

ParkSmart: An Intelligent and Interactive Smart Parking Reservation System for Muscat Mall

Louay Al Nuaimy^{1,*}, Waad Salim Al Salhi², Ahed Salim Al Alawi³

Abstract

Parking problem has become a recurring issue in main commercial malls particularly during weekends, holidays, and peak shopping periods. Customers often spend excessive time searching for available spaces which leads to unnecessary internal traffic, higher fuel consumption, and growing low satisfaction. These challenges not only affect the customer satisfaction but also put operational pressure on mall management. This study introduces ParkSmart a smart and interactive parking reservation system developed specifically for Muscat Mall. The system combines IoT-based sensors to detect space occupancy, AI-supported analysis for real-time monitoring, and a smart phone application that allows users to reserve and pay for parking in advance. A web-based administrative dashboard supports mall management by providing up-to-date information on occupancy levels, reservations, and overall parking activity. Through the ParkSmart platform drivers can check live availability and secure a parking space before arrival. Complete payment digitally and follow guided directions to their assigned slot. At the same time, management gains access to structured data that supports more informed operational planning. By moving away from the traditional search-for-parking approach and adopting a reservation-based model, the system aims to ease congestion, lower vehicle emissions, and improve the overall experience for customers.

Keywords: Smart parking, IoT, reservation system, real-time occupancy, AI analytics, urban mobility, Muscat Mall

INTRODUCTION

Managing parking facilities has become an increasingly challenging task in modern urban environments, particularly in large shopping malls, where the number of visitors changes throughout the day. Finding an available parking space at Muscat Mall during weekends, holidays, and peak shopping hours is often difficult for customers. Drivers usually spend a significant amount of time searching for vacant slots, which creates unnecessary traffic congestion within the parking area. This situation not only causes frustration and delays for visitors but also leads to increased fuel consumption and environmental pollution due to vehicles moving around the premises. Traditional parking management methods mainly depend on manual supervision, security staff, and static signboards, which

cannot provide accurate and real-time information about parking availability. In addition, these conventional systems do not support advanced features such as online booking, digital payments, or navigation assistance, making the parking experience inconvenient and inefficient for the users.

To address these issues, ParkSmart was developed as an intelligent and fully integrated smart parking management solution designed specifically to improve parking operations and customer convenience at the Muscat Mall. The system uses Internet of Things (IoT) technology and

*Author for Correspondence

Louay Al Nuaimy
E-mail: loay.alneimy@ocmt.edu.om

¹Senior Lecturer, Department of Computer Science, Oman College of Management and Technology, Sultanate of Oman.

^{2,3}Student, Department of Computer Science, Oman College of Management and Technology, Sultanate of Oman.

Received Date: March 05, 2026

Accepted Date: March 31, 2026

Published Date: April 10, 2026

Citation: Louay Al Nuaimy, Waad Salim Al Salhi, Ahed Salim Al Alawi. ParkSmart: An Intelligent and Interactive Smart Parking Reservation System for Muscat Mall. Journal of Computer Technology & Applications. 2026; 17(2): 1–8p.

smart occupancy sensors installed in parking slots to detect vehicle presence in real time. The collected information is instantly updated in a centralized database and displayed on a mobile application and management dashboard. Using the ParkSmart mobile application, visitors can easily check the current availability of parking spaces before arriving at the mall. They can also reserve a parking slot in advance, reducing the uncertainty and stress associated with parking during busy periods.

Furthermore, the application provides additional features, such as secure digital payment options and guided navigation that directs drivers to their allocated parking spaces quickly and efficiently. This minimizes unnecessary vehicle movement inside the parking facility and improves the overall traffic flow within the mall premises. From a management perspective, ParkSmart offers a centralized dashboard that provides live occupancy monitoring, reservation records, payment tracking, and statistical reports. These features enable mall administrators to make informed operational decisions, optimize parking space utilization, and improve customer satisfaction at the mall. Overall, the implementation of ParkSmart aims to create a smarter, more organized, and environmentally friendly parking system that enhances both the user experience and parking management efficiency while supporting the growing demand for modern smart city solutions [1–6].

