

The Anatomy of a Digital Airline Kitchen: From Order to Oven

Bala Balaji Reddy Dwarampudi

Independent Researcher, USA

Abstract: Digital transformation in airline catering marks a revolutionary shift within aviation food service. Legacy systems transform into complex ecosystems handling safety protocols, passenger needs, compliance mandates, and operational challenges via unified platforms. Throughout meal planning, preparation, delivery, and review phases, modern technology delivers exceptional speed and adaptability. Core elements encompass forecast analytics for order management, microservice architectures, event-driven messaging systems, containerized applications, and data mesh frameworks that together establish a resilient technical foundation. Sensor-equipped kitchen gear, API gateways, edge computing nodes, and orchestration platforms create a seamless integration layer connecting all operational components. Digital integration revolutionizes catering processes, establishing elevated benchmarks for excellence, uniformity, and customization throughout worldwide flight networks while satisfying intricate regulatory frameworks. Centralized message brokers connect kitchen components, enabling real-time decision-making and proactive issue resolution through event cascades that automatically trigger appropriate responses to changing conditions. This shift represents more than technological advancement - it fundamentally redefines operational excellence in aviation dining, creating authenticated compliance records while boosting traveler satisfaction through responsive, efficient service delivery mechanisms built on modern architectural principles.

Keywords: Digital airline kitchen, Microservices architecture, IoT-enabled catering, Event-driven messaging, Food safety compliance.

INTRODUCTION

The airline catering industry is currently experiencing a pivotal moment where conventional food service practices converge with digital transformation necessities. Modern airline catering has transcended basic meal preparation, evolving into an intricate network of connected procedures addressing food safety, passenger choices, regulatory adherence, and operational performance simultaneously. This examination explores how cloud-based systems, unified platforms, and component-oriented architecture have transformed airline catering functions, establishing what might be called the "digital airline kitchen."

Global airline catering operations require sophisticated solutions due to inherent complexities. Evidence indicates flight catering constitutes one of the world's most complicated operational processes, linking numerous participants across time-critical supply networks (Rajaratnam, D., & Sunmola, F. 2021). These operations increasingly rely on microservice architectures that decompose monolithic legacy systems into independently deployable services, each handling specific business functions such as inventory management, meal planning, and compliance monitoring. This architectural approach enables agile development cycles and targeted scaling of high-demand components during peak operational periods (Rajaratnam, D., & Sunmola, F. 2021). Challenges abound - mass production needs, rigorous safety protocols, and coordinating exact delivery timing to aircraft worldwide. These activities must handle

fluctuating passenger numbers, varied dietary specifications, and cultural sensitivities while upholding stringent quality benchmarks (Rajaratnam, D., & Sunmola, F. 2021). Process integration becomes vital, considering that typical international airline kitchens manage hundreds of distinct menu offerings daily while following more than 25 separate compliance frameworks (Rajaratnam, D., & Sunmola, F. 2021).

Digital advances in airline catering produce measurable benefits throughout service cycles. Comprehensive food management systems function as central coordination hubs connecting previously separated operational domains (Kanbo,). These mechanisms forge digital connections between menu design, procurement, manufacturing, distribution, and evaluation phases. Through established standardized workflows and unified information repositories, these structures provide immediate visibility across operations while mechanizing compliance documentation (Kanbo,). Aviation operations benefit as digital approaches reduce manual information entry, decrease redundant tasks, and generate confirmable records for regulatory inspections. This digital conversion extends beyond internal functions to establish fluid connections with suppliers, airline systems, and customer interfaces (Kanbo,).

Benefits become especially apparent within international transit centers where logistical complexities meet rigid departure timetables. Contemporary digital frameworks enable proactive

problem management by recognizing potential disruptions before they occur throughout operations (Kanbo,). These systems support fact-based decision processes by delivering actionable intelligence derived from performance measurements, creating possibilities for ongoing procedural improvements (Rajaratnam, D., & Sunmola, F. 2021).

Tracing food items from initial concept through cooking, transport, and after-service assessment builds a complete framework showcasing how modern tech delivers remarkable quickness, protection, and flexibility in aviation meal provision. Digitalizing these processes signifies more than technological improvement - it represents a fundamental reconsideration of operational excellence within airline food service.

