ParkSense: Arduino Embedded Parking Management System

Project Documentation Submitted to the Faculty of the

School of Computing and Information Technologies

Asia Pacific College

In Partial Fulfillment of the Requirements for

Introduction to Systems and Design for CS/IT

M/S NTSDEV

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Executive Summary

The Parking Management System targets to automate the management of Asia Pacific College’s basement parking facility by integrating modern technology to improve operations and enhance user convenience. The objectives of the project are to provide real-time monitoring of parking space occupancy, reduce manual supervision, and improve the overall parking experience for all stakeholders, including security personnel, parking users, and building management staff.

This project is divided into different phases, beginning with conducting interviews and research about the client and the problem, followed by development, testing, and implementation. The timeline spans approximately six months, with resources allocated for hardware such as occupancy sensors, Wi-Fi modules, and a centralized dashboard, as well as adding data analytics into the project. The project will also involve training for security guards and building management staff to ensure effective use of the system.

The primary audience for this project includes the school's security personnel, parking users (students, employees, visitors, and outsiders), and building management office (BMO) staff. Each group will benefit from tailored functionalities: security guards will have real-time data to manage parking spaces efficiently and BMO staff will have access to data analytics for better decision-making.

The system is expected to enhance the efficiency of parking operations and reduce the time spent searching for parking spaces. For students and other parking users, the system will provide a seamless parking experience, while security guards will benefit from doing a manual inspection of availability of parking slots. BMO staff will gain valuable insights from data analytics, enabling more informed decisions and better management of the parking facility.

Following the successful implementation of the system, the next steps include continuous monitoring and evaluation to ensure the system meets its objectives and remains effective. Key stakeholders involved in the project are the school administration, IT department, security personnel, and parking users, all of whom will play crucial roles in the system's success.

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I. Introduction

1.1 Project Context

This project is for the client, namely the Building Maintenance Office, one of the offices in Asia Pacific College on the 10th floor of the building. Among their responsibilities are managing various facilities such as reservations, sewage, and basement parking. Upon approaching them, the client wants the developers to focus on basement parking and give them the processes and problems.

Currently, they are using a manual process in managing the basement parking. When a vehicle owner drives its way to the basement parking, upon entering it the security personnel commands it to stop and conducts an identification check to determine if the owner is an APC staff, student, guest, or an outsider. Follows the inspection of the underside of the vehicle. If the owner is an outsider, the security in charge will issue a parking ticket and will collect the parking fee. After all of that, they can proceed to the basement parking. After parking, the owner will surrender their valid ID to the security in the basement. Upon exiting the facility, the visitor will get their valid ID and hand over the parking ticket to the exit guard for verification of payment. Aside from those responsibilities, the officer in charge inspects each parking lot to determine whether they are vacant or occupied and informs the security personnel at the entrance about the status of the parking slots.

The mentioned processes take a lot of time to complete, and it is hassle for those who are in charge in both entrance and basement. With the wide space of the basement parking and having 2 levels of it, it takes a while before the officer-in-charge can update the status to the security personnel at the entrance which can cause a misinformation of the status that can possibly cause overcrowding within the basement parking.

With this automated parking tracking system, it will enhance the efficiency and accuracy of parking slot management, improving the overall experience for drivers and security personnel.

1.2 Statement of the Problem

The Building Maintenance Office identified the problems related to the basement parking at Asia Pacific College. The problems they encounter include:

1. Not fully utilized parking space.
2. Lack of visibility into available parking slots.
3. Manual and inefficient process of checking parking availability.

1.3 Objectives

1.3.1. Main Objective

ImPossible aims to automate the manual process of checking parking slot availability. By implementing this system, it will be easier to check the status in the basement parking area of Asia Pacific College, ensuring a more efficient and organized parking experience for everyone.

1.3.2. Specific Objectives

The specific objective of the project is to develop a tracking system that can help:

1. To advertise Asia Pacific College’s basement parking to the customer segments.
2. Install parking sensors and a monitoring system to provide real-time visibility of parking slot availability.
3. To reduce the reliance on manual labor for parking management tasks.

1.4 Significance of the Project

If the project is implemented, the project will eliminate the client's manual process of checking basement parking availability. By providing a monitor to display the status of each parking slot, it will significantly reduce the staff's workload and improve overall efficiency.

Furthermore, the following roles will benefit from the project:

Client

As the manager of parking operations, this project will significantly enhance efficiency by automating the process of monitoring parking space availability, thereby reducing the need for manual checks. Additionally, it will offer valuable data analytics to understand parking usage patterns, enabling better planning and resource allocation.

Vehicle Owners

Most of the school's stakeholders have their own vehicles and require parking during each visit to the campus. This project will provide them with real-time information on parking availability, significantly reducing the time spent searching for parking spots and lowering gas consumption. Additionally, it will greatly enhance their overall satisfaction with the parking experience at Asia Pacific College.

Security Personnel

For security personnel, streamlining operations simplifies their task of monitoring and managing the basement parking. This allows them to focus more on critical tasks. Additionally, real-time monitoring of parking spaces enhances overall campus security and safety by enabling the quick identification of vehicles parked in restricted areas, and potential safety hazards such as blocked fire lanes or emergency exits.

School

Since the basement parking is located at Asia Pacific College, this project will enhance the operational efficiency of the parking facility, reflecting positively on the school's infrastructure. The integration of analytics will support informed decision-making regarding campus facilities and future developments, ensuring that resources are allocated effectively, and improvements are made based on data-driven insights.

Future Developers

Future developers will benefit from this project as it provides a solid baseline for further development and identifies areas for enhancement. It offers practical experience in developing and maintaining an embedded system. Additionally, they can collaborate with the same client for continuous improvement and ensuring the project evolves to meet the client's needs effectively.

Sustainable Development Goals

The proposed project aligns with the following Sustainable Development Goal (SDG):

SDG 9: Industry, Innovation, and Infrastructure

This project contributes to building resilient and sustainable infrastructure by enhancing and improving parking management through a technology solution.

SDG 11: Sustainable Cities and Communities

It enhances parking experience, making it more efficient and organized which contributes to safer and more accessible transportation systems within the school campus community.

SDG 12: Responsible Consumption and Production

This project optimizes parking spade usage and reduces time effort in looking for parking which promotes efficient resource use and reduces unnecessary fuel consumption.

1.5 Scope and Limitations

This project intends to improve the efficiency and functionality of parking for individuals at Asia Pacific College. Our proposed solution will assist the Building Maintenance Office and Security Personnel by developing an embedded system that will cover the basement parking with sensors per slot. These sensors will offer real-time updates to the monitor, which displays the available and occupied parking slots per basement level. The developers will also incorporate analytics into the project to establish how many spots were used on a daily, monthly, and yearly basis, allowing us to measure the effectiveness of basement parking and our project. This study's primary target includes the building maintenance office, information technology resource office, stakeholders, visitors, and students. The primary targets of this study include the building maintenance office, stakeholders, visitors, and students. The study will be conducted from the 2nd year, 3rd term to the 3rd year, 3rd term of our stay at Asia Pacific College. The project will be dependent and focused on what the developers and client agreed upon, as well as financial considerations. If further features are not agreed upon, they should be communicated to future project-based learners to improve the project and meet the client's needs.

II. Review of Related Literature / Systems

Parking a car can be challenging, even for experienced drivers. According to Parklio [1], managing parking lot occupancy traditionally required significant time and effort. However, recent technological advancements have transformed the parking sector. Notably, parking space detection sensors and camera detection systems have emerged as leading solutions for real-time monitoring of parking lot occupancy, forming the foundation for smart parking systems. These sensors, embedded in various road surfaces, provide accurate, real-time data on vehicle presence and notify users of available parking spaces for both on-street and off-street scenarios. These innovations not only streamline parking management but also enhance driving efficiency and convenience, paving the way for the future of urban transportation.

