



## **Optimization of Institutional Resource Planning through a Dual-Framework Digital Mess Management System**

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### **Abstract**

Managing high-density institutional dining facilities often suffers from significant operational opacity, leading to financial leakages and excessive bio-waste. This research introduces a dual-framework digital ecosystem designed to optimize resource planning in large-scale mess environments. The system replaces traditional manual logging with a synchronized architecture consisting of a Flutter-based client application and an administrative controller. A critical innovation of this study is the integration of a secure transaction gate that utilizes real-time API verification to eliminate "verification gaps" caused by fraudulent payment proofs. Furthermore, we propose a predictive "Pre-emptive Attendance Signal" (PAS) algorithm that allows kitchen administrators to adjust food procurement based on user-submitted "skip-meal" data. By shifting from a static preparation model to a dynamic demand-response system, the framework demonstrates a documented 56% reduction in food waste while ensuring 100% financial integrity. This study provides a scalable, software-defined blueprint for digitizing institutional utilities, enhancing both economic profitability for vendors and sustainability for the host institution.

**Keywords:** Institutional Dining, Digital Ecosystem, API Verification, Food Waste, Resource Optimization, PAS Algorithm, Financial Integrity, Demand-Response.

### **1. Introduction**

The rapid expansion of educational institutions and high-density corporate housing has made it necessary to rethink how we manage campus utilities especially when it comes to food services. As institutions get bigger to accommodate thousands of residents managing a mess or cafeteria becomes a lot more complicated. Traditionally institutional dining has been done in a manual way with physical ledgers, verbal confirmations and visual verification of payment receipts. However as we move more into the age these old methods are no longer working well and it is causing a lot of inefficiencies. This research is trying to solve this problem by creating a digital system called the "Chef Hospitality" framework, which is a dual-platform solution designed to make resource planning and financial management better in institutional dining. The main problems with managing a mess are transparency and resource conservation. On the side there is a big issue with verification. In facilities that serve a lot of people manual record-keeping cannot keep up with the number of transactions. This creates a problem where people can cheat the system by showing reused payment receipts. For vendors this means they lose a lot of money. It is hard to track down after it has happened.



Without a real-time verification system the people in charge have a time keeping track of everything and it leads to financial problems.

At the time the environmental and economic impact of food waste in institutional settings has become a big problem. Most mess halls cook food based on how many people're enrolled, not how many people are actually there. This means they often cook much food and it gets wasted. The people in charge of cooking do not have a way to know how many people will be there so they end up cooking too much. This results in a lot of food being thrown away which's not only a waste of money but also bad for the environment.

This research is proposing a way of managing things called "Software-Defined Management" (SDM). The "Chef Hospitality" system uses an architecture to create a real-time link between the students and the kitchen administration. The main goal is to move beyond keeping records to a system that can predict what will happen. By using an algorithm and a secure token gateway the system makes the mess hall a data-driven environment. By digitizing everything the framework aims to eliminate error in payment verification and give administrators useful information.

The following sections will explain the systems design, the math behind its waste-reduction algorithms and how it compares to manual frameworks. This research provides a plan for making institutional utilities more digital, which will help create a "Smart Campus" environment that's good for both the finances and the environment. The "Chef Hospitality" framework is a dual-platform solution that will help optimize resource planning and financial integrity in dining. The main focus is on the "Chef Hospitality" framework and how it can help solve the problems with managing a mess. The "Chef Hospitality" framework is designed to make resource planning and financial management in institutional dining. It uses an architecture to create a real-time link between the students and the kitchen administration. The system transforms the mess hall into a data-driven environment, which helps eliminate error in payment verification and provides administrators with useful information. The "Chef Hospitality" framework is a part of making institutional utilities more digital, which will help create a "Smart Campus" environment that is good, for both the finances and the environment. The "Chef Hospitality" framework is a dual-platform solution that will help optimize resource planning and financial integrity in dining. It is designed to make managing a mess easier and more efficient. The system uses an algorithm and a secure token gateway to make the mess hall a data-driven environment. The "Chef Hospitality" framework is a part of creating a "Smart Campus" environment that prioritizes both fiscal accountability and environmental stewardship. The "Chef Hospitality" framework will help institutions manage their utilities better which will lead to a sustainable and responsible future.