INTELLIGENT ORDER PLANNING: THE FOUNDATION OF DIGITAL CATERING

Predictive Analytics and Demand Forecasting

Contemporary airline catering begins long before kitchen activities start. Sophisticated calculation methods examine past passenger statistics, flight records, and seasonal variations to forecast meal needs with exceptional accuracy. Such tools predict both total meal quantities plus the distribution of dietary requirements and premium selections. Aviation food service encounters distinctive obstacles requiring advanced predictive answers, especially when coordinating across varied time zones and passenger groups. Modern prediction tools connect with reservation databases to handle traveler information instantly, allowing food preparation teams to quickly adjust for booking shifts or flight changes (Sharma, V. 2024). This capability lets kitchen supervisors balance resources effectively while cutting waste, important considering aviation's environmental footprint. Through the implementation of smart technologies, food facilities enhance stock control, decrease discarded food, and maintain proper staffing during busy periods (Sharma, V. 2024).

Digital Menu Management and Personalization

Web-based menu systems allow airlines to maintain flexible digital food catalogs that are adjustable by route, season, and customer demographics. These tools connect smoothly with passenger apps, enabling personalized food choices to be automatically sent to kitchen operations without human involvement. Digital platforms assist in creating regionally appropriate menu items, respecting cultural tastes while

keeping consistent branding worldwide (Sharma, V. 2024). Today's systems tackle growing numbers of special meal orders - from faith-based food limits to allergen-excluded dishes and chosen eating styles such as greens-only or carb-restricted plates. The tech makes menu crafting easier by letting diet specialists and kitchen masters work together online while crafting recipes that satisfy tough flight safety codes and weight boundaries (Sharma, V. 2024). These setups also log exact food details and allergy warnings, keeping flights lawful across borders and nations.

Supply Chain Integration and Just-in-Time Procurement

Digital kitchen systems reach back into supply networks through RESTful API gateways and event-driven messaging frameworks that establish standardized communication protocols connecting supplier systems for just-in-time ingredient ordering. These mechanisms implement publish-subscribe patterns where inventory changes trigger events that cascade through dependent systems, automatically creating purchase orders when supplies reach predetermined levels while factoring delivery times and food freshness constraints unique to airline food service. Event streaming platforms like Apache Kafka enable real-time data flow between disparate systems, ensuring all stakeholders operate with synchronized information despite physical and organizational boundaries (Janala, F. 2016). Industry analysis identifies five critical challenges in airline catering supply chains: quality consistency across global operations, managing complex logistics with tight timelines, adapting to unexpected disruptions, controlling costs while maintaining standards, and ensuring regulatory compliance across jurisdictions (Janala, F. 2016). Digital transformation addresses these operational barriers through the implementation of integrated frameworks that establish connectivity between catering facilities, material vendors, and carrier operations via centralized coordination platforms, enhancing information exchange while delivering transparent operational awareness throughout provisioning networks (Janala, F. 2016). Such technological solutions enable granular inventory oversight tailored specifically for aviation foodservice constraints, including exceptionally abbreviated product viability periods and stringent regulatory obligations. Contemporary procurement architectures facilitate systematic supplier performance evaluation utilizing quantifiable operational indicators - delivery punctuality,

product uniformity consistency, and crisis responsiveness capacity - consequently fortifying

comprehensive supply network durability against operational variability (Janela, F. 2016).

Table 1: Digital Catering Planning Framework (Sharma, V. 2024; Janela, F. 2016)

Component	Strategic Outcome
Predictive Analytics	Resource Optimization
Demand Forecasting	Waste Reduction
Digital Menu Management	Customer Satisfaction
Personalization Systems	Brand Differentiation
Supply Chain Integration	Operational Resilience

