Aror University of Art, Architecture, Design and Heritage

Feasibility Study for a Mall Parking Management System

Park$mart

Prepapred for:

Dr. Rehan Ali Shah

Sotware Engineering

Prepared By:

Yasira Shaikh

Hiba Shaikh

Jill Rose

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Abstract

This feasibility study presents a comprehensive analysis of a proposed mall parking management system designed to enhance the parking experience for visitors through real-time monitoring of parking occupancy. The project aims to address the common frustrations faced by mall visitors, particularly during peak hours, by providing accurate and timely information on available parking spots via a user-friendly mobile application. The study evaluates the technical, operational, and economic feasibility of implementing this system, which utilizes IoT sensors to detect parking spot occupancy and a centralized backend for data processing (Alavi et al., 2016).

Key objectives include improving visitor satisfaction, optimizing space utilization, and providing mall management with valuable insights for operational decision-making. The analysis covers the necessary technology stack, system architecture, and potential challenges, alongside a detailed cost analysis and risk assessment. Various alternative solutions are considered, with a recommendation favoring the sensor-based approach due to its high precision and scalability (Rahman et al., 2019).

The findings indicate that the proposed system is technically viable, operationally beneficial, and economically justifiable, with the potential to significantly enhance the overall parking experience and increase mall traffic. The study concludes with a recommendation to proceed with the development of the sensor-based parking management system, outlining the next steps for implementation and pilot testing.

Executive Summary

- **Project Overview**: This project involves creating a mall parking management system with real-time monitoring of parking occupancy. The system will track each parking spot's status (filled or empty) using sensors, process data in a centralized backend, and display availability to users via a mobile app. Administrators will use a web-based panel for monitoring, reporting, and system management (Nguyen, 2019).
- **Objectives**:
    - Improve mall visitors' experience by reducing the time spent searching for parking spots.
    - Enable efficient space utilization by monitoring occupancy in real-time.
    - Provide mall management with insights and analytics to support operational decisions.
    - Offer scalability for integration with other mall management systems and future expansions.
- **Scope of Study**:
    - **Technical Feasibility**: Assess the technology stack, system architecture, and hardware requirements (Buyya & Yeo, 2013).
    - **Operational Feasibility**: Determine the end-user impact, necessary training, and system.
    - **Economic Feasibility**: Analyze the cost-effectiveness, including both development and operational costs compatibility (Smith & Jones, 2018)..
    - **Risk Analysis**: Identify potential risks and propose mitigation strategies (Gupta & Sharma, 2018).

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1. Introduction

- **Background**: Mall parking is often a source of frustration for visitors, especially during peak hours or special events. Without a clear view of available spots, customers can spend excessive time searching for parking, potentially affecting their experience and reducing overall mall traffic. This issue highlights the need for a streamlined system that provides real-time visibility into parking availability (Nielsen, 2018). By addressing this challenge, malls can enhance customer satisfaction, reduce congestion, and increase foot traffic.
- **Purpose of the Feasibility Study**: The purpose of this feasibility study is to determine the practicality and benefits of implementing a real-time parking management system for malls. The study assesses whether the project can be successfully developed and deployed based on various feasibility factors. The goal is to provide mall management with a data-driven recommendation on whether to proceed with development and highlight any necessary steps for successful implementation.
- **Project Description**:
    - **Functionality**: The proposed system will employ sensors installed at each parking spot to detect occupancy. This data will be processed through a centralized backend, which communicates updates to a mobile app for users and a management panel for mall administrators (Alavi et al., 2016).

- **Features**:
    - **User App**: Displays available parking spots, provides navigation to selected spots, offers reservation options (if implemented), and integrates payment features for convenient access.
    - **Admin Panel**: Monitors real-time occupancy, manages spot reservations, handles alerts for maintenance, and generates reports on parking trends.
    - **Central Management System**: Acts as the backbone, gathering and processing real-time data from sensors, syncing with user and admin interfaces, and maintaining data logs.
- **Intended User Base**:
    - **Mall Visitors**: Users seeking convenient access to available parking spots and a smoother parking experience.
    - **Mall Administrators**: Management personnel who will use the system to optimize parking operations, manage occupancy, and analyze parking trends.