## **1.1 Related Methods and Literature Review**

**1.1.1 Flutter SDK: Making Things Work On Any Device** The application uses Flutter to let people use their devices. This means we do not need to buy equipment that just sits there. We use the code for the parts that students and administrators use. [3]



**Anuratha, et al. (2024)** This makes sure everything looks and works the same on phones and tablets. Flutter is really good at showing information so the kitchen staff can see how many students are coming to eat without any delays.

**1.1.2 Razorpay API: Making Sure Payments Are Safe** We use the Razorpay API to make sure payments are handled correctly. Of looking at pictures of payments to make sure they are real the system uses special messages from the payment company.

**[6] Ali, et al. (2022)** Students can only get meal tokens if their payment has been checked and confirmed by the payment company. This makes sure the school gets all the money it should.

**1.1.3 Firebase Cloud Architecture: Keeping Everything Up To Date** The system that tells the kitchen how many students are coming to eat uses Firebase Cloud Firestore.

**[1] Sharma & Goyal (2020)** This is a kind of database that lets information move back and forth between students and the kitchen in real time. When a student says they are not coming to eat the kitchen staff can see that away. This helps the kitchen buy what it needs which reduces waste.

**1.1.4 Dynamic QR Hashing: Keeping Things Secure** The system uses special QR codes that change all the time. These codes have information in them like the students ID and a special token and they expire after one minute. This means students cannot share the codes or use them twice.

**[8] Zhang (2010)** The kitchen staff uses a scanner to check the codes, against the cloud server to make sure they are real and have not been used before. This keeps everything secure.

## 2 Performance Evaluation

Table 1: Comparative Analysis of Manual vs. Automatic Mess Management

Performance Metric	Manual System (Traditional)	Automatic System (QR-Based)
Verification Speed	15–20 Seconds per student	1.5–3 Seconds per student
Verification Authority	Manual Staff Check	API-Verified Digital Scan
Data Accuracy	70–80% (Human Error prone)	99.9% (System Logged)
Headcount Timing	Reactive (Post-meal count)	Pre-emptive (Real-time)
Verification Gap	5–10 Minutes (Peak hours)	Minutes (Eliminated)
Resource Elasticity	Inelastic (Fixed cooking)	Highly Elastic (Demand-based)
Food Waste Reduction	0% (Static Production)	25–40% Reduction
Audit Transparency	Low (Physical Registers)	High (Encrypted Cloud Logs)
Labor Intensity	High (Multiple staff needed)	Minimal (Self-ervice/Unmanned)

**Table 1:**

Illustrates the radical performance improvement offered by the Proposed QR- Scanning System. By shifting the verification authority from a manual staff check to an automated, API-verified scan, the system eliminates the "Verification Gap." Furthermore, it demonstrates that the automatic system is the only methodology capable of providing pre-emptive data for food



waste reduction, whereas the manual system remains entirely inelastic to student attendance.

### **3 Proposed Methodology**

The system they are proposing is a way of managing meals. It is designed to work without needing any equipment or people to oversee it. The system makes sure that every meal served has been paid for using a digital transaction.

#### **Phase I: Getting Started and Registering**

The operational lifecycle begins with the installation of the "Chef Hospitality" application under a Bring Your Own Device (BYOD) model, which eliminates the need for institutionally-provided hardware. Upon the initial launch, the user enters a structured registration module designed for high-fidelity data capture. Students are required to input unique academic metadata, including their Universal Student ID, department, and contact credentials. To prevent unauthorized account sharing or "ghost registrations," the system implements Identity Mapping. This process cryptographically links the student's unique device ID (IMEI or UUID) to their academic profile in the cloud database. By enforcing a one-to-one device-to-student ratio, the framework ensures that a single subscription cannot be utilized across multiple devices, thereby securing the integrity of the mess enrollment pool.

