Unified Restaurant Management and AI-Assisted Customer Service Platform: Design, Implementation, and Evaluation of GTL Utsav Dining

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Abstract — This paper presents the design, implementation, and evaluation of an integrated restaurant management and AI-assisted customer service platform, GTL Utsav Dining, that unifies customer workflows (reservations, ordering, tracking) with administrative operations (inventory, analytics, reporting) within a single full-stack architecture. The system comprises three independent subsystems: (1) a customer-facing React/Vite application supporting table bookings, online and dine-in ordering, real-time order tracking, and chatbot interaction; (2) an administrative React/Vite application providing menu management, order lifecycle control, inventory visibility, and operational reporting; and (3) a modular Python chatbot service using hybrid rule-based and machine-learning approaches for menu guidance, order tracking assistance, and FAQ handling. The backend employs Flask REST API organized into modular blueprints, MongoDB relational database with normalized schema, and independent scheduling for lead generation and event processing. Evaluation encompasses functional completeness across 45 API endpoints and 37 UI screens, automated testing of 23 chatbot scenarios achieving 100% pass rate with 94.3% intent classification accuracy, security assessment of OTP and TOTP multi-factor authentication achieving 95% and 92% success rates respectively, and operational analytics demonstrating 2.1-second order-to-dashboard synchronization time. The platform demonstrates that modern full-stack patterns can unify fragmented restaurant operations while maintaining security and conversational AI support, reducing manual operational overhead and improving decision-making latency. This implementation study contributes empirically to understanding integrated architecture patterns for hospitality domain challenges, with specific implications for small and medium-sized restaurant operations and hospitality informatics education.

Keywords: Restaurant Management System, Full-Stack Architecture, Workflow Integration, Multi-Factor Authentication, Conversational AI, CRM Automation, Operational Analytics, Hospitality Informatics

I. Introduction

Digital transformation in hospitality extends far beyond basic online ordering. Modern restaurants require integrated platforms that simultaneously support customer interactions (reservations, ordering, tracking), administrative operations (menu management, inventory, analytics), and customer support (conversational assistance). However, current academic and industry implementations often fragment these concerns into separate tools, creating operational inefficiencies: booking systems lacking order visibility, analytics requiring manual data aggregation, and customer support disconnected from transaction context.

This fragmentation introduces measurable costs: (1) data inconsistency when reservation systems diverge from operational table status; (2) delayed decision-making when analytics require manual aggregation across disconnected sources; (3) poor user experience when customers navigate between separate applications for ordering, reservations, and support; and (4) security vulnerabilities when authentication mechanisms differ across subsystems.

This paper presents GTL Utsav Dining—an implementation study of an integrated restaurant management platform combining customer workflows, administrative operations, and AI-assisted support. Rather than proposing novel algorithms, this work contributes through three principal areas: (1) architectural patterns for unifying restaurant workflows through a shared data backbone, eliminating manual synchronization overhead; (2) security enhancements through industry-standard multi-factor authentication (OTP and TOTP) in a hospitality context; and (3) practical integration of bounded hybrid conversational AI that augments rather than replaces human support.

The platform employs a four-tier architecture: React/Vite frontend (presentation), Flask REST API (application), MongoDB database (data), and Python chatbot service (conversational support). Both customer and administrative subsystems share a normalized relational database, ensuring that customer actions (order placement, reservation confirmation) immediately propagate to administrative views (dashboard, reports) without manual intervention.

This paper is organized as follows: Section II articulates the research gap; Section III formalizes research questions and objectives; Section IV details system architecture and design; Section V presents implementation specifics; Section VI evaluates functional completeness, security, and operational performance; Section VII compares contributions against existing systems; Section VIII discusses implications and limitations; Section IX identifies future work; and Section X concludes with summary of contributions.

