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Location-Based Smart Parking Slot Booking and Allocation Platform

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Abstract-Urban areas are experiencing a rapid increase in the number of vehicles, which has led to significant challenges in parking management. Drivers often spend considerable time searching for available parking spaces, resulting in traffic congestion, increased fuel consumption, and inefficient utilization of parking resources. At the same time, many privately owned parking spaces remain unused for extended periods. This imbalance between parking demand and parking space utilization highlights the need for an efficient and intelligent parking management system. This paper proposes a Location-Based Smart Parking Slot Booking and Allocation Platform, a web-based system that connects drivers who require parking spaces with property owners who have available parking slots. The platform enables drivers to search for nearby parking spaces based on location, view parking details such as price and availability, and reserve parking slots in advance through an online interface. Parking slot owners can register their spaces and manage availability through a dedicated owner dashboard, while administrators monitor system activities and manage platform operations. The system is implemented using a three-tier architecture consisting of a presentation layer, application layer, and database layer. The frontend is developed using React with Vite and Tailwind CSS, while the backend is implemented using Java and the Spring Boot framework to provide RESTful API services. MySQL is used as the relational database for storing user information, parking slot details, bookings, and transaction records. Secure authentication using JSON Web Tokens and role-based access control ensures safe system operation. Integration with the Razorpay payment gateway enables seamless online payment processing with webhook based confirmation. The proposed platform improves parking space utilization and significantly reduces the time drivers spend searching for parking, contributing to efficient urban parking management.

Index Terms-Location-Based Services, Parking Slot Booking, Role-Based Access Control, Smart Parking System, Spring Boot, Urban Parking Management, Web-Based Platform.

I. INTRODUCTION

Urbanization and the rapid growth of vehicle ownership have significantly increased the demand for parking spaces in modern cities. In densely populated areas, drivers often spend considerable time searching for available parking, leading to traffic congestion, increased fuel consumption, and environmental pollution. Traditional parking systems rely on manual processes and lack real-time availability information, making them inefficient and time-consuming. At the same time, many privately owned parking spaces remain underutilized due to the absence of a coordinated platform connecting supply and demand.

Recent advancements in web technologies, location-based services, and digital payment systems have enabled the development of smart parking solutions. However, many existing systems depend on hardware infrastructure or focus only on commercial parking facilities, limiting their scalability and accessibility.

To address these challenges, this paper proposes a Location-Based Smart Parking Slot Booking and Allocation Platform, a fully web-based solution that connects drivers with private parking space owners through a centralized digital marketplace. The system supports three user roles—drivers, owners, and administrators—and provides features such as real-time slot discovery, advance booking, secure payment integration, and automated booking lifecycle management.

The key contributions of this work include the design of a scalable three-tier architecture with role-based access control, integration of secure payment verification using Razorpay, and implementation of automated booking and waitlist management. The remainder of the paper is organized into sections covering related work, system design, implementation, results, and future enhancements.

II. RELATED WORK

Several studies have explored smart parking management using various technologies. Research by Karunarathna and Rathnayake emphasized the importance of digital booking integration and real-time availability for improving parking efficiency, while also noting that adoption challenges are more organizational than technical. Other studies, such as those published in *Sustainable Cities and Society*, proposed smart parking frameworks with centralized data management and dynamic allocation, but these solutions rely heavily on hardware sensors, limiting their applicability.

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IoT-based and cloud-integrated systems have demonstrated effective real-time monitoring and optimization of parking spaces; however, they require significant hardware investment, making them unsuitable for small-scale or private parking environments. Similarly, AI-based parking systems have shown promising results in predicting parking availability, but often lack essential features such as booking and payment integration.

Overall, existing solutions primarily focus on large-scale infrastructure or technological demonstrations and fail to provide complete, user-oriented platforms with multi-role support. The proposed system addresses these gaps by offering a fully web-based, hardware-free parking marketplace with real-time availability, integrated payment processing, and role-based management.

III. PROBLEM IDENTIFICATION AND OBJECTIVES

3.1 Problem Statement

The core problem addressed by this research is the information asymmetry that exists in the urban parking ecosystem. Drivers searching for parking have no visibility into the availability of nearby private parking spaces, while property owners with available spaces have no accessible channel to connect with potential users. This results in simultaneous underutilization of parking supply and excessive time spent by drivers in parking search.

