 2025). Breeze's point-to-point model, serving markets abandoned by major airlines, allowed it to be the sole carrier on 87% of its 220 non-stop routes, demonstrating the potential for innovation even in a mature, consolidated market (Aviation Business News, 2025). The success of Breeze underscores academic findings that hybrid models, which combine operational efficiency with passenger comfort, are increasingly viable in the post-pandemic landscape (Lurkin et al., 2018).
Among the legacy giants, American Airlines stands as the world's largest carrier by daily flights and passengers. Its origins trace back to the 1920s, when a collection of small airlines merged under the Aviation Corporation (AVCO) banner. After reorganizing as American Airways in 1930 and then American Airlines in 1934, the company quickly transitioned from mail to passenger services, pioneering innovations like the Douglas DC-3, which made air travel profitable and accessible (Flightradar24, 2025). American's influence extended to the development of the DC-10 widebody jet and the early adoption of lie-flat seats, cementing its role as an industry leader in both technology and service (Flightradar24, 2025). Today, American's vast network and fleet modernization initiatives reflect the broader trend among major carriers to invest in next-generation, fuel-efficient aircraft as travel demand recovers (Mordor Intelligence, 2025).

United Airlines, another titan of the industry, was born from William Boeing's early aviation ventures and became a major player through a series of mergers and strategic expansions. United operates more domestic widebody flights than any other U.S. carrier and maintains unique domestic configurations for some of its aircraft. Its Chicago hub, established out of necessity as a major transit point between the coasts, remains central to its operations. United is known for its experimental route network, boasting the most connections to the Asia-Pacific region among U.S. airlines, a legacy of its 1986 purchase of Pan Am's Pacific Division and the 2012 merger with Continental, which added a Guam hub (Aviation Week, 2024). In 2025, United continues to expand internationally, adding new routes to China and Europe, reflecting the airline's strategy of leveraging global connectivity to drive growth (Aviation Week, 2024).

JetBlue occupies a unique space in the U.S. market, straddling the line between low-cost and full-service models. Founded in 1999 by David Neeleman, JetBlue made its mark with low fares, in-flight entertainment, and complimentary snacks, quickly gaining a loyal following. Over time, JetBlue introduced premium products like the Mint business class and expanded into transatlantic markets. Despite its innovative spirit, JetBlue has faced significant challenges, including a failed bid to acquire Virgin America in 2016 (losing to Alaska Airlines), a blocked Northeast Alliance with American Airlines in 2023, and the thwarted hostile takeover of Spirit in 2024 (Investing.com, 2025). JetBlue's future hinges on its ability to execute strategic shifts, manage operational

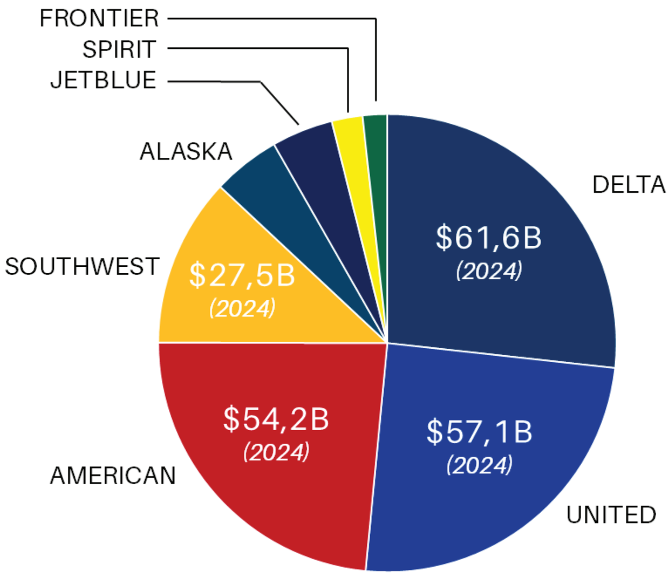

Figure X
US Carriers Compared
Total Revenue (2024)

challenges, and maintain its competitive edge amid industry consolidation and capacity constraints (Investing.com, 2025). The airline's continued focus on fleet renewal, with a majority of its aircraft being A320s and new A220s on order, reflects the broader industry trend toward modernization and efficiency (Mordor Intelligence, 2025).

Alaska Airlines, though smaller than the legacy giants, has demonstrated remarkable adaptability. Originating as McGee Airways in 1932, Alaska grew as a regional carrier and capitalized on deregulation in the 1980s to expand its network, even offering flights to the Russian Far East before launching transcontinental service in 1999. The 2016 acquisition of Virgin America, the 2021 entry into the oneworld alliance, and the 2023 purchase of Hawaiian Airlines have transformed Alaska into a West Coast powerhouse with new international capabilities. These strategic moves allowed Alaska to fill gaps left by larger carriers and leverage partnerships to enhance its competitiveness, aligning with research that highlights the importance of alliances and mergers in sustaining mid-sized carriers (Irwin & Kasarda, 1991).

Southwest Airlines, often described as a "super friendly cult," has long been a disruptor in the U.S. market. Founded in 1967 as Air Southwest and rebranded in 1971, Southwest initially flew only within Texas to avoid federal regulations, enabling it to undercut competitors and build a fiercely loyal customer base. Its point-to-point model and rolling hub system set it apart from the hub-and-spoke networks of legacy carriers. For 47 consecutive years, Southwest remained profitable, a testament to its operational discipline and customer-centric culture. However, the post-pandemic era brought unprecedented challenges. In December 2022, a combination of a massive winter storm and outdated scheduling software led to the cancellation of up to 70% of Southwest's flights over nine days, costing the airline $1.1 billion. The crisis exposed vulnerabilities in the airline's decentralized crew system and prompted a wave of changes, including a $1.9 billion investment from Elliott Investment Management, the introduction of premium seating, and a 15% reduction in corporate workforce. These shifts illustrate the broader pressures facing even the most successful carriers to modernize and adapt to changing market conditions (Mordor Intelligence, 2025).

