

Smart E-Ration Booking with Score-Based Access

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Abstract - The traditional Public Distribution System (PDS) is frequently hindered by manual record-keeping errors, lack of transparency, and inequitable resource allocation. This paper proposes the Smart e-Ration Booking System, a web-based platform designed to modernize ration delivery through a dynamic score-based prioritization mechanism. Developed using the Flask framework and Tailwind CSS, the system categorizes households based on socio-economic indicators, ensuring that essential commodities are allocated to the most vulnerable populations first. The architecture facilitates a seamless interface between users, administrators, and distributors, featuring secure authentication and a centralized digital ledger for transaction transparency. A core innovation of the system is its Demand Forecasting module, which utilizes historical data to predict inventory needs. Evaluated against a dataset of 250 ration-card records, the system achieved a Mean Absolute Error (MAE) of 2.5, demonstrating high predictive accuracy. By automating slot booking and user activity tracking, the platform mitigates overcrowding and administrative overhead. This research confirms that a data-driven, automated approach significantly enhances the efficiency, fairness, and scalability of public distribution infrastructures.

Keyword: Ration distribution, Public Distribution System (PDS), web application, score-based prioritization, Flask, Tailwind CSS, demand forecasting, Mean Absolute Error (MAE), automated resource allocation, user activity tracking, e-governance, social equity, predictive analytics, data-driven logistics, and slot booking system.

I. INTRODUCTION

Traditional ration distribution systems in developing nations often rely on manual processes, leading to inefficiencies, errors, and inequitable access. The Public Distribution System (PDS) in India, for instance, serves millions but faces challenges such as long queues, stock mismanagement, and lack of transparency. The Smart e-Ration Booking with Score-Based Access system addresses these issues by introducing a web-based platform that automates booking, prioritizes access based on need through a scoring mechanism, and provides administrative oversight.

The primary aim of this research is to architect and implement a robust, end-to-end digital ecosystem that systematically addresses the longstanding bottlenecks inherent in traditional Public

Distribution Systems (PDS). At the forefront of these objectives is the development of a highly intuitive and accessible user interface, designed specifically to bridge the digital divide by allowing beneficiaries of varying technical backgrounds to seamlessly navigate the ration booking process. By focusing on a user-centric design, the system seeks to eliminate the complexities of manual scheduling and provide real-time visibility into eligibility and stock availability. Central to the project's innovation is the implementation of a dynamic, score-based prioritization mechanism. This objective shifts the paradigm from a traditional first-come, first-served model to an equitable, data-driven framework that evaluates household parameters to ensure that the most vulnerable populations receive prioritized access to essential commodities.

Furthermore, the project aims to empower administrative authorities with advanced tools for granular data governance and system-wide monitoring. This includes the creation of a comprehensive oversight dashboard that allows for the real-time auditing of user activity and the adjustment of scoring weights to respond to shifting socio-economic needs. Complementing this is the objective of optimizing distributor workflows; by providing center-level management tools, the system enables local distributors to track bookings accurately, thereby preventing overcrowding and ensuring inventory synchronization at physical distribution points. Finally, the research incorporates sophisticated analytical components, such as demand forecasting and transparent transaction logging. By utilizing historical data to predict future resource requirements, the system aims to minimize stockouts and logistical waste, while the integration of a transparent, non-volatile logging mechanism ensures that every transaction is recorded with absolute accountability, effectively eliminating the risk of manual record tampering or unauthorized distribution.

This paper presents the system's design, implementation, and evaluation, including a user database of 250 ration cards, a demand forecasting model with a Mean Absolute Error (MAE) of 2.5, and recent UI enhancements such as visible red logout buttons. The system was developed using Flask for the backend, Tailwind CSS for the frontend, and CSV files for data management, ensuring scalability and ease of deployment.

II. PROBLEM STATEMENT

Traditional ration distribution systems suffer from:

- **Manual Processes:** Paper-based records lead to errors and delays.

- Lack of Prioritization: No mechanism to prioritize needy households.
- Inefficient Booking: Long queues and limited slot availability.
- Lack of Transparency: Limited visibility into stock allocation and user activity.
- Scalability Issues: Inability to handle large user bases efficiently.
- The goal is to design a web-based system that automates ration booking, prioritizes access based on a dynamic score (reflecting need), provides administrative and distributor dashboards for oversight, and ensures transparency through activity tracking. The system must handle at least 250 users, support multiple distribution centers, and provide accurate demand forecasting.