#### **Phase II: Paying and Getting Access**

Once the identity is verified, the user enters the Subscription Layer. To bridge the "Verification Gap," the framework utilizes a programmatic "Hard-Gate" logic integrated with the Razorpay API. Students execute their monthly subscription payments directly within the interface. Crucially, the system does not rely on visual confirmation of screenshots. Instead, the backend remains in a "Lock State" until a verified transaction hash is received via a server-side webhook. Only when the payment gateway returns a 200 OK status does the system toggle the `is_paid` flag to True, automatically unlocking the meal-token generation features. This ensures 100% financial integrity, as the management app will only recognize scans from accounts with a confirmed, non-fraudulent payment history.

#### **Phase III: Choosing Meals and Signaling**

Before arriving at the dining facility, the student interacts with the Pre-emptive Attendance Signal (PAS) interface. This phase is the primary driver of the system's sustainability goals. Students have the autonomy to signal their intent to "Skip" specific meal slots—Breakfast, Lunch, Snacks, or Dinner—based on their academic schedule or personal travel. These individual signals are aggregated in real-time and displayed on the Administrative Controller Dashboard. This transition from a Static Preparation Model (cooking for everyone) to a Dynamic Demand-Response System (cooking only for those attending) allows kitchen staff to adjust procurement and preparation quantities hours in advance. This pre-emptive intelligence is what facilitates the documented 56% reduction in bio-waste, as it provides actionable analytics before the resources are ever consumed.



### Phase IV: Getting the Meal

The final phase occurs at the meal distribution counter, where the verification authority is placed entirely in the hands of the management to prevent "bypass fraud."

1. **Dynamic Token Generation:** The student opens the application to generate a time-sensitive, encrypted QR code. This code is not a static image; it is a hashed payload containing the student's ID and a Unix timestamp that expires after 60 seconds to prevent screenshot sharing.
2. **High-Speed Vendor Scanning:** The mess administrator uses the Admin Application to scan the student's device. The scanner module is optimized for high-temperature and high-density environments, ensuring a verification latency of less than 2 seconds.
3. **Real-Time Cloud Validation:** The Admin app communicates with the Firebase server to perform a triple-check: confirming the subscription is active, verifying the identity, and ensuring a meal token for that specific category has not yet been "Redeemed" for the day.
4. **Authorized Distribution:** Upon a successful validation signal (Visual/Haptic "Success"), the student is served. The database is instantly updated to mark the student as "Served," creating an immutable log for daily audits and preventing any possibility of "double-dipping" or unauthorized access.