The U.S. aviation market is thus characterized by a complex interplay of legacy power, disruptive innovation, and relentless competition. The market remains highly consolidated, with major players leveraging their scale, technological expertise, and strategic partnerships to maintain dominance (Mordor Intelligence, 2025). At the same time, volatility—driven by economic shocks, regulatory interventions, and evolving consumer preferences—continues to shape the fortunes of individual airlines (PMC7185465, 2013). The COVID-19 pandemic, in particular, underscored the industry's vulnerability to external shocks, with recovery timelines varying widely by region and business model (PMC9759425, 2020). While legacy carriers have rebounded more robustly, ULCCs like Spirit and Frontier face existential challenges, and hybrids like JetBlue and Breeze experiment with new models to capture shifting demand.

Forecasting demand in this environment remains a formidable challenge, requiring airlines to balance long-term planning with the flexibility to respond to sudden disruptions (PMC10150678, 2023). The growing importance of ancillary revenues, the push for fleet modernization, and the integration of sustainability initiatives further complicate the competitive landscape (PMC9116065, 2022; Mordor Intelligence, 2025). As the industry looks to the future, the lessons of the past decade—resilience, adaptability, and the capacity to innovate—will remain central to the success of American airlines in an increasingly uncertain world.

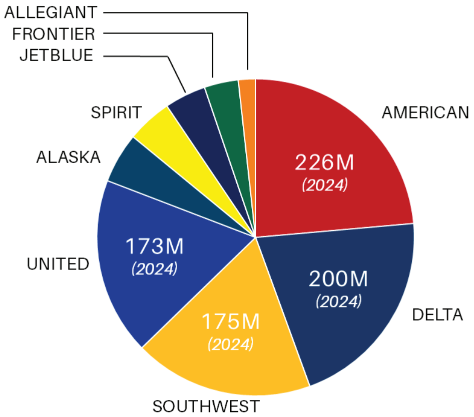

Figure X
US Carriers Total PAX Carried (2024)

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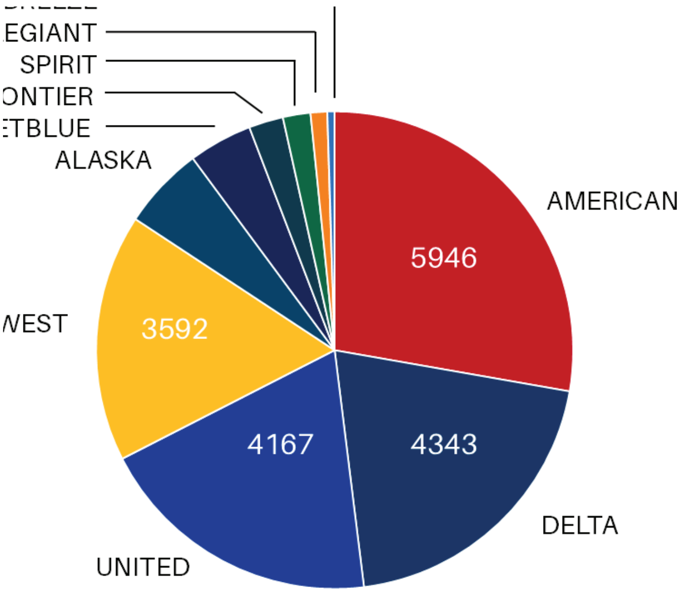

Figure X
US Carriers
Compared Flight per Day

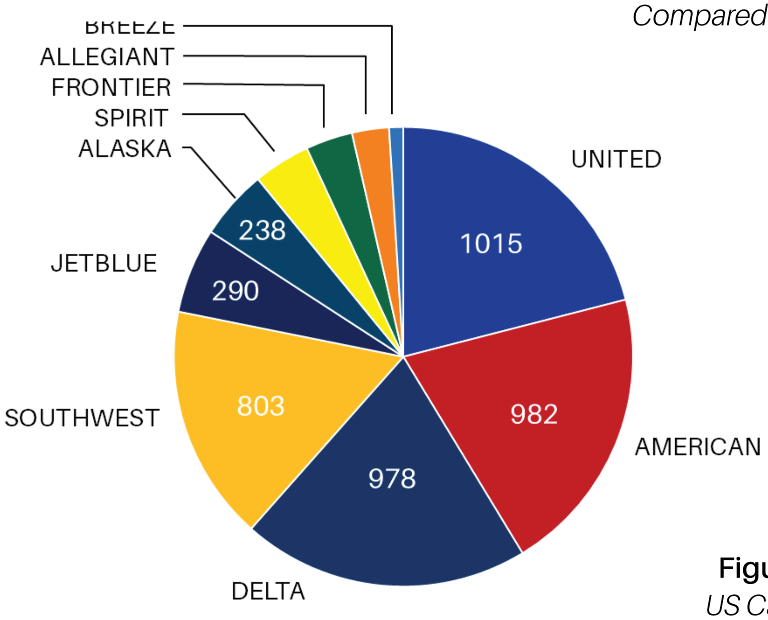

Figure X
US Carriers
Aircraft in Fleet

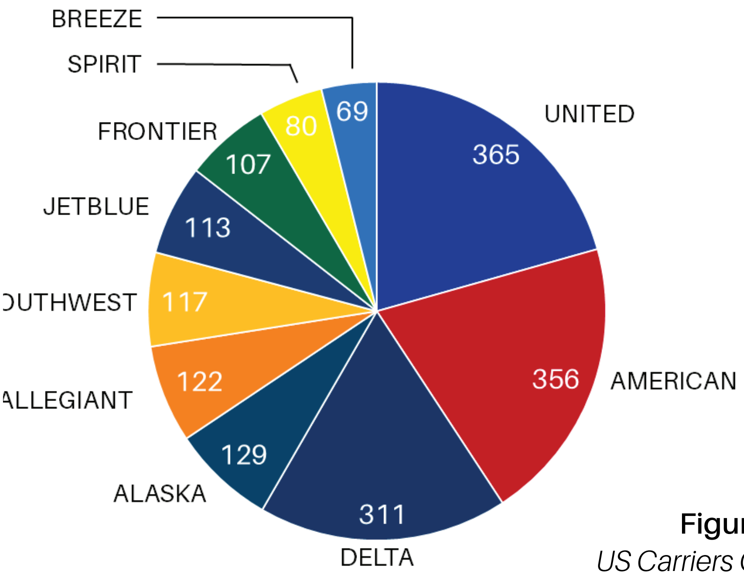

Figure X
US Carriers Compared
Destinations Served

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A2

The Airport Lounge

The Evolution of Airport Lounges

Airport lounges have come a long way since American Airlines opened the first one in 1939 as an exclusive space for VIPs. By the late 20th century, lounges had become synonymous with road warriors—mostly solo travellers heading to medical-device sales conventions or engineering job sites. Back then, offerings were modest: cheese and crackers paired with $5 beers.

