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AN EFFICIENT AND USER-FRIENDLY ANDROID APPLICATION FOR PARKING SLOT RESERVATION

Bazam e Jahan[1], Khadija Nadeem[*2], Mehreen Masood[3], Dure Sameen Munawar[4]

[1,*2,3,4]*Department of Computer Sciences, The University of Faisalabad, Faisalabad, Pakistan*

[1]bazam.e.jahan1@gmail.com, [*2]khadijanadeem547@gmail.com, [3]mehreenmasood17@gmail.com, [4]duresameen6060@gmail.com

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Corresponding Author: * **Khadija Nadeem**

Abstract
Parking inefficiencies in densely populated urban areas of Pakistan contribute significantly to traffic congestion, time loss, environmental degradation, and driver frustration, primarily due to limited space and the lack of real-time information on available parking spots. This paper presents the design and development of a Smart Parking Reservation Application as a practical solution to these issues. Developed using Android Studio with Java and integrated with Firebase for backend services, the proposed system introduces a two-role structure comprising Users and Administrators. The application allows users to register with email verification, locate nearby parking areas via a GPS-enabled map with color-coded markers, and reserve visualized slots through a booking form. It supports"Cash on Arrival" and includes a placeholder module for future integration of digital payment options. Upon booking confirmation, the system generates a QR code for ticket ver- ification. The administrative interface enables the addition of new parking locations, monitoring of reservations, transaction records, and management of registered users. Although real-time IoT integration and user feedback modules are identified as future enhancements, the current implementation offers a functional, scalable foundation for smart parking systems in Pakistan. By incorporating features such as dynamic pricing, push notifications, and potential AI-driven recommendations, the application demonstrates significant promise in enhancing urban mobility, reducing parking search times, and minimizing traffic-related environmental impacts in major Pakistani cities.

INTRODUCTION

Parking management has become a growing concern in modern urban environments. Due to rapid urbanization, increasing population density, and the continuous rise in vehicle ownership, many cities are struggling to keep up with the demand for parking spaces. As noted by the International Parking Institute, a significant portion of urban traffic congestion is caused by drivers searching for parking spots [1]. This inefficiency contributes to time delays, increased fuel consumption, traffic buildup, and negative environmental effects. In Pakistan, the parking problem is even more critical because of outdated infrastructure, a shortage of designated parking areas, and the absence of smart, technology-driven parking solutions. Research highlights that traffic issues in major Pakistani cities are closely linked to ineffective parking systems [2]. Key challenges include unauthorized on-street parking,

poor signage, and reliance on manual parking management. Many urban drivers regularly face difficulties finding available parking, particularly during busy hours in commercial and densely populated residential zones [2]. To address these challenges, this project introduces a Smart Parking Reservation System implemented as an Android mobile application [3]. The app enables users to check the availability of nearby parking spaces in real-time, compare locations based on distance, cost, and timing, and reserve a space in advance [4]. This system aims to improve convenience, reduce time spent searching for parking, and ease the overall burden on urban traffic. The application is equipped with GPS-based navigation, real-time updates integrated with Firebase, and secure digital payment methods, including contactless options and mobile wallets [4] [5].

Intelligent algorithms are used to recommend parking spots based on users' preferences and past behaviors [8]. Additional functions include booking alerts, QR-code ticket generation, and the ability to modify or cancel reservations with ease [6]. In addition to improving user experience, the system supports wider urban planning and sustainability goals. By helping reduce unnecessary driving and idle vehicle time, smart parking solutions contribute to more efficient fuel use and less congestion in crowded city zones [7]. The platform also promotes better use of existing parking infrastructure and offers potential for future integration with IoT sensors, municipal systems, and third-party services [7] [9]. Ultimately, this project delivers a forward-thinking and adaptable solution to one of the most pressing urban issues in Pakistan. Through the use of smart technology, it enhances daily driving experiences and aligns with broader objectives for sustainable, efficient, and connected urban living [6] [10]. Figure 1 illustrates the high-level workflow of the Smart Parking Reservation System. The process begins with the user interacting with the Android mobile application from their home or vehicle. Through the app, users can access real- time booking features and view available parking lots in their vicinity. Once a parking slot is selected, the system initiates a current booking that links directly to the designated parking area. Upon arrival, the user gains entry via a digital pass, and the process concludes with a payment step, which can be completed through integrated or offline payment options. This flowchart emphasizes the seamless integration between user interaction, booking management, parking availability, entry authorization, and payment handling within the proposed system.

