Black & White: A Web-Based Smart Laundry Management System with Multi-Role Architecture

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***Abstract*—The digitization of service-oriented industries has necessitated the development of integrated platforms capable of unifying operations across multiple stakeholders. This paper presents Black & White, a web-based Smart Laundry Management System engineered to automate and streamline the end-to-end workflow of laundry service businesses. The proposed system introduces a multi-role architecture supporting four distinct user categories: Customers, Shop Owners, Delivery Personnel, and Administrators, each governed by dedicated functional modules. Core capabilities include slot-based service booking with garment image upload, real-time order tracking, delivery management through a dedicated portal, and a centralized administration dashboard. The system is developed using contemporary front-end technologies including React.js, augmented by a scalable back-end infrastructure. Experimental evaluation through structured usability testing and system performance analysis demonstrates significant improvements over conventional manual-based laundry operations, reducing booking time by approximately 67% and improving order tracking transparency. The paper further outlines a forward-looking roadmap encompassing AI-powered garment recognition, integrated payment gateways, and mobile application deployment, positioning Black & White as a scalable and cost-effective solution for small-to-medium laundry enterprises.**

***Index Terms*—Laundry Management System; Multi-Role Web Application; Service Automation; Order Tracking; Garment Classification; React.js; Digital Booking System**

I. INTRODUCTION

The global laundry services market has witnessed substantial growth over the past decade, driven primarily by urbanization, increasing disposable incomes, and a rising preference for outsourced domestic services. Despite this growth trajectory, a considerable segment of laundry businesses, particularly small and medium enterprises (SMEs), continues to rely on manual, paper-based operational workflows that are inherently prone to inefficiency, miscommunication, and garment mismanagement. The absence of integrated digital tools creates operational silos between customers, service staff, and management, ultimately undermining service quality and customer retention.

Existing digital solutions in the laundry domain are predominantly single-function applications, addressing only isolated aspects of the operational pipeline, such as appointment booking or payment processing, without providing a unified platform that connects all stakeholders. This fragmentation prevents businesses from achieving operational coherence and data continuity across the service lifecycle.

To address these systemic limitations, this paper introduces Black & White, a comprehensive, web-based Laundry Management System designed around a multi-role architecture. The system integrates booking management, garment tracking, delivery coordination, and administrative oversight within a single cohesive platform. The primary contributions of this work are as follows:

1. Design and implementation of a multi-role system architecture supporting Customers, Shop Owners, Delivery Personnel, and Administrators.
2. Development of a slot-based service booking module augmented with garment image upload functionality for enhanced service accuracy.
3. Integration of a real-time delivery management

portal enabling end-to-end order status visibility.
4. Proposal of an AI-augmented service recommendation pipeline for future deployment.

The remainder of this paper is structured as follows. Section II presents a survey of relevant literature. Section III defines the problem statement and outlines the system objectives. Section IV describes the proposed system architecture and methodology. Section V details the implementation and module descriptions. Section VI presents result analysis and performance evaluation. Section VII outlines future enhancement directions, and Section VIII concludes the paper.

II. LITERATURE SURVEY

The evolution of laundry management technology has followed the broader trajectory of web-based service digitization. Early systems in this domain were largely characterized by rudimentary HTML-based interfaces with limited interactivity, primarily serving as static information portals rather than transactional platforms [1]. These systems lacked backend integration and were incapable of supporting dynamic operations such as real-time booking or order tracking.

The proliferation of server-side scripting technologies, particularly Node.js and PHP, introduced the possibility of constructing database-driven laundry applications. Anitha and Sangeetha [2] developed a web-based dry cleaning management application using PHP and MySQL that demonstrated the feasibility of digital appointment scheduling in small laundry businesses. While this work validated the potential of browser-based access to laundry services, its single-role architecture limited its applicability in multi-stakeholder operational environments.

Research in the adjacent domain of smart home energy management has produced relevant insights for laundry system optimization. Alam et al. [3] proposed an IoT-integrated scheduling framework for household appliances that demonstrated measurable reductions in peak energy demand through time-slot-based load distribution. Although not directly addressing commercial laundry management, the scheduling primitives introduced in this work inform the slot-booking mechanisms employed in the proposed system.

The application of machine learning techniques to garment analysis has been explored in several recent studies. Zheng et al. [4] presented a convolutional neural network (CNN)-based approach to fabric type classification from digital images, achieving classification accuracy exceeding 92% on a benchmark dataset. This line of research establishes the technical feasibility of AI-driven garment recognition, which constitutes a planned enhancement in the Black & White system.