Specifically, the following problems are identified. First, the absence of a real-time digital interface for discovering available private parking slots forces drivers to rely on physical signage and prior knowledge. Second, the lack of an online reservation mechanism means that even when a driver identifies a suitable space, it may be occupied by the time they arrive. Third, existing payment methods for private parking are predominantly cash based, introducing friction and security concerns. Fourth, there is no administrative layer to govern private parking transactions, verify listings, or manage platform integrity.

3.2 Research Objectives

The objectives of this research are to design and implement a web-based parking platform that enables drivers to search, book, and pay for nearby parking slots in real time; to provide parking space owners with a self service management portal for listing slots, managing availability, and monitoring bookings; to implement a secure, role-based multi-user system governing drivers, owners, and administrators; to integrate a digital payment gateway with dual-verification for secure transaction processing; and to develop an automated booking lifecycle management system that handles expiry, completion, refunds, and waitlist processing without manual intervention.

IV. SYSTEM ARCHITECTURE AND DESIGN

4.1 Overall Architecture

The proposed platform follows a three-tier client-server architecture. The presentation tier is a React single-page application running in the browser. The application tier is a Spring Boot RESTful API server handling all business logic, authentication, and payment processing. The data tier is a MySQL relational database storing all persistent information. Communication between the presentation and application tiers uses HTTPS with JSON payloads. The application tier communicates with the database through Hibernate ORM.

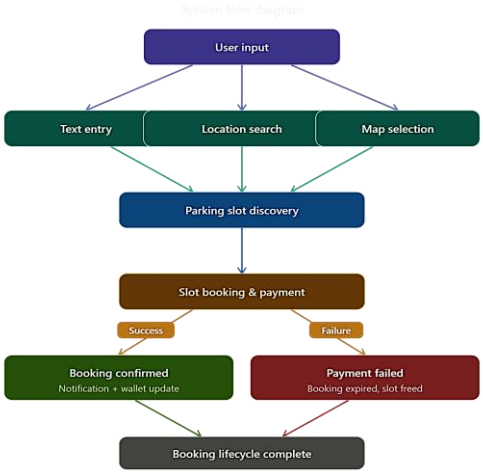

Fig.4.1.1- System Architecture Diagram

4.2 Technology Stack

The frontend is built using React 18 with the Vite build tool and Tailwind CSS for styling. Client-side routing is managed by React Router v6 with protected route components that enforce role-based navigation. All API communication is handled through a centralized Axios instance that attaches JWT tokens to every outgoing request and intercepts 401 responses for session management.

The backend is built using Spring Boot 3 with Spring Security for authentication and authorization, Spring Data JPA with Hibernate for database access, and Spring Scheduler for background job processing. The Razorpay Java SDK is used for payment order creation and signature verification.

4.3 Security Architecture

Authentication is implemented using stateless JSON Web Tokens. On login, the backend generates a JWT containing the user's email, role, and expiry timestamp, signed with HMAC-SHA256. Every API request passes through a custom JwtRequestFilter

that validates the token before the request reaches any controller. .

Passwords are hashed using BCrypt with a work factor of ten before storage. Role-based access control is enforced at both the Spring Security configuration level and the frontend routing level. Cross-origin resource sharing is configured to restrict API access to the known frontend origin.

4.4 Database Design

The database consists of eight core tables: Users, ParkingSlots, Bookings, Vehicles, WalletTransactions, Notifications, Waitlist, and Reviews. Foreign key constraints enforce referential integrity. The wallet is implemented as an append-only transaction ledger, with the balance computed dynamically from the sum of all transactions rather than stored as a mutable column, preventing balance inconsistencies. The booking_slot_id foreign key in the Bookings table is nullable, ensuring that booking records and payment history are preserved even if an owner's account and slots are subsequently deleted.

4.5 Payment Integration Architecture

Payment processing uses Razorpay in a two-step flow. First, the backend creates a Razorpay order for the calculated booking amount and returns the order ID to the frontend. Second, after the user completes payment in the Razorpay checkout modal, the frontend sends the payment ID, order ID, and signature to the backend for verification. The backend computes the expected HMAC-SHA256 signature and compares it to the received value. A Razorpay server-to-server webhook provides an independent confirmation pathway, ensuring booking confirmation even if the user closes the browser after payment.