Today's lounges are rapidly evolving to meet growing demand from travellers seeking more than basic amenities. Private lounge networks have expanded significantly over the past decade, catering to a broader demographic beyond business travellers. This shift is largely driven by Americans rushing back into travel post-pandemic and applying for credit cards that promise perks like lounge access.

The Modern Lounge Experience

Perhaps the defining characteristic of today's airport lounges is their bustling activity. In summer 2024, lounge visits hit an all-time high, and this year's vacation season is expected to surpass it. The new wave of lounge-goers includes work-from-home travellers tapping away on laptops between pleasure trips.

To maintain exclusivity while accommodating increasing demand, lounge operators are building bigger and more extravagant spaces. Globally, there are now over 3,000 airport lounges, with major operators adding new locations annually. These mega-lounges boast culinary expertise, cocktail programs, and spa amenities like massages and private showers.

For instance:

- United Airlines' new 3000-square-meter Denver lounge features brewery-style tasting flights.
- Delta is opened a new ultra-premium club at JFK airport with a full-service French bistro.
- American Express recently unveiled its largest-ever lounge in Atlanta with a whiskey bar and outdoor space overlooking planes.

While these amenities may seem excessive, they address real issues in air travel. As airlines shrink seats and increase fees while airports struggle with outdated infrastructure, lounges offer frequent fliers respite from these indignities.

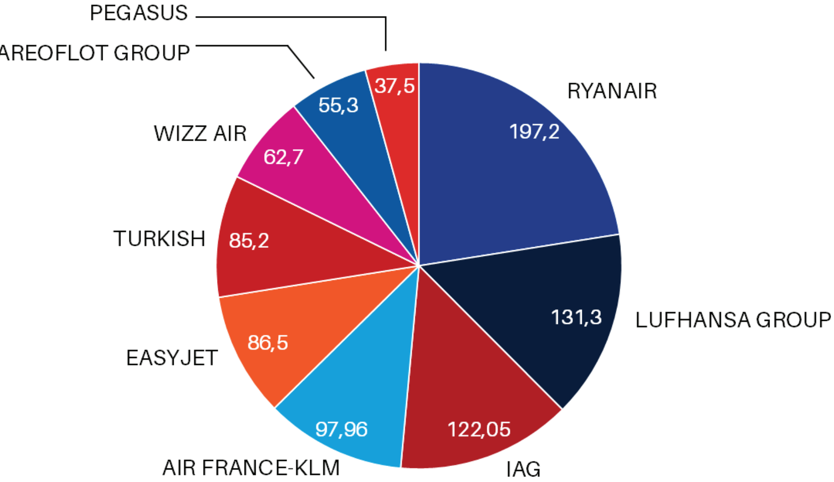
Credit Cards and Lounges: A Strategic Partnership

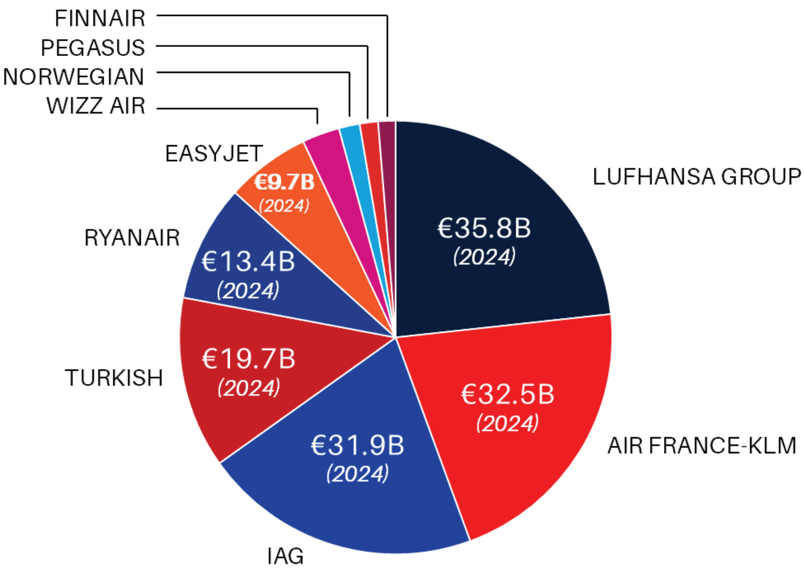
Credit-card companies have entered the lounge market aggressively as part of their strategy to attract high-income customers who spend frequently and pay bills on time. Lounges are less about direct revenue generation and more about fostering brand loyalty among cardholders. • Chase's LaGuardia lounge is for example accessible to anyone paying a $550 annual fee for its credit card but offers private suites costing up to $3,000 for three hours. The perks arms race has ripple effects beyond frequent travellers. Premium-card usage drives higher interchange fees for retailers—costs often passed on to all consumers through higher prices. Meanwhile, companies like Capital One are experimenting with public spaces like cafés aimed at younger customers who may someday become high earners.

Despite their extravagance and exclusivity, lounges remain effective tools for enticing customers into loyalty programs that benefit credit-card issuers immensely.