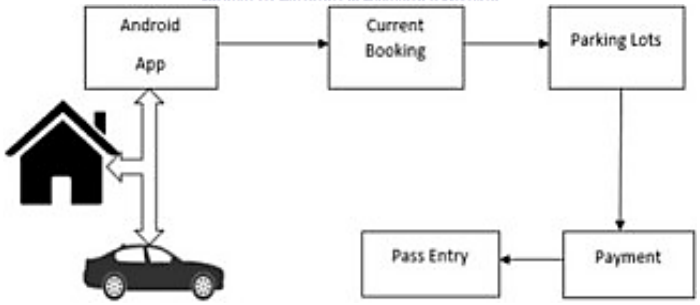

Fig. 1. Proposed Smart Parking System Architecture

Literature Review

The literature review highlights the growing trend toward technology-driven parking solutions, particularly mobile applications, as an effective response to urbanization, traffic congestion, and limited parking spaces [1] [2]. Modern parking apps prioritize user-centric design, offering intuitive interfaces, easy navigation, personalized recommendations, and features like voice-guided navigation and multi-language support [8]. Seamless payment integration has become a standard, enabling users to pay directly through various methods such as mobile wallets, contactless systems, and credit cards, with additional options like payment reminders and subscription plans [4] [5]. Location-based services leverage GPS technology for precise navigation, while advanced features like geofencing and augmented reality provide added convenience [4] [6]. Real-time data powered by IoT devices is essential for monitoring parking availability, delivering accurate

updates to users, and employing AI-driven predictive analytics to identify availability of its trends [2] [7].

Cloud-based infrastructure ensures scalable and secure data management, enabling real-time synchronization and multi-location operations [3] [7]. These apps also integrate with broader transportation systems, including public transit and EV charging networks, enhancing urban mobility and contributing to smart city initiatives [7]. The importance of user experience is evident, with features like personalized parking suggestions, one-tap booking, and real-time feedback driving user satisfaction [6] [8]. Accurate real-time data on parking availability remains crucial for effective management, while integration with other systems further improves urban mobility [2] [7]. Robust security measures, including encryption and multi-factor authentication, safeguard user data and ensure compliance with global data protection regulations [9] [10]. Additionally, these solutions have a positive environmental impact by reducing traffic congestion and emissions and offer economic benefits through dynamic pricing and optimized space utilization [5] [7]. Despite challenges such as high initial costs and connectivity issues in developing regions, the opportunities for innovation, such as cost-effective IoT solutions and offline-capable systems, continue to grow [7]. This review underscores the pivotal role of technology in addressing urban parking challenges and provides a foundation for developing parking apps tailored to the specific needs of Pakistani cities, with a focus on improving user experience and urban efficiency [1] [6] [8].

Use Case Requirements

The Parking Reservation App offers a comprehensive set of features to enhance the user experience and ensure efficient parking management. Users can create accounts, securely log in, and log out of the system. The app displays real-time availability of parking slots in nearby locations, enabling users to view and select available spots. Once a suitable spot is found, users can reserve it for a specific time period. Upon booking, the system sends push notifications for confirmations, cancellations, and account verification. A built-in payment module allows users to simulate payments by entering card details, which are securely stored in Firebase for reference, although live payment integration is not implemented. Users also have the flexibility to cancel or modify their reservations when needed. The app maintains a complete history of all user bookings, which can be accessed through the dashboard. For ease of access, GPS and map integration provide navigation to the reserved parking locations. Administrators are equipped with a dedicated dashboard where they can manage users, review booking and payment histories, oversee user feedback, and add or remove map locations. After a successful reservation, the system generates a unique QR code for ticket validation at the parking site. Lastly, the app includes a feedback feature, allowing users to submit reviews, which the admin can view and manage for service improvement.

