IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 14, Issue 9, September 2025

DOI: 10.17148/IJARCCE.2025.14915

Smart Parking Management System: An IoT and AI-Based Approach for Efficient Urban Mobility

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Abstract: Parking space management has become extremely difficult due to the sharp rise in urban vehicle ownership, which has increased carbon emissions, wasted fuel, and traffic congestion. Urban mobility is inefficient due to the lack of real-time monitoring, intelligent allocation, and predictive capabilities in traditional parking management systems. In order to maximize parking utilization, this paper introduces a Smart Parking Management System (SPMS) that combines artificial intelligence (AI) and Internet of Things (IoT) sensors. IoTenabled sensors identify the presence of vehicles and send real-time occupancy data, while AI-based algorithms evaluate both live and historical data to forecast availability and direct drivers. digital payments, booking, and navigation are all made possible by a mobile application. Reduced cruising time, better space use, lower emissions, and scalable deployment for smart cities are the goals of the suggested system. Architecture, implementation options, testing methods, assessment metrics, and future directions are all covered in the paper.

1 INTRODUCTION

1.1 Background

Urbanization and the exponential growth of vehicles have made parking management one of the most pressing challenges in metropolitan cities. Traditional parking systems, which rely on manual supervision and limited infrastructure, fail to meet the increasing demand for realtime, efficient, and user-friendly solutions. A large percentage of urban traffic congestion is attributed to drivers searching for vacant parking spaces. Smart cities demand intelligent systems that can integrate IoT sensors, AI algorithms, and mobile technologies to provide realtime parking availability, predictive analysis, and seamless user interaction.

1.2 Motivation

The motivation for this project arises from the growing inconvenience faced by urban commuters and the environmental impact of unmanaged parking systems. Drivers often waste valuable time and fuel while searching for available parking, leading to increased stress, higher emissions, and economic loss. By integrating IoT and AI into parking management, it becomes possible to:

- Provide real-time updates to drivers.
- Reduce traffic congestion and pollution.
- Increase revenue generation for parking authorities through better utilization of spaces.
- Support the vision of sustainable smart cities.

1.3 Problem Definition

The primary problem addressed in this research is the lack of an efficient, real-time, and intelligent parking management system that can handle the challenges of urban mobility.
Current systems suffer from:

- Absence of real-time monitoring of parking spaces.
- Inefficient allocation of resources.
- Lack of predictive analytics for future availability.
- Manual payment systems prone to errors.
- Limited user convenience and accessibility.

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1.4 Scope of the Project

The scope of the Smart Parking Management System includes:

- Deployment of IoT sensors (ultrasonic, magnetic, or camera-based) to monitor occupancy.
- AI-based analysis for predicting space availability and optimizing allocation.
- Integration with a mobile/web application for real-time slot booking, navigation, and payment.
- Applicability in urban areas such as shopping malls, hospitals, corporate campuses, and public parking lots.
- Scalable architecture that can be expanded across multiple cities in line with smart city initiatives.

1.5 Objectives

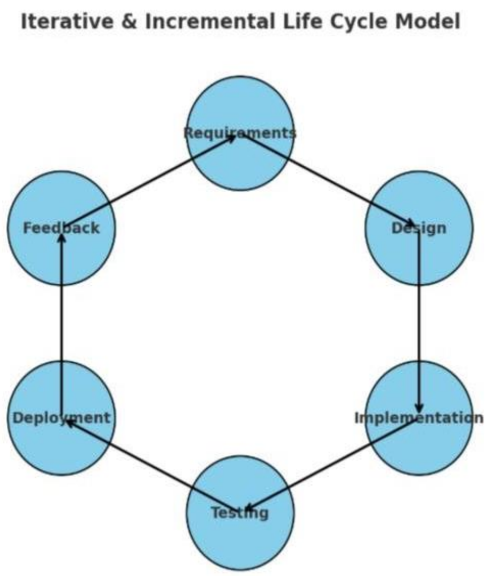
The main objectives of the Smart Parking Management System are:

1. To design an IoT-enabled system for real-time detection of parking space occupancy.
2. To apply AI algorithms for predicting availability and guiding drivers effectively.
3. To provide a user-friendly interface for booking, navigation, and digital payments.
4. To reduce traffic congestion and vehicle emissions by minimizing search time.
5. To develop a scalable and sustainable solution for smart city implementation.