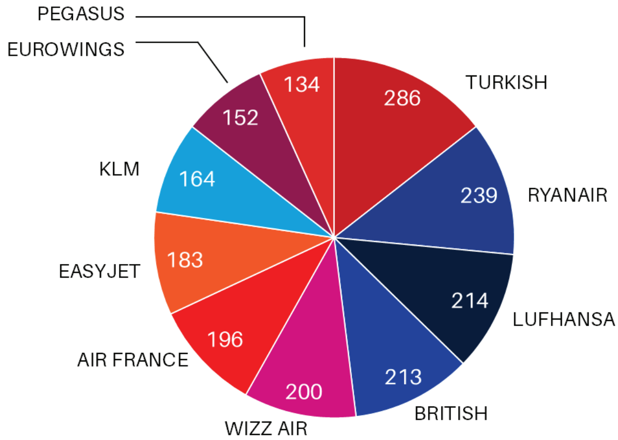
A3 EU Carriers Compared

EU Carriers Compared
Total PAX Carried (in Millions)

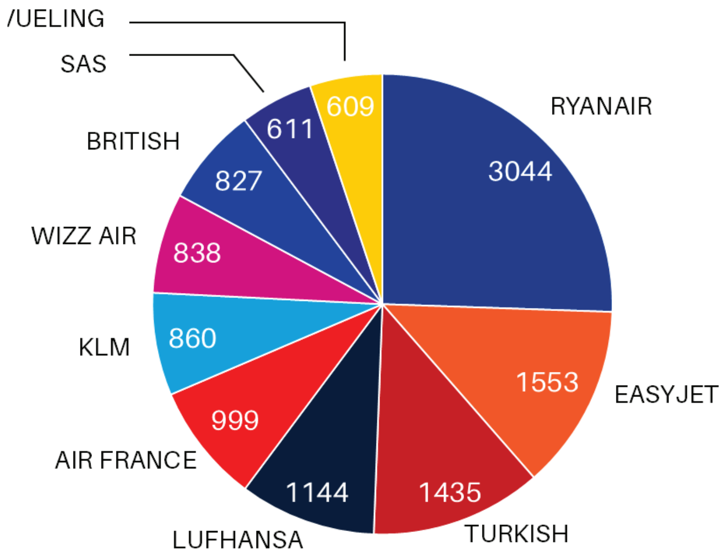




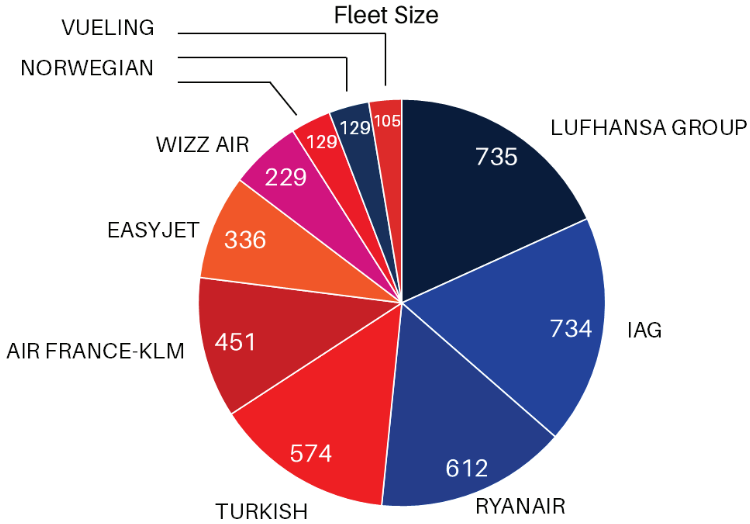
EU Carriers Compared
Destinations Served