Methodology

The development of the Smart Parking Reservation App employed a modular and agile methodology, blending scholarly insights with iterative, user-focused engineering practices. Agile development facilitated continuous integration, rapid prototyping, and adaptive changes in response to stakeholder feedback—an approach particularly well-suited for evolving mobile applications in smart city contexts [6] [8]. At the outset, functional and non-functional requirements were established based on common user expectations, including real-time slot tracking, GPS-based location discovery, secure login, and payment simulation. These features were prioritized in early sprints and refined through feedback loops and testing cycles. To structure the system, Object-Oriented Design (OOD) principles were applied, organizing software entities such as User, Reservation, Parking Slot, Admin, and Payment into distinct reusable classes, thereby ensuring modularity, code reusability, and easier debugging [8]. Real-time functionality was enabled through Firebase Realtime Database and Firebase Authentication, which supported user data storage, login management, slot status synchronization, and transaction recording in real time [2] [7]. Android Studio and Java were selected for frontend and backend development due to their compatibility.

scalability, and ease of integration with Google's APIs and Firebase services. Though not heavily cited in research, these tools provided a reliable foundation for mobile app develop- ment in constrained urban environments.

The booking mechanism includes a simulated card payment module with proper input validation and error handling, based on digital payment workflows found in literature on smart transaction systems [4] [5]. Booking confirmation generates a secure QR code, which encodes unique identifiers like user ID, slot ID, and timestamp—drawing from established models of digital authentication and access control [9]. Testing was conducted using black-box and white-box techniques, validating critical functions like form validation, slot conflict resolution, and map rendering. Concurrency testing and logical verification strategies were partially inspired by reinforcement learning algorithms proposed for smart parking optimization in prior studies [1].

Although current implementation excludes direct integration with IoT-based sensors or AI-driven recommendation engines, the system architecture is designed with flexibility to support these enhancements in future iterations. These include live slot availability through embedded hardware, predictive sugges- tions based on user history, and dynamic pricing models tied to demand fluctuations [7] [8]. Overall, the methodology reflects a balanced application of theoretical models and practical engineering, resulting in a scalable, maintainable, and user- oriented smart parking solution tailored to the urban challenges of Pakistan.

System Architecture Design

The system architecture of the Smart Parking Reservation App is designed using a layered, modular Object-Oriented Design (OOD) approach, with components structured around real-world entities such as Users, Administrators, Reservations, Parking Slots, and Payments. Developed in Java using Android Studio and integrated with Firebase, the architecture separates concerns across multiple layers—frontend user interfaces, backend data services, and application logic—enhancing scalability, maintainability, and performance [2] [6] [7]. Agile development principles guided the project lifecycle, enabling iterative progress, user feedback integration, and flexible feature expansion throughout the development process [6] [8]. The app supports two primary user roles: Users and Admins. Users register with email verification and log in to view GPS-enabled maps (Google Maps API) showing nearby parking zones with color-coded markers. They can select a location, view slot availability, fill a booking form, and choose between "Cash on Arrival" or a simulated card payment method, after which a QR code is generated for digital ticket verification [4] [9]. Admins, after logging into the dashboard, can manage users, view bookings and transactions, add new parking locations or slots, and eventually monitor feedback, which is reserved for future integration. The system includes modules for user management, parking availability, card payment simulation, notification, QR code generation, and admin control—all interconnected through Firebase Authentication and Realtime Database [2] [5] [7]. This modular and agile-enabled architecture not only ensures robust operation and data security but also prepares the system for future enhancements like IoT-based slot detection, AI-powered suggestions, and real-time dynamic pricing. The overall architecture is illustrated in Figure 2, showcasing interaction flows among components, validating the system's suitability for scalable deployment in urban Pakistani environments.

Fig. 2. System Architecture Overview

IMPLEMENTATION

The Smart Parking Reservation App was implemented using Java in Android Studio, supported by Firebase for real-time backend services, authentication, and cloud-based data storage. The development process followed agile methodology principles, enabling incremental progress, continuous testing, and iterative enhancements based on user and stakeholder feedback [6] [8]. The app architecture was grounded in Object-Oriented Design (OOD), which allowed the system to be structured around modular, reusable classes such as User, Admin, Slot, Booking, and Payment, improving code clarity and long-term scalability [8]. Two core roles were defined: regular users and administrators. Users are required to register with email verification and then log in to access the system. Upon successful authentication through Firebase Authentication, users are directed to a GPS-enabled map interface powered by the Google Maps API, where nearby parking locations—added by the admin—are displayed with color-coded markers that reflect their availability [4] [6]. Users can either tap directly on a location marker or search using the integrated Google Places search bar to view available slots. Once a location is selected, users are presented with a visualized slot selection interface. Though these slots are simulated in the current version, they mimic real-world functionality and are managed through Firebase Realtime Database, ensuring synchronization across devices [2] [7].