Problem Statement

The current parking approach at Muscat Mall faces several operational gaps:

1. *Lack of real-time automation:* Drivers do not receive accurate live occupancy information, particularly on busy days.
2. *Search-driven congestion:* Vehicles circulate inside the parking lot searching for vacancies, increasing internal traffic and delays.
3. *No reservation capability:* Visitors cannot secure parking ahead of arrival, which reduces predictability and increases their frustration.
4. *Limited data-driven management:* Without analytics and monitoring, administrators cannot reliably track demand patterns, occupancy peaks, or abnormal behaviors to improve operations.

Contribution

ParkSmart provides four primary contributions:

1. *Reservation-based parking workflow:* Reduces search time and internal congestion by shifting behavior from exploration to confirmed allocations.
2. *Real-time operational intelligence:* A management dashboard supports monitoring, trend analysis, and operational planning.
3. *Improved customer experience:* Confirmation, prepayment options, and guided directions reduce uncertainty upon arrival.
4. *User-centric platform design:* A streamlined booking-to-arrival flow supports adoption and operational effectiveness.

AIM AND OBJECTIVES

Aim

This study aims to design and implement an integrated smart parking system for the Muscat Mall that improves parking efficiency and user satisfaction through real-time monitoring, reservations, and intelligent management.

Objectives

- Drivers can reserve and prepay for parking spaces in real time via a mobile/web interface.
- They reduce internal congestion and the time spent searching for parking, supporting more sustainable mobility outcomes [2].
- A real-time dashboard was provided to mall management to monitor occupancy and analyze usage patterns.
- Ensure usability through a clear, user-friendly workflow for visitors and administrators.

Related Work

Recent advancements in smart parking systems have mainly focused on improving convenience through digital payment, online reservation, and citywide parking discovery platforms. Applications such as ParkMobile, SpotHero, Way.com, and ParkWhiz allow users to search for nearby parking facilities, compare prices, and reserve parking spaces in advance of their arrival. These platforms have significantly improved user accessibility and reduced the time spent searching for parking in crowded urban areas. In many cases, they also support contactless payments and provide navigation assistance, making the parking experience more efficient and user friendly [7–12].

Despite these developments, many existing solutions operate primarily as reservation aggregators or payment management systems rather than as complete smart parking management frameworks. Most systems focus on reserving access to a parking facility rather than guaranteeing a dedicated numbered parking slot for the user upon arrival. Consequently, drivers may still experience delays, confusion, or competition for available parking spaces. Furthermore, several current platforms have limited integration with real-time occupancy detection technologies, reducing their ability to provide highly accurate parking availability data. Enforcement mechanisms are often weak, with insufficient coordination between digital reservations and physical slot monitoring systems [6, 10].

ParkSmart extends the capabilities of existing parking technologies by introducing a more integrated and intelligent approach to parking management. The proposed system combines real-time occupancy sensing, automated slot status updates, and streamlined booking workflows in a single high-demand commercial environment. Unlike conventional systems, ParkSmart aims to allocate and monitor specific parking slots, ensuring better accuracy, improved space utilization, reduced waiting times, and enhanced user satisfaction. This tighter integration between hardware-based occupancy detection and software-driven reservation management creates a more reliable and efficient smart parking ecosystem [13–16].

PROPOSED SYSTEM OVERVIEW

High-Level Architecture

ParkSmart is implemented as a coordinated system with these core components:

- *IoT sensing layer*: Sensors detect the occupancy status (occupied/vacant) per slot or per defined zone.
- *Data and control layer*: A central server/database receives sensor updates, manages reservations, and synchronizes the system state.
- *User application layer*: A mobile/web interface provides live availability, reservation, payment, and navigation support.
- *Administration layer*: A secure web dashboard supports monitoring, slot management, reservations, and reporting.