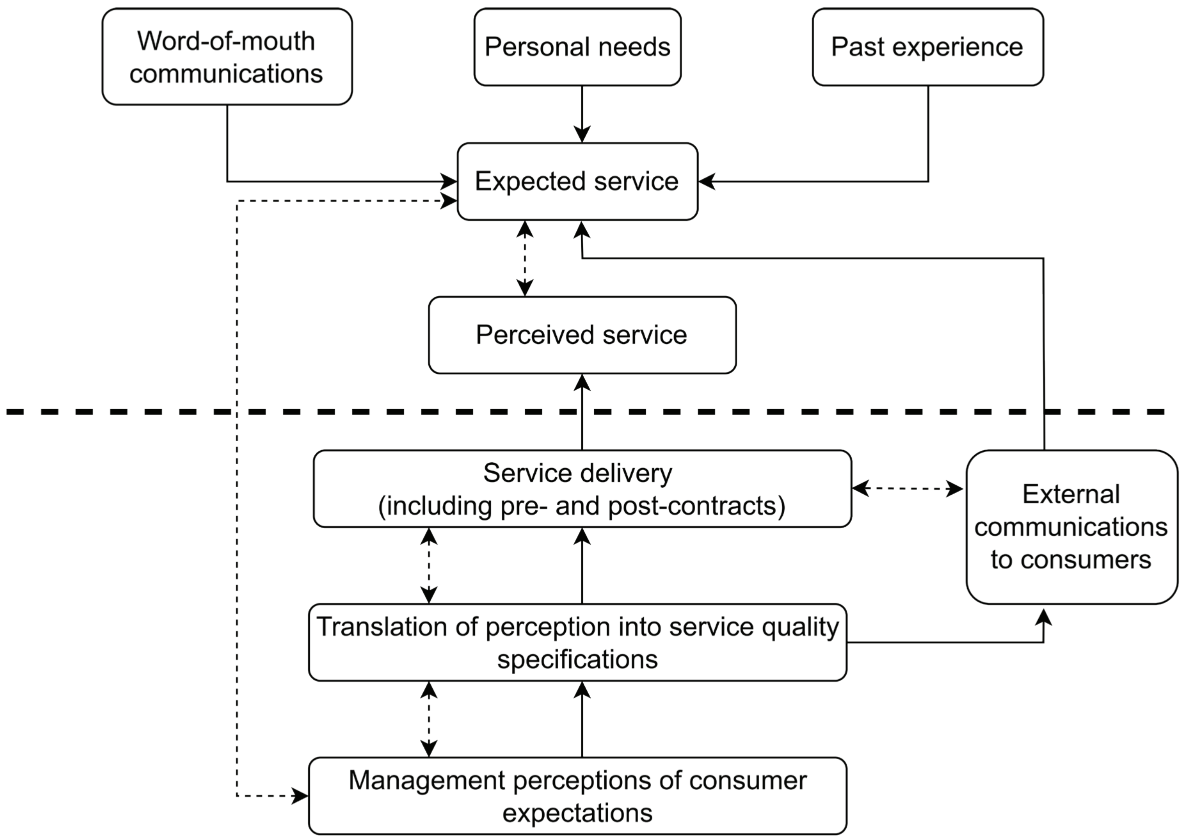
EU Carriers Compared
Flights per Day



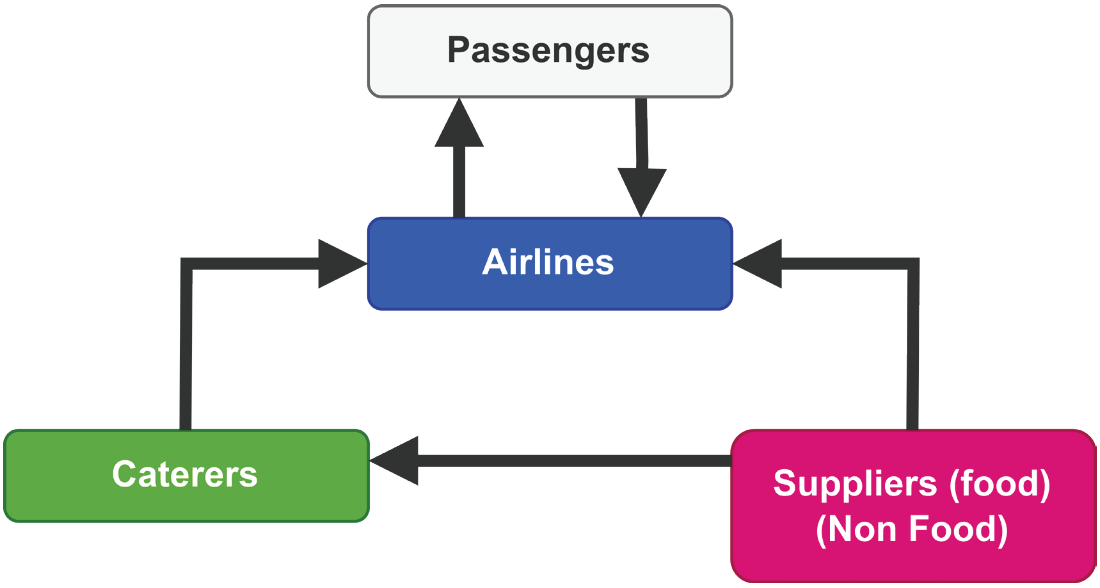
EU Carriers Compared
Fleet Size

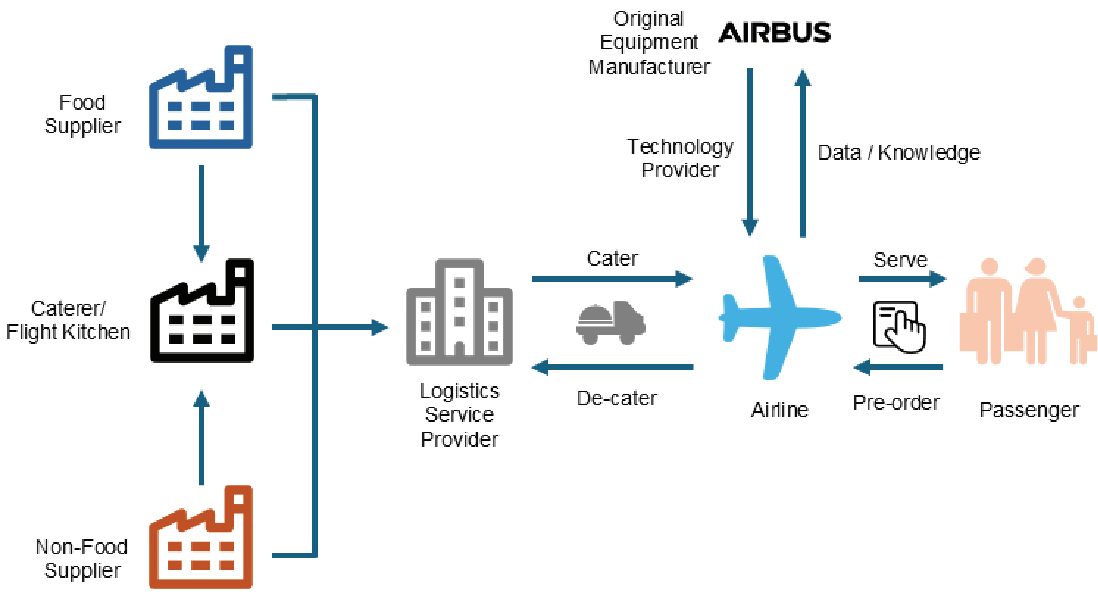


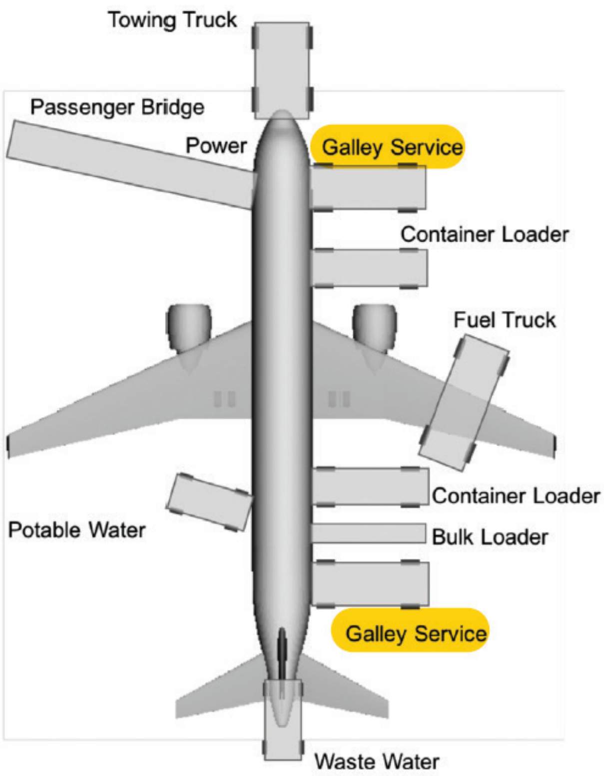
A4 Service Quality Model



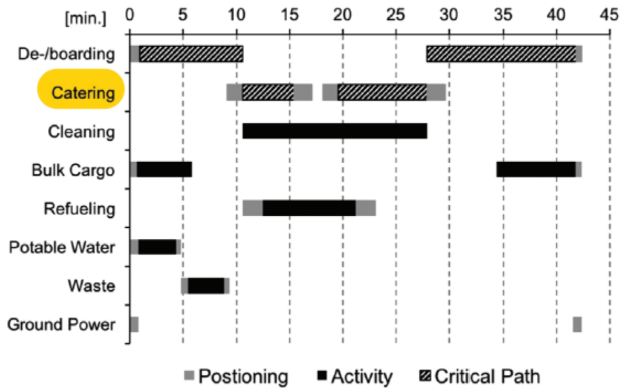
A5 The interface between the ‘players’ involved in flight catering - simplified