Users can choose a slot and complete a booking form, selecting between two payment modes: "Cash on Arrival" or a simulated card payment module. The card simulation validates inputs like card number, expiry date, and CVV, laying the groundwork for future integration of actual digital payment gateways [4] [5]. After submitting the booking, users receive a confirmation via Firebase Cloud Messaging and are issued a unique QR code ticket. This QR code, generated using encoded booking ID, user ID, slot ID, and timestamp, enables secure, contactless check-in at the parking facility and is inspired by modern blockchain- based digital verification frameworks [9]. The system ensures that every booking is traceable and secure, promoting trust and accountability. On the admin side, administrators log in to a dedicated dashboard where they can add new parking locations (shown only to users in the relevant vicinity), update or remove parking slots, and manage all active reservations, transaction records, and registered user accounts in real time [7]. While user feedback and advanced alert systems are reserved for future updates, the current version ensures stable core operations. Firebase serves as a centralized hub for real- time data communication and consistency across modules. Together, these components form a robust, scalable solution for urban parking challenges, demonstrating how scholarly insights and real-world engineering tools can be blended to produce a smart, maintainable, and extensible application suitable for

the Pakistani urban environment [2] [8]. The implementation effectively reflects a thoughtful integration of modern technologies, agile software engineering, and modular architecture, ensuring the app is both functional now and ready for future enhancements such as IoT sensor input, AI-based slot prediction, and secure financial integrations.

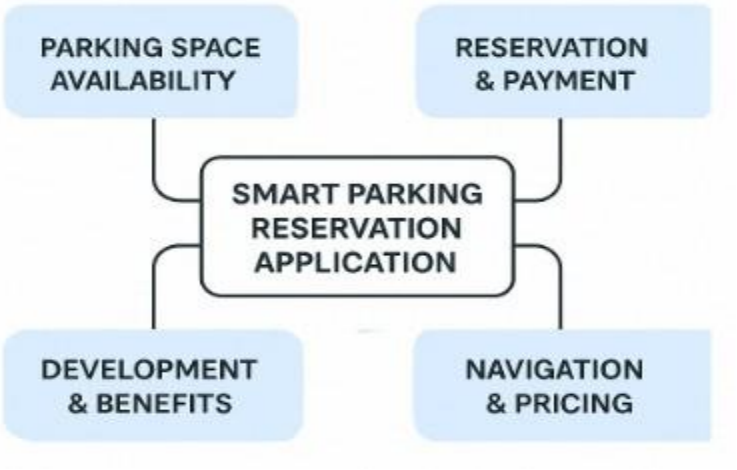

Fig. 3. System Workflow Diagram

Result And Discussion

Mobile Users 2022–2025

The number of mobile connections was recorded at approximately 195 million in 2022, dropping to 191 million in 2023, and slightly further to 189 million in 2024. However, a rebound occurred in 2025, reaching 190 million mobile users. This consistent mobile penetration indicates a stable digital user base, highlighting Pakistan's readiness for online service platforms. Figure 4 shows the yearly trend in mobile phone usage across Pakistan, based on survey data collected between 2022 and 2025. The insights from this figure are particularly valuable for evaluating the feasibility of mobile-based solutions such as smart parking apps. Despite minor fluctuations, the consistently high user base confirms that mobile-based applications will continue to gain traction, especially in urban areas where parking and traffic management are pressing concerns.