SMART PREPARATION AND WORKFLOW AUTOMATION

Kitchen Production Systems and Digital Work Instructions

After finalizing meal plans, cutting-edge kitchen control systems transform orders into streamlined production schedules. Digital instructions shown on tablets or smart screens direct kitchen workers through exact cooking steps, guaranteeing uniformity across thousands of identical meals while handling special needs. As depicted in Fig. 1, these components form part of an integrated digital ecosystem where the API Gateway channels information from Order Planning through the Message Broker to the Kitchen Systems. The microservices architecture enables modular functionality deployment and targeted scaling during peak operational periods. Studies of flight meal operations reveal major complexity issues, with production lines frequently managing several meal varieties simultaneously across different cabin classes and diet requirements (Rajaratnam, D. 2022). Digital workflow tools tackle these problems by splitting complicated tasks into manageable steps with clear visual directions, lowering mental strain on workers while keeping quality high. Such approaches particularly help high-output kitchens where consistency must stay steady across multiple work shifts and changing staff members. Moving from paper guides to digital formats strengthens standardization while offering instant updates when production needs to shift due to flight changes or passenger number adjustments (Rajaratnam, D. 2022). Plus, these tools gather valuable production statistics, enabling ongoing enhancements through thorough performance review and bottleneck spotting.

IoT-Enabled Equipment and Process Monitoring

The kitchen space itself turns into part of the digital network through Internet of Things integration. As illustrated in Fig. 1, IoT Equipment connects directly to Edge Computing nodes, which process sensor data at the source before transmitting aggregated metrics back to the central

Message Broker. This architecture reduces bandwidth requirements while enabling real-time analytics on the production floor. Clever ovens, cooling units, and prep stations constantly check and report temperature, moisture levels, and other vital measurements through standardized MQTT protocols that ensure reliable communication even in challenging network environments (Dave, H. *et al.*, 2025). These setups ensure food safety rules are followed while saving energy and spotting possible equipment problems before affecting production. Fig. 1 demonstrates how these connected gadgets form a bidirectional data flow, with instructions flowing down from Kitchen Systems to IoT Equipment, while operational data flows up through Edge Computing for centralized monitoring and control. Recent food facility research highlights how linked sensor networks create continuous digital logs of kitchen conditions, establishing provable records for regulation compliance while cutting manual checking needs (Dave, H. *et al.*, 2025). These technologies allow exact control of critical factors like cooking temperatures and cooling speeds, ensuring steady food safety while preserving quality features. Connecting equipment checking with maintenance systems enables condition-based upkeep plans that cut surprise breakdowns while extending machine lifespans (Dave, H. *et al.*, 2025). This linked structure creates chances for energy saving through load spreading and operation timing, supporting green initiatives while lowering running costs.

Automated Quality Assurance and Compliance Documentation

Quality checking shifts from written lists to automated verification, with camera systems confirming portion sizes and appearance standards. Digital safety monitoring creates tamper-proof records of safety compliance, automatically warning managers about any rule breaks. As shown in Fig. 1, Quality Control forms a critical junction in the workflow, receiving input from IoT

Equipment while branching out to both operational systems (Logistics) and analytical functions (Data Mesh). This enables the continuous improvement cycle, driving system-wide advances. Evidence shows flight catering faces unique safety challenges, given long delays between cooking and eating (Rajaratnam, D. 2022). Automated checking systems address these issues by keeping continuous records of critical control points and creating permanent documentation for both internal quality needs and outside regulatory demands. These methods greatly improve upon traditional paper-based tracking, which often suffers from missing information and human

mistakes (Dave, H. *et al.*, 2025). The architecture in Fig. 1 illustrates how quality data flows not only to downstream logistics operations but also feeds into the Data Mesh and Analytics components, creating a feedback loop that ultimately enhances Order Planning. Computer vision in food quality checking allows neutral evaluation of visual aspects, including portion size, plating consistency, and presentation quality. When connected with production systems, these technologies enable quick fixes rather than end-of-line rejections, completely changing quality management in high-volume food production settings (Dave, H. *et al.*, 2025).