One of the most persistent challenges individuals face is finding parking. During peak hours, parking zones fill up quickly, forcing drivers to search for available spots in other areas, which leads to added stress and uncertainty. This problem is especially pronounced in multilevel parking garages, where locating an empty spot can be particularly troublesome on weekends or public holidays. During these peak times, it can take over 10 minutes for approximately two-thirds of visitors to find a space. This insufficient car parking capacity leads to traffic congestion and driver frustration. A study by Nandyal et al. [2] revealed that over one year, the search for parking spots resulted in the equivalent of 38 trips around the world, consuming 177,914.8 liters of petrol and emitting 730 tonnes of CO2. These findings underscore the urgent need for more efficient parking solutions to alleviate environmental and logistical burdens associated with traditional parking practices.

In addition to this, Kotkar et al. [3] observed that with increasing reliance on personal vehicles over public transport, traffic congestion has intensified, making parking even more challenging. The most significant challenge for city travelers is finding a place to park their vehicles. This not only wastes time and fuel but also exacerbates traffic congestion and causes frustration for other drivers. In multilevel parking garages, finding a vacant spot quickly is especially difficult during weekends or holidays. Stadiums and commercial malls are particularly overcrowded during peak seasons, making it hard for customers to find unoccupied spaces. This inadequate parking capacity leads to activity blocking and driver dissatisfaction.

Furthermore, Deepthi [4] highlighted that the rapid growth of urban populations has significantly increased vehicle usage, exacerbating parking issues and contributing to traffic congestion, driver frustration, and air pollution. Popular destinations like shopping malls, multiplex cinemas, and hotels experience intensified parking problems during peak times and festive seasons. Recent studies indicate that drivers spend an average of 8 minutes searching for a parking spot,

contributing to 30 to 40% of traffic congestion. To address these challenges, recent projects have explored smart parking systems, such as those using the Slot Allocation strategy with Arduino UNO, to reduce parking difficulties and provide secure parking solutions. The primary objective of these systems is to monitor the status of parking areas and ensure secure parking, thereby reducing congestion and improving urban efficiency.

Lastly, Yusnita et al. [5] emphasized the importance of analyzing the impact of parking technology on various stakeholders, including students, faculty, staff, school administration, visitors, maintenance and security personnel, the nearby community, parking enforcement, and vendors. Understanding these impacts can help manage the complexities of implementing new technology and allow for a more statistical approach to data gathering. As people adapt to new technologies, they often struggle with parking in city lots, highlighting the necessity for continued innovation in parking solutions.

In conclusion, the implementation of parking sensors and other advanced parking technologies is crucial for addressing the persistent challenges associated with finding parking in urban areas. These innovations offer significant benefits, including reducing search time, alleviating traffic congestion, and minimizing environmental impacts. By understanding and managing the effects on various stakeholders, such as students, faculty, and the local community, schools and other institutions can effectively navigate the complexities of these technological improvements. As the reliance on personal vehicles continues to grow, the adoption of smart parking solutions becomes increasingly essential for enhancing urban transportation efficiency and sustainability.

III. Current Systems

3.1 Current System

The Building Maintenance Office's current system still involves a manual process. When someone asks the guard whether there is a spot open, the officer in charge checks the basement parking level to determine if there is still a spot available for the first level. If there are no available spaces, he will notify the basement 1 guard to display a notice stating, "This parking area is full, please proceed to the next floor". If a spot is still open, he will notify the entry guard. Their communication and inspection processes remain heavily dependent on human interaction.

3.2 Technical Background

Currently, the Building Maintenance Office's parking management system is mostly manual, depending heavily on basic communication methods and labor-intensive physical inspections. They utilize physical signs to warn parking users whether the parking area is full or not, and this is determined by the information communicated by the officer in charge. They use radio to convey this information, which can cause delays and dissatisfaction among parking users. The absence of software and innovative hardware technologies significantly hinders the ability to manage the parking facility effectively.

3.3 List of Processes

Table I List of Processes

Process ID	Process Name	Process Details
P001	Security Personnel Identification Check	1. The security personnel commands the driver of the vehicle entering the basement parking to stop. 2. The personnel on duty does identification check whether the outsiders or entities affiliated with APC are to enter the basement parking.
P002	Vehicle Inspection	1. The guard proceeds to inspect the underside of the vehicle, mainly for security purposes.
P003	Ticket Issuance and Payment Collection	1. If the driver of the vehicle is an outsider, he/she is given a parking ticket and the guard in charge is responsible for collecting the payment of the parking.

P004	Entry Authorization	1. After following preceding steps, the guard shows a go signal to the driver of the vehicle to enter the basement parking.
P005	ID Surrender for Building Entry	1. When the vehicle is parked, the driver then surrenders his/her valid ID to the security personnel in charge on the basement.
P006	Inspection of every level of basement parking	1. The officer in charge of the certain level of basement parking inspects every parking slot, whether vacant or occupied. 2. Once the officer in charge completes roaming around the area, he then notifies the security personnel on the entrance about the status of the parking slots.
P007	Ticket Surrender at Exit	1. Upon exiting the parking facility, the visitor surrenders the parking ticket to the exit guard to verify payment and authorization.

3.4 Gap Analysis

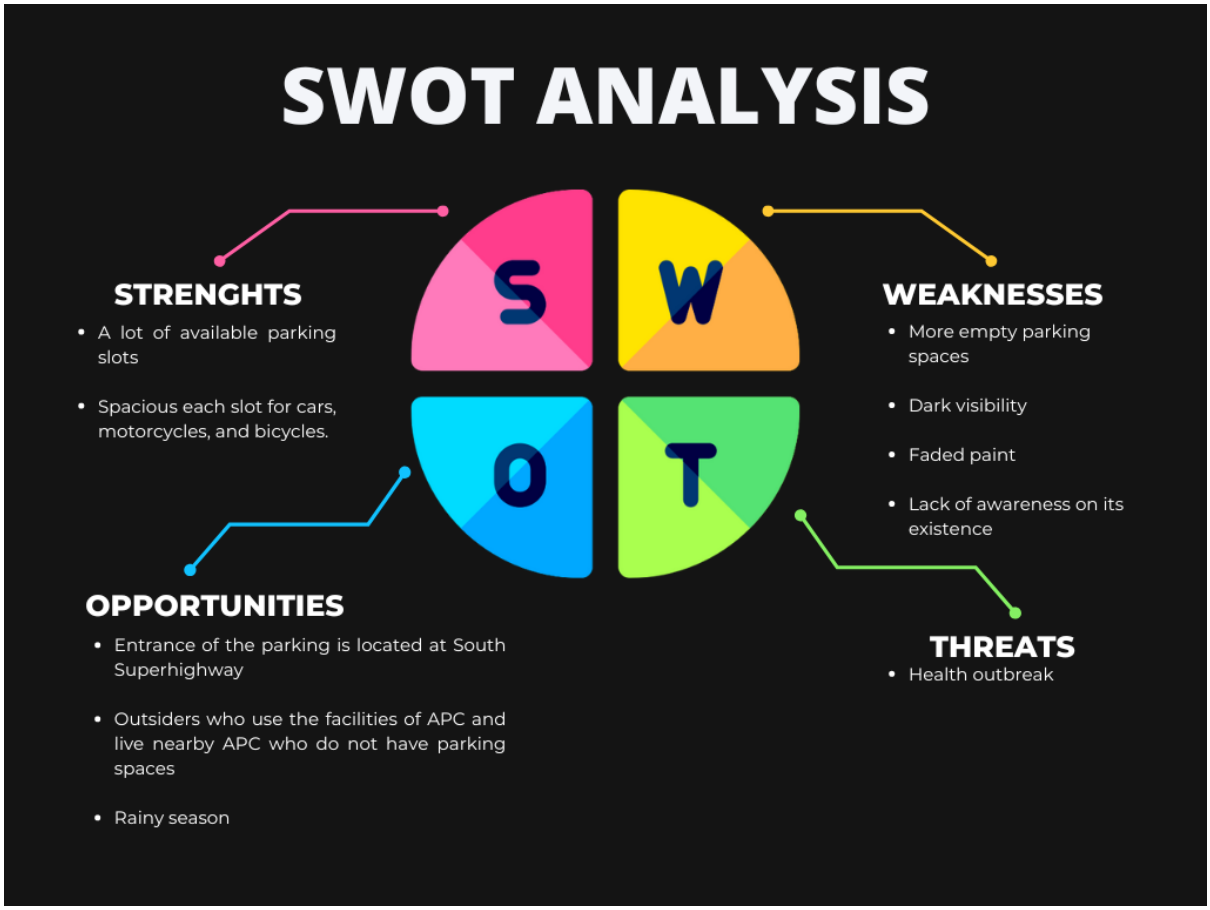


Figure 1 SWOT Analysis

3.4.1 Strength

A lot of available parking slots

Knowing plenty of available parking slots is a significant strength as it means that there is ample capacity to accommodate vehicles, reducing the likelihood of congestion and ensuring that users can find parking easily.