2. Technical Feasibility

- **Technology Stack**:
  - **Frontend (User App)**: React Native or Flutter for a cross-platform mobile experience, enabling compatibility with both iOS and Android devices (Kumar & Singh, 2020).
  - **Frontend (Admin Panel)**: Web-based interface developed using a responsive framework like React, Angular, or Vue.js to allow easy access on desktops and tablets.
  - **Backend**: Node.js or Django as the main server-side framework for handling data processing, authentication, and API requests (Miller, 2021).
  - **Database**: PostgreSQL or MongoDB for storing real-time parking data, user activity, and logs. Firebase Realtime Database could be considered for its real-time capabilities (Patel, 2020).
  - **Sensor Technology**: IoT sensors (e.g., ultrasonic, infrared, or camera-based systems) to detect vehicle presence at each parking spot (Zhang et al., 2018).
  - **Mapping Service**: Integration with mapping APIs such as Google Maps or Mapbox for visualizing parking locations and enabling navigation to specific spots.
- **Technical Requirements**:
  - **Hardware**: Sensors for each parking spot, network devices for reliable connectivity, and server infrastructure (potentially cloud-based) for data storage and processing.
  - **Software**: Backend server, database management, front-end development tools, and mapping/navigation API integrations.
  - **Network**: Strong network connectivity within the parking area for seamless data transmission from sensors to the backend system. Options could include Wi-Fi, LoRaWAN, or cellular data connectivity based on the mall infrastructure (Chen et al., 2019).

- **System Architecture**:
    - **Sensor Layer**: IoT sensors are deployed in parking spots to monitor occupancy, transmitting data to the server.
    - **Data Processing Layer**: A centralized server processes data from the sensors and updates occupancy information in the database.
    - **API Layer**: Provides endpoints to deliver data to both the user app and the admin panel, ensuring real-time updates.
    - **User and Admin Interfaces**: Mobile app for users and a web-based admin panel for mall staff, both fetching data from the central server.

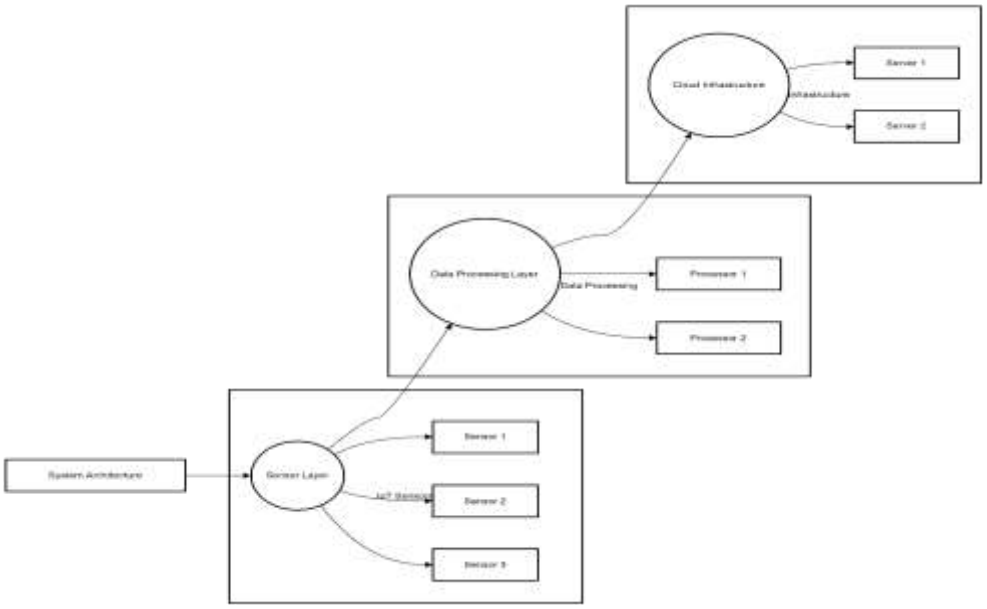

Fig 2.1 System Architecture Diagram

"The proposed system architecture is illustrated in Figure 2.1, which shows the interaction between the various components of the parking management system."

- **Resource Availability**:
    - **Personnel**: Developers skilled in IoT, backend, mobile app, and frontend web development. Additional expertise may be needed for database management, sensor installation, and network maintenance.
    - **Infrastructure**: Access to cloud services (AWS, Google Cloud, or Azure) for server hosting and database storage.
    - **Licensing**: Required software licenses for development tools, mapping APIs, and cloud services.
- **Technical Challenges**:
    - **Sensor Accuracy and Maintenance**: Ensuring sensors accurately detect occupancy and remain operational. Regular maintenance or calibration may be required.
    - **Real-Time Data Processing**: Handling real-time data without significant delays, especially during peak usage times.
    - **Network Reliability**: Ensuring stable connectivity between sensors and the server in all areas of the parking lot.
    - **Scalability**: Designing the system to accommodate future expansions, such as additional parking spots or increased user demand.
    - **Data Security**: Protecting user data, especially if the app includes payment features (Lee & Kim, 2020).