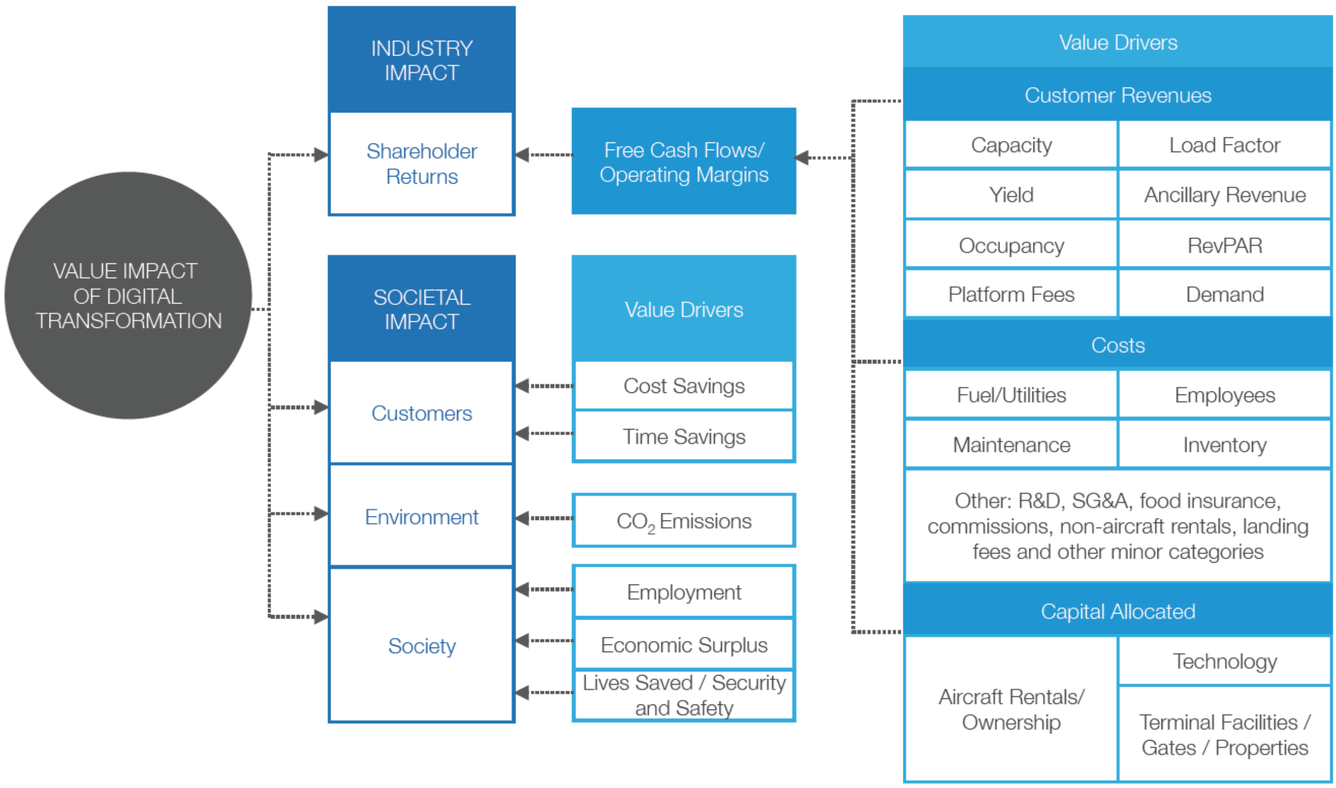




Towing Truck
Passenger Bridge
Power
Galley Service
Container Loader
Fuel Truck
Container Loader
Potable Water
Bulk Loader
Galley Service
Waste Water

