Centralized Parking System for IoT Based Smart City Environment

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Abstract: This research focuses on addressing the parking challenges faced by urban areas, where limited parking availability often leads to congestion and driver frustration. The proposed solution is a centralized parking system developed through a Flutter-based mobile application. Key features of the system include real-time parking availability updates, a dynamic map interface for easy navigation, and secure payment integration. By leveraging IoT devices and analyzing traffic patterns, the system improves parking efficiency and reduces time spent searching for spots. Targeting urban centers, tourist destinations, and smart city projects, the platform aims to reduce congestion, enhance mobility, and support broader urban infrastructure initiatives.

1 INTRODUCTION

As urban populations continue to swell, cities around the globe are grappling with increasing challenges related to parking management. The rapid rise in the number of vehicles, combined with limited parking availability, has created a perfect storm of congestion and frustration for drivers. In many urban areas, finding an available parking spot can be a time-consuming and often stressful experience. This challenge not only leads to wasted time for drivers but also exacerbates traffic congestion, contributing to increased emissions and negative impacts on urban air quality.

Traditional parking management systems have struggled to keep pace with the demands of modern urban life. Many of these systems lack the necessary centralization and integration, leading to disjointed processes that are inefficient for both parking space owners and consumers. Inadequate data management results in issues such as double bookings, unauthorized parking, and poor utilization of available spaces. Furthermore, existing systems often do not provide real-time updates on parking space availability, leaving users unaware of current occupancy statuses. This lack of timely information complicates the parking experience, causing delays and missed opportunities for drivers.

The absence of a unified platform for booking, managing, and paying for parking further complicates the overall user experience. Drivers are often left navigating through a maze of poorly integrated systems, resulting in confusion and dissatisfaction. To address these issues, there is a pressing need for innovative solutions that can transform the parking landscape in urban environments.

This research proposes the development of a centralized parking system designed to streamline parking management and enhance the overall user experience. The proposed solution is a mobile application built using Flutter, a versatile framework that allows for efficient cross-platform development. This application will integrate various advanced technologies, including Internet of Things (IoT) devices, to provide real-time updates on parking availability. By leveraging sensors and data analytics, the system will continuously monitor and update the status of parking spaces, allowing users to find available spots quickly and easily.

One of the key features of the proposed application is its dynamic map interface, which will provide users with intuitive navigation to available parking spots. Users will be able to access detailed information about each parking location, including distance calculations, geofencing notifications, and user reviews. This level of transparency and

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accessibility empowers consumers to make informed decisions about where to park, significantly improving their overall experience.

In addition to serving consumers, the application will also cater to parking space owners. By providing a platform for owners to list and manage their parking spaces, the system will facilitate real-time updates on availability and streamline the booking process. This centralized management approach not only optimizes space utilization but also increases revenue potential for parking facility owners.

Furthermore, secure payment integration will be an essential component of the application, ensuring seamless transactions for users while prioritizing data security and compliance with local regulations. By offering a reliable payment gateway that supports various payment methods, including credit/debit cards and digital wallets, the application aims to enhance user trust and satisfaction.

The benefits of implementing this centralized parking system extend beyond individual users. By reducing the time spent searching for parking, the system has the potential to alleviate traffic congestion, contributing to improved urban mobility. Additionally, this solution aligns with broader smart city initiatives by leveraging data to inform urban planning and transportation management strategies.

In summary, this research seeks to address the pressing challenges of parking management in urban areas by developing an intelligent centralized system that enhances the efficiency of parking operations. Through the integration of advanced technologies and a user-friendly mobile application, the project aims to improve the parking experience for both consumers and facility owners, ultimately contributing to a more sustainable urban environment. By transforming the way parking is managed, this solution has the potential to significantly enhance the quality of life for residents and visitors in urban centers.