Spacious Each Slot for Cars, Motorcycles, and Bicycles

Having spacious slots for different types of vehicles (cars, motorcycles, bicycles) enhances the user experience by providing adequate space for parking and maneuvering, which can prevent damage and improve safety.

3.4.2 Weakness

More Empty Parking spaces

While having available spaces is generally positive, an excessive number of empty spaces indicates underutilization, which could imply inefficiency in attracting users.

Dark Visibility

Poor lighting conditions can create safety hazards, make it difficult for users to navigate the parking area, and deter people from using the facility, especially at night.

Faded Paint

Faded paint on parking lines and directional signs can lead to confusion and inefficient use of the space. It may also negatively impact the overall appearance of the parking facility.

Lack of Awareness of Its Existence

If potential users are unaware of the parking facility, it will remain underutilized. Effective communication and advertising are necessary to inform and attract users.

3.4.3 Opportunities

Entrance of the Parking is Located at South Superhighway

This strategic location offers high visibility and accessibility, making it convenient for drivers passing by or coming from the South Superhighway, potentially increasing the number of users.

Outsiders Who Use the Facilities of APC and Live Nearby APC Who Do Not Have Parking Spaces

There is an opportunity to attract external users who visit APC for various purposes and nearby residents lacking parking facilities, thereby increasing the usage and revenue of the parking facility.

Rainy Season

During the rainy season, the demand for secure, covered parking typically increases as people seek to protect their vehicles from harsh weather conditions. This can lead to higher utilization of the basement parking facility.

3.4.4 Threats

Health Outbreak

A health outbreak, such as the COVID-19 pandemic, can drastically reduce the number of people using public and shared facilities, including parking spaces, due to lockdowns, remote work, and safety concerns, impacting the utilization and revenue of the parking facility.

IV. Proposed Solution

4.2 Lean Canvas

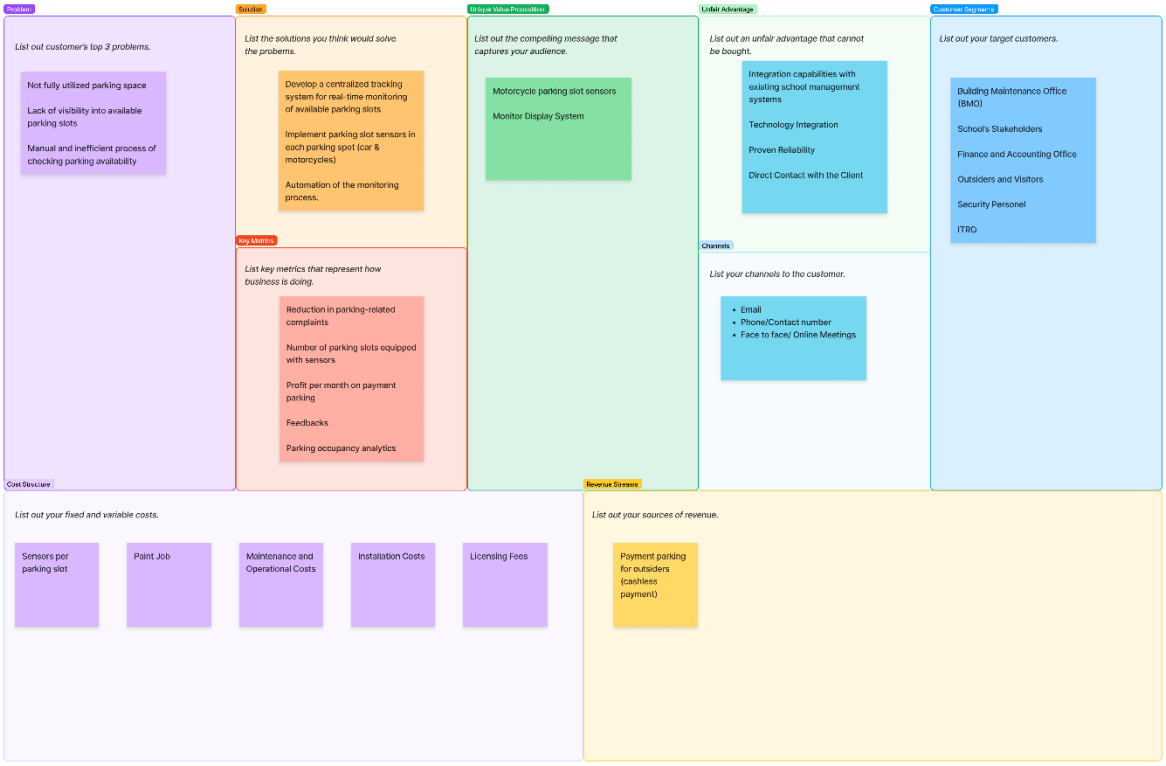


Figure 2 Lean Canvas

Problem

- Not fully utilized parking space
- Lack of visibility into available parking slots
- Manual and inefficient process of checking parking availability

Solution

- Develop a centralized tracking system for real-time monitoring of available parking slots
- Implement parking slot sensors in each parking spot (car & motorcycles)
- Automation of the monitoring process.

Key Metrics

- Reduction in parking-related complaints
- Number of parking slots equipped with sensors
- Profit per month on payment parking
- Feedback

- Parking occupancy analytics

Unique Value Proposition

- Motorcycle parking slot sensors
- Monitor Display System

Customer Segment

- Building Maintenance Office (BMO)
- School's Stakeholders
- Finance and Accounting Office
- Outsiders and Visitors
- Security Personnel
- Information Technology Resource Office (ITRO)

Channels

- Email
- Phone/Contact number
- Face to face/ Online Meetings

Revenue Streams

- Payment parking for outsiders (cashless payment)

Cost Structure

- Sensors per parking slot
- Paint Job
- Maintenance and Operational Costs
- Installation Costs
- Licensing Fees

Unfair Advantage

- Integration capabilities with existing school management systems
- Technology Integration
- Proven Reliability
- Direct Contact with the Client

4.3 Product Vision

Table II Product Vision

For	Building Maintenance Office of Asia Pacific College
Who	Needs an effective, automated way to keep an eye on parking space usage, manage it, and enhance users' overall parking experiences.
ParkSense	is an Arduino-embedded parking management system
That	Increases operational efficiency by reducing the need for manual intervention by security personnel and provides real-time monitoring of available parking spaces per basement level. In addition, it keeps track of the parking spaces that have been utilized and offers data on how frequently they are used.
Unlike	Current parking management systems, which usually require human intervention and do not provide real-time monitoring for cars and motorcycles.
Our Product	Will provide a parking slot sensor for both cars and motorcycles, a centralized real-time display system, and a centralized monitoring display for basement level occupancy, resulting in a comprehensive and automated parking management solution. This will ensure optimal space usage, decrease manual oversight of security staff, and offer analytics on how frequently the parking lot is used.

4.4 Technology Specifications

The developers proposed developing a parking sensor to monitor the availability of parking spaces in Asia Pacific College's basement car park. They chose C++ as the programming language because it is compatible with Arduino IDE. The developers will use Arduino boards for their prototype as they are suitable for building embedded systems. In addition, a screen in the entrance to the basement park is not the only way to monitor the parking spaces, but also a monitor through a personal computer that will show a cartooned car in a parking space if it is taken. Considering the developers' idea in integrating the trends into the project's addition, it is in best desire of the developers to incorporate a database, specifically MySQL, to store data of how many vehicles park in every level of the basement in daily, monthly, and yearly basis. The data gathered from the database will be reflected on the dashboard, served as analytics, in the sense of

displaying a statistical graph of the volume of vehicles parked in the mentioned time periods.