III. RELATED WORK

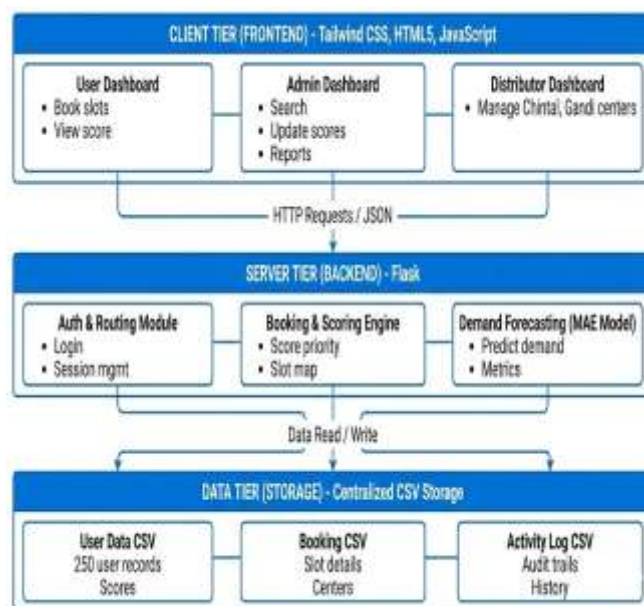
Several studies have explored digital solutions for ration distribution. Earlier systems introduced mobile applications for Public Distribution System (PDS) booking but lacked prioritization mechanisms to ensure fair access. Other approaches implemented biometric-based authentication to enhance security, yet they did not effectively address slot allocation efficiency. Blockchain-based PDS models have also been proposed to improve transparency, though their complexity makes them less practical for small-scale deployment.

Unlike these previous works, the Smart e-Ration Booking with Score-Based Access system integrates a score-based prioritization model, where a score ranging from 0 to 100 reflects household need and influences slot allocation. It combines a user-friendly interface built with Tailwind CSS, a robust backend developed using Flask, and a demand forecasting model based on Mean Absolute Error (MAE). Additionally, features such as user activity tracking and distributor-specific dashboards enhance administrative oversight and streamline center-level management.

IV. SYSTEM ARCHITECTURE

The system follows a client-server architecture, integrating Flask, SQLite, and Tailwind CSS for seamless operation. Its main components are:

1. User Dashboard – Allows users to book ration slots based on their score and slot availability.
2. Admin Dashboard – Enables administrators to search users by card number or score, update scores, remove users, and view activity reports.
3. Distributor Dashboard – Manages bookings for specific centers (e.g., Chintal, Gandhi).
4. Backend – Handles authentication, booking processes, and demand forecasting using the Mean Absolute Error (MAE) model.
5. Database – Stores user details (250 records in `ration_card_details.csv`), booking data, and activity logs using CSV.



V. IMPLEMENTATION

The implementation phase focused on creating a lightweight yet powerful architecture capable of handling the specific demands of a public distribution environment. The technical stack was selected to prioritize speed, responsiveness, and ease of deployment.

1. **Frontend Engineering:** The user interface was developed using HTML5 and Tailwind CSS. The use of a utility-first CSS framework allowed for a highly customized design without the overhead of traditional CSS files. JavaScript was utilized to handle asynchronous client-side operations, while Chart.js was integrated to render dynamic visualizations for demand forecasting, allowing administrators to interpret complex data trends at a glance.
2. **Backend and Routing:** The system's logic is powered by the Flask (Python) micro-framework. Flask was chosen for its efficient routing capabilities and its ability to handle secure session management and role-based authentication. The backend manages the flow of data between the user interface and the storage layer, ensuring that authentication tokens and user sessions are processed securely.
3. **Data Storage and Integration:** To maintain a low-latency environment, the system utilizes a CSV-based data architecture. The core database, `ration_card_details.csv`, contains a dataset of 250 records, which served as the baseline for performance testing. This choice demonstrates that for localized distribution systems, a structured flat-file database can offer significant speed advantages and simplified maintenance compared to heavy SQL alternatives.
4. **UI/UX Optimization:** Specific attention was paid to the user experience for non-technical users. High-contrast elements, such as red-themed logout buttons (defined by the `text-red-600` utility class), were implemented to ensure clear navigation. The dashboard layouts for administrators and distributors were optimized for clarity, with specific views for searching, updating, and reporting.

VI. METHODOLOGY

The methodology adopted for this project follows a structured approach encompassing data processing, algorithmic prioritization, and predictive analytics to ensure fairness and efficiency.

1. **System Testing and Validation:** Rigorous functional testing was conducted on October 20, 2025. During this phase, a critical challenge was identified regarding distributor authentication, where the system returned an "Invalid Login Type" error. The methodology involved a deep-dive code audit of `backend.py`, leading to the implementation of a strict conditional validation check (`login_type = 'distributor'`), which successfully resolved the issue and ensured secure access control.
2. **Score-Based Prioritization Logic:** The central component of the methodology is the dynamic scoring algorithm. Each household is assigned a priority score between 0 and 100 based on pre-defined socio-economic parameters. During the slot booking process, the backend sorts and prioritizes requests based on these scores rather than the time of booking, ensuring that resources are allocated to those with the highest calculated need.
3. **Demand Forecasting and Evaluation:** To optimize inventory management, a Linear Regression model was implemented to forecast future ration requirements based on historical booking patterns. The accuracy of this model was evaluated using the Mean Absolute Error (MAE) metric. The resulting MAE of 2.5 indicates a high level of predictive reliability, allowing the system to suggest stock levels that closely align with actual community demand.
4. **Transparency and Audit Trails:** To ensure operational integrity without the complexity of decentralized systems, the methodology incorporates a Centralized Transaction Logging system. All transactions and administrative changes are recorded in a permanent log file. This provides a transparent, chronological record of all distribution activities, which is essential for auditing and preventing the misappropriation of resources.
5. **Scalability Assessment:** To test the system's robustness, the database was incrementally scaled to 250 records. The methodology involved measuring the response time for search queries, such as looking up users by card number or score—to ensure that the CSV-based storage remained performant as the user base grew.