Customer Relationship Management (CRM) integration within service-oriented web applications has been investigated by Nguyen and Tran [5], who demonstrated that personalized service recommendations based on historical transaction data significantly improved customer retention metrics in hospitality and personal care services. Their findings underscore the importance of preference capture and behavioral analytics, capabilities incorporated in the Black & White architecture through its CRM-enabled customer module.

Multi-role web application architectures have been studied in various service domains. Sharma et al. [6] examined role-based access control (RBAC) frameworks in healthcare appointment systems and established that granular permission structures improve both security posture and operational efficiency. These principles are directly applied in Black & White four-tier user hierarchy, where each role accesses only the functional modules pertinent to their operational responsibilities.

Delivery management systems integrated within service platforms have received increasing scholarly attention. Patel and Mehta [7] presented a GPS-augmented delivery routing module embedded within a pharmaceutical logistics application, demonstrating a 34% reduction in average delivery time through dynamic route optimization. This work informs the delivery portal design in the proposed system, which is structured to support route-optimized dispatch in a planned future release.

Despite these individual advances, no existing work presents a holistic, production-ready platform that integrates booking, tracking, delivery management, and administrative oversight within a unified laundry management architecture. The Black & White system is designed to bridge this gap by synthesizing insights from each of the aforementioned research streams into a cohesive, deployable solution.

III. PROBLEM STATEMENT AND OBJECTIVES

Conventional laundry service operations are encumbered by several structural inefficiencies. Manual order intake processes generate handwritten records that are susceptible to transcription errors and are difficult to query or audit. Garment tracking is performed informally, creating risk of loss or misattribution. Customer communication regarding order readiness and delivery status is reactive rather than proactive, necessitating repeated customer-initiated inquiries. Administrative oversight is constrained by the absence of consolidated reporting tools, impeding data-driven business decisions.

Furthermore, existing digital alternatives fail to serve the complete stakeholder ecosystem. Most web-based solutions address only customer-facing booking functionality, leaving shop operations, delivery logistics, and platform administration unserved by a unified interface. This forces businesses to maintain parallel manual workflows alongside their digital tools, negating a substantial portion of the efficiency benefits that digitization is intended to deliver.

The objectives of the proposed Black & White system are defined as follows:

a) Develop a responsive, modular web platform that consolidates booking, tracking, delivery, and administration within a single application.
b) Implement a four-role user architecture with granular access control to ensure operational security and role-appropriate functionality.
c) Enable garment image upload at the point of booking to reduce service misclassification errors.
d) Provide real-time order status visibility to all relevant stakeholders throughout the service lifecycle.
e) Establish a scalable architectural foundation amenable to subsequent integration of AI-based garment analysis, payment processing, and mobile deployment.

IV. PROPOSED METHODOLOGY

A. System Overview

The Black & White system is conceived as a unified service platform that mediates interactions among four categories of stakeholders: Customers who submit laundry orders, Shop Owners who manage services and processing, Delivery Personnel who coordinate pickup and delivery logistics, and Administrators who govern platform-wide operations. Each stakeholder category interacts with the system through a dedicated functional interface tailored to their specific operational responsibilities, while underlying data is maintained in a shared persistence layer accessible across roles according to defined authorization rules.

B. System Architecture

The system architecture adopts a three-tier client-server model comprising a presentation layer, an application logic layer, and a data management layer. The presentation layer is implemented using React.js, selected for its component-based architecture that facilitates the development of modular, reusable UI elements appropriate for a multi-role application. The application logic layer handles routing, session management, authorization enforcement, and business rule processing. The data management layer employs a relational database schema optimized for transactional laundry service data, including orders, garments, service definitions, and user profiles.

Inter-module communication is governed by a RESTful API design pattern, enabling the decoupling of front-end and back-end components and facilitating the independent evolution of each layer. Authentication is implemented using token-based mechanisms, and role permissions are enforced server-side to prevent unauthorized cross-role data access.

C. Data Flow Model

Upon customer registration, the system captures profile information including contact details, address, and service preferences. When a customer initiates a booking, they select a service category (wet cleaning, dry cleaning, or ironing), choose an available time slot, and optionally upload images of garments requiring special attention. This submission triggers the creation of an order record, which is immediately visible to the associated Shop Owner. The Shop Owner updates the order status through defined service stages, and these status changes are propagated in real time to relevant stakeholders. Upon service completion, the order is dispatched to the Delivery Portal, where Delivery Personnel access assigned deliveries and mark them as in-transit or

completed. Throughout this workflow, the Administrator retains visibility and control over all platform entities through the administration dashboard.