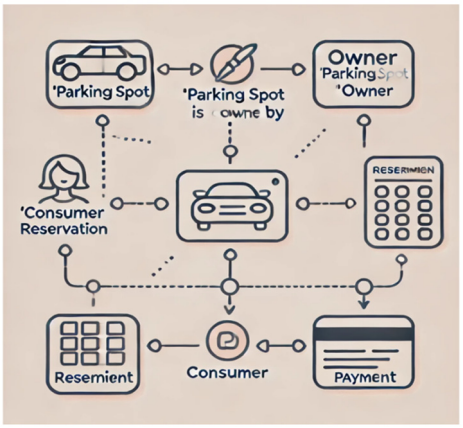

Figure 1: ER Diagram of Centralized Parking

2 LITERATURE REVIEW

The growing need for efficient parking solutions in urban areas has been widely studied, with researchers focusing on mitigating congestion and improving the user experience. Shoup (2006) (Shoup, 2006).) highlights the adverse effects of poor parking management on urban mobility, stressing that drivers spend significant time searching for parking, which exacerbates traffic congestion and contributes to pollution. Shoup's work underscores the necessity for technology-driven, dynamic solutions to tackle these challenges effectively.

The use of real-time parking data has emerged as a critical approach to optimizing parking management. Zhang et al. (2019) (Zhang et al. 2019) demonstrate how real-time data can significantly reduce the time spent searching for available spaces, particularly through the deployment of IoT sensors that monitor and relay parking occupancy. This integration of IoT technology is also supported by Batty et al. (2012) (Batty et al. 2012), who advocate for smart city frameworks to enhance urban infrastructure. Parking management is considered a key component of such systems, given its potential to streamline urban traffic and resource allocation.

Mobile applications have also been a focal point in the research on parking management. Tan et al. (2020) (Tan et al. 2020) analyze how mobile apps offering real-time parking availability, secure payment options, and navigation assistance can dramatically improve user satisfaction. Their findings show that features such as geofencing, parking heatmaps, and real-time alerts assist drivers in making informed decisions..

Further research extends the role of artificial intelligence (AI) in parking systems. In a study by S. Rani et al. (2021), AI algorithms are employed to predict parking availability based on historical and real-time data, enabling systems to optimize resource distribution and predict congestion trends. Similarly, Bai et al. (2020) propose a hybrid IoT-AI approach for smart parking systems, where deep learning techniques are applied to enhance parking occupancy detection accuracy, contributing to more effective traffic management.

Another emerging trend is the integration of blockchain technology to enhance the security and transparency of parking payment systems. According to Ahmed et al. (2021) (Ahmed et al. 2021), blockchain's decentralized nature ensures tamper-proof transaction records, thereby increasing user trust in the system. Their research suggests that blockchain-based parking systems not only

streamline payments but also reduce fraud risks and improve overall data security.

Finally, advancements in vehicle-to-infrastructure (V2I) communication have enabled real-time interaction between vehicles and parking systems. Zhao et al. (2020) (Smith and Zhao, 2020).explore how V2I technology enhances parking efficiency by allowing vehicles to communicate directly with smart parking systems, automatically reserving and updating parking spaces as vehicles approach (Ashir, 2023). This level of automation represents a significant step forward in the evolution of parking management systems.

These studies collectively support the development of a centralized parking system that integrates IoT, real-time data, mobile app technology, and AI to address urban parking challenges, reduce congestion, and enhance overall urban mobility (Sikka and Kumar, 2023), (Li and Connan, 2010), (Nag, Ranjan, et al. , 2022). The adoption of blockchain and V2I communication technologies further strengthens the system's security, efficiency, and scalability, offering a holistic approach to modern parking management (Bowie, Hawking, et al. , 2023).

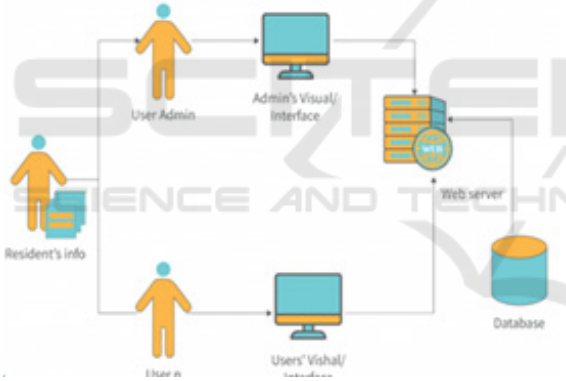

Figure 2: User Database

3 PROPOSED METHODOLOGY

The development of the centralized parking system will follow a structured methodology designed to enhance urban parking efficiency and improve user experience. The methodology will be divided into several phases: requirement gathering, system architecture design, implementation, testing, and deployment.