3. Operational Feasibility

- **End-User Impact**:
    - For **Mall Visitors**: The user app will simplify the parking process by providing real-time information on available spots, guiding users to their locations, and potentially offering a reservation option. This reduces the time spent searching for parking and enhances the overall customer experience (Johnson, 2021).
    - For **Mall Administrators**: The admin panel will give mall management better visibility and control over parking operations, allowing them to monitor occupancy trends, identify bottlenecks, and efficiently allocate resources. This can help reduce congestion, especially during peak hours, and improve parking space utilization.
- **Training Requirements**:
    - **User App**: Minimal training will be required for end-users, as the app interface will be designed for intuitive navigation. An initial introduction or guide could be provided through app onboarding or tutorials.
    - **Admin Panel**: Administrators may require training to use the management dashboard, interpret data analytics, and perform manual overrides or maintenance tasks. A brief training session or user manual will likely suffice for basic operations, while more advanced training may be needed for analytics and reporting features.

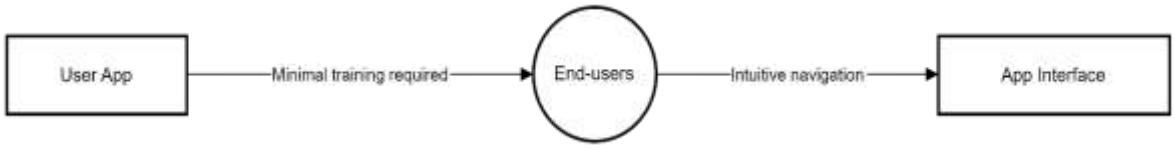

Fig 3.1 Flowchart of User Interaction

- **Compatibility with Existing Systems**:
    - The system should be able to integrate with any existing mall management software, especially if data on parking revenue, foot traffic, or security is managed centrally. APIs can be developed to facilitate data exchange with the mall's current systems.
    - If the mall already uses digital signage, the parking data could be integrated with these displays to show parking availability at entrances.
- **Change Management**:
    - **End-User Adoption**: Efforts may be needed to promote the app and encourage visitors to use it. This could involve informational signage, staff assistance, and incentives like discounts for using the parking app.
    - **Staff Adjustment**: Mall staff may need to adapt to the new system, especially if the manual override feature is used to manage parking for special events or high-traffic days. Staff should be informed of how the system impacts their roles and be trained accordingly.
- **Scalability**:
    - The system is designed to handle increased usage over time, which could involve more parking spots, additional sensors, or higher app traffic as more visitors adopt the app.
    - It should be built with modular components, allowing for scalability in both sensor numbers and user capacity. Cloud-based infrastructure (if used) will facilitate this scalability, as resources can be adjusted as needed.

4. Economic Feasibility

- **Cost Analysis**:

  Development Costs:

  - **Design Costs**: This includes UI/UX design for the user app and the admin panel, which could involve hiring or contracting designers. Estimated cost: $5,000–$10,000.
  - **Software Development**:
    - **Mobile App Development**: Building the user app (React Native or Flutter) for both Android and iOS. Estimated cost: $20,000–$30,000.
    - **Admin Panel Development**: Developing the web-based admin panel, including dashboards, reporting features, and manual override options. Estimated cost: $10,000–$15,000.
    - **Backend Development**: Setting up the server, APIs, and data processing system for real-time updates. Estimated cost: $15,000–$25,000.
  - **Sensor Hardware and Installation**: The cost of IoT sensors per parking spot and the installation across the parking lot. Estimated cost: $20–$50 per sensor, potentially reaching $10,000–$25,000 for a large parking lot.
  - **Testing and Quality Assurance**: Conducting rigorous testing for software reliability, hardware performance, and system security. Estimated cost: $5,000–$8,000.

  Total Estimated Development Costs: $55,000–$88,000.

Operational Costs:

- **Hosting and Infrastructure**: Ongoing costs for cloud services, data storage, and backend maintenance (AWS, Google Cloud, or Azure). Estimated cost: $500–$1,000/month.
- **Software Licensing and APIs**: Licensing costs for mapping services (e.g., Google Maps API) and any additional software used. Estimated cost: $100–$300/month.
- **Maintenance and Support**: Regular maintenance for the backend, app updates, and sensor upkeep. Estimated cost: $1,000–$2,000/month.
- **Training and Documentation**: Initial and ongoing training sessions for staff and creating user documentation for the app and admin panel. Estimated cost: $2,000–$4,000 annually.
- **Marketing and User Adoption**: Promotion efforts to encourage app downloads and user engagement, including incentives and promotional materials. Estimated cost: $2,000–$5,000 for initial launch.