D. Technology Stack

The technology selection was guided by criteria of developer ecosystem maturity, scalability characteristics, and open-source availability. The front-end is built on React.js (v18), utilizing functional components with hooks for state management. Back-end services are implemented in Node.js with an Express.js framework, providing lightweight and performant API endpoints. Data persistence is managed through a MySQL relational database, chosen for its strong transactional integrity guarantees and compatibility with the structured order management data model. User authentication employs JSON Web Tokens (JWT), and password storage uses bcrypt hashing with a work factor of 12. The system is containerized using Docker to facilitate consistent deployment across development, testing, and production environments.

V. IMPLEMENTATION

A. Customer Module

The Customer Module serves as the primary interface through which end-users engage with laundry services. Upon successful authentication, customers are directed to a dashboard displaying available laundry shops in proximity to their registered address. The booking workflow guides the customer through service selection, slot reservation, garment detail entry, and optional image upload. Image uploads are validated for file type and size constraints before storage, and are associated with the corresponding order record to provide visual context to Shop Owners during service execution. Customers receive notifications upon order status transitions, maintaining transparency throughout the service lifecycle.

B. Shop Owner Module

The Shop Owner Module provides a comprehensive interface for service business management. Shop owners can define their service catalog, specifying service types, pricing schedules, and capacity constraints per time slot. Incoming orders are displayed on a live dashboard with customer details, garment images where provided, and service requirements. The Shop Overview panel consolidates key operational metrics including total order volume, active service count, and cumulative earnings. Order status management is performed through a structured workflow interface that enforces sequential stage progression, ensuring operational discipline. Newly registered shops are subject to administrator approval before becoming discoverable to customers, maintaining platform quality standards.

C. Delivery Portal

The Delivery Portal constitutes a specialized interface for personnel responsible for order pickup and delivery logistics. Upon login, delivery staff are presented with a queue of orders classified by status: orders marked READY are pending dispatch, while orders in OUT FOR DELIVERY status require completion confirmation. Each order entry displays the customer name, delivery address, and action controls enabling the delivery agent to initiate transit or confirm delivery completion. The portal is designed with a simplified interaction model to accommodate use on mobile browsers during field operations, minimizing interaction complexity while ensuring accurate status updates.

D. Administration Dashboard

The Administration Dashboard provides platform-wide governance capabilities accessible exclusively to users holding the Administrator role. The dashboard presents aggregated platform metrics including total registered user count, total shop registrations, pending shop approval queue, and cumulative order volume. The pending approvals panel enables administrators to review and approve or reject shop registration requests from prospective service providers. The recent users panel provides a chronological listing of new registrations annotated with assigned roles, facilitating onboarding oversight. Administrative actions are logged for auditability, supporting accountability and regulatory compliance requirements.

E. Data Privacy and Security Module

Security considerations are addressed at multiple layers of the system. Input validation is enforced both client-side and server-side to mitigate injection

vulnerabilities. API endpoints are protected by middleware that verifies JWT validity and role authorization before processing requests. Sensitive user data fields, including passwords and payment-related identifiers, are never transmitted in plaintext. Database queries are parameterized to prevent SQL injection. Rate limiting is applied to authentication endpoints to mitigate brute-force attacks. The role-based access control model ensures that no user can access data or functionality outside the scope defined for their assigned role.

VI. RESULT ANALYSIS AND PERFORMANCE EVALUATION

System performance was evaluated through a structured usability study involving 25 participants drawn from three groups: prospective laundry customers (n=10), laundry shop owners (n=8), and platform administrators (n=7). Participants were assigned role-appropriate tasks and measured on task completion rate, time-on-task, and subjective satisfaction using a five-point Likert scale instrument.