Table III Technology Specifications

Category	Specifications
Hardware	• Arduino uno board/ Arduino Wi-Fi • Infrared Sensor • Monitor for display • PC/Laptop for development
Software	• Arduino IDE • Visual Studio • C++ Language • Python Language • MySQL
Peopleware	• Developers • Building Maintenance Office staffs • Project Adviser • Project Consultants • Security Personnel
Network	• Internet connectivity • Local/Cloud server

4.5 Feasibility

4.5.1 Operational Feasibility

The client and the staff express their utmost support for the project to be implemented. The clients believe the project will be a useful asset in modernizing the parking management operations and automatically assist the guards of the establishment in detecting the number of cars parking in a certain level of the basement parking without making an effort in roaming around the parking to report the availability of the parking slots on the staff on duty in the entrance. The project will also help in marketing the basement parking for the students, stakeholders, and outsiders.

4.5.2 Economic Feasibility

The developers and the client have a mutual agreement on the project's potential expenses. The client is prepared to cover all the costs associated with

the purchasing of Arduino kits and other hardware items. About expenditures, the project plan will increase parking income since it involves marketing of the basement parking. The project's target audience consists of visitors and outsiders who use Asia Pacific College facilities, particularly the court, auditorium, and multi-purpose hall. This will open the client's source of revenue.

4.5.3 Technical Feasibility

The technical considerations to consider when developing the basement parking project include using an Arduino board, breadboard, and other Arduino-related materials to achieve our aim of recognizing vehicles parked in certain slots. To modify Arduino, write it in the Arduino IDE using C++ as the programming language. The developers want to utilize Python on the project's back-end server to process sensor data and store it in a database. As the database said, they have opted to store the data in MySQL, which can then be utilized for data analysis. The three essential web technologies, HTML, CSS, and JavaScript will be used to create the dashboard that displays the parking spots from basements 1 to 3. The web frameworks they will consider using are React and Angular. A prototype will be sent to the client for approval and to get valuable feedback and recommendations.

4.5.4 Schedule Feasibility

Our schedule feasibility is based on the project roadmap and release plan provided in this project paper. The group members will use the Scrum Waterfall Framework to complete the project. The subjects MSYADD1, MCSPROJ, and PROJMAN will cover the development of this project. Once authorized, this Project-Based Learning (PBL) will last three terms for third-year college students on Asia Pacific College's academic schedule.

V. Requirements Analysis

5.1 Product Backlog / User Stories

Table IV Product Backlog

ID	As a…	I want to be able to…	So That…	Priority
1	Security Guard	Check the dashboard	I can see the current status of the parking facility	Must
2	Security Guard	Monitor parking space occupancy	I can ensure that all spaces are utilized efficiently	Must
3	Security Guard	Direct traffic	Traffic flow within the parking facility is smooth	Should
4	Parking User	Use the parking facility	I can park my vehicle quickly and securely	Must
5	Parking User	Authenticate my identity	I can access the parking facility	Must
6	Parking User	Report issues	Any problems can be addressed quickly	Should
7	BMO Staff	Analyze data	I can make informed decisions based on the data given	Must
8	BMO Staff	Generate reports	I can provide detailed information to stakeholders	Should
9	BMO Staff	Oversee maintenance	The parking facility is maintained regularly and efficiently	Should

5.2 Use Case Diagram

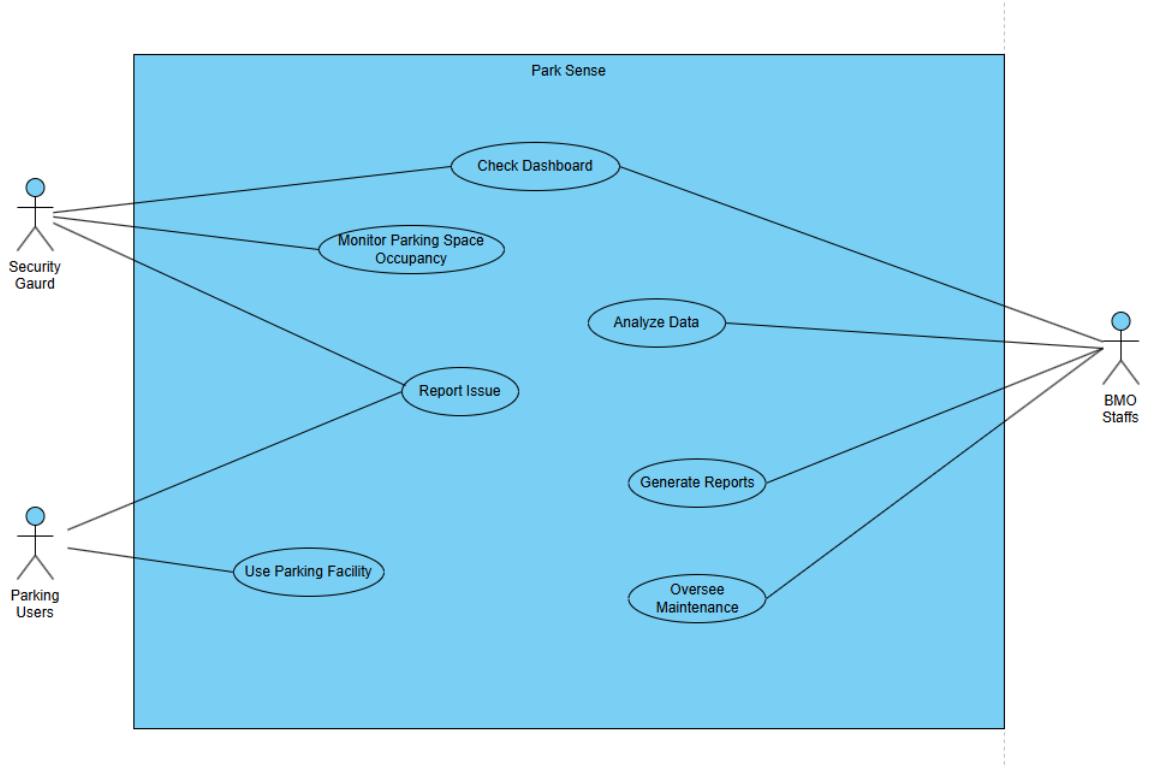


Figure 3 Use Case

5.3 User Classes and Characteristics

Table V User Classes

Roles	*Description*
Security Guard	This user is responsible for ensuring the efficient use of parking spaces and maintaining order within the facility.
Parking Users	These users are different groups of people with respective parking needs.
Building Staff	This user is knowledgeable about the parking system, responsible for administrative tasks and decision-making.