SECTION A: CUSTOMER WORKFLOWS AND UNIFIED DATA ARCHITECTURE

II. Problem Statement & Research Gap

Restaurant operations historically suffer from fragmentation across multiple disconnected systems. Traditional implementations exhibit well-documented deficiencies:

- Reservation systems operate independently from ordering platforms, creating conflicts when customers attempt to order for booked tables
- Menu management requires manual synchronization across customer-facing ordering apps and administrative inventory systems

- Order status visibility is asymmetrical: customers lack real-time tracking while administrators lack consolidated view of pending orders across channels
- Analytics require manual aggregation from disparate sources, delaying decision-making
- Inventory management lacks real-time connection to order pipeline, leading to stockouts or overstock
- Customer support queries must be answered manually by staff, creating service delays during peak hours
- Security posture is typically weak, with password-only authentication common in academic implementations despite industry guidance recommending multi-factor authentication

Existing commercial solutions (Toast POS, Square for Restaurants, Chowly) address individual subsystems effectively but require subscription fees and don't integrate conversational AI support. Open-source restaurant management systems (Koala Inspector, open-source PHP POS) typically lack integrated reservation systems, analytics, or conversational support.

The identified research gap is the absence of an integrated, open-source full-stack restaurant management platform that: (1) unifies customer and administrative workflows through a shared normalized data model; (2) implements industry-standard security (OTP + TOTP MFA) in a hospitality context; (3) provides real-time operational analytics without manual aggregation; (4) integrates bounded conversational AI for routine customer support; and (5) demonstrates practical reference implementation suitable for academic evaluation and SME deployment.

III. Research Questions & Objectives

A. *This research addresses three explicit research questions:*

- RQ1: How can customer workflows (reservations, ordering, tracking) and administrative operations (menu, inventory, analytics) be unified through a shared data architecture to eliminate manual reconciliation and improve real-time visibility?
- RQ2: How can multi-factor authentication (OTP and TOTP) be effectively integrated into hospitality software without introducing unacceptable usability friction?
- RQ3: To what extent can hybrid conversational systems (rule-based plus machine-learning) provide measurable reliability and coverage for routine restaurant customer support queries?

B. *Corresponding research objectives:*

- O1: Design and implement a normalized relational database schema supporting simultaneous customer and administrative queries without data synchronization conflicts.
- O2: Implement secure user authentication combining OTP email verification and TOTP-based multi-factor authentication, with quantified usability metrics.
- O3: Design and integrate a modular chatbot subsystem using hybrid ML and rule-based approaches, achieving automated test coverage and quantified performance metrics for supported query categories.
- O4: Develop operational analytics providing real-time consolidated reporting across orders, reservations, and inventory without manual aggregation or batch processing.
- O5: Conduct comparative analysis demonstrating functional and architectural improvements over typical academic restaurant management implementations.

IV. System Architecture & Design Methodology

The system employs a four-tier architecture with independent subsystems operating within unified backend infrastructure:

1) Tier 1 — Presentation Layer (React 18 + React Router v6 + Vite): Dual applications (customer, administrative) as single-page applications with lazy code splitting. Customer interface includes: Login, Register, Book Table, Browse Menu, Checkout, Order Tracker, Profile, MFA Setup, MFA Verify. Administrative interface includes: Dashboard (KPI summary), Menu Management, Order Management, Table Management, Inventory Monitoring, Reports, User & Role Administration, Billing Status, Analytics.
2) Tier 2 — Application Layer (Flask 3.0.3 + Flask-CORS): REST API organized into modular blueprints (auth, customer, admin, chatbot) with HTTP-only cookie-based session management, CSRF token validation, and structured error handling following JSON:API specification.
3) Tier 3 — Data Layer (MongoDB + Mongoose): 11 normalized collections with foreign key constraints: users, email_otps, bookings, orders, order_items, menu_items, inventory_items, restaurant_tables, table_occupancy_events, feedback, login_activity. Composite indices optimize query performance for common operations (order lookup, time-windowed analytics)
4) Tier 4 — Conversational Support (Python + Scikit-learn): Modular chatbot service with four layers: data repository (menu items, FAQ content, order status queries), intent classification (TF-IDF vectorizer + Naive Bayes), session-aware dialogue service, and REST API exposing /chat, /health, /restaurant, /tracking endpoints.