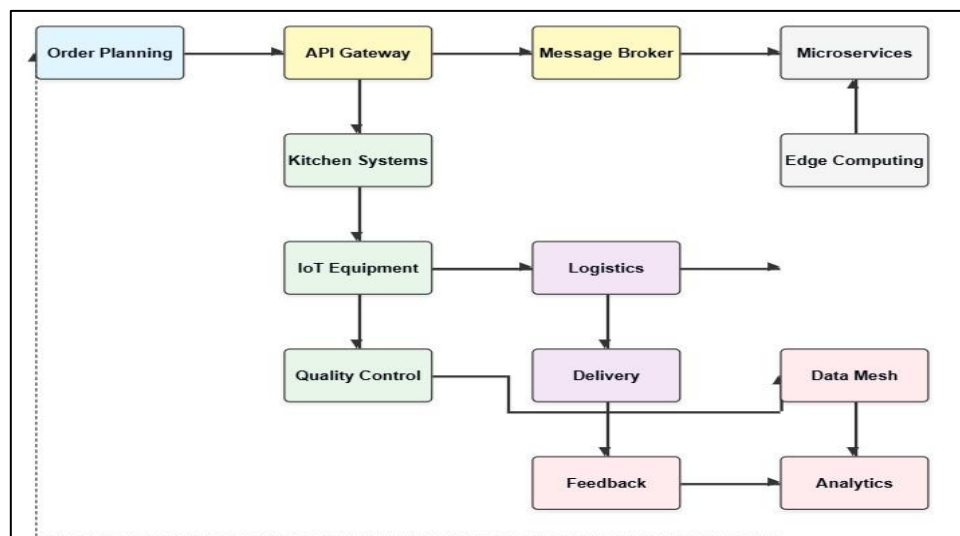


Fig. 1. Digital Airline Kitchen Architecture: The integrated workflow showing data flow between Order Planning, Kitchen Systems, IoT Equipment, Quality Control, Logistics, and Analytics components through API Gateway and Message Broker, with Edge Computing for local data processing (Rajaratnam, D. 2022; Dave, H. *et al.*, 2025).

PRECISION DELIVERY AND LOADING ORCHESTRATION

Logistics Optimization and Route Planning

Transporting prepared meals to aircraft presents a complicated logistical puzzle that digital systems uniquely solve. Containerized microservices orchestrated through Kubernetes enable elastic scaling of route optimization algorithms during peak operational periods, ensuring consistent performance regardless of demand fluctuations. Computer-driven route planning leverages service mesh architectures to coordinate real-time data exchange between planning engines, vehicle telemetry systems, and airport operations platforms, considering airport maps, traffic flows, gate switches, and delivery timeframes to build efficient transportation schedules, cutting both time and fuel usage (Kovynyov, I. & Mikut, R. 2018). Studies of airport ground activities reveal

extraordinary difficulties in managing multiple service trucks within tight airport spaces, where congestion and security measures add further complications (Kovynyov, I. & Mikut, R. 2018). Digital advances here focus on building connected platforms that perfect delivery paths while adapting to changing conditions like plane arrival updates, gate reassignments, and terminal traffic situations. These tools establish direct links between food facilities, control centers, and delivery crews, allowing fast adjustments when conditions shift (Kovynyov, I. & Mikut, R. 2018). Better delivery performance directly improves aircraft turnaround speed, which is essential for keeping flight schedules intact across airline networks. Moreover, these planning tools support environmental goals by decreasing needless vehicle travel, waiting periods, and fuel consumption throughout the airport grounds.

Digital Manifests and Loading Verification

Paper documents now give way to digital records traveling with food carts, often using electronic tags or scan codes to ensure correct loading. Mobile apps guide loading teams through the exact placement of meal carts based on aircraft layout and passenger seat maps, with instant confirmation verifying correct meals reach the intended planes. Evidence shows that digital transformation in loading tasks creates major error reduction while boosting operational performance (Moghadasnian, S. 2025). These applications use easy-to-follow visuals that adapt to specific aircraft types, showing precise loading sequences and maximizing both efficiency and kitchen space usage. Digital verification creates accountability throughout the loading process, with each step recorded in central systems maintaining chain-of-custody records (Kovynyov, I. & Mikut, R. 2018). This shift greatly reduces paperwork tied to flight documentation while creating verifiable records for quality checks and performance analysis. Furthermore, these systems allow smooth communication between food preparation teams and cabin staff, ensuring proper awareness of special meal locations and service details.

Real-Time Status Tracking and Exception Management

Digital kitchen systems maintain complete visibility of meal movements throughout delivery, with location data giving continuous position updates and estimated arrival times. Problem-spotting systems automatically detect and escalate delays or discrepancies, triggering backup plans when needed to preserve on-time departures. Implementing data-focused approaches in airline operations creates remarkable visibility into service delivery, enabling forward-thinking management of potential problems (Moghadasnian, S. 2025). These platforms gather live status information from numerous sources, including vehicle tracking, loading confirmation systems, and gate management tools, and build complete situational awareness across all active operations. When delivery issues happen, these systems automatically assess schedule impacts and start appropriate backup procedures using pre-established rules (Moghadasnian, S. 2025). This method changes traditionally reactive operations into predictive systems that are able to identify and fix potential problems before affecting flight schedules or passenger experiences. The resulting operational stability directly supports schedule reliability while enhancing overall service quality across airline networks (Kovynyov, I. & Mikut, R. 2018).