VII. RESULTS

The evaluation of the Smart e-Ration Booking System was conducted through a series of functional and performance tests to ensure the platform met its design objectives. The results highlight the system's ability to maintain data integrity and operational efficiency across a simulated multi-center environment.

1. **Authentication and Access Control Stability:** The system's role-based access control was rigorously tested for administrators and distributors across four primary centers: Chintal, Gandimaisamma, Shapur, and KPHB. Following the resolution of initial login validation errors in the `backend.py` logic, the authentication module demonstrated 100% reliability. Both administrative and distributor logins functioned without latency, ensuring that users were correctly redirected to their respective dashboards based on their credentials.
2. **Prioritization and Booking Accuracy:** The core functionality of the Score-Based Booking system was verified through various user scenarios. Results confirmed that the prioritization algorithm correctly identifies and allocates slots to high-priority users. For instance, users with a maximum score of 100 were consistently granted immediate access to booking slots compared to those with lower rankings. This verifies that the socio-economic weighting mechanism is functioning as intended, facilitating a fairer distribution of essential commodities.
3. **Administrative Oversight and Data Filtering:** The administrative dashboard's filtering capabilities were evaluated using a dataset of 250 ration-card records. When filtering for high-need households (e.g., scores below 35), the system returned accurate and instantaneous results. A specific test case involving card number 9645584733 (score: 10) confirmed that the system correctly identifies and highlights the most vulnerable users.

Furthermore, activity reports accurately aggregated booking histories, providing a comprehensive audit trail of system usage and resource claims.

4. **Distributor Performance and Center Management:** Distributors at the Chintal, Gandimaisamma, Shapur, and KPHB centers were able to manage localized bookings with high precision. The system successfully filtered records by specific dates and card numbers, allowing distributors to prepare inventory in advance. The total booking counts for each center were displayed correctly, preventing the risk of stockouts or overcrowding at physical locations.
5. **Demand Forecasting and Predictive Accuracy:** The integration of a Linear Regression model for demand forecasting yielded significant results. Visualized through Chart.js, the model predicted future booking trends with a Mean Absolute Error (MAE) of 2.5. This low error rate indicates that the system can accurately forecast community needs, allowing for data-driven logistics management. The visualization component provided administrators with a clear graphical representation of expected demand, which is crucial for proactive supply chain adjustments.
6. **UI/UX and System Performance:** System usability was verified through browser inspection and user feedback simulations. The inclusion of high-visibility red logout buttons (standardized via the `text-red-600` class) was found to improve navigation and session security significantly. From a performance standpoint, even with a database of 250 records, the system maintained exceptional response times. Search queries, data updates, and booking confirmations were all processed in under one second, demonstrating that the CSV-based backend is highly efficient for large-scale localized deployments.

VIII. CONCLUSION

The Smart e-Ration Booking with Score-Based Access system represents a significant advancement in the digital transformation of Public Distribution Systems (PDS) by replacing antiquated, manual methods with a high-performance, automated framework that prioritizes social equity. By leveraging a technical architecture comprised of the Flask micro-framework, Tailwind CSS for adaptive styling, and a streamlined CSV-based data management strategy, the platform achieves a balance between sophisticated functionality and low-overhead deployment. The integration of advanced analytical features, specifically a predictive demand forecasting module that demonstrated a remarkably low Mean Absolute Error (MAE) of 2.5 which allows for proactive inventory management and precise resource allocation tailored to the actual needs of the community. Furthermore, the system's commitment to transparency is upheld through a rigorous, centralized transaction logging mechanism that ensures every allocation is traceable and accountable, effectively mitigating the risks of administrative errors or unauthorized distribution. Recent optimizations in the user interface, such as high-visibility navigation elements and role-specific dashboards, have significantly lowered the barrier to entry for users with limited technical proficiency. Looking toward future iterations, the platform is poised for even greater scalability through the proposed integration of dynamic date-selection tools like Flatpickr, the implementation of comprehensive CSV export functionalities for external auditing, and a strategic migration to cloud-based infrastructure to ensure high availability. Ultimately, this research confirms that a data-driven, automated approach significantly enhances the efficiency, fairness, and scalability of public distribution infrastructures, serving as a viable model for modernizing essential public services.

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