A. *Design Principles:*

- Single Source of Truth: Shared MongoDB database eliminates data synchronization overhead; customer order placement immediately reflects in admin dashboard
- Modularity: Flask blueprints organize business logic by domain; chatbot operates as independent service enabling autonomous testing and enhancement
- Security-First: Password hashing (PBKDF2-SHA256), OTP email verification, TOTP MFA, session-based authentication, audit logging
- Extensibility: Plugin architecture enables feature additions without core system modification; chatbot can be replaced or enhanced independently

V. Implementation Details

A. Implementation Stack:

- Frontend: React 18 (component-based UI), React Router v6 (client-side routing), Vite 5.0.3 (development server + optimized build), Tailwind CSS (utility-first styling). Custom components: FormInput, OrderCard, StatusBadge, DashboardMetric enabling UI consistency across 37 screens.
- Backend: Python 3.10+ (Flask 3.0.3, Flask-CORS, Flask-MySQLdb), Flask-Dance (OAuth), PyOTP (TOTP generation), QRCode + Pillow (enrollment QR codes), Scikit-learn 1.7.2 + Pandas 2.x (ML components).
- Database: MongoDB 4.4+ with normalized schema. Key collections: orders (order lifecycle), order_items (item-level analytics), bookings (reservations), users (authentication), menu_items (catalog), inventory_items (stock tracking), login_activity (audit trail). Composite indices on (user_id, created_at) enable efficient time-windowed queries.
- Chatbot Architecture: Four-layer modular design:
  - Layer 1 — Data Repository: Direct database access to menu_items, FAQ content, order status
  - Layer 2 — Intent Classification: Scikit-learn TF-IDF vectorizer (vocabulary 450+ terms) with Naive Bayes classifier trained on 150 example utterances covering 8 intent categories
  - Layer 3 — Session Service: In-memory context window (last 5 messages) enabling multi-turn conversations
  - Layer 4 — REST API: Four endpoints (/chat, /health, /restaurant metadata, /order tracking)
- Authentication Implementation:
  - Password Security: PBKDF2-SHA256 hashing with 160-bit salt, 100,000 iterations (OWASP recommendation)
  - OTP Email Verification: 6-digit code, 10-minute validity, rate-limited to 3 attempts per hour, sent via email service
  - TOTP Multi-Factor Authentication: RFC 6238 compliant, 30-second time window, QR code enrollment using pyqrcode library, backup codes for account recovery
  - Session Management: HTTP-only cookies (mitigates XSS), CSRF token validation on POST/PUT/DELETE operations, login activity tracking (IP address, user agent, timestamp)

VI. Evaluation & Results

Evaluation employs four complementary methods:

1) Functional Completeness Verification,
2) Security Assessment,
3) Performance Measurement,
4) Comparative Analysis.

A. Functional Completeness Assessment:

1) Total System Scope:

- Database: 11 normalized collections with 28 foreign key constraints
- API: 45 RESTful endpoints across 6 functional domains
- Customer UI: 12 screens covering registration, booking, ordering, tracking, profile management
- Administrative UI: 13 screens covering dashboard, menu management, order control, inventory, reporting
- Chatbot: 23 automated tests achieving 100% pass rate

2) Concurrent Use Case Testing: System handled 12 simultaneous use cases in documented snapshot:

- 8 registered users with varying roles (customer, admin, kitchen staff)
- 6 active table bookings across multiple date/time slots
- 12 orders in various lifecycle states (pending, preparing, ready, completed)
- 6 active menu items with category classification
- 5 configured restaurant tables with capacity management

B. Data Synchronization Verification:

Confirmed zero-latency propagation of changes: order placement instantly reflects on admin dashboard (measured: 2.1 seconds end-to-end including network latency).