TABLE I. *System Performance and Usability Evaluation Results*

Metric	Proposed System	Manual Process	Improvement
Booking Time (avg)	1.8 min	5.4 min	67% faster
Task Completion Rate	96.4%	78.2%	+18.2%
Order Tracking Accuracy	99.1%	61.3%	+37.8%
User Satisfaction (1-5)	4.6	2.9	+1.7 pts
Error Rate	1.8%	12.4%	85% reduction

Booking time was measured from the initiation of the order creation workflow to the system confirmation of a successfully placed order. For the proposed system, the average booking time across all customer participants was 1.8 minutes, compared to an estimated 5.4 minutes required for the equivalent telephone-based manual booking process, representing a 67% reduction. Task completion rate, defined as the proportion of assigned tasks completed without requiring external assistance, reached 96.4% in the proposed system versus 78.2% in the manual baseline, yielding an 18.2 percentage point improvement.

Order tracking accuracy was assessed by presenting participants with order status queries and measuring the proportion of accurate status retrievals. The proposed system achieved 99.1% accuracy through its real-time database synchronization architecture, compared to 61.3% accuracy for the manual process, which was subject to communication delays and record-keeping inconsistencies. Overall user satisfaction, captured through post-task questionnaire responses, averaged 4.6 out of 5.0 for the proposed system, representing a substantial improvement over the 2.9 average recorded for the manual process.

System-level performance testing was conducted using Apache JMeter to simulate concurrent user loads. The application maintained response times below 300 milliseconds for API endpoints under loads of up to 100 concurrent users, with graceful degradation observed at higher load levels. These results confirm the system's suitability for deployment in small-to-medium scale laundry operations with typical daily transaction volumes.

TABLE II. *Feature Comparison with Existing Systems*

Feature	Black&White	Anitha et al. [2]	Manual Ops
Multi-Role Access	Yes (4 roles)	No	No
Real-Time Tracking	Yes	Partial	No
Garment Image Upload	Yes	No	No
Delivery Portal	Yes	No	No
Admin Dashboard	Yes	No	No
Scalable Architecture	Yes	Limited	N/A
AI Roadmap	Yes (planned)	No	No

VII. FUTURE ENHANCEMENTS

The current implementation of Black&White establishes a functional foundation that is deliberately architected to accommodate a structured set of planned enhancements. These future developments are prioritized according to their expected impact on platform utility and commercial viability.

A. AI-Powered Garment Recognition

A significant planned enhancement involves the integration of a convolutional neural network-based garment analysis pipeline into the booking workflow. Drawing on methodologies demonstrated by Zheng et al. [4], the system will be extended to automatically analyze uploaded garment images to identify fabric type, detect visible stains, and recommend the most appropriate cleaning method from among wet cleaning, dry cleaning, and steam ironing options. This capability is expected to reduce service misclassification rates and improve customer satisfaction by ensuring that garments receive the treatment most suited to their material properties and soiling conditions.

B. Mobile Application Deployment

The React.js foundation of the current implementation is amenable to progressive web application (PWA) conversion, which will enable mobile device installation without requiring separate native application development. In the longer term, dedicated Android and iOS applications developed using React Native are planned, providing access to platform-native capabilities such as push notifications, GPS-based delivery tracking, and camera integration for garment image capture directly at the point of service initiation.

C. Integrated Payment Gateway

The integration of a payment processing module constitutes a high-priority enhancement that will transform the platform from a service coordination system into a fully transactional application. The planned implementation will support multiple payment modalities including UPI, credit and debit card processing, and digital wallet transactions. Subscription-based pricing models enabling customers to purchase prepaid service packages will also be supported, providing a mechanism for customer retention and predictable revenue streams for shop operators.

D. Real-Time Delivery Tracking with Route Optimization

The current Delivery Portal will be augmented with GPS-based real-time tracking functionality, enabling customers to monitor delivery agent location during active delivery operations. Integration with mapping services will provide delivery personnel with optimized routing suggestions that account for traffic conditions, delivery sequence, and distance constraints, consistent with approaches demonstrated in prior work on logistics optimization [7].

E. Analytics and Customer Intelligence

A data analytics module is planned that will provide shop owners with actionable insights derived from historical order data, including service demand patterns, peak booking periods, customer lifetime value metrics, and service quality indicators derived from customer ratings. These capabilities will support data-driven decision making in areas such as staffing allocation, service pricing optimization, and targeted promotional campaigns.

VIII. CONCLUSION

This paper has presented Black&White a web-based Smart Laundry Management System designed to address the operational inefficiencies endemic to manually managed laundry service businesses. The proposed system introduces a multi-role architecture that unifies the operational workflows of Customers, Shop Owners, Delivery Personnel, and Administrators within a single, cohesive platform, eliminating the fragmentation that characterizes current digital alternatives in this domain.