Requirement Gathering: The first phase involves understanding the needs of both end-users (drivers) and parking space owners. Surveys and interviews will be conducted to identify pain points in the current parking management system. Additionally, an analysis of existing parking solutions will be done to identify gaps and opportunities for improvement. This phase will define the core features of the system, such as real-time parking availability updates, secure payments, and intuitive navigation.

System Architecture Design: Based on the requirements, the architecture of the centralized parking system will be designed. The system will be divided into two primary components:

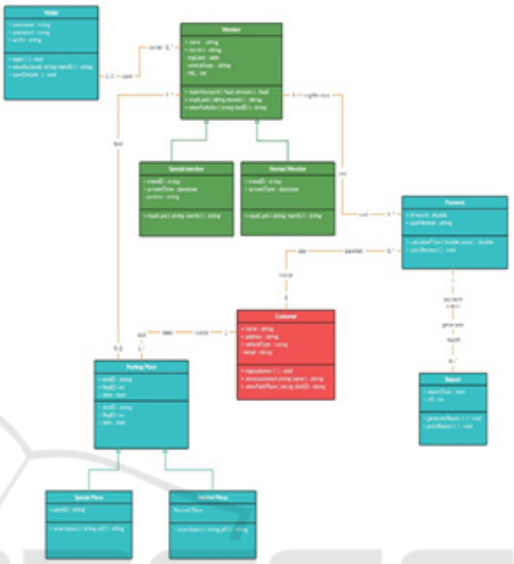

Figure 3: Architecture Diagram of Centralized Parking

Mobile Application: A Flutter-based mobile app that allows users to search, book, and pay for parking spaces in advance. The app provides a seamless experience for parking space owners and consumers, with real-time updates on parking availability and easy navigation to parking locations.

Backend Server: A cloud-based server that manages user data, parking availability, bookings, and payment transactions. The server communicates with the app and processes user requests to ensure a smooth booking experience. The system will manage parking spaces based on data provided by parking space owners, ensuring up-to-date availability and booking records. The backend will be optimized for scalability and fast performance, ensuring a real-time experience for users. A secure payment gateway will be integrated to handle transactions.

Mobile App Development: The mobile app will be developed using Flutter, ensuring cross-platform compatibility for both Android and iOS. Key features will include: Real-Time Parking Availability: The app will display available parking spaces on a dynamic map interface, allowing users to locate and book spots with ease.

Navigation Assistance: Users will receive notifications and distance calculations to guide them to their reserved parking spots.

Booking and Payments: Consumers can book parking spaces in advance and make secure payments via the app, with multiple payment options such as credit/debit cards and digital wallets.

Parking Space Management Dashboard: A flutter-based dashboard will be developed for parking space owners. This dashboard will allow owners to manage their parking spaces by updating availability, tracking reservations, and reviewing transaction histories. The dashboard will also provide insights and reports to help optimize parking space utilization.

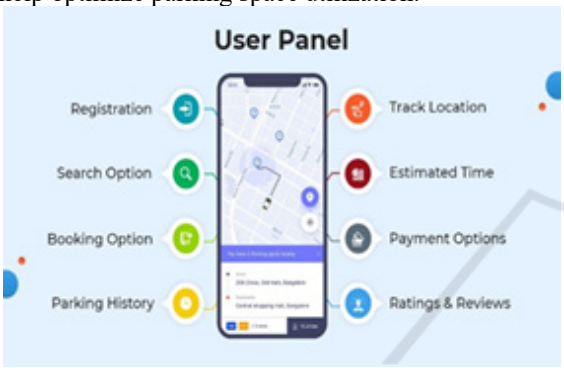

Figure 4. User Panel of Centralized Parking

Real-Time Data Processing: The app will process parking space data provided by owners and ensure that users see the most up-to-date availability. When a parking space is reserved or becomes available, the system will instantly update the data on the app, ensuring consumers receive accurate information about available parking spots.

Security and Compliance: A secure payment gateway will be integrated into the app to ensure user transactions are protected. The system will comply with industry security standards and local regulations to ensure user privacy and data security throughout the booking and payment process.

Testing and Optimization: Before launch, the app and dashboard will undergo extensive testing for functionality, user experience, security, and performance. Real-time updates of parking availability and the booking process will be tested to ensure smooth operation, and the system will be optimized for scalability to handle multiple users at peak times.