Functional Flow

Typical user workflow

Figure 1 illustrates the typical workflow followed by users in the ParkSmart parking reservation system. Initially, users create an account or log in to access the platform. After authentication, the system displays real-time parking slot availability, allowing users to select suitable parking spaces. Once a slot is chosen, the user proceeds with the digital payment through the integrated payment gateway. After a successful payment, a confirmation notification is generated, and navigation assistance is provided to guide the user directly to the reserved parking location. This workflow improves convenience, minimizes parking search time, and enhances the overall user experience of the app.

Administrative Workflow

The administrative workflow of the ParkSmart system enables efficient monitoring and management of parking operations. Administrators can track the real-time occupancy status, manage parking slot

availability, and update slot information when required. The system also provides reporting features that help administrators analyze parking usage, booking records and overall system performance. This workflow supports better decision-making, improves operational efficiency, and ensures smooth parking management, as illustrated in Figure 2.

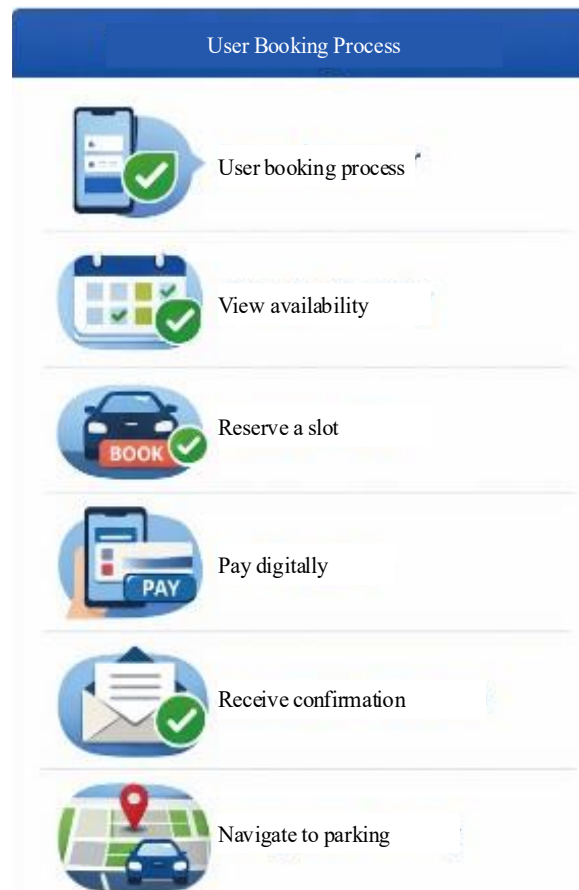


Figure 1. User booking process in the ParkSmart system.

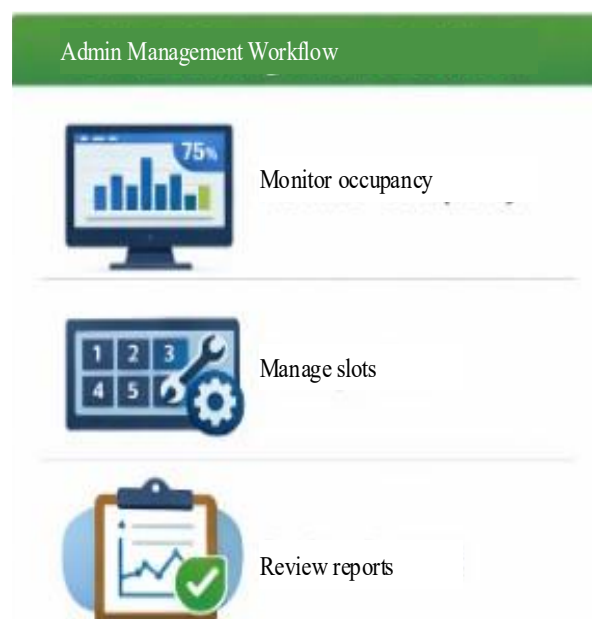


Figure 2. Administrative workflow of the Parksmart system.