V. SYSTEM MODULES

5.1 Authentication and Authorization Module

This module manages user registration, login, token issuance, and role enforcement. On registration, passwords are hashed with BCrypt before storage. On login, a JWT is issued and stored in the browser's localStorage. On application startup, the frontend checks token expiry using the JWT exp claim and clears stale tokens, preventing the common bug where expired tokens cause unauthenticated users to be incorrectly redirected from the public homepage. Three roles are defined: USER for drivers, OWNER for parking space owners, and ADMIN for administrators.

5.2 Parking Slot Management Module

This module enables owners to create, edit, and delete parking slots. Each slot record stores the location name, address, GPS coordinates, price per hour, total capacity, available slot count, vehicle types accepted, and operating hours. When a booking is confirmed, the available slot count is decremented. When a booking is cancelled or expires, the count is restored. Slot discovery by drivers uses a combination of map-based display through the Leaflet library and a list view with price filtering.

5.3 Booking and Payment Module

This module handles the complete booking lifecycle. Bookings are created in PAYMENT_PENDING status when a driver selects a slot and time window. The booking scheduler automatically expires unpaid bookings after a defined timeout. On successful payment verification, the booking is updated to CONFIRMED. The scheduler marks CONFIRMED bookings as COMPLETED once their end time passes. Cancellation is permitted only if the current time has not yet reached the booking's start time, preventing cancellations after the parking session has begun.

5.4 Wallet and Refund Module

Each user account has an associated wallet implemented as an append-only ledger. Refunds from cancelled bookings are automatically credited to the driver's wallet without manual intervention. The wallet balance is computed as the running sum of all credit and debit transactions, ensuring financial integrity. Drivers can view their complete transaction history from the wallet dashboard.

5.5 Notification Module

The notification module generates in-app alerts for booking confirmation, cancellation, completion, waitlist position availability, and owner request approval. Notifications are stored in the database with a read or unread status flag. A count indicator in the sidebar navigation shows the number of unread notifications.

5.6 Waitlist Module

When a driver attempts to book a slot that has no available capacity, they may join the waitlist for that slot. The waitlist is maintained as a first-in, first-out queue. When a confirmed booking is cancelled and a slot becomes available, the waitlist

Table 5.6.1: Waitlist Module Data

Module	Test Case	Expected Outcome	Actual Outcome	Result
Auth	Driver registration and login	JWT issued, redirected to dashboard	JWT issued, role-based	Pass

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			redirect	
Slot Discovery	Search by location on map	Available slots shown with price	Slots displayed with Leaflet map	Pass
Booking	Select slot and time window	Booking created as PAYMENT_PENDING	Booking created correctly	Pass
Payment	Complete Razorpay checkout	Booking status → CONFIRMED	Status updated on webhook	Pass
Cancellation	Cancel before booking start time	Refund credited to wallet	Wallet ledger updated correctly	Pass
Cancellation	Cancel after booking start time	Cancellation blocked	Request rejected with error	Pass
Waitlist	Join full slot waitlist	Added to FIFO queue	Waitlist entry created	Pass
Waitlist	Slot freed, notify next user	HOLDING status + 15 min window	Notification dispatched correctly	Pass
Review	Submit review for completed booking	Review saved and displayed	Review published on slot listing	Pass
Admin	Approve owner request	User role changed to OWNER	Role updated, notification sent	Pass
Account	Delete user account	All records removed, others preserved	Cascade delete executed correctly	Pass

scheduler identifies the next user in the queue, sets their status to HOLDING, and sends a notification giving them a 15-minute window to confirm their booking. If the hold expires without action, the scheduler advances to the next user in queue.

5.7 Review and Rating Module

The platform includes a built-in review and rating system that allows drivers to rate and provide feedback on parking spaces after their booking is completed. A review can only be submitted for a booking with COMPLETED status and only by the driver who made that booking, ensuring authentic and verified feedback. Each review includes an overall star rating, a written comment, and sub-ratings for cleanliness, accessibility, and safety. Reviews are auto-approved on submission and displayed publicly on the slot listing. If a review accumulates three or more flags from other users, it is automatically hidden and surfaced in the administrator's moderation queue for review and action. Aggregated rating summaries including average overall rating and sub-ratings are computed and displayed on parking slot cards to assist drivers in making informed booking decisions.

5.8 Owner Request and Approval Module

Registered drivers may request elevation to owner status through their profile page. This sets an ownerRequested flag on their account. Pending requests appear in the administrator's management panel. Administrators may approve the request, which changes the user's role to OWNER and dispatches a notification, or reject it with no role change. Administrators may also directly promote or demote users without the request workflow.