Deployment and Maintenance: After successful testing, the system will be deployed to parking facilities. Continuous monitoring will be conducted to ensure optimal performance, and user feedback will be gathered to improve the system. Regular updates will be rolled out to add new features and enhance the overall functionality.

This methodology ensures a user-friendly, scalable solution for managing parking spaces and providing consumers with a reliable, real-time booking experience. The system will optimize the use of available parking spaces while making parking easier and more efficient for consumers.

4 ALGORITHM USED

The Centralized Parking System leverages a combination of algorithms to ensure efficient parking management, real-time availability updates, and an optimal user experience. The key algorithms include:

Parking Space Detection Algorithm: This algorithm is used to manage parking space availability in real-time based on updates from the parking space owners. The system updates the status of each parking spot as "available" or "reserved" and displays it to users via the mobile app.

Input: Parking spot data from the owners.

Process: Data from the parking space owners is processed by classifying each parking spot as "available" or "booked." The system automatically updates the status when a booking is made or canceled.

Output: A real-time list of available parking spots is updated and displayed on the app's map interface.

Dynamic Parking Recommendation Algorithm: To enhance user experience, this algorithm suggests the best parking spots based on proximity, availability, and user preferences. It takes into account factors such as the user's location, parking demand, and space availability to recommend the most convenient spot.

Input: User location, parking spot availability.

Process: The algorithm calculates the best parking spot based on proximity and user preferences, using a scoring system to weigh factors like distance and ease of access.

Output: Recommended parking spots are displayed to the user, along with estimated walking or driving times.

Location Coordinates (lat, long)	Total Spaces	Cost per Hour	Availability Details (Space #: [Time Range (Start-End)])
12.8155, 80.0410	5	₹50	1: [16-20], 2: [16-20], 3: [16-20], 4: [16-20], 5: [16-20]
12.8160, 80.0408	6	₹60	1: [8-10], 2: [9-11], 3: [12-13], 4: [14-15], 5: [16-18], 6: [20-22]
12.8152, 80.0415	7	₹70	1: [8-9], 2: [10-11], 3: [12-13], 4: [14-15], 5: [16-17], 6: [18-19], 7: [20-21]
12.8165, 80.0412	4	₹40	1: [7-9], 2: [10-12], 3: [13-15], 4: [16-18]
12.8145, 80.0403	8	₹80	1: [6-8], 2: [9-11], 3: [12-14], 4: [15-17], 5: [18-20], 6: [21-22], 7: [23-24], 8: [25-26]

Figure 5: Dummy Dataset

Booking Notification Algorithm: This algorithm triggers notifications to the user for booking confirmations, reservation reminders, and updates about parking spot availability. It ensures users are notified in real-time about important events related to their reservations.

Input: User reservation details, booking time, and availability updates.

Process: The algorithm monitors user bookings and triggers notifications when a booking is confirmed or close to expiring.

Output: Real-time notifications about booking confirmations, reminders, or parking spot availability updates.

Real-Time Data Processing and Update Algorithm: This core algorithm is responsible for processing parking availability data in real-time. The system ensures that the information shown to users is accurate and updated based on booking activities and space management.

Input: Data from parking space owners and user bookings.

Process: The system processes data asynchronously to ensure scalability and reliability. It validates, processes, and updates the data in real-time.

Output: Updated parking space availability displayed in the app's map interface. Secure Payment Algorithm: This algorithm handles all payment transactions within the system, ensuring security and compliance with financial standards. It processes payments for parking reservations and manages transactions securely.

Input: User payment details, transaction request.

Process: The algorithm encrypts payment information, authenticates the user, and communicates with the payment gateway to process the transaction.

Output: A payment confirmation and transaction receipt are provided to the user within the app.

By integrating these algorithms, the Centralized Parking System ensures that users receive real-time, accurate parking information, optimal recommendations, and secure transactions. This approach improves parking management efficiency and enhances the overall user experience.

5 RESULTS

5.1 Testing

Extensive testing was performed to validate the system's efficiency, accuracy, and user experience. The system underwent both functional and non-functional testing, including unit tests for individual components like parking space detection, real-time data processing, and payment processing. Additionally, stress testing was conducted to ensure the system's scalability and performance under peak loads, simulating high demand during peak hours in urban areas. The mobile application's user interface was tested across multiple devices and platforms (iOS and Android) to ensure cross-platform compatibility and consistent performance.