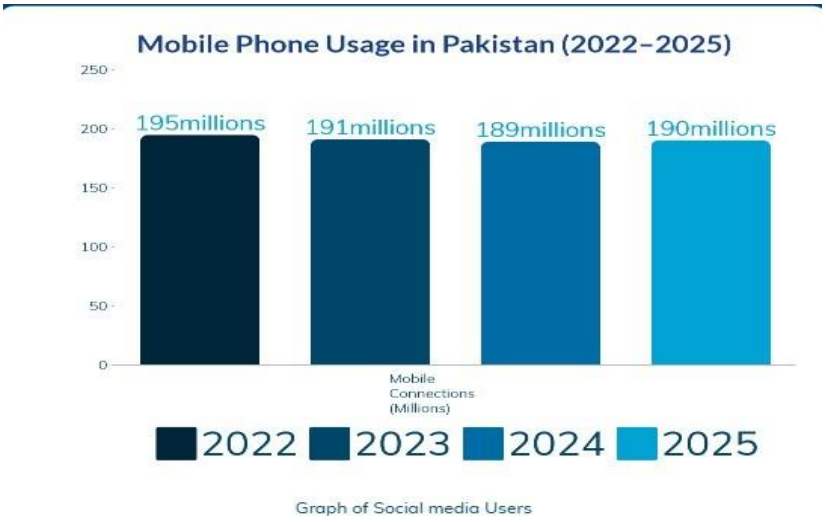

Fig. 4. Mobile users 2022-2025

Overall Result: The results of this survey demonstrate that mobile connectivity remains widespread and steady in Pakistan, with an average of around 191 million users over the observed period, as shown in Figure **4**. This high penetration rate indicates a strong foundation for deploying smart mobile applications, such as the Smart Parking Reservation App. The consistency in mobile user volume reinforces the potential for mass adoption of digital services, particularly those focused on urban mobility, parking management, and smart infrastructure.

Car Parking Reservation App Usage Trend in Major Pakistani Cities (2022–2025)

Figure 5 illustrates the increasing trend in the adoption of car parking reservation applications across major Pakistani cities from 2022 to a projected 2025. The upward movement is attributed to the growth of digital initiatives and the integration of QR-based payment technologies. The data suggests a substantial rise in user adoption in all four cities: Karachi from 3% to 30%, Faisalabad from 10% to 50%, Lahore from 5% to 40%, and Islamabad from 10% to 65%. Among these, Islamabad exhibits the highest projected adoption rate, reflecting strong momentum toward the adoption of digital parking solutions in the capital's urban ecosystem.

Fig. 5. Digital Parking Adoption Report

LIMITATIONS OF THE PROJECT

The project faced several constraints that impacted its overall effectiveness. One major limitation was its limited geographical coverage, as the app currently operates only within a specific region. Additionally, the existing infrastructure may not efficiently handle a large volume of users, raising concerns about scalability. The absence of dynamic pricing restricts the app's flexibility in adapting to peak and off-peak demand, while the integration of only basic pay- ment gateways limits user convenience. Moreover, the app lacks real-time availability of slots, an effective application management system that could prioritize booked users over walk-in users, and IoT-based sensors or alarms to monitor and manage booked parking slots efficiently. Despite these challenges, these limitations have highlighted valuable areas for future improvement and expansion.

FUTURE WORK

Future enhancements for the parking reservation app include integrating IoT sensors for real-time spot detection to improve accuracy and forming partnerships with parking providers to expand coverage and available options. The app could also support advanced payment methods such as digital wallets, UPI, and contactless transactions. AI-powered recommendations can be introduced to suggest optimal parking spots based on user habits and current location, while a dynamic pricing system could adjust rates based on demand and availability. Additionally, implementing priority-based parking allocation would help reduce search time by favoring

nearby users. In cases where a reserved slot is occupied, the app could trigger alerts, suggest alternatives, and offer cancellation or waitlist options to enhance the user experience.

CONCLUSION

The Parking Reservation App effectively addresses the core challenges of unorganized and time-consuming parking by offering a digital platform for advance slot reservations and location-based parking discovery. Through a user-friendly interface, GPS-based real-time location tracking, and visual slot management, the app significantly improves user convenience and urban mobility. Users can seamlessly navigate, search, and book available slots, while administrators maintain full control over location management, slot allocation, and user data. Although the app currently employs a simulated card payment option and lacks real-time slot updates and feedback systems, its modular design ensures ease of future enhance- ments, including IoT integration, automated payments, and AI-driven recommendations. Overall, the application stands as a scalable solution for modern urban parking management, promising reduced traffic congestion, minimized search time, and enhanced user satisfaction.

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