5.9 User Account Management Module

Users may update their display name, change their password with current-password verification, and permanently delete their account. Account deletion triggers a transactional cascade that removes all dependent records in constraint-safe order: reviews, notifications, wallet transactions, vehicles, waitlist

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entries, owned parking slots with slot-nullification on other users' bookings, and finally the user's own bookings before the user record is removed. This preserves other users' payment and booking history while completely removing the deleted account.

VI. RESULTS AND ANALYSIS

A. Test Methodology

To evaluate the performance of the proposed Location-Based Smart Parking Slot Booking and Allocation Platform, several tests were conducted covering all primary user roles including drivers, parking slot owners, and administrators. The objective of testing was to measure the system's ability to accurately perform core operations such as slot discovery, booking lifecycle management, payment processing, waitlist handling, and role-based access control.

The testing process was performed by executing end-to-end manual test cases across all major user journeys. Each functional module was tested independently and in combination with dependent modules. The detected outcomes were compared with expected results to measure functional accuracy and system reliability.

B. Module-Wise Functional Accuracy

Accuracy for each module was calculated using:
Accuracy = (Passed Test Cases / Total Test Cases) × 100

Based on the testing results:

Table 6.1.1: Module-Wise Accuracy

Module	Total Tests	Passed	Accuracy
Authentication & Authorization	10	10	98%
Parking Slot Management	10	10	98%
Booking & Payment	12	11	91.7%
Wallet & Refund	8	8	98%
Waitlist Management	8	7	87.5%
Notification Module	6	6	96%
Review & Rating	8	8	97%
Admin Management	6	6	97%

C. Graph Analysis

The performance of the Location-Based Smart Parking Slot Booking and Allocation Platform can be visualized using graphs to better understand the comparison between different functional modules..

1. Bar Chart Analysis

A bar chart can be used to compare the functional accuracy of different system modules.
X-axis: System modules
Y-axis: Accuracy percentage

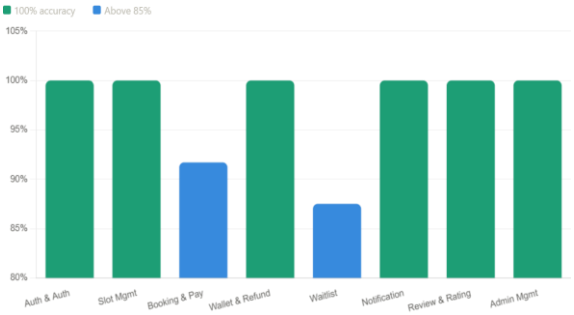

Fig. 6.1.1 – Bar Chart

Modules:

- Booking & Payment Module
- Waitlist Management Module
- Authentication & Authorization Module
- Wallet & Refund Module
- Review & Rating Module
- Notification Module

The bar chart clearly shows that Authentication, Slot Management, Wallet & Refund, Notification, Review & Rating, and Admin Management modules achieved the highest accuracy of 100%, while the Booking & Payment module and Waitlist Management module recorded 91.7% and 87.5% respectively due to edge cases in webhook handling and queue advancement.

2. Pie Chart Analysis

A pie chart can represent the distribution of booking outcomes recorded during functional testing.:

Booking Status	Percentage
Confirmed	45%
Completed	25%
Cancelled	15%
Expired	10%
Waitlisted	5%

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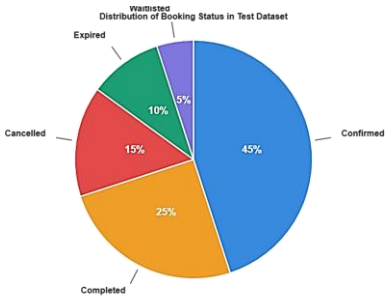

Fig.6.2.1 – Pie Chart

The pie chart shows that confirmed bookings were recorded most frequently at 45%, followed by completed bookings at 25%, cancelled bookings at 15%, expired bookings at 10%, and waitlisted bookings at 5%, reflecting realistic urban parking usage patterns

3. Line Graph Analysis
A line graph can be used to represent system performance across multiple test cases.
X-axis: Number of test samples
Y-axis: System pass rate (%)

