COMP3030J Software Engineering Project 2024-2025 System Document

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Abstract

This system document outlines the design and implementation of a campus waste classification management platform developed for the COMP3030J Software Engineering Project (2024–2025). In response to challenges faced by Beijing University of Technology—such as low student participation, lack of transparency in waste bin information, and insufficient educational resources—the project proposes a digital platform that integrates AI-powered recognition, real-time bin mapping, educational content, and an incentive system to improve waste management efficiency and environmental awareness on campus.

The platform adopts a web-based architecture. The frontend is built using HTML, CSS, JavaScript, and jQuery, with UI components styled using Bootstrap and Font Awesome. The backend is developed with the Flask framework, while SQLite is used for lightweight local data storage and management. Core system features include user management, waste recognition logging, map-based labeling, learning and quizzes, feedback collection, and reward tracking. The database schema follows normalization principles and employs foreign keys to maintain data integrity and scalability.

The project was developed through a milestone-based plan with six team members assigned to different roles, covering frontend/backend development, architecture design, testing, and deployment. The platform ensures system stability and user experience through unit testing and code review, with a strong focus on security and user data protection during deployment.

Throughout the development process, the team addressed technical and collaboration challenges via regular communication, refined task allocation, and clear responsibility assignments. The resulting platform successfully delivers core waste classification and educational functionalities and establishes a solid foundation for future extensions such as self-trained AI models, campus-wide reward integration, and advanced administrative tools.

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1 Project Introduction

1.1 Problem Statement:

In today's digital-first world, universities struggle with effectively managing campus waste and promoting sustainable practices. Beijing University of Technology faces challenges including low student engagement in waste sorting, unclear guidelines, inconvenient waste bin placement, and insufficient educational resources. Current solutions lack integrated technology and motivating incentives. Our project aims to address these issues by creating a digital platform utilizing real-time data, AI-assisted sorting, educational content, and rewards, significantly enhancing waste management efficiency and sustainability on campus.

1.2 Scope

This project will deliver a digital platform that provides AI-assisted waste sorting, real-time bin maps, educational content, and a reward system for students at Beijing University of Technology. The platform will include the following key features:

- Development of a web platform with AI image recognition, real-time smart bin map, and question modules to promote classifying.
- Integration of reward systems and data analytics for waste management optimization based on users' recognition history data.
- Implementation of an admin panel allowing management of users, feedback, and the map, as well as access to full system data for monitoring and expansion planning.

Physical infrastructure changes (e.g., location of bin installation won't change) and off-campus waste management partnerships are **not included** in this project.

1.3 Use Case Diagram

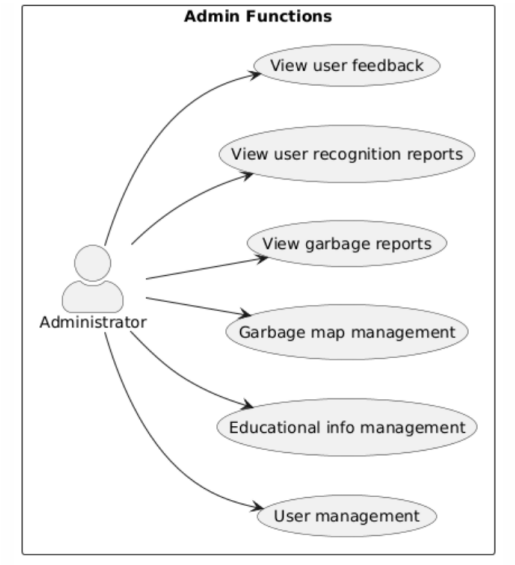


Figure 1: Administrator Use Case Diagram

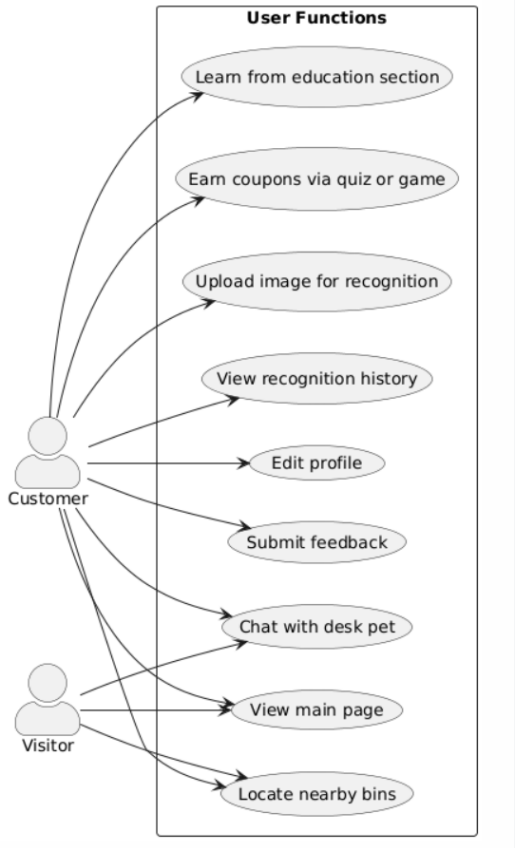


Figure 2: User Use Case Diagram

2 Project Plan

2.1 Time Management

We divided our project into six different milestones, with each milestone being managed by different members.