1.6 Selection of Life Cycle Model for Development

For the development of the Smart Parking Management System, the Iterative and Incremental Model (Agile approach) is most suitable.

- Parking systems require continuous updates and improvements as technologies evolve.
- Iterative development allows early deployment of a basic system with IoT sensors and mobile application.
- New features such as AI-based prediction, reservation modules, and analytics dashboards can be added incrementally.
- Agile ensures user feedback is incorporated at every stage, improving reliability and usability.



1.7 Summary

This chapter introduced the need for a Smart Parking Management System in modern cities and described the background, motivation, problem statement, scope, objectives, and development model. By leveraging IoT and AI technologies, the proposed system aims to deliver a scalable, efficient, and user-friendly parking solution. The following chapters will discuss existing research, the proposed methodology, implementation, and results in detail.

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2 PROJECT PLANNING AND MANAGEMENT

2.1 Feasibility Study

A feasibility study evaluates whether the Smart Parking Management System (SPMS) is practical, achievable, and beneficial. It is categorized into:

- **Technical Feasibility** o IoT sensors (ultrasonic, infrared, or camera-based) are available and can be integrated with microcontrollers.

o AI algorithms and cloud services support real-time data processing.

o Mobile applications can easily display parking availability and allow booking.

- **Operational Feasibility** o Drivers can conveniently book slots and navigate to free parking spaces.

o Administrators can monitor parking usage through dashboards.

o Reduced congestion and improved traffic flow ensure public acceptance.

- **Economic Feasibility** o Initial cost includes sensors, microcontrollers, servers, and app development.

o Long-term benefits include reduced congestion, fuel savings, improved air quality, and revenue generation through optimized parking utilization.

- **Legal Feasibility** o The system complies with government regulations for IoT deployment, data privacy, and smart city initiatives.

- **Schedule Feasibility**

o The project is designed to be completed in multiple phases (requirement gathering, design, development, testing, and deployment) within a 6–8 month period.

2.2 Risk Analysis

Identifying and addressing potential risks is crucial:

- **Technical Risks** o Sensor malfunction or inaccurate readings.

o Connectivity issues (Wi-Fi, LoRa, or GSM) causing delays.

o Cybersecurity threats to user data**.**

- **Operational Risks** o User resistance to adopting new technology.

o Difficulty in managing large-scale deployments in cities.

- **Economic Risks**

o High initial installation costs.

o Budget overruns due to unforeseen expenses.

• **Mitigation Strategies** o Redundancy in hardware (backup sensors). o Use of secure communication protocols. o Pilot testing before full-scale deployment.

2.3 Project Scheduling

The project is planned using the Iterative & Incremental Model, divided into phases:

1. Requirement Analysis → 2 weeks

2. System Design → 3 weeks

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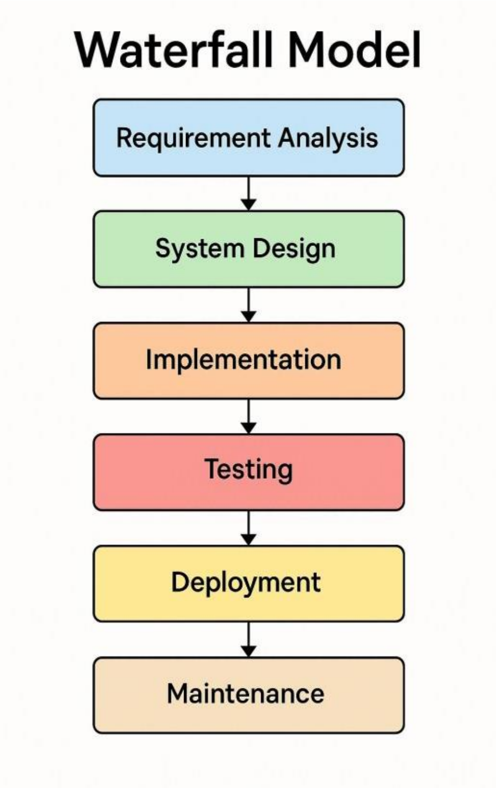
3. Implementation (IoT + App) → 8 weeks