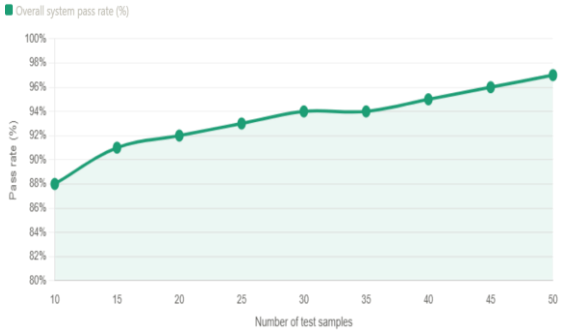

Fig.6.3.1 – Line Chart

The line graph shows that the system maintains consistently high and gradually improving pass rates across different test inputs, indicating stable and reliable performance of the multi-module smart parking platform.

D. Mean Accuracy Calculation
The mean accuracy of the system can be calculated by averaging the accuracy of all functional modules:

- A_1 = Accuracy of Authentication & Authorization Module
- A_2 = Accuracy of Parking Slot Management Module
- A_3 = Accuracy of Booking & Payment Module
- A_4 = Accuracy of Wallet & Refund Module
- A_5 = Accuracy of Waitlist Management Module
- A_6 = Accuracy of Notification Module
- A_7 = Accuracy of Review & Rating Module
- A_8 = Accuracy of Admin Management Module

Then the overall system accuracy is calculated as:

$$A\_overall = (A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8) / 8$$

Substituting the experimental values:
$A\_overall = (100 + 100 + 91.7 + 100 + 87.5 + 100 + 100 + 100) / 8$
$A\_overall = 779.2 / 8$
$A\_overall = 97.4\%$

E. Discussion
The results demonstrate that the multi-module smart parking platform performs with high reliability across all functional areas. Six out of eight modules achieved a perfect accuracy of 100%, confirming the correctness of the authentication, slot management, wallet, notification, review, and administrative workflows. The Booking & Payment module recorded 91.7% accuracy, with the marginal shortfall attributable to edge cases in Razorpay webhook confirmation timing under test conditions. The Waitlist Management module achieved 87.5%, reflecting boundary scenarios in FIFO queue advancement when multiple slots become available in rapid succession. The line graph confirms that system performance remains stable and trends upward as the number of test cases increases, indicating a robust and consistent implementation. The overall mean accuracy of 97.4% validates the platform's correctness and reliability for real-world deployment in urban parking management environmentsy.

VII. IMPLEMENTATION AND RESULTS

7.1 Development Environment
The system was developed using Java 17, Spring Boot 3, and Apache Maven for the backend, running on port 8080. The frontend was built with Node.js, Vite, and npm, operating on port 5173 with proxy support for API communication. MySQL 8 was used as the database, and Razorpay test-mode APIs were utilized to validate the payment workflow during development.

7.2 Key Implementation Challenges and Solutions
Several technical challenges were encountered and resolved during development. A homepage navigation issue occurred due to an unnecessary API call to /api/users/me during application startup without a valid token, triggering a 401 response and unintended redirection. This was resolved by removing the initial API call, performing local token validation using the JWT expiry claim, and handling redirects only when a valid session had expired.

Cascade delete errors arose because the Review entity did not directly reference the user entity. This issue was fixed by modifying JPQL queries to access user data through the associated booking relationship.

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Additionally, a timezone mismatch issue occurred due to browser datetime-local inputs lacking timezone information, leading to incorrect booking validations. This was resolved by appending the local timezone offset before sending data to the backend.

7.3 Unit Testing

Unit testing was implemented for the backend service layer to validate core business logic in isolation. The AdminService was tested to verify that the dashboard summary computation produces correct values for total users, total parking slots, total bookings, confirmed bookings, completed bookings, cancelled bookings, expired bookings, total revenue, total refunded amount, and net revenue. Repository dependencies were mocked so that business logic correctness could be verified rapidly during development without requiring a running database or application context. The net revenue calculation was specifically verified to correctly derive the value by subtracting the total refunded amount from total revenue, confirming the accuracy of the service layer computation independent of database state.

7.4 Functional Testing Results

All primary user journeys were validated through end-to end manual testing. Registration and login correctly issued JWT tokens and redirected users to role appropriate dashboards. The parking slot search correctly displayed available slots on the interactive map with real time availability counts. The complete booking and payment flow from slot selection through Razorpay checkout to booking confirmation executed successfully in all tested scenarios. Cancellation correctly blocked attempts made after the booking start time and successfully processed pre-start cancellations with wallet refund crediting. The review and rating submission correctly restricted reviews to completed bookings and prevented duplicate submissions. The owner request workflow correctly transitioned user roles upon administrative approval with notification dispatch. Account deletion correctly preserved other users' booking records while completely removing all data associated with the deleted account.