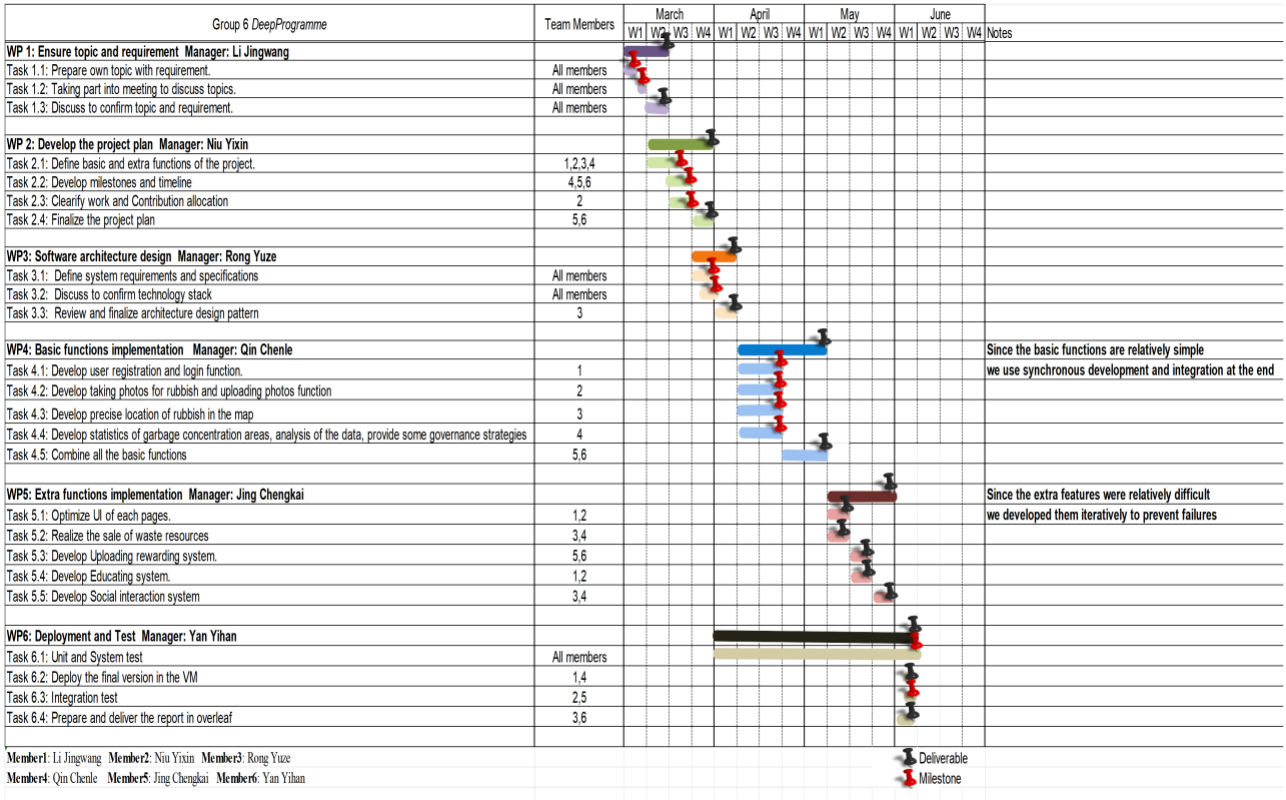


Figure 3: Gantt Chart for Project Plan

- **Milestone 1:** Ensure topic and requirement by Jingwang Li, finalized by March 9th.
- **Milestone 2:** Develop the project by Yixin Niu, finalized by March 29th.
- **Milestone 3:** Software architecture design by Yuze Rong, finalized by April 5th.
- **Milestone 4:** Basic functions implementation by Chenle Qin, finalized by May 7th.
- **Milestone 5:** Extra functions implementation by Chengkai Jing, finalized by June 14th.
- **Milestone 6:** Deployment and test by Yihan Yan, finalized by June 14th.

2.2 Technology Stack

UI Library: Bootstrap was used to design responsive layouts, along with Font Awesome for iconography.

Database: SQLite was chosen for lightweight and easy-to-integrate data storage.

Backend: Flask served as the backend framework to handle server logic and API requests.

Frontend: The frontend was built using HTML5, CSS3, JavaScript, and jQuery to support dynamic and interactive web elements.

API: Google Map API, Alibaba cloud recognition API, and ChatGPT-3.5 API.

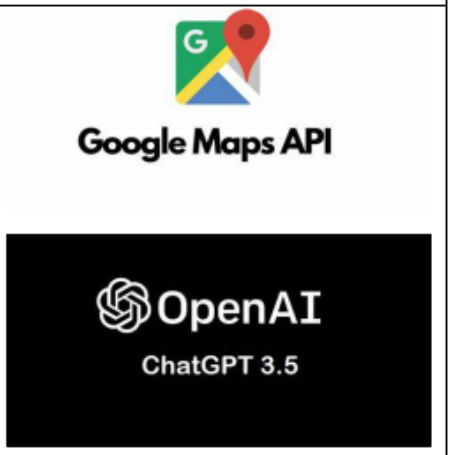
UI Library		
Database		
Back End		
Front End		
API		

Figure 4: Garbage classification result interface.