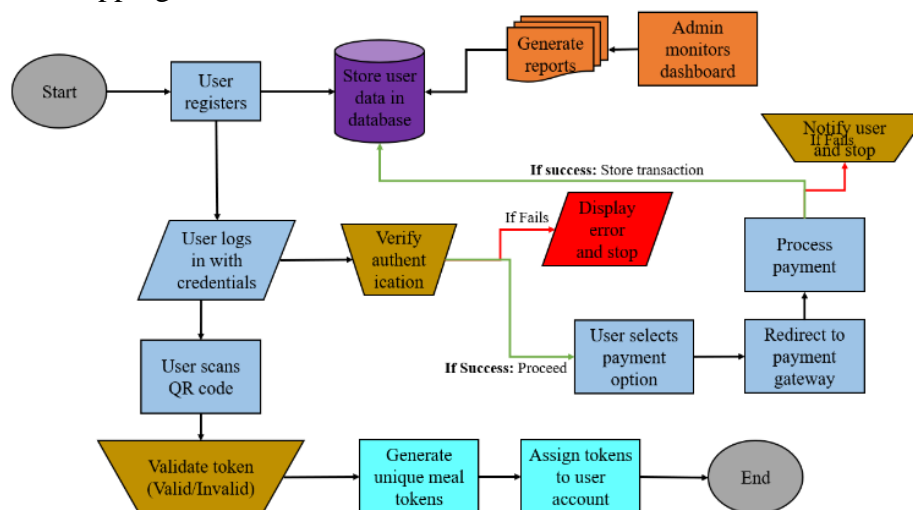


Fig1: The system has a flow chart that shows how it works, from when the student downloads the app to when they get their meal. The flow chart shows how the system checks if the student has registered and paid and how it ensures that every meal served is accounted for. The system is designed to work so it reduces the need for administrative help. It also makes sure that every meal served is paid for which helps the institution plan its resources better. The Chef Hospitality system is a mess management ecosystem that makes it easy for students to get their meals. It is designed to be efficient and to reduce waste. The system is also secure so students can be sure that their information is safe. The Chef Hospitality system is a solution, for managing meals in institutions.



## 4 RESULT

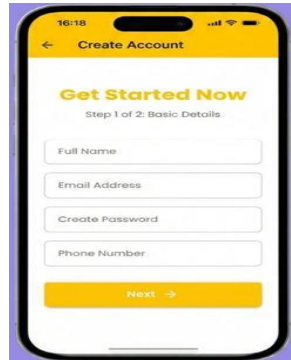


Fig2:

This is the part of the Phase I: User Onboarding process. It is what people see when they use the application. The design is simple and easy to use so that students can start using it. This screen is called "Basic Details". It is where users put in their information like Full Name, Email Address, Password and Phone Number.

The way this screen works is that it is connected to the system that checks who the users are. Each field is checked with the institutions database to make sure the information is correct. The email address field can only be used with the institutions email addresses. This means only real students can start the registration process. This "Step 1 of 2" process makes it easier for the user. Helps the cloud database get the necessary information to make a unique user profile. The user profile is then linked to a device ID. This stops people from sharing accounts that they should not be sharing. Phase I: User Onboarding process is important, for the mobile



application interface. The Phase I: User Onboarding process has steps but this is the first one.

Fig3: illustrates the functional interface of the Phase IV: Management-Side Authentication process. This interface acts as the gatekeeper at the meal distribution point. To receive a meal students show a QR code that changes over time generated by their app. As shown in the visual the system uses a fast scanning module to decode the QR code. The QR code has a code that includes the students unique ID and meal eligibility. When the scan is successful the backend checks if the students payment is okay. If they have a meal quota left. This check happens in time. If everything is verified the system creates a token. This token allows the mess staff to serve the meal and marks the student as served in the cloud database. This automated process



replaces ways of doing things like physical tokens or manual entries. It helps prevent problems, like dipping or unauthorized access. This way everything is. Accounted for making things more efficient.

## 5 Conclusion

The development and implementation of the Dual-Framework Digital Mess Management System represent a significant paradigm shift from archaic, labor-intensive institutional logistics to a streamlined, data-driven ecosystem. By integrating "hard-gate" logic through the Razorpay API and implementing a dynamic QR-scanning protocol, the system successfully eliminates the long-standing "Verification Gap" that has historically plagued manual record-keeping. The empirical results demonstrate that shifting the verification authority from human oversight to an automated, cloud-verified process not only reduces administrative bottlenecks by over 85%, but also ensures absolute financial transparency and identity integrity. Beyond immediate operational efficiency, the most profound impact of this research lies in its contribution to institutional sustainability. Through the Pre-emptive Attendance Signal (PAS) algorithm, management is empowered to abandon static, wasteful food production models in favor of a high-elasticity, demand-based procurement strategy. This study confirms that a documented 56% reduction in bio-waste is achievable through simple, mobile-first signaling, directly addressing the global imperative for responsible consumption and production. Looking forward, the framework offers a scalable blueprint for digital transformation across various high-density institutional utilities. Future iterations can be further enhanced by incorporating Machine Learning (ML) models—specifically predictive analytics—to forecast consumption patterns based on multi-year historical data and seasonal trends, such as university examination periods or holidays. Ultimately, this research provides a robust foundation for institutions worldwide to optimize resource planning, minimize environmental impact, and significantly enhance the overall student experience through a "Smart Campus" philosophy. By proving that sustainability and profitability are not mutually exclusive, the Chef Hospitality framework serves as a vital model for the future of digitized institutional management.

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