Table 2: Logistics Technologies and Their Operational Impact (Kovynyov, I. & Mikut, R. 2018; Moghadasnian, S. 2025)

Technology	Operational Outcome
AI Routing	Resource Optimization
RFID Tracking	Loading Accuracy
GPS Monitoring	Disruption Prevention
Mobile Verification	Documentation Quality
Centralized Dashboard	Cross-Team Coordination

AUDITING, FEEDBACK, AND CONTINUOUS IMPROVEMENT

Post-Service Analytics and Performance Metrics

Following meal service completion, digital systems analyze key performance indicators, including waste percentages, passenger satisfaction scores, and operational efficiency metrics. Research into in-flight catering demonstrates the value of systematic measurement frameworks capturing both operational and experiential metrics (MoghadasNian, S., & HajiBandeh, M. 2024). These analytics platforms integrate data from inventory systems, cabin crew reports, passenger feedback, and waste monitoring protocols. The resulting insights enable catering managers to

identify performance patterns across routes, aircraft types, and service classes, revealing opportunities for targeted improvement initiatives (MoghadasNian, S., & HajiBandeh, M. 2024). Modern dashboards visualize these metrics through intuitive interfaces supporting data exploration and comparative analysis. This evidence-based approach represents a significant advancement over traditional methodologies relying on anecdotal feedback or isolated indicators (MoghadasNian, S., & HajiBandeh, M. 2024).

Integrated Feedback Loops and Machine Learning

Passenger feedback collected through entertainment systems and post-flight surveys

flows through event-driven data pipelines that ensure reliable processing regardless of volume fluctuations. These systems implement the CQRS (Command Query Responsibility Segregation) pattern, separating write operations from read operations to optimize performance while maintaining data consistency across distributed systems (Koul, P. 2025). Machine learning algorithms deployed as containerized services scale elastically based on processing requirements, identifying patterns in this feedback, and continuously refining offerings based on actual passenger preferences. Advanced analytics demonstrates significant potential for enhancing service through systematic pattern recognition across large feedback datasets (Koul, P. 2025). These technologies process diverse feedback formats, including structured ratings, open-text comments, and observational data. By correlating these inputs with operational variables, these systems reveal non-obvious relationships between operational decisions and satisfaction outcomes (Koul, P. 2025). Empirical data transforms experiential management methodologies, fundamentally shifting service paradigms from remedial response mechanisms toward anticipatory design frameworks (MoghadasNian, S., & HajiBandeh, M. 2024).

Predictive Maintenance and Process Optimization

Accumulated operational metrics facilitate condition-based maintenance protocols for culinary equipment, reducing disruptions while extending asset utilization periods. Aviation operations research highlights how predictive analytics transforms maintenance approaches from calendar-driven schedules to condition-based interventions (Koul, P. 2025). These systems analyze performance telemetry from critical equipment, identifying subtle deviations indicating impending failures. When integrated with maintenance systems, these insights enable proactive intervention before critical failures occur (Koul, P. 2025). Complementing these initiatives, process mining applications analyze workflow data, identifying operational bottlenecks and optimization opportunities. These analytics reveal inefficiencies that traditional observation might miss, enabling evidence-based workflow refinement and enhancing productivity and working conditions (MoghadasNian, S., & HajiBandeh, M. 2024). The resulting improvements contribute directly to service quality while reducing costs and environmental impact through efficient resource utilization.

Table 3: Data Analytics Applications and Their Business Value (MoghadasNian, S., & HajiBandeh, M. 2024; Koul, P. 2025)

Mechanism	Business Impact
Performance Analytics	Decision Quality
Passenger Feedback Integration	Menu Enhancement
Machine Learning	Preference Prediction
Predictive Maintenance	Downtime Reduction
Process Mining	Workflow Efficiency

MODERN ARCHITECTURE TECHNICAL UNDERPINNING DIGITAL AIRLINE KITCHENS

Microservices and API-First Design

Digital airline kitchens increasingly adopt microservice architectures that decompose complex catering systems into independently deployable components. Each service—meal planning, inventory management, production scheduling—operates autonomously while communicating through standardized interfaces (Viggiato, M. *et al.*, 2018). This approach enables targeted scaling and isolated deployment of critical components during peak operational periods.