3 Collaboration

3.1 Group Work Division

First, our work is divided into the front-end and back-end,which is also divided in detail to the specific role and special function. The group consists of six members and diagram below explains the division of labor.

Table 1: Team Member Roles and Responsibilities

Name	**Role**	**Responsibility**
Li Jingwang	Technical Lead	Oversees system architecture, backend implementation, and final acceptance.
Niu Yixin	UI/UX Designer	Leads user interface design and tracks progress across development phases.
Qin Chenle	User Evaluator	Handles documentation, user feedback, CI/CD integration, and backend support.
Jing Chengkai	Frontend Engineer	Develops frontend modules, contributes to design, and performs testing.
Rong Yuze	Backend Quality Engineer	Ensures code quality through reviews, testing, and backend development.
Yan Yihan	Frontend DevOps Engineer	Maintains CI/CD pipeline and optimizes frontend code through refactoring.

3.2 Challenges Faced by Teams

Unclear Role Definitions

When team members lack clarity about task ownership, responsibilities may be avoided or duplicated, leading to delays, miscommunication, and reduced accountability.

Communication Gaps

Infrequent or ineffective communication—such as delayed responses or lack of shared updates—can result in misaligned expectations, delivery errors, and increased team conflicts.

Timeline Delays

Missing deadlines due to underestimated task complexity, limited resources, or scope creep can compromise quality and place pressure on subsequent milestones.

Quality Assurance Problems

Inadequate testing and peer review often lead to buggy code, inconsistent designs, or incomplete research outputs, requiring rework and delaying releases.

Technical Hurdles

Technical barriers such as tool incompatibility, lack of expertise, or external API failures can stall project progress, require additional training, and increase project costs.

Effective conflict management strategies

- **Regular Progress Meetings:** Implement routine check-ins to keep the team synchronized and to detect issues early before they escalate.
- **Focused Work Sessions:** Conduct collaborative work sessions to resolve complex problems, align understanding, and ensure team-wide clarity.
- **Rigorous Review Process:** Establish a structured peer-review mechanism to identify errors early, ensure task consistency, and promote accountability.
- **Clear Communication Channels:** Define and maintain efficient communication tools (e.g., messaging platforms, email protocols) to ensure responsiveness and transparency.
- **Information Security Protocols:** Apply strict measures to manage access rights, protect project data, and prevent unauthorized sharing or leakage.

3.3 Solutions for Team Conflicts

Clarifying Roles and Expectations

To prevent conflicts stemming from unclear responsibilities, teams should proactively define each member's role using a responsibility matrix such as RACI. This reduces confusion and ensures accountability. Regular check-ins help reinforce role boundaries and support task reallocation when needed.

Aligning Goals and Priorities

Misalignment on goals often leads to disagreements and delays. The team should collaboratively set shared objectives using SMART criteria and review them periodically. Using a visual priority matrix (e.g., urgency vs. impact) helps teams make faster, consensus-driven decisions.

Improving Communication Processes

Conflicts are often the result of communication breakdowns. To address this, teams should define clear communication channels (e.g., Slack for quick updates, meetings for strategic discussions) and agree on response time expectations. A shared communication protocol promotes transparency and reduces frustration.

Balancing Workloads and Supporting Team Members

Imbalances in workload can cause tension or burnout. Conflict can be mitigated by regularly auditing task assignments, reallocating work based on availability and skills, and offering support to members who are struggling—through mentoring, training, or peer assistance.

For more detailed information on team agreements and handling conflicts, refer to the team agreement document.

3.4 RACI Chart

Our group use RACI Chart to specify responsibilities of different group members to improve our efficiency. This chart clearly clarifies the the role of different members and avoids unclear work division.

Table 2: Team Member Responsibilities (RACI Matrix)

Activity	**Jingwang Li**	**Yixin Niu**	**Yuze Rong**	**Yihan Yan**	**Chengkai Jing**	**Chenle Qin**
Requirement Analysis	A	R	I	I	C	C
Project Implementation	A	C	R	C	I	I
Project Testing	I	A	I	R	C	C
Document	I	I	C	C	R	A
Develop and Design the Plan	C	R	I	I	A	I

4 User Type

4.1 Consumers

The website does not distinguish between different user types during account creation. Any account generated through the login or registration process is collectively referred to as *Consumers*.

4.2 Administrator

The **Administrator** is responsible for maintaining the overall integrity, security, and fairness of the platform. This role has elevated privileges and access to system-level features, including:

- **Monitor Reports:** Review and verify user-submitted waste bin reports for action.
- **Manage User Accounts:** Suspend, activate, or edit user roles and credentials.
- **Update Educational Content:** Add, modify, or remove quiz questions and learning materials.
- **Maintain Platform Security:** Enforce authentication, encryption, and data protection protocols.
- **View Users' Feedback:** Analyze feedback submitted by users to enhance the platform.