METHODOLOGY

The ParkSmart system was developed using the Waterfall Software Development Life Cycle (SDLC) model to maintain a clear and systematic flow throughout the project. This methodology was selected because it provides a structured sequence of phases, allowing each stage to be completed and documented before moving to the next. Since the project was designed as a prototype for controlled deployment in Muscat Mall, the Waterfall approach was considered suitable because of its focus on stable requirements, proper planning, and detailed documentation [17–19].

The methodology began with the planning phase, in which the objectives, scope, and expected outcomes of the smart parking system were identified. During this stage, the project requirements and available resources were carefully studied to ensure their feasibility. The second phase involved system analysis, in which user needs, parking challenges, and operational requirements were examined in detail. After gathering the necessary information, the design phase was conducted to prepare the system architecture, database structure, user interface, and communication flow between the hardware and software components.

In the implementation phase, the proposed modules and features were developed and integrated into the system. This was followed by testing, where the system functionality, accuracy, and reliability were verified using different test cases. Finally, the evaluation phase assessed the overall performance and usability of ParkSmart to determine whether the system met the intended project goals and user expectations.

SYSTEM ANALYSIS

ParkSmart models the movement and structure of data across the platform to ensure consistency and traceability.

- *DFD Level 0*: shows external entities (drivers, mall/admin, payment gateway) and overall information exchange (Figure 3).
- *DFD Level 1*: expands internal processes such as authentication, availability checking, reservation/payment processing, confirmation, and reporting (Figure 4).
- *ERD*: defines core entities (User, Parking Slot, Reservation, Sensor, Admin) and their relationships to maintain a structured Figure 5, consistent data storage [15, 16].



Figure 3. DFD Level 0: Smart parking system.

IMPLEMENTATION SUMMARY

Tools and Technologies

- *Development environment*: PyCharm
- *Backend/logic*: Python (with support for AI modules and system workflows) [19].
- *Database*: MySQL for structured reservation and operational data [20].
- *Interfaces*: HTML/CSS for the administrative dashboard.
- *AI module (optional/enhanced)*: Computer vision-based occupancy detection using CCTV feeds (e.g., OpenCV-based workflows) [21].
- *IoT integration*: Sensor-to-server communication and real-time database updates.

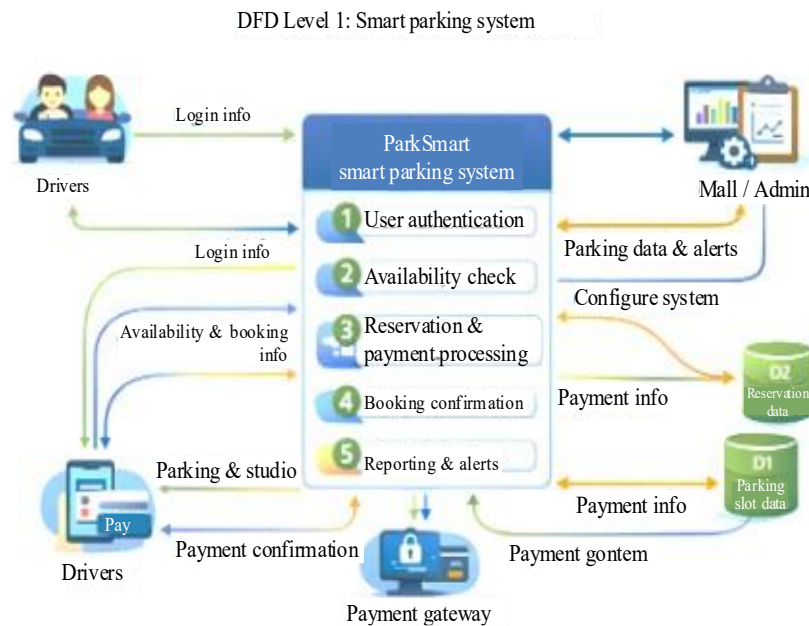


Figure 4. DFD Level 1: Smart parking system.