5.4 Prototype

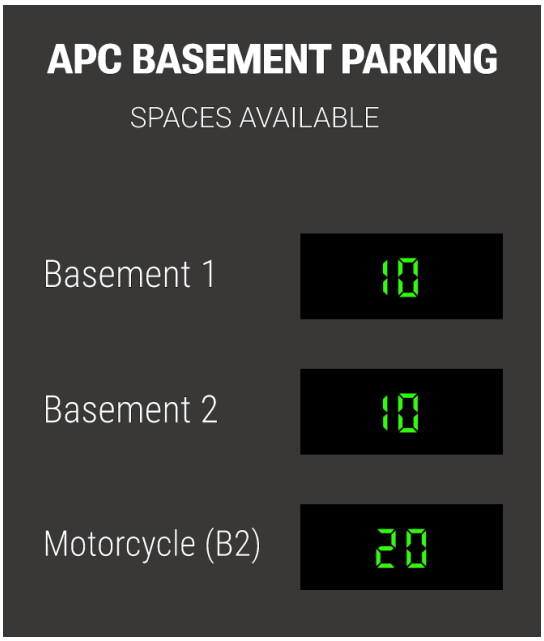


Figure 4 Prototype: Tracker Display

Figure 5 Prototype: Dashboard

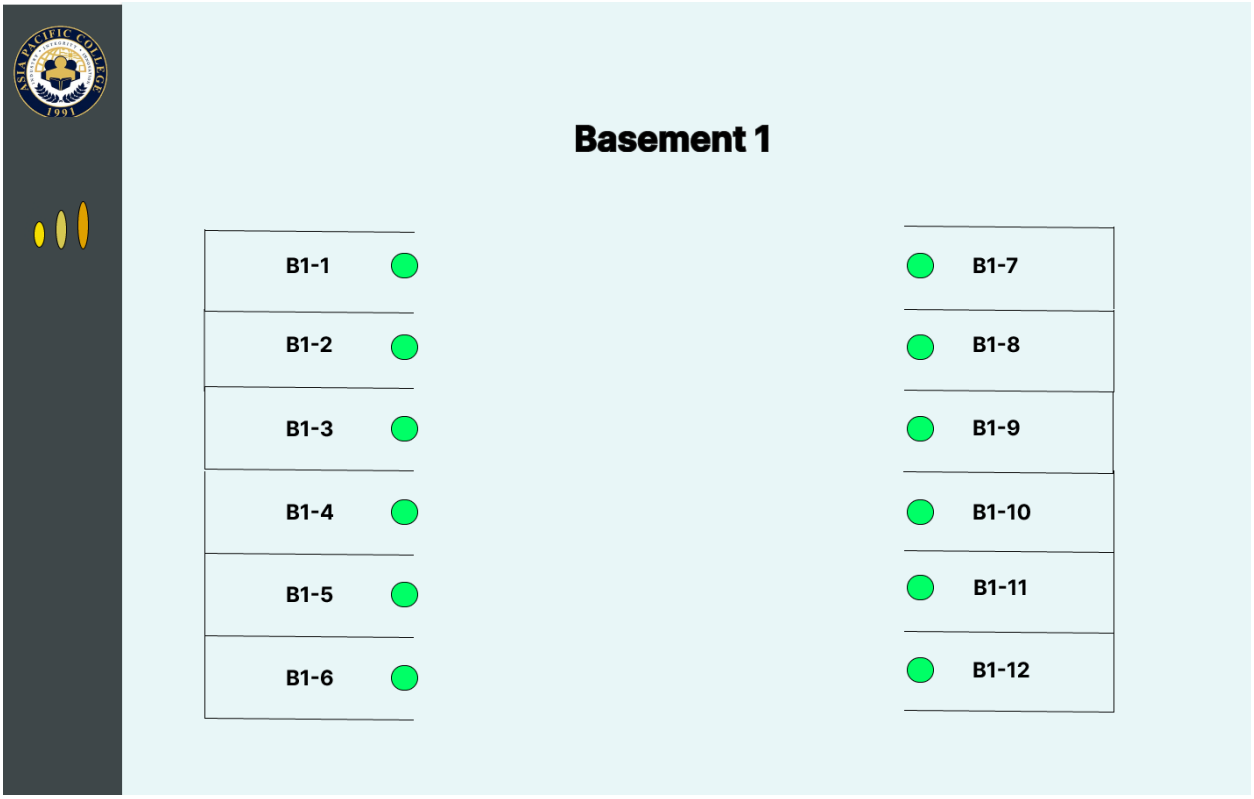


Figure 6 Prototype: Basement 1 Display

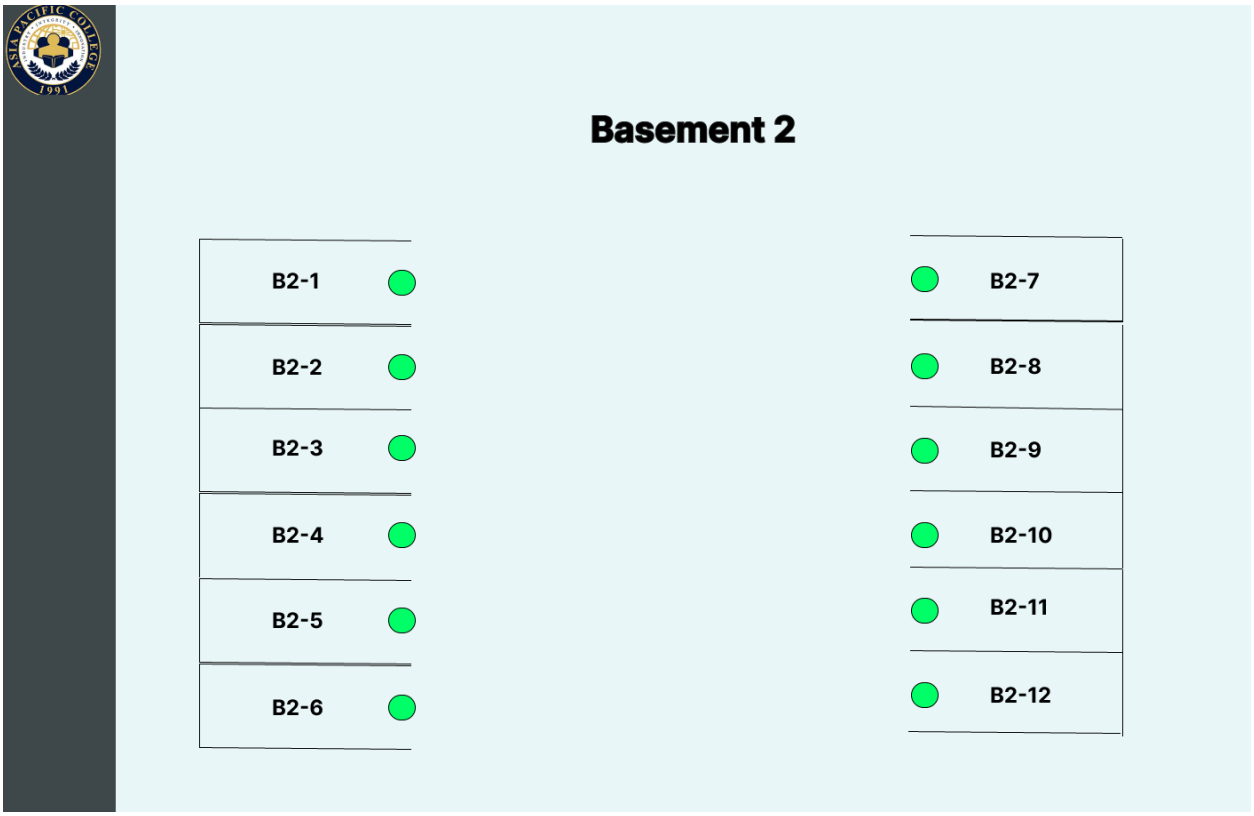


Figure 7 Prototype: Basement 2 Display

Figure 8 Prototype: Basement 1 Slots Taken

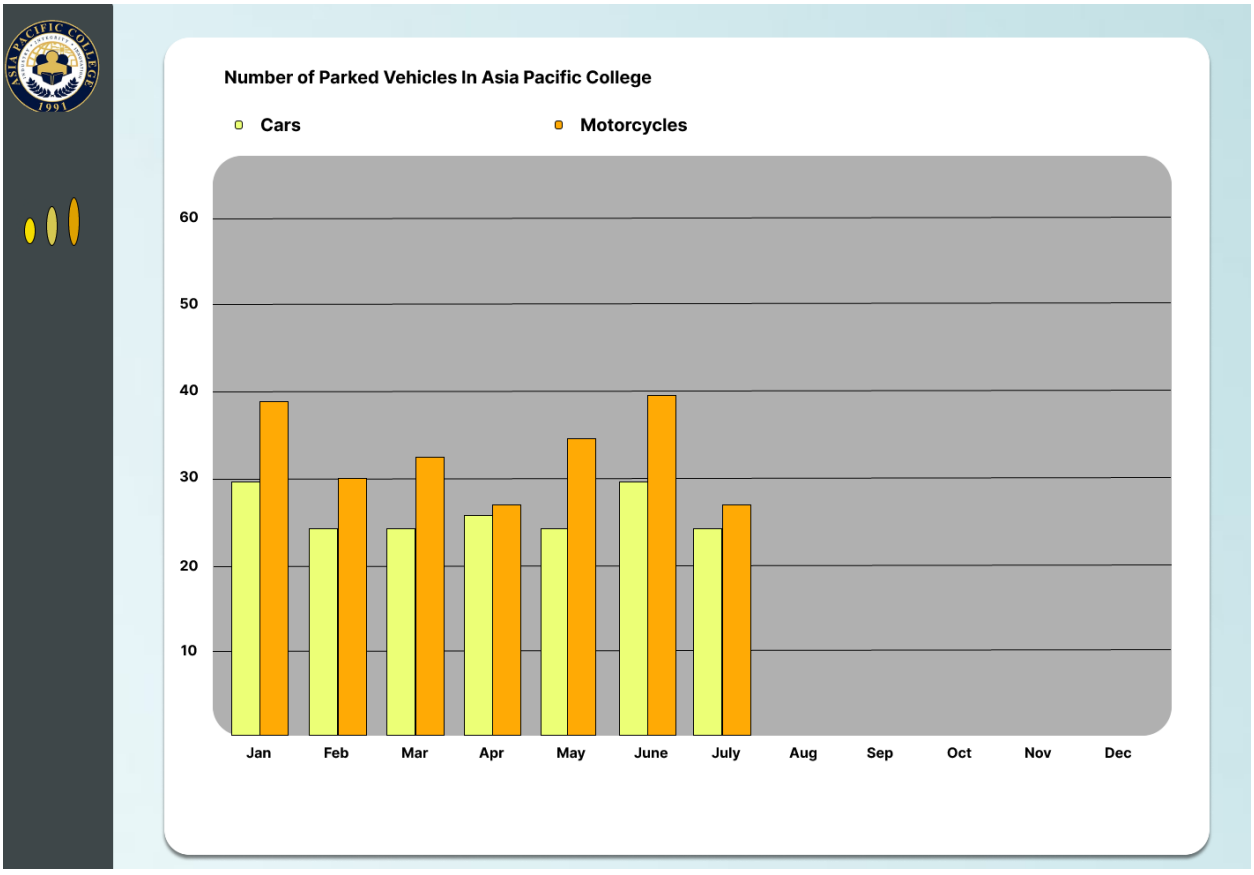


Figure 9 Prototype: Analytics

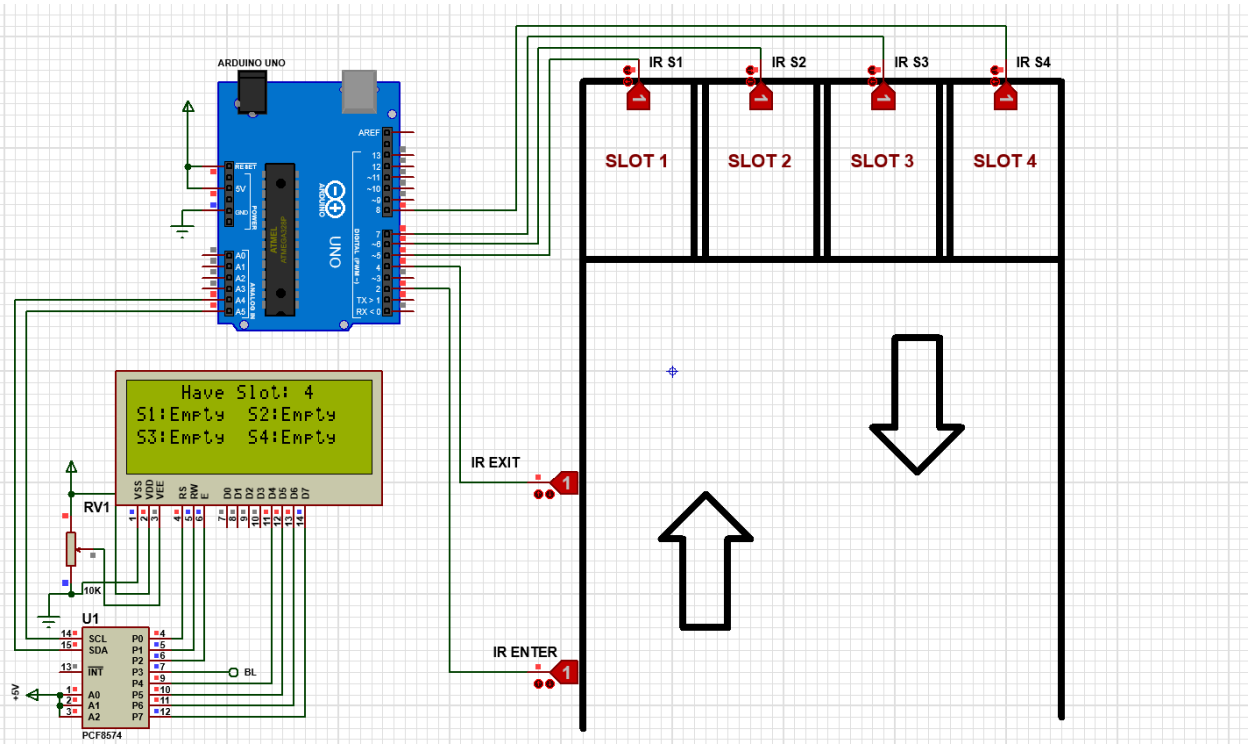


Figure 10 Prototype: Schematic Diagram

5.5 Release Plan

The release plan for our proposed system will be divided into four terms of the Project Based Learning courses based on the academic calendar for the Bachelor of Science in Information Technology with Specialization in Mobile and Internet Technologies 2022. This plan will include the milestones, deliverables, and timelines for each phase of the whole Project Based Learning course. Refer to Appendix B for the project's Gantt Chart and Appendix C for the product roadmap.

Target Group: Building Maintenance Office (BMO)

Goal: To create a completely automated parking management system that combines modern technology with the subjects we studied at Asia Pacific College. This contains sensors for each parking slot, display trackers to keep track of available slots on each basement level, and a real-time monitoring system that provides analytics and indicates whether or not the basement level is filled.

Needs:

- Real-time monitoring and analytics of parking usage

- Reduction of manual checking for available slot for BMO and Security Guard
- Precise and dependable data from trackers and sensors.
- Efficient management of parking spaces.

Values: ParkSense will allow the Building Maintenance Office (BMO) and security guards to simply examine the state of the basement parking spots without having to walk down and roam around. The technology will also allow them to measure how many students, staff, stakeholders, and visitors utilize our basement parking on a daily, monthly, and annual basis.

Key Features: Sensor integration, Display tracker, Real-time monitoring system, User interface with analytics and reporting

Release Plan

Release 1

- Research Paper
- Prototype

Release 2

- Designing the website interface
- Hardware acquisition and setup
- Integration of the system components
- Implementation of database system