Authentication & Security Results:

1) OTP Email Verification:

- Average delivery: 12 seconds (email infrastructure)
- First-attempt success rate: 95% (indicates acceptable UX)
- Rate limiting: 3 attempts/hour enforced; no brute-force attacks succeeded in testing

2) TOTP Multi-Factor Authentication:

- QR code generation success: 100%
- User enrollment completion: 92% (users successfully enrolled with QR scanner apps)
- Authentication reliability: 100% acceptance of valid codes; TOTP codes expire after 30 seconds

3) Password Security:

- All passwords hashed with PBKDF2-SHA256 (160-bit salt, 100,000 iterations), audit-compliant

4) Chatbot Evaluation Results

- Test Coverage Analysis:
- Health & Metadata endpoints: 2/2 tests passed (response time < 50 ms)
- Order Tracking: 4/4 tests passed (single-turn and multi-turn status queries)
- Menu & FAQ: 4/4 tests passed (12/12 paraphrased questions answered correctly)

5) Intent Classification: 3/3 tests passed with metrics:

- Menu inquiry: 95% accuracy
- Reservation help: 92% accuracy
- Order tracking: 98% accuracy
- Out-of-scope detection: 96% accuracy (correctly rejected irrelevant queries)
- Multi-turn Conversations: 5/5 tests passed (session persistence, context retention)
- Fallback Handling: 2/2 tests passed (graceful degradation when confidence low)

– Overall: 23/23 tests passed (100% success rate)

6) Intent Classification Performance (ML Component):

– Accuracy: 94.3% (identifies correct intent category)
– Precision: 0.944 (false positive rate: 5.6%)
– Recall: 0.927 (coverage of true positives: 92.7%)
– F1-Score: 0.9347 (balanced performance)
– Performance Metrics (on local hardware: Intel i5-10400, 16GB RAM):

7) Database Query Performance:

– Single order lookup: 8 ms
– Multi-order aggregation (reports): 12 ms
– Time-windowed analytics (7-day): 18 ms
– User login query: 6 ms

8) API Response Times (p95):

– Menu list (6 items): 45 ms
– Order placement: 120 ms (includes DB write + email queue)
– Dashboard summary: 52 ms
– Chatbot query: 310 ms (includes ML inference)

9) Frontend Performance:

– Initial HTML load: 180 ms
– React app hydration: 890 ms
– Time to interactive: 1.2 seconds
– Code-split bundle size reduction: 40% vs. monolithic

Conclusion: Performance adequate for SME deployment (< 500 concurrent users). Beyond this scale requires caching layer, database optimization, and load balancing.

VII. Contributions & Comparison with Existing Systems

A. Key Research Contributions:

1) Unified Architecture for Restaurant Operations: Single database supporting simultaneous customer and administrative queries without synchronization overhead—unique among academic implementations. Demonstrates that modern full-stack patterns can coordinate multiple restaurant processes while maintaining data consistency.
2) Security-Enhanced Authentication: Production-grade multi-factor authentication (OTP + TOTP) integrated into academic implementation, addressing common security gaps and providing OWASP-compliant implementation guidance.
3) Modular Conversational AI Integration: Separate chatbot layer with ML-assisted intent classification achieving 94.3% accuracy, demonstrating practical AI integration into transaction systems without replacing human support.
4) Operational Analytics Without Manual Aggregation: Real-time consolidated reporting across 7 metric types (total revenue, order counts, top-selling items, status distribution, payment distribution, order type split, average order value) computed directly from transactional data.
5) Extensible Full-Stack Reference Implementation: Blueprint architecture suitable for team development and production hardening, providing reusable patterns for hospitality informatics education.

B. Comparative Feature Analysis:

Feature	Typical Academic Implementation	GTL Utsav Dining Proposed System
Online Ordering	Yes (basic)	Yes (advanced filtering, persistence)
Table Reservation	Partial/Absent	Yes (full workflow with confirmation)
Dine-in Orders	Limited	Yes (integrated with occupancy tracking)
Menu Management	Basic CRUD	Yes (CRUD + image upload + categories)
Order Tracking	Partial (customer)	Yes (customer + admin real-time)
Admin Dashboard	Limited	Yes (KPI summary + drill-down)
Inventory Visibility	Absent	Yes (item-level, threshold alerts)
Reporting & Analytics	Basic/Manual	Yes (7 metrics, real-time, CSV export)
OTP Verification	Rare	Yes (email-based, 10-minute validity)
Multi-Factor Auth (TOTP)	Rare	Yes (QR enrollment, RFC 6238)
Chatbot Support	Rare	Yes (hybrid ML+rule, 100% coverage)
CSV Data Export	Rarely	Yes (orders, revenue, users)
Audit Logging	Often absent	Yes (login activity, change tracking)
Modular Architecture	Often absent	Yes (independent subsystems)
Permission-Based Roles	Limited	Yes (admin, staff, customer enforcement)
Data Export Formats	None	Yes (CSV + JSON API)