The system's core contributions, encompassing slot-based booking with garment image upload, real-time order tracking, a dedicated delivery management portal, and a centralized administration dashboard, collectively address the principal pain points identified in the problem formulation. Evaluation results from structured usability testing demonstrate meaningful improvements over manual operational baselines across all measured performance dimensions, including a 67% reduction in booking time, a 37.8 percentage point improvement in order

tracking accuracy, and a user satisfaction rating of 4.6 out of 5.0.

The architectural choices underpinning the Black&White implementation, particularly the component-based React.js front end, RESTful API design, and containerized deployment model, provide a scalable foundation for the planned enhancements described in Section VII. The integration of AI-powered garment recognition, in particular, is anticipated to substantially elevate the system's value proposition by automating service selection decisions that currently require manual interpretation.

In conclusion, Black&White demonstrates that thoughtfully engineered web-based platforms can deliver meaningful operational improvements in service-oriented SME contexts, and provides a replicable architectural template for similar digitization initiatives in adjacent service domains.

REFERENCES

[1] R. K. Singh and A. Verma, "Web-Based Service Management Systems: A Review of Early Architectures and Interaction Paradigms," International Journal of Web Engineering, vol. 4, no. 2, pp. 45-58, 2018.

[2] S. Anitha and P. Sangeetha, "Design and Development of a Web-Based Dry Cleaning Management Application Using PHP and MySQL," Proceedings of the International Conference on Computing and Communication Systems, Chennai, India, 2019, pp. 201-207.

[3] M. M. Alam, H. Reaz, and M. A. Islam, "IoT-Integrated Scheduling Framework for Household Appliance Energy Management in Smart Home Environments," IEEE Transactions on Consumer Electronics, vol. 65, no. 3, pp. 312-321, 2019.

[4] L. Zheng, Y. Wang, and J. Chen, "Fabric Type Classification from Digital Images Using Convolutional Neural Networks," Pattern Recognition Letters, vol. 142, pp. 88-96, 2021.

[5] T. T. Nguyen and V. H. Tran, "Personalized Service Recommendation in CRM-Enabled Hospitality Applications: A Behavioral Analytics Approach," Journal of Service Management, vol. 31, no. 4, pp. 703-724, 2020.

[6] R. Sharma, A. Gupta, and M. Patel, "Role-Based Access Control in Multi-Stakeholder Healthcare Web Applications: Security and Efficiency Implications," IEEE Access, vol. 8, pp. 119341-119354, 2020.

[7] K. Patel and S. Mehta, "GPS-Augmented Delivery Route Optimization in Pharmaceutical Logistics Applications," Computers and Industrial Engineering, vol. 156, p. 107292, 2021.

[8] A. Mukherjee and S. Roy, "Progressive Web Applications for Service Industry Digitization: Adoption Barriers and Technical Considerations," ACM SIGWEB Newsletter, vol. 2022, no. Spring, pp. 1-12, 2022.

[9] F. Petropoulos, D. Apiletti, and V. Assimakopoulos, "Forecasting: Theory and Practice," International Journal of Forecasting, vol. 38, no. 3, pp. 705-871, 2022.

[10] M. Khoury and T. Andersson, "Real-Time Order Management Architectures for Scalable Multi-Tenant Service Platforms," IEEE Software, vol. 39, no. 1, pp. 54-62, 2022.

[11] S. R. Bogi Reddy, N. Varshney, and V. Sharma, "Scalable Web Service Architectures for SME Digitization: Design Patterns and Deployment Considerations," Proceedings of the IEEE International Conference on Cloud Engineering, San Jose, CA, 2021, pp. 88-95.

[12] C. Molitor, A. Antipov, and A. Laouir, "Smart City Energy Optimization via Appliance Scheduling: A Constraint-Based Approach," Sustainable Cities and Society, vol. 52, p. 101798, 2020.

[13] P. Siano, "Demand Response and Smart Grids: A Survey," Renewable and Sustainable Energy Reviews, vol. 30, pp. 461-478, 2014.

[14] J. Matamoros, F. Gregori, and A. Pages-Zamora, "Energy Consumption Modeling for Smart Home Appliance Management Systems," IEEE Transactions on Smart Grid, vol. 9, no. 4, pp. 3171-3180, 2018.

[15] H. Wang, Z. Lei, and X. Zhang, "Deep Learning Methods for Peak Demand Forecasting in Smart Grid Applications," Applied Energy, vol. 259, p. 114168, 2020.