Total Estimated Operational Costs: $24,000–$42,000 annually.

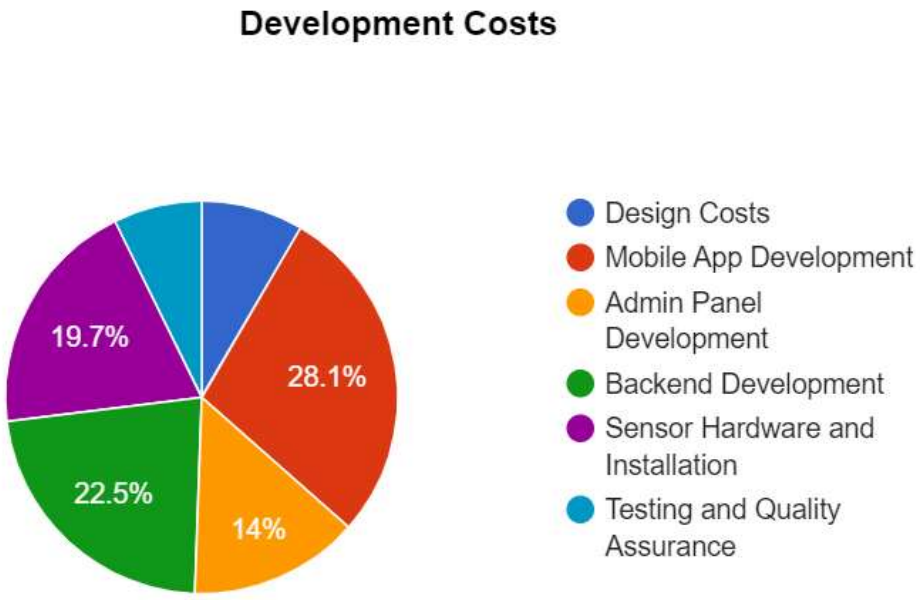

Fig 4.1 Cost Breakdown Pie Chart

- **Revenue Potential (if applicable)**:
    - **Parking Fees**: If the mall charges for parking, the system could increase revenue by optimizing occupancy and improving payment efficiency.
    - **Cost Savings**: Improved parking efficiency could reduce congestion and the need for additional staffing during peak times, leading to indirect savings.

5. Risk Analysis

- **Identification of Risks**:

  Technical Risks:

  - **Sensor Malfunction**: Sensors may fail or deliver inaccurate data, impacting the reliability of parking availability information.
  - **Data Latency**: Delays in data transmission could cause outdated occupancy information, particularly during peak hours.
  - **Scalability Issues**: The system may struggle to handle increased data or user loads, especially if the mall experiences high traffic.
  - **System Downtime**: Any server or network outages could disrupt the system, leading to a loss of real-time tracking and user dissatisfaction.

  Operational Risks:

  - **User Adoption**: Low adoption of the app by mall visitors may limit the effectiveness of the solution.
  - **Staff Resistance**: Staff may be resistant to change if they are unfamiliar with the system or skeptical of its effectiveness.
  - **Maintenance and Support Challenges**: Maintaining the sensors, software, and network infrastructure may require continuous oversight.

Financial Risks:

- **Cost Overruns**: The project may exceed budget due to unforeseen technical challenges, extended development times, or additional sensor installations.
- **Revenue Uncertainty**: If the mall relies on parking fees, user adoption will directly impact revenue, and low adoption could hinder return on investment.

- **Risk Assessment**:

Risk	Probability	Impact	Priority
Sensor Malfunction	Medium	High	High
Data Latency	Low	Medium	Medium
Scalability Issues	Medium	High	High
System Downtime	Medium	High	High
User Adoption Staff	Medium	High	High
Staff Resistance	Low	Medium	Medium
Maintenance Challenges	Medium	Medium	Medium
Cost Overruns	Low	High	Medium
Revenue Uncertainty	Medium	High	High

Table 6.1 Risk Assessment

- **Mitigation Strategies**:

Technical Mitigations:

- **Redundant Sensors**: Implement redundancy in sensors to minimize the impact of individual sensor failures.