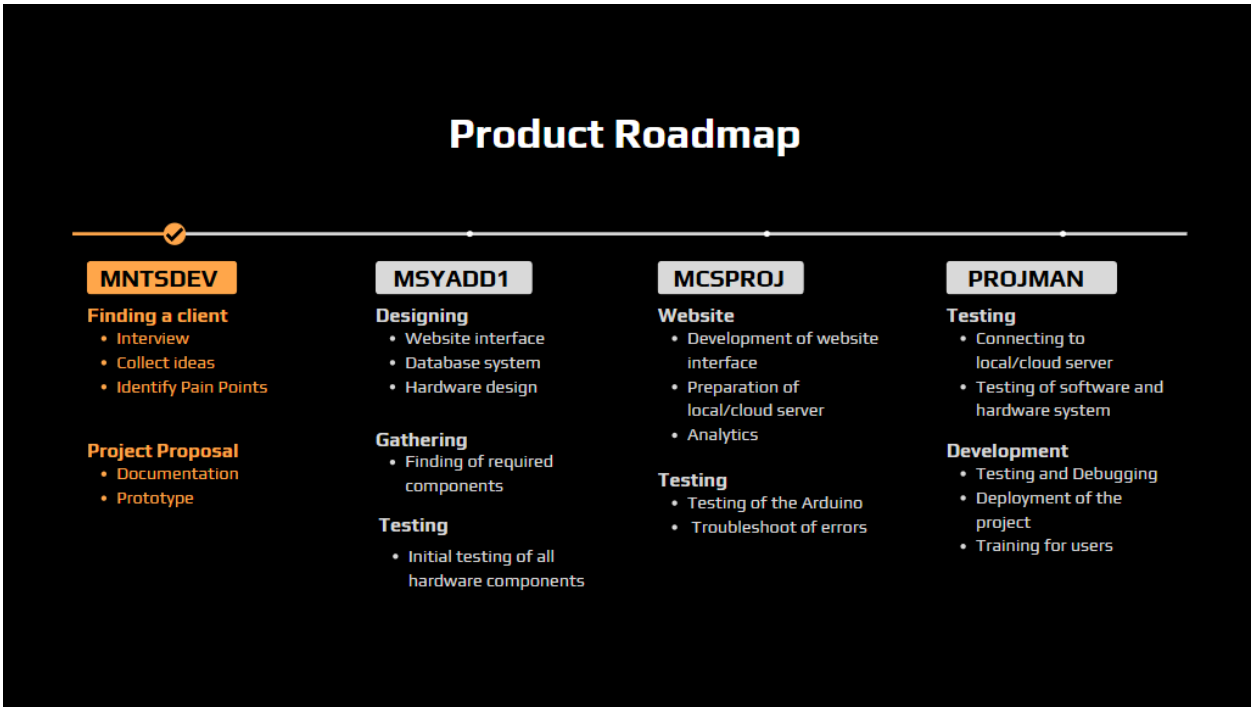
Release 3

- Development of website interface
- Testing and troubleshooting
- Preparation of local/cloud server

Release 4

- Final testing
- Deployment and installation
- Project video teaser
- Training for BMO staff and security guard

Product Roadmap



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Appendices

Appendix A: Project Vision

Our vision is to utilize innovative methods to make parking at Asia Pacific College more convenient, efficient, and user-friendly. Our goal is to create a completely automated parking management system that combines modern technology with the subjects we studied at Asia Pacific College. This contains sensors for each parking slot, display trackers to keep track of available slots on each basement level, and a real-time monitoring system that provides analytics and indicates whether or not the basement level is filled. By deploying this system, we want to improve the security and overall experience of all target users. The initiative aims to enhance campus parking by promoting a more orderly and sustainable environment.