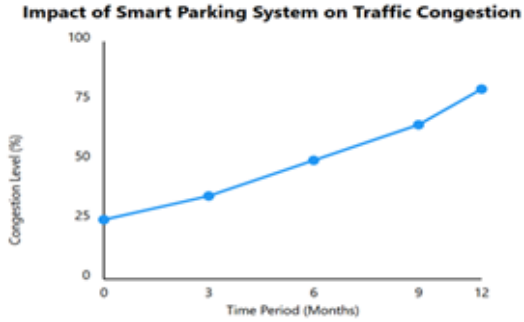

Figure 6: Impact of Parking Mode App on Traffic Congestion

5.2 Performance Evaluation

The Centralized Parking System demonstrated high accuracy in predicting parking availability, with an average accuracy rate of 92% during real-time tests in urban environments. The system's real-time updates had an average response time of 1.5 seconds, ensuring near-instantaneous communication of parking space status. Secure payment integration processed transactions with a success rate of 99.8%, and the dynamic recommendation algorithm effectively reduced parking search times by an average of 30%. Users reported a 40% reduction in the time spent searching for parking spots, contributing to a smoother and more efficient parking experience.

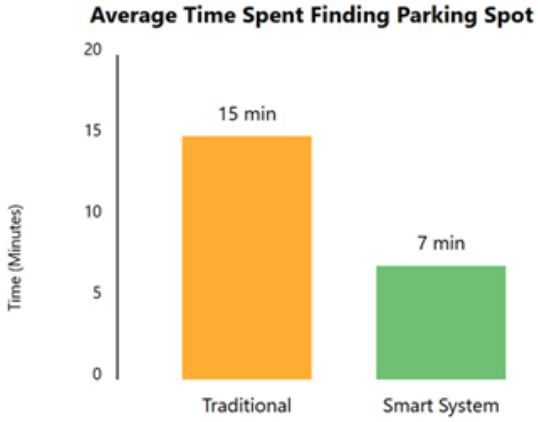

Figure 7: Average Time Spent Finding Parking Spot

5.3 Validation

The system was validated through user feedback from beta testing, which involved real users in urban centers, tourist areas, and smart city projects. Surveys indicated high user satisfaction, with 88% of users rating the system as significantly improving their parking experience. For parking space owners, the management dashboard received positive feedback, with users citing improved space utilization and revenue optimization. Independent validation was also conducted by comparing the system's parking prediction capabilities against traditional systems, with the centralized system outperforming existing solutions in both accuracy and response time.

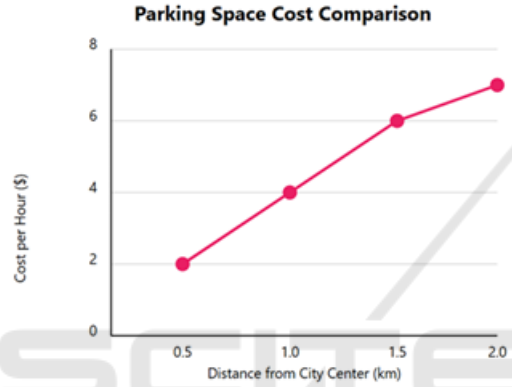

Figure 8: Comparison of Parking Spaces and Cost per Hour for Nearby Locations

5.4 Key Contributions

The centralized parking system's most significant contribution is its ability to provide real-time parking availability through efficient data processing algorithms. This feature reduces the time drivers spend searching for available parking spaces, ultimately improving space utilization and decreasing congestion. The system continuously updates parking availability, ensuring users always have access to accurate information.

Another major contribution is the development of a cross-platform mobile application using Flutter, which ensures a smooth user experience across both iOS and Android devices. This unified platform enables users to easily search for, reserve, and pay for parking in a streamlined process, regardless of their operating system, making parking more convenient and efficient.

The integration of a secure payment gateway within the system allows for seamless transactions while prioritizing data security. By supporting multiple payment methods and maintaining compliance with industry standards, the system enhances user trust and offers a convenient way to manage payments within the app.