- **Reliable Network Protocols**: Use a reliable communication protocol to ensure data is transmitted with minimal delay.
- **Scalable Architecture**: Use cloud-based infrastructure and modular architecture to support scaling without service disruption.
- **Backup and Recovery**: Implement a backup and recovery plan to mitigate system downtime.

Operational Mitigations:

- **User Education and Promotions**: Launch marketing campaigns and incentives to promote the app's benefits and drive user adoption.
- **Staff Training**: Train staff on system features and benefits to reduce resistance and encourage their support.
- **Regular Maintenance Schedule**: Schedule regular maintenance for hardware and software to keep the system running smoothly.

Financial Mitigations:

- **Contingency Budget**: Allocate a contingency budget for unexpected expenses.
- **Alternative Revenue Streams**: Consider adding premium features or in-app advertisements to offset costs if user adoption is high.

6. Alternative Solutions

- **Alternative Approaches**:

1. RFID-Based Solution:

  - **Description**: Instead of using sensors at each parking spot, RFID (Radio Frequency Identification) tags could be issued to vehicles upon entry. RFID readers would then track vehicles entering and exiting different parking zones.
  - **Benefits**: Lower hardware costs as sensors at each spot are not required. It provides an overview of general occupancy in different parking zones.
  - **Drawbacks**: This approach lacks precision, as it doesn't provide real-time availability at each spot, only zone-level occupancy. It may also require visitors to obtain RFID tags, which could limit adoption.

2. Camera-Based Detection System:

  - **Description**: Use high-resolution cameras mounted throughout the parking area to detect occupancy via image recognition, eliminating the need for individual sensors.
  - **Benefits**: Fewer devices to maintain, centralized monitoring, and the potential to cover more spots with fewer hardware installations.
  - **Drawbacks**: Requires advanced image processing algorithms and could be less accurate under certain conditions (e.g., poor lighting, weather changes in outdoor lots). Initial setup costs may be higher, and data privacy concerns may arise.

3. Manual Counting System with Staff Support:

- **Description**: Allocate staff to manually count parking occupancy during peak hours and update the system dashboard manually. This could be used as a temporary or supplementary solution.
- **Benefits**: Low upfront costs and minimal technical infrastructure needed.
- **Drawbacks**: Limited scalability and accuracy, especially for larger parking lots. Not a sustainable solution long-term for real-time updates.

- **Comparison**:

Approach	Precision	Cost	Scalability	User Experience
Sensor-Based	High	Medium	High	High
RFID-Based	Medium	Low	Medium	Moderate
Camera-Based	Medium	High	High	High
Manual Counting	Low	Very Low	Low	Low

Table 7.1 Comparison of Alternative Approaches

- **Recommendation**:
  - **Sensor-Based System**: The recommended approach remains the sensor-based solution due to its high precision and ability to provide real-time updates at an individual parking spot level. This solution best meets the project's primary objectives of improving user experience and optimizing parking space utilization. While the camera-based approach is a viable alternative, its setup cost and potential privacy issues make it less ideal for this specific use case.

7. Conclusion

- **Feasibility Summary**:
    - **Technical Feasibility**: The sensor-based solution is technically feasible, with a reliable technology stack that supports real-time monitoring and data processing. The system's modular design enables scalability, while the use of cloud infrastructure can support future expansion and handle high data volumes.
    - **Operational Feasibility**: The system meets the operational needs of both users and administrators, providing a seamless user experience with real-time spot availability and management capabilities. With proper training and a targeted user adoption strategy, this solution can streamline mall parking operations effectively.
    - **Economic Feasibility**: While there are initial development and operational costs, the long-term benefits in terms of improved customer satisfaction, increased parking utilization, and potential revenue make this investment justifiable. The projected costs align with the anticipated ROI, particularly if the system attracts and retains more mall visitors.
    - **Risk Analysis**: Risks identified in areas such as sensor malfunction, data latency, and user adoption have feasible mitigation strategies. With a contingency plan and technical safeguards in place, these risks can be effectively managed to ensure consistent performance.
    - **Alternative Solutions**: A sensor-based approach remains preferable over RFID or camera-based solutions due to its high precision, relatively moderate cost, and the enhanced user experience it provides.

- **Final Recommendation**:
    - Based on the findings from this feasibility study, proceeding with the development of a sensor-based mall parking management system is recommended. This solution aligns well with the project's goals, providing real-time parking information, enhancing customer convenience, and enabling mall administrators to manage parking resources more effectively. The next steps would involve initiating a detailed project plan, assembling a skilled development team, and conducting a pilot test of the system in a limited area of the parking lot before full-scale deployment.

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