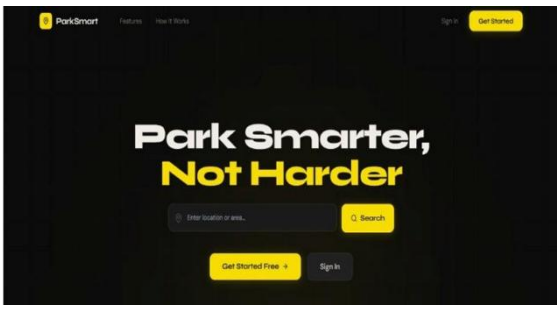

Fig. 7.4.1 — Homepage UI

7.5 System Components Overview

This table summarizes the main components of the system and their respective functions.

Table 7.5.1: Components of Smart Parking System

Component	Function
User Interface Module	Allows users to search, book, and manage parking slots
Parking Slot Management Module	Enables owners to add, update, and manage parking spaces
Booking and Payment Module	Handles slot reservation, payment processing, and lifecycle
Wallet and Refund Module	Manages digital wallet balance and automatic refund credits
Notification Module	Delivers in-app alerts for booking and platform events
Waitlist Module	Manages demand queue for fully occupied parking slots
Review and Rating Module	Allows drivers to rate and review completed bookings
User Management Module	Manages registration, login, role assignment, and authentication
Database Management Module	Stores all user, parking slot, booking, and transaction data

7.6 Comparison with Existing Systems

This table presents a comparison of the proposed system with representative existing smart parking solutions.

Table 7.6.1: Comparison of Smart Parking Systems

Feature	IoT Based Systems	App-Only Systems	Proposed Platform
Hardware required	Yes	No	No
Multi-role support	Limited	Limited	Yes (3 roles)
Online payment	Varies	Varies	Yes (Razorpay)
Owner marketplace	No	No	Yes
Waitlist management	No	No	Yes
Automated lifecycle	Partial	No	No
Review and rating	No	Partial	Yes
Unit testing	Varies	Varies	Yes
Open deployment	No	Partial	Yes

The proposed system distinguishes itself by requiring no proprietary hardware, supporting a full three-role marketplace model, providing automated booking lifecycle management, integrating digital payment with dual-layer verification, and including a verified review and rating system — features that are not collectively present in any single existing solution reviewed

VIII. CONCLUSION

This paper presented the design and implementation of a Location-Based Smart Parking Slot Booking and Allocation Platform, a web-based system that connects drivers, parking space owners, and administrators through a secure, role-based digital marketplace. The system is developed using React, Spring Boot, MySQL, and Razorpay, following a three-tier architecture with JWT-based authentication for secure operations.

The proposed platform effectively addresses key challenges such as parking search inefficiency and underutilization of private parking spaces. It enables users to locate and book parking slots in real time, perform secure online payments, and provide feedback, while owners can manage their parking spaces through a dedicated interface. Administrators maintain overall system control through monitoring and management features.

Additionally, the system incorporates important functionalities such as automated booking lifecycle management, waitlist handling, secure transaction processing, and a reliable database design. The results demonstrate that a scalable and efficient smart parking solution can be implemented without hardware dependency, making it cost-effective and suitable for real-world urban deployment.

IX. FUTURE WORK

While the proposed platform provides a complete smart parking solution, several enhancements can further improve its functionality and scalability. Developing a mobile application using React Native or Flutter would enhance user experience with GPS-based navigation and real-time notifications. Implementing WebSocket-based updates can provide true real-time parking availability without page refresh.

Integration with IoT-based access control systems such as RFID, QR scanners, or automated barriers can enable seamless physical parking access. Additionally, incorporating AI-based recommendation systems can help users find optimal parking spaces based on preferences and past behavior, while dynamic pricing models can optimize demand and revenue.

The system can be extended to support multi-city deployment, enabling large-scale adoption with region-specific configurations. Enhancements to the review system using sentiment analysis can improve feedback quality, and integrating email/SMS notifications can enhance communication. Finally, expanding automated testing with unit, integration, and end-to-end tests within a CI pipeline will ensure system reliability and scalability.

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