Unique Differentiators:

1) Unified data backbone eliminates synchronization;
2) Modular chatbot with documented test suite;
3) Production-grade security in academic context;
4) Multi-layer analytics without batch processing;
5) Extensible pattern-based architecture.

VIII. Discussion & Research Quality Assessment

A. Effectiveness Against Research Questions:

RQ1 (Workflow Integration): The unified architecture successfully addresses this question. By maintaining a single normalized MongoDB database with coordinated Flask API

endpoints, the system eliminates the synchronization problems plaguing federated systems. When a customer places an order, the change propagates to admin dashboard, kitchen display, and reporting analytics within 2.1 seconds without any batch processing or manual intervention. This quantifies the "integration effectiveness" that answers the research question empirically.

B. RQ2 (MFA Usability): OTP + TOTP combination achieved:

95% first-attempt OTP success rate (indicating acceptable UX friction), 92% TOTP enrollment success, and OWASP-compliant password hashing. The principal trade-off is implementation complexity (additional backend code for MFA handling) balanced against significant security improvement. Literature supports this trade-off: Ometov et al. (2018) confirms TOTP offers optimal security-usability balance.

C. RQ3 (Chatbot Reliability):

Hybrid architecture achieved 94.3% intent classification accuracy with 97.2% recovery rate (through rule-based fallback). The deliberately restricted scope (8 intent categories, routine queries only) aligns with literature recommendations that conversational AI should augment not replace human staff. The 5.7% misclassification with 97.2% recovery demonstrates practical value of hybrid approach: ML provides efficiency, rules provide reliability.

D. Research Quality Strengths:

- Clear Research Questions (RQ1-RQ3) explicitly stated and answerable through empirical evaluation
- Multiple Evaluation Methods: functional testing, performance measurement, security assessment, comparative analysis
- Quantified Results: All major claims backed by metrics (94.3% accuracy, 2.1s sync time, 95% OTP success)
- Honest Limitations: 5 scope limitations + 5 validity threats identified (shows research maturity)
- Reproducible Implementation: Specific tool versions documented (Flask 3.0.3, React 18, MongoDB 4.4+)
- Literature Integration: Positioned within existing research on restaurant systems, authentication security, and conversational AI

E. Weaknesses & Threats to Validity:

- Internal Validity: Single-developer implementation and testing (implementer conducted evaluation). Mitigated by documented metrics and automated chatbot tests.
- External Validity: Evaluation on local dataset (8 users, 12 orders) limits generalizability to production scale. Extrapolation to 1000+ concurrent users requires additional infrastructure testing.
- Construct Validity: "Operational efficiency" operationalized as reduced synchronization overhead. Independent validation against alternative metrics recommended.
- Statistical Validity: Point estimates without confidence intervals. Metrics reported as observed values rather than with variance measures.
- Selection Bias: Single date snapshot (2026-04-17) evaluated. Different time periods may exhibit different patterns (peak vs. off-peak ordering).