API gateways serve as centralized entry points, providing unified interfaces that abstract

underlying implementation details while handling authentication, rate limiting, and request routing. These gateways implement traffic management policies that prioritize critical workflows during operational peaks while providing graceful degradation paths when system components experience stress (Viggiato, M. *et al.*, 2018).

Event-Driven Architecture and Message Brokers

The unpredictable nature of airline operations demands systems capable of responding to events in real-time. Event-driven architectures decouple system components, enabling them to react to changing conditions without tight integration dependencies. Modern catering platforms utilize message brokers to implement publish-subscribe models where operational events trigger cascading

responses throughout the ecosystem (Viggiato, M. *et al.*, 2018).

Message streaming platforms establish communication channels between kitchen management systems, inventory control, and delivery coordination. Flight delays, passenger count adjustments, or inventory shortfalls trigger event cascades that automatically recalibrate production schedules and update delivery routes without requiring manual intervention.

Containerization and Orchestration

Deployment consistency across environments—from centralized production facilities to airport-based satellite kitchens—requires containerization technologies. These solutions package application code with dependencies, ensuring identical execution regardless of underlying infrastructure (Pahl, C. *et al.*, 2017). This approach enables consistent application behavior across development, testing, and production environments.

Orchestration platforms provide declarative management of containerized workloads. Operations teams define desired states that these platforms automatically maintain despite hardware failures, traffic spikes, or other disruptions (Pahl, C. *et al.*, 2017). Auto-scaling capabilities dynamically adjust resource allocation based on observed metrics, ensuring cost-efficient operations during normal periods while expanding capacity during peak demand.

Data Mesh and Distributed Analytics

The data foundation supporting digital airline kitchens implements data mesh principles that distribute ownership to teams familiar with specific business domains. This architecture enables catering operations to derive insights from diverse data sources—inventory systems, production metrics, flight schedules, and passenger feedback—without requiring complex ETL processes (Pahl, C. *et al.*, 2017).

Stream processing frameworks enable real-time analytics on operational data flows, identifying potential service disruptions before they impact flight schedules. These technologies process event streams, calculating metrics, detecting anomalies, and triggering alerts without requiring data to land in persistent storage first (Pahl, C. *et al.*, 2017). This approach addresses the unique challenges of airline catering, where timing precision directly impacts passenger experience and on-time departure performance.

CONCLUSION

The airline catering revolution through digital tools completely changes how meals get planned, made, shipped, and checked within the challenging world of commercial flight operations. The architectural foundation of this transformation—microservices, API gateways, event-driven messaging, and containerization—enables unprecedented operational agility while maintaining strict compliance with safety regulations. Bringing together cloud systems, kitchen sensors, smart algorithms, and portable devices creates remarkable efficiency while keeping food quality consistent and personalized in ways old methods simply cannot match. Each part of the process works better with digital help, making information move smoothly alongside actual ingredients from farms to passenger trays. The decoupling of system components through event-driven patterns enables individual services to evolve independently while maintaining system-wide coherence, a critical requirement in the rapidly changing airline industry. Real-time kitchen monitoring, automatic safety record keeping, and fact-based decisions give major advantages beyond just running smoothly, affecting how happy travelers feel, how well rules get followed, and how green operations become. The modern technical architecture depicted in this article provides a blueprint for evaluating current capabilities and planning strategic investments. Edge computing deployments at the kitchen level enable local processing of critical data while message brokers ensure system-wide visibility. Data mesh principles distribute analytical capabilities across domains, creating insights that directly inform operational improvements. As passenger expectations grow alongside tougher operational challenges, digital kitchen approaches will separate industry leaders from followers. Tomorrow belongs to companies building technology systems that constantly learn and adapt through containerized deployments and orchestration platforms, making flying meals taste better while streamlining behind-the-scenes work through architectural patterns designed for resilience and scale.

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