4. Testing & Integration → 4 weeks

5. Deployment → 2 weeks
6. Maintenance & Feedback Incorporation → Ongoing

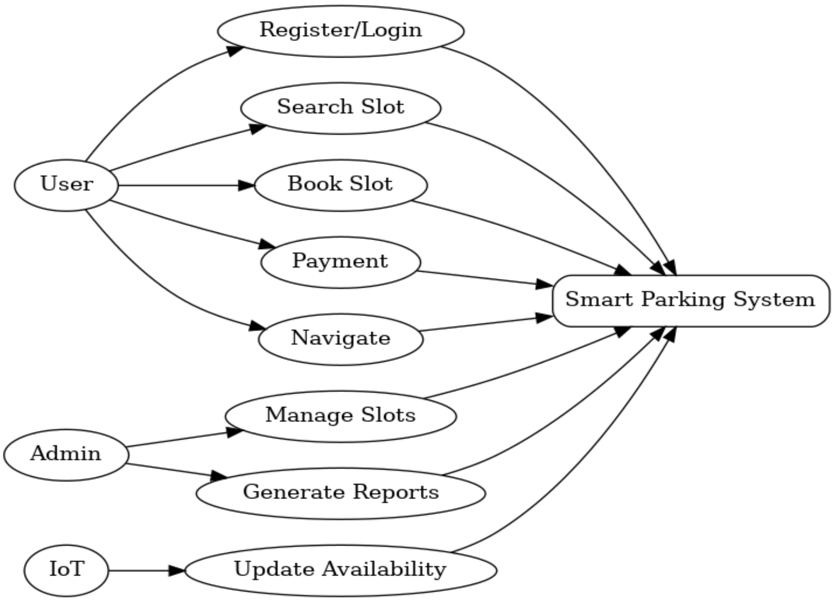


2.4 Effort Allocation

- Requirement Analysis → 10% of effort
- System Design → 15% of effort
- Implementation (Coding + IoT Setup) → 40% of effort
- Testing → 20% of effort
- Deployment & Documentation → 15% of effort

2.5 Use Case Diagram Actors:
- **User** → Register, Login, Search Slot, Book Slot, Pay, Navigate.
- **Admin** → Manage Slots, Update Status, Generate Reports.
- **IoT Sensors/System** → Provide real-time slot availability.

❖ **Use Cases:**
- User → Book & Pay for Slot.
- Admin → Manage Slots & Reports.
- IoT System → Send availability updates.



2.6 Summary

This chapter analyzed the feasibility, risks, scheduling, effort allocation, and cost estimation of the Smart Parking Management System. The project is technically feasible, economically beneficial, and socially impactful. Risks can be mitigated through redundancy, cybersecurity, and phased deployment. With proper planning and resource allocation, the system can be developed and deployed effectively in urban areas.

3 LITERATURE SURVEY

3.1 Classification of SPMS architectures

Literature typically classifies SPMS by sensing approach (per-slot sensing vs. area-level sensing), processing location (edge vs. cloud), and service model (real-time guidance, reservation, enforcement). Per-slot sensor deployments (magnetic, ultrasonic, IR, or inductive loops) give high accuracy but higher installation cost; area-level camera or sensor fusion can cover many slots with fewer devices but requires heavier processing. Edge computing is growing in popularity to reduce latency and bandwidth needs for camera-based systems.

4 CONCLUSION

From tiny prototypes to reliable pilot deployments, research on smart parking management systems has advanced. Trends suggest hybrid strategies that combine cameras and analytics for wide-area coverage and additional services with per-slot sensors for mission-critical accuracy. More scalable, real-time systems are being made possible by edge-AI and low-power wide-area networking (LoRa/NB-IoT). The remaining gaps include robust predictive algorithms that generalize across sites, privacy-preserving vision techniques, interoperability standardization, and cost-effective large-scale deployment strategies. Long-term field studies, total-cost-of-ownership evaluations, and explainable, privacy-compliant AI for parking analytics should be the focus of future research.

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