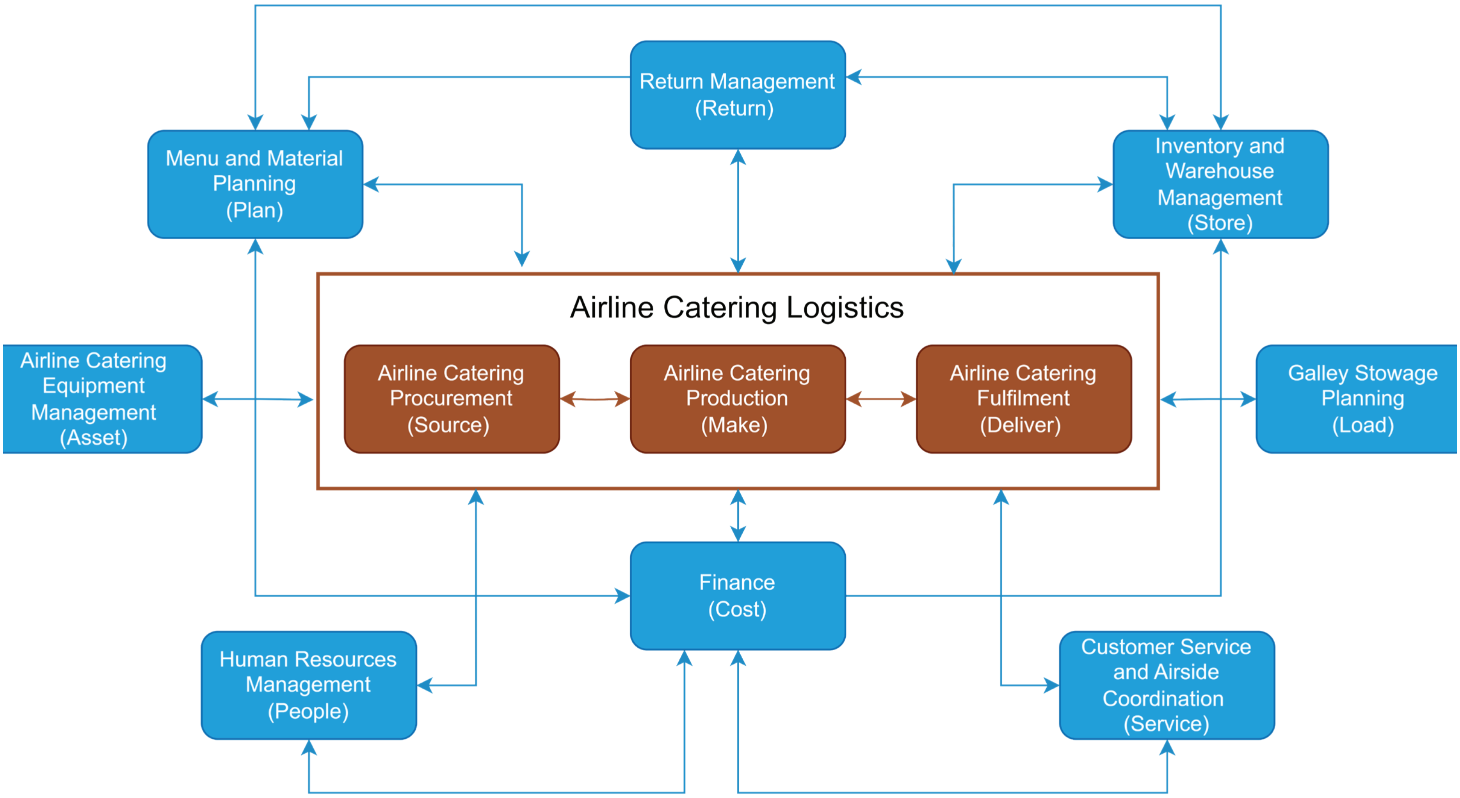


[min.]
0
5
10
15
20
25
30
35
40
45
De-/boarding
Catering
Cleaning
Bulk Cargo
Refueling
Potable Water
Waste
Ground Power
Postioning
Activity
Critical Path

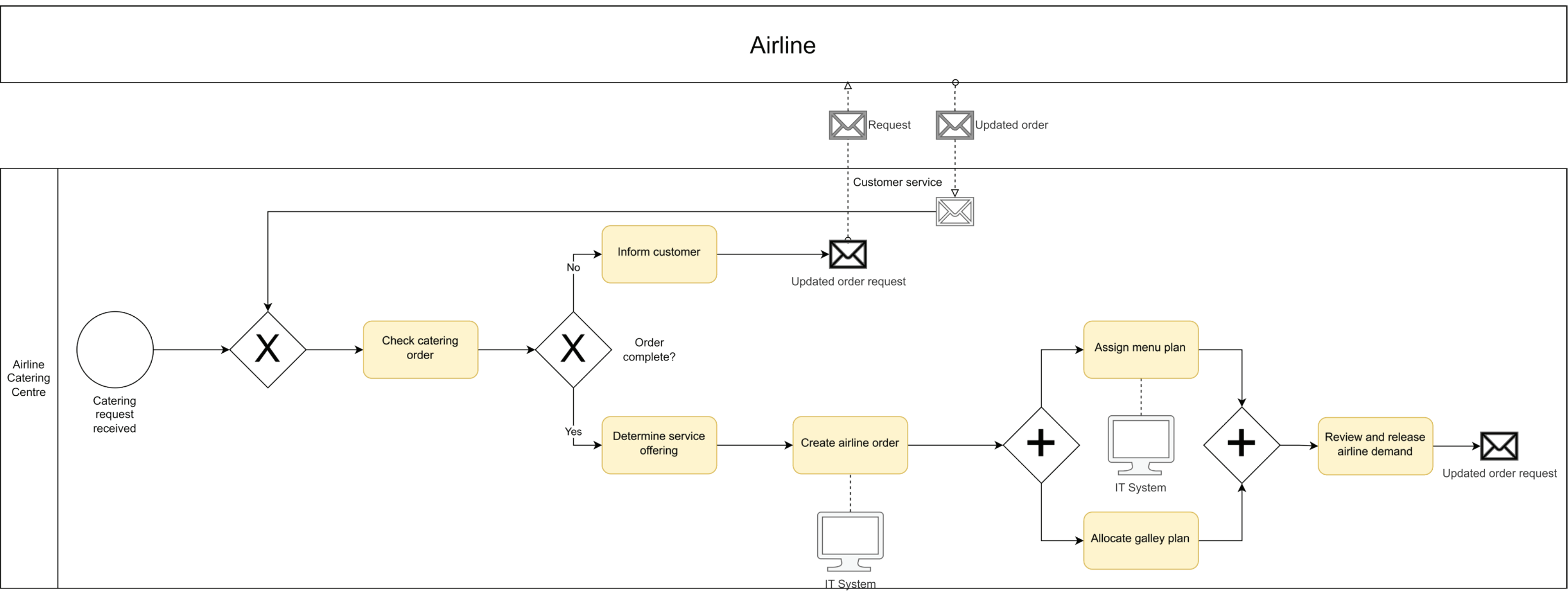


VALUE IMPACT OF DIGITAL TRANSFORMATION
INDUSTRY IMPACT
Shareholder Returns
SOCIETAL IMPACT
Customers
Environment
Society
Free Cash Flows/ Operating Margins
Value Drivers
Cost Savings
Time Savings
CO_2 Emissions
Employment
Economic Surplus
Lives Saved / Security and Safety
Value Drivers
Customer Revenues
Capacity
Load Factor
Yield
Ancillary Revenue
Occupancy
RevPAR
Platform Fees
Demand
Costs
Fuel/Utilities
Employees
Maintenance
Inventory
Other: R&D, SG&A, food insurance, commissions, non-aircraft rentals, landing fees and other minor categories
Capital Allocated
Aircraft Rentals/ Ownership
Technology
Terminal Facilities / Gates / Properties

A6 Airline Catering Logistics



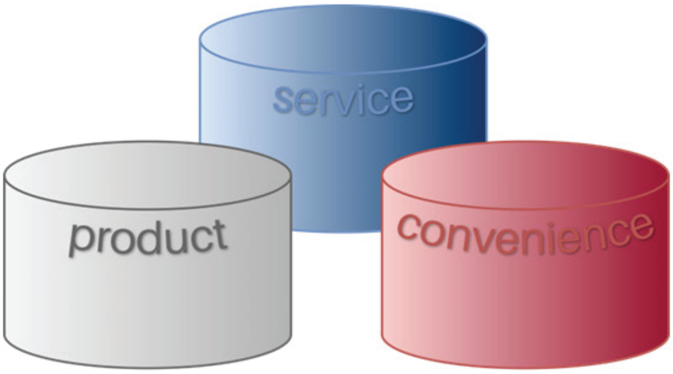
A7 Process Diagram for Airline Catering Order Entry



The framework: product vs service vs convenience

What do travellers prioritize most when it comes to airline travel? What motivates them to choose one airline over another? And how can airlines build and maintain customer loyalty? These questions can be explored by applying the following framework to gain insight into the values and preferences of airline passengers.