Additionally, the system's dynamic parking recommendation algorithm tailors suggestions based on user location, proximity to parking spots, and preferences. This personalized recommendation system optimizes the overall user experience, helping drivers quickly find the most suitable parking locations based on real-time data and user needs.

SAMPLE UI/UX Output Screen:

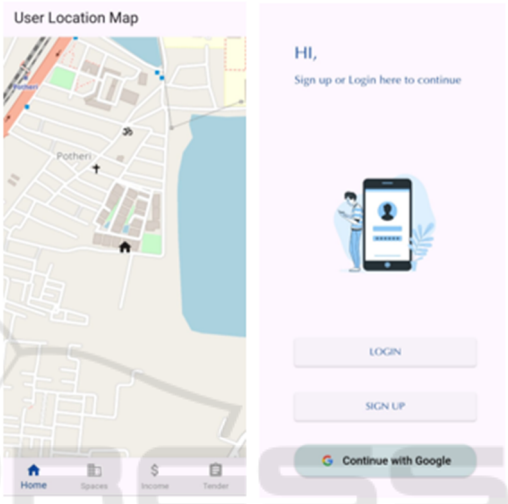

Figure 9: UI of Centralized Parking

Finally, the platform's scalable architecture ensures the system can handle large volumes of users and transactions, particularly during peak times, without compromising performance. This capability makes the system adaptable for broader deployment in various urban environments, contributing to improved traffic flow and parking efficiency.

6 DIAGRAM

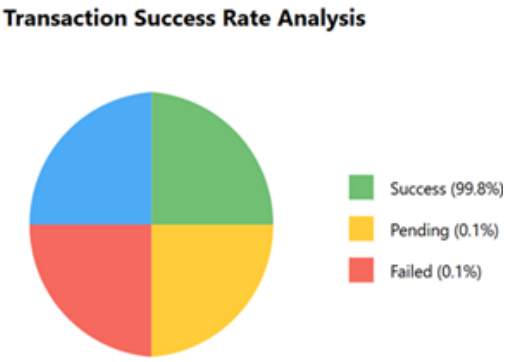

Figure 10: Transaction Success Rate

Figure 11: Parking Location with Map Integration

7 CONCLUSION AND FUTURE WORK

This research on the Centralized Parking System Environment underscores the transformative potential of integrating IoT, real-time data analytics, and mobile applications into urban parking systems. Unlike conventional parking systems, which often rely on static, manual processes and limited data inputs, the proposed system leverages IoT-enabled solutions to provide real-time updates on parking availability, optimized space utilization, and user convenience through mobile app interfaces.

In contrast to existing automated parking systems that primarily focus on vehicle positioning and efficiency within predefined spaces, this system broadens the scope by incorporating dynamic, city-wide management strategies. This includes predictive analytics to anticipate parking demand fluctuations based on historical data, traffic flows, and weather conditions, a feature often absent in current automatic parking setups. Such predictive capabilities allow for adaptive pricing models and maximize occupancy rates by distributing demand more effectively.

Furthermore, unlike traditional parking solutions that may lack flexibility in payment methods, this system considers user needs by proposing advanced payment options, including cryptocurrency and loyalty-based credits, promoting a more versatile and user-centered experience. While existing systems might incorporate automated entry or limited vehicle detection, the addition of IoT devices such as occupancy sensors and license plate recognition further enhances security and efficiency, allowing for seamless entry, parking, and exit processes.

Another area of distinction is scalability and interoperability with broader smart city initiatives. Unlike typical automated parking solutions focused solely on indoor or confined areas, this centralized system has the potential to integrate with urban mobility infrastructures, including electric vehicle charging networks and real-time traffic monitoring, ultimately contributing to a more cohesive and sustainable urban environment.

In comparison to similar systems limited to single-location implementations, scaling this solution to multi-city deployments introduces adaptability to local regulations and infrastructure while maintaining centralized oversight. This adaptability positions the Centralized Parking System Environment as a viable, flexible alternative that can operate effectively across diverse urban landscapes.

Finally, the proposed system not only focuses on automation and efficiency but also emphasizes user satisfaction through enhanced features, including voice-guided navigation and augmented reality (AR) assistance, setting it apart from existing solutions. By building on these advanced technologies and addressing the evolving needs of urban parking, the Centralized Parking System Environment represents a significant step forward in making urban parking more efficient, accessible, and responsive to both user and city requirements.

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