Appendix B: Schedule/Release Plan

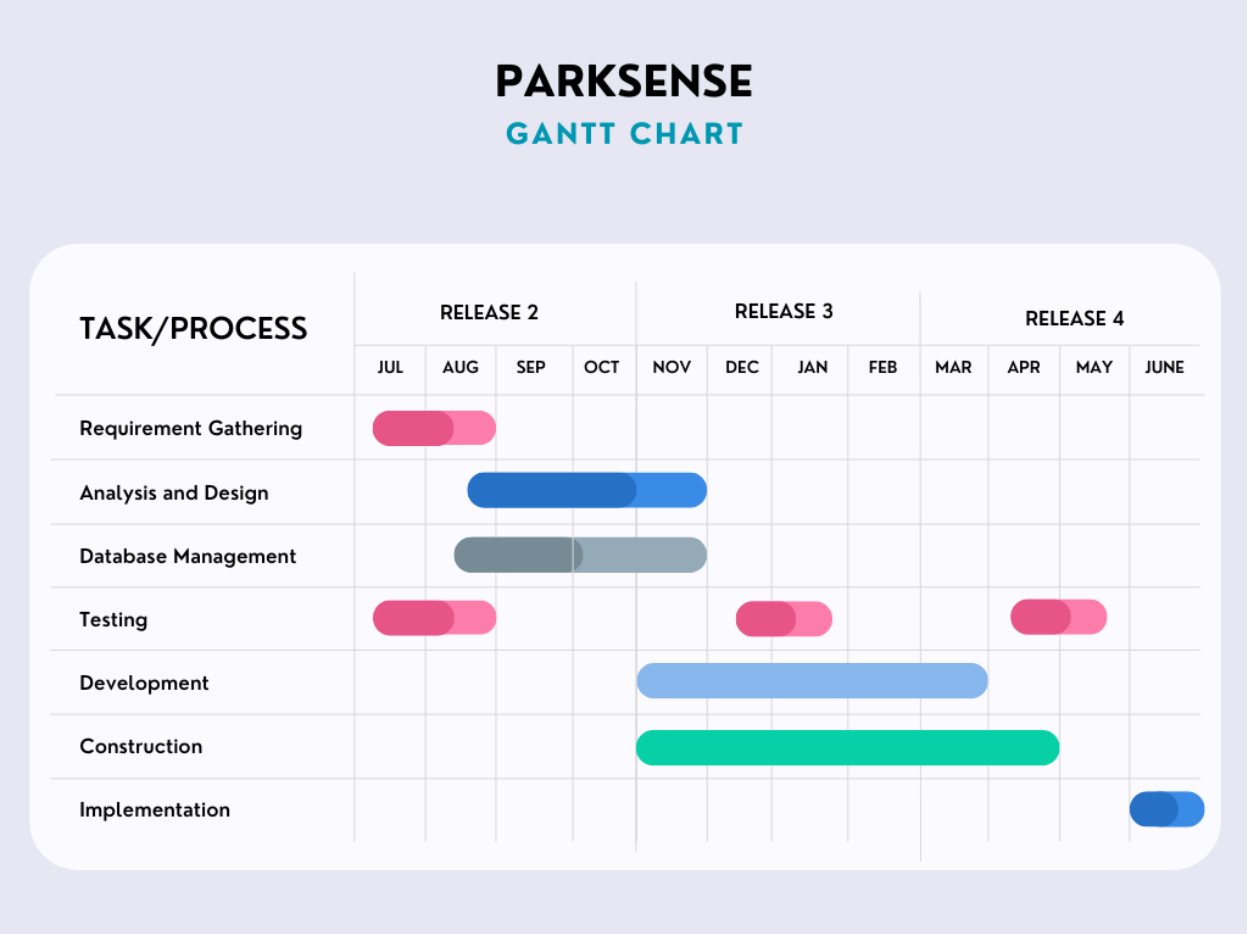

Figure 11 Release Plan

Appendix C: Product Roadmap

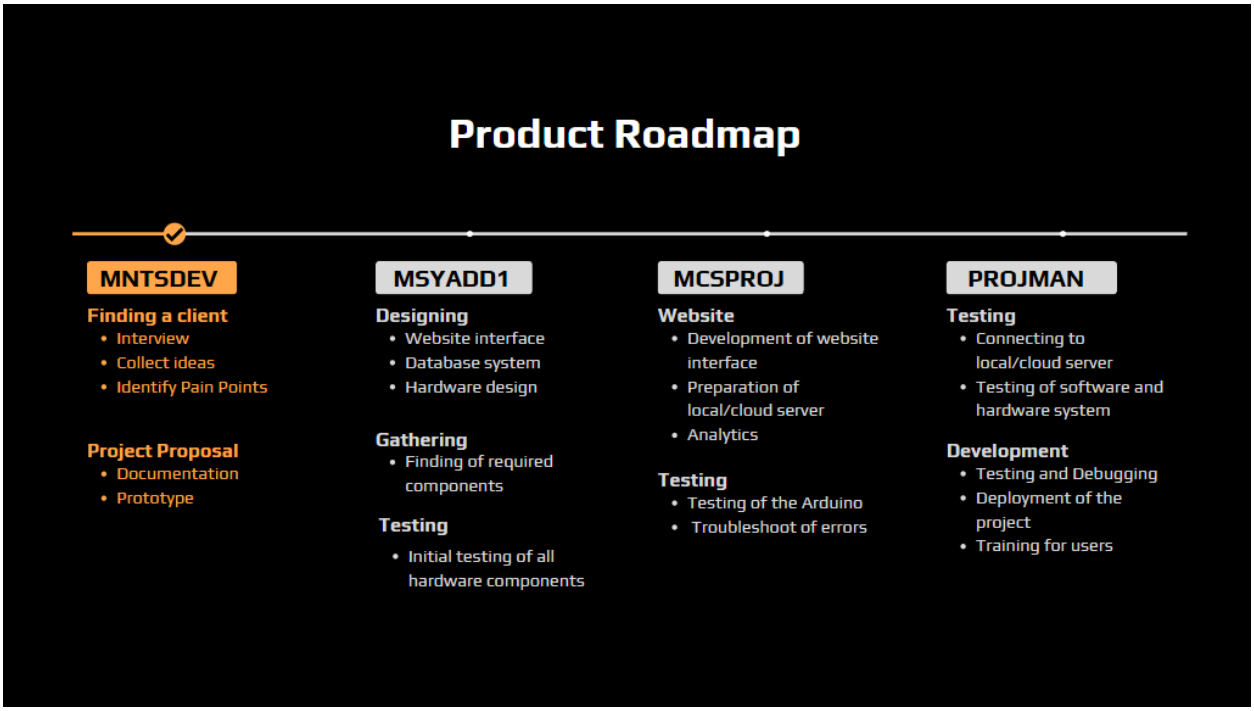

Figure 12 Roadmap

Appendix D: Meetings

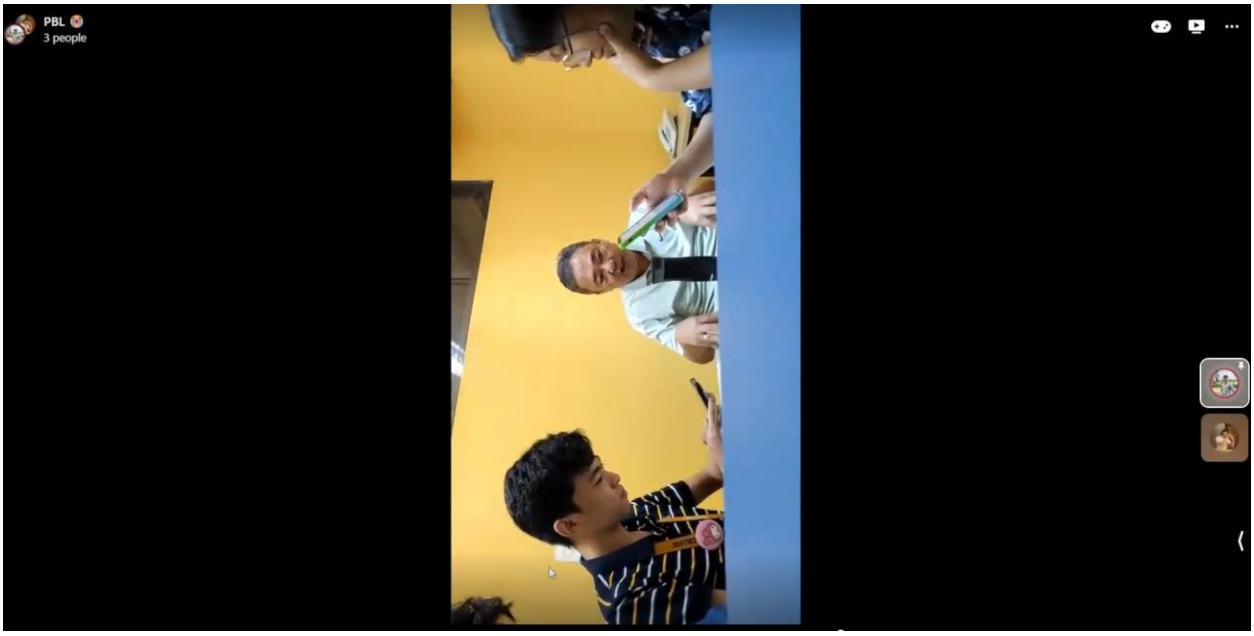

Figure 13 May 16,2022 - Post-Midterm Meeting with Adviser

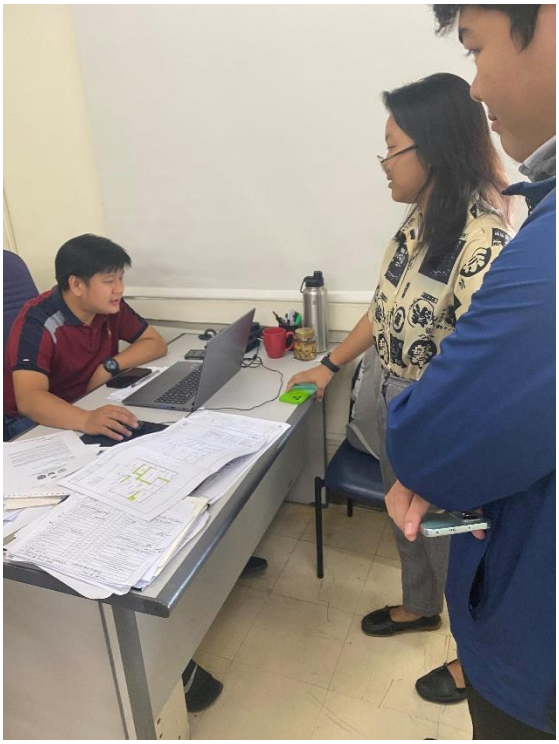

Figure 14 May 23, 2024 - Meeting with Client

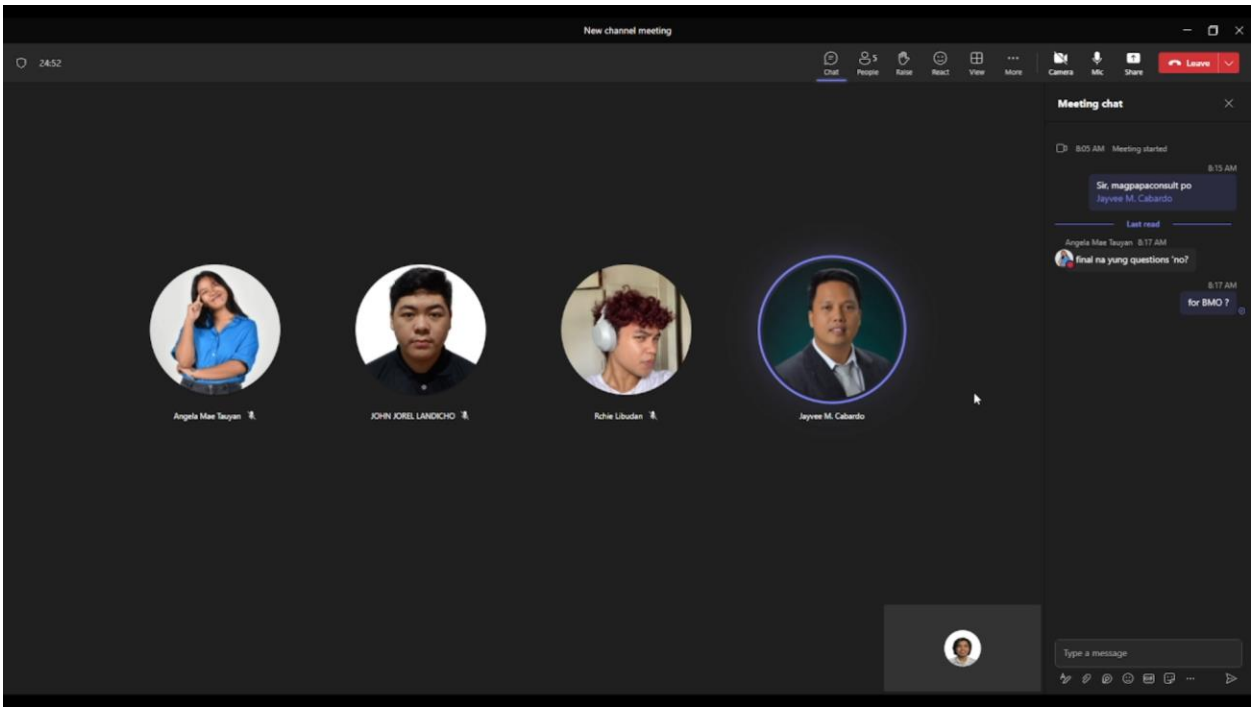

Figure 15 May 30,2024 - Meeting with Project Consultant