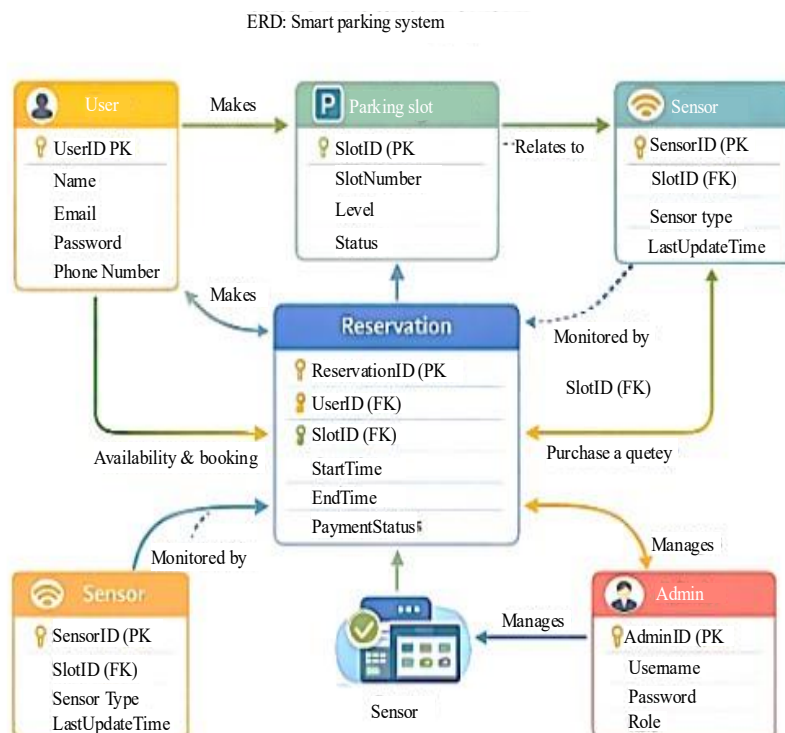


Figure 5. ERD: Smart parking system.

TESTING AND EVALUATION

Testing focused on functional correctness, system reliability, and readiness for peak-demand conditions.

- *Validation*: Ensures that the system meets user needs (e.g., successful booking and confirmation).
- *Verification*: Confirms conformance to design and requirements across modules (availability, reservation, payments, and analytics).
- *Black-box testing*: Validates user workflows without internal knowledge (booking-to-confirmation path).
- *White box testing*: Validates internal logic (fee calculation, sensor state updates, reservation conditions).

Performance and security considerations have also been addressed to support stable operations and protect user data and transactions [22–24].

Limitations

Despite its benefits, ParkSmart faces realistic implementation constraints:

- *Sensor reliability and maintenance*: faults or calibration errors can produce inaccurate availability data.
- *Network dependency*: Real-time synchronization requires stable connectivity; disruptions may delay updates.
- *Scalability costs*: expanding coverage increases sensor, infrastructure, and maintenance requirements.
- *Feature maturity*: Advanced AI features (prediction, fully automated navigation, enforcement integration) may require additional time and resources.

CONCLUSION

ParkSmart provides an integrated, reservation-driven parking management solution tailored for the Muscat Mall. By combining IoT-based occupancy detection, real-time system updates, a customer reservation/payment workflow, and an administrative dashboard, the system targets the key pain points of conventional parking operations: congestion, uncertainty, and lack of actionable operational insight. The proposed design supports improved visitor satisfaction, reduced parking search times, and more informed parking operations. Future enhancements may include improved sensing accuracy through hybrid detection, stronger analytics for demand prediction, deeper integration with mall systems, and expanded deployment to other high-demand sites.