Service
How customers interact with the airline during the journey



Product
Hard & soft products of the flight

Convenience
Time-saving components

The idea that "everyone has a price" suggests that everyone also has a sense of value. For airline customers, this value is found at the point where product quality, service, and convenience come together in a way that feels right to them. When travellers search for flights, they each bring their own unique preferences and priorities to the process. Depending on the specific trip, a passenger might value one aspect—such as comfort, service, or convenience—more than the others.

Below is a breakdown of the components that airline passengers value, organised into the categories of product, service, and convenience.

Product

- legroom
- aircraft type
- seat comfort
- food & drinks selection
- Connectivity
- amenities
- baggage allowance
- lounge access
- loyalty points
- IFE

Service

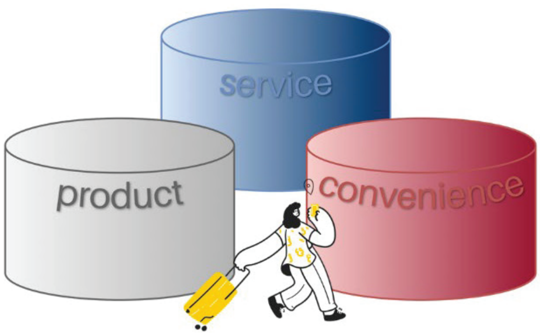
- Self-check-in options
- Mobile boarding pass
- Automated rebooking during disruptions
- Seat reservation and selection
- Assistance for special needs
- Unique touches

Convenience

- Flight Schedule and Routing
- Booking and Check-in
- Baggage Handling
- Personalisation and Flexibility
- Seat reservation and selection
- Airport Access

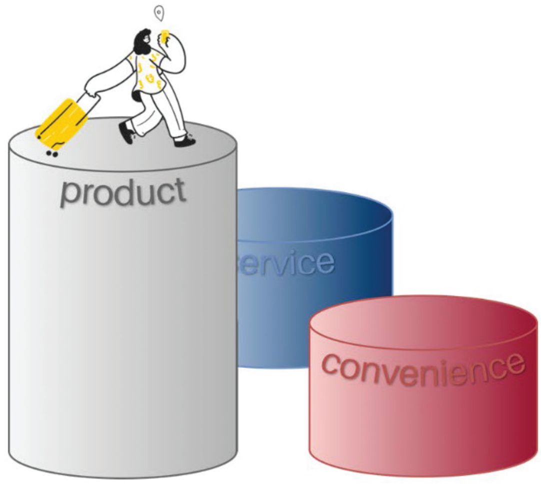
What do customers value?

By using this framework with various travel personas, we can gain a clear understanding of how to effectively upsell valuable offerings to each type. The more a traveller appreciates one or more of these elements, the better airlines can tailor their marketing strategies to encourage customers to buy products or services that truly matter to them.



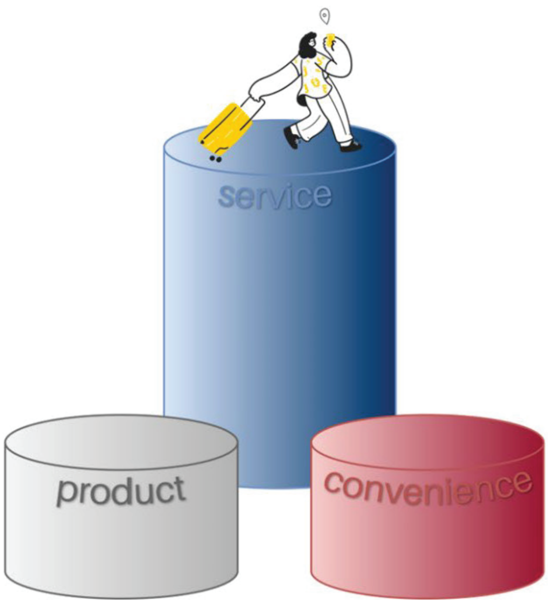
Budget Traveller

"I want to travel without breaking the bank, and since I don't mind waiting, I'm looking for the absolute cheapest ticket."



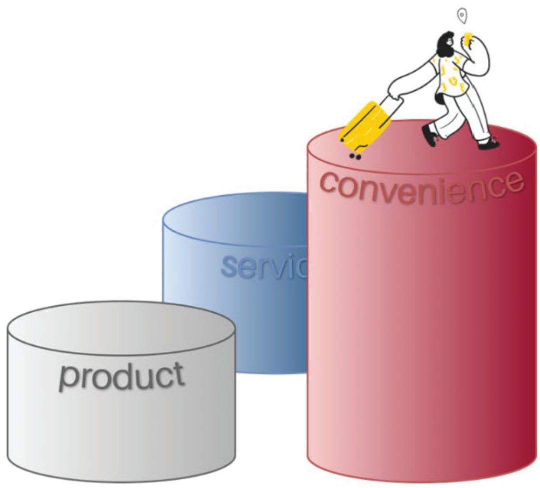
Frequent Flyer

"I want to travel without breaking the bank, and since I don't mind waiting, I'm looking for the absolute cheapest ticket."



Family Traveller

"I'm new to flying with an infant and will need some guidance and support, so I'm looking for an airline known for its warm, helpful service."



Business Traveller

"I want to fly in comfort with extra legroom, ample luggage allowance, and the ability to rack up frequent flyer points."