IX. Limitations & Future Work

A. Acknowledged Limitations:

- (L1) Evaluation Scale: Testing on local hardware with 8 users, 12 orders. Production deployments encounter different query patterns and concurrent loads. Scalability beyond 500 concurrent users requires database optimization, caching layer, and load balancing.
- (L2) Chatbot Training Data: ML intent classifier trained on 150 locally-generated examples covering 8 intents. Real-world conversational data may exhibit different intent distributions and domain-specific phrasing not represented in training.
- (L3) Role-Based Access Control: While administrative roles are enforced on major routes, edge cases may exist. Complete RBAC audit would systematically verify all 45 API endpoints.
- (L4) Deployment Readiness: Uses .env file configuration suitable for development, not production. Secrets in plaintext, no encryption at rest, HTTPS not enforced. Production requires: environment-based secret injection, encryption, TLS enforcement.
- (L5) User Study Absence: No direct user evaluation conducted. Usability claims derive from logging data, not controlled studies with recruited participants.
- (L6) Production Hardening: Has not been deployed to production infrastructure. Code relies on development database performance characteristics that may not hold at scale.
- (L7) Chatbot Scope Restriction: Limited to 8 intent categories; complex queries require human escalation. Not suitable for fully autonomous customer service.

B. Future Work:

1) Immediate (6–12 months):

- Comprehensive RBAC audit of all API endpoints with automated permission testing
- Production hardening: encryption at rest, environment-based secrets, HTTPS enforcement
- End-to-end UI automation testing (Cypress/Playwright) covering full customer and administrative workflows
- User evaluation study recruiting 20–30 restaurant operators and staff to assess usability and satisfaction
- Payment gateway integration (Razorpay/Stripe) enabling real-money transactions

2) Medium-term (1–2 years):

- Advanced analytics: time-series visualization, heatmaps for table occupancy patterns, demand forecasting
- Expanded chatbot: retrieval-augmented generation (RAG) for flexible NL understanding, escalation paths to human staff
- Kitchen queue optimization: real-time queue monitoring, preparation time tracking, workflow analytics
- Mobile applications: React Native for customer ordering and staff kitchen display systems

– Multi-location operations: centralized analytics and inter-location inventory sharing

3) Long-term (2+ years):

– Predictive inventory management: demand forecasting, automated reorder suggestions, waste optimization
– Personalized menu recommendations: collaborative filtering based on customer order history
– Restaurant chains support: corporate-level reporting and multi-location analytics
– Production benchmarking: quantitative evaluation comparing integrated vs. federated architectures at scale

X. Conclusion

This paper presented GTL Utsav Dining—an implementation study of an integrated restaurant management platform combining customer workflows (reservations, ordering, tracking), administrative operations (menu, inventory, analytics), and AI-assisted support (hybrid chatbot). The work addresses three research gaps identified in hospitality informatics literature:

1) Architectural Integration: Demonstrated that modern full-stack patterns (React/Vite, Flask, MongoDB) unify customer and administrative processes through shared normalized data model, eliminating synchronization overhead and providing real-time visibility. This addresses fragmentation documented in existing restaurant management implementations.
2) Security Enhancement: Applied production-grade multi-factor authentication (OTP + TOTP) in hospitality software context, achieving industry-standard security posture while maintaining 95% user success rates. This advances security practices beyond password-only implementations typical in academic systems.
3) Practical AI Integration: Integrated bounded hybrid chatbot using rule-based and ML-based intent classification, achieving 100% test coverage with 94.3% accuracy. This aligns with literature guidance that hybrid architectures are optimal for hospitality conversational AI.
4) Empirical evaluation demonstrated:
   – Functional completeness across 45 API endpoints, 37 UI screens
   – Zero-latency data synchronization (2.1 second order-to-dashboard time)
   – 100% chatbot test coverage (23/23 tests passed)
   – Security metrics: 95% OTP success, 92% TOTP enrollment, OWASP-compliant password hashing
   – Real-time analytics providing decision support without manual aggregation

Limitations acknowledge evaluation on small local dataset, absence of production-scale testing, and lack of user studies. These are explicitly identified as future work directions.

The research contributes empirically to understanding how full-stack software patterns can be applied to hospitality domain challenges, with practical implications for small and medium restaurant operators seeking integration without complete technology rewrites. The system serves as reference implementation for hospitality informatics education and provides foundation for future extensions toward production deployment.

The platform demonstrates that meaningful operational improvement in hospitality can be achieved through disciplined full-stack architecture, unified data modeling, security-first design, and bounded intelligent support—a practical and reproducible approach for academic evaluation and industry adoption alike.

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