REFERENCES

1. Al-Turjman F, Malekloo A. Smart parking in IoT-enabled cities: A survey. *Sustainable Cities and Society*. 2019 Aug 1;49:101608.
2. Geng Y, Cassandras CG. New “smart parking” system based on resource allocation and reservations. *IEEE Transactions on intelligent transportation systems*. 2013 Apr 2;14(3):1129-39.
3. Shoup D. High cost of free parking. Routledge; 2021 Feb 25. *Journal of Planning Education and Research* 1997 vol. 17, pp. 3-20.
4. Bibri SE. The IoT for smart sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability. *Sustainable cities and society*. 2018 Apr 1;38:230-53.
5. Liu J, Wu J, Sun L. Control method of urban intelligent parking guidance system based on Internet of Things. *Computer Communications*. 2020 Mar 1;153:279-85.
6. Lin T, Rivano H, Le Mouél F. A survey of smart parking solutions. *IEEE transactions on intelligent transportation systems*. 2017 Apr 12;18(12):3229-53.
7. Larraquel MG. A Smarter Parking System Mobile Application. The Catholic University of America; 2023.
8. Ashraf A, Sultana Z, Islam I, Pinky AA, Toma SA, Zinia A, Islam MN. Park with ease: Evaluating usability to design intuitive interfaces for car parking applications. In 2023 IEEE 9th International

-
- Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE) 2023 Nov 25 (pp. 367-372). IEEE.
9. Way | Find & Reserve Parking, Auto Insurance, Car Wash & More. Way. 2020. Available from: <https://www.way.com/> .
 10. ParkWhiz: Find and Book Parking Anywhere. ParkWhiz. 2024. Available from: <https://www.parkwhiz.com/> .
 11. Kerzner H. Project management: a systems approach to planning, scheduling, and controlling. John Wiley & Sons; 2025 Apr 8.
 12. Rosenberger P, Tick J. Suitability of PMBOK 6 th edition for agile-developed IT Projects. In 2018 IEEE 18th International Symposium on Computational Intelligence and Informatics (CINTI) 2018 Nov 21 (pp. 000241-000246). IEEE.
 13. Ashton K. That ‘internet of things’ thing. RFID journal. 2009 Jun 22;22(7):97-114.
 14. Ray PP. A survey on Internet of Things architectures. Journal of King Saud University-Computer and Information Sciences. 2018 Jul 1;30(3):291-319.
 15. Wixom BH, Tegarden DP, Dennis A, editors. Systems Analysis and Design: An Object Oriented Approach with UML. J. Wiley; 2015.
 16. Thalheim B. Extended Entity-Relationship Model. Encyclopedia of database systems. 2009;1:1083-91.
 17. Riddle WE, Fairley RE. Software development tools. Springer Science & Business Media; 2012 Dec 6.
 18. Sommerville I. Software Engineering Tenth Edition. 2016. Available from: <https://dn790001.ca.archive.org/0/items/bme-vik-konyvek/Software%20Engineering%20-%20Ian%20Sommerville.pdf> .
 19. Van Rossum G, Drake FL. Introduction to PYTHON 2.6. CreateSpace; 2009 Apr 13.
 20. MySQL 8.0 Reference Manual. Oracle.com. 2026. Available from: https://docs.oracle.com/cd/E17952_01/mysql-8.0-en/ .
 21. Bradski G. The opencv library. Dr. Dobb's Journal: Software Tools for the Professional Programmer. 2000;25(11):120-3.
 22. Myers GJ, Badgett T, Thomas TM, Sandler C. The art of software testing. Chichester: John Wiley & Sons; 2004 Jun 1.
 23. Ammann, P., & Offutt, J. Introduction to software testing (2nd ed.). Cambridge University Press 2016.
 24. Beizer, B. (1995) Black-Box Testing Techniques for Functional Testing of Software and Systems. John Wiley & Sons, Inc., Hoboken. - References - Scientific Research Publishing. Scirp.org. 2026. Available from: <https://www.scirp.org/reference/referencespapers?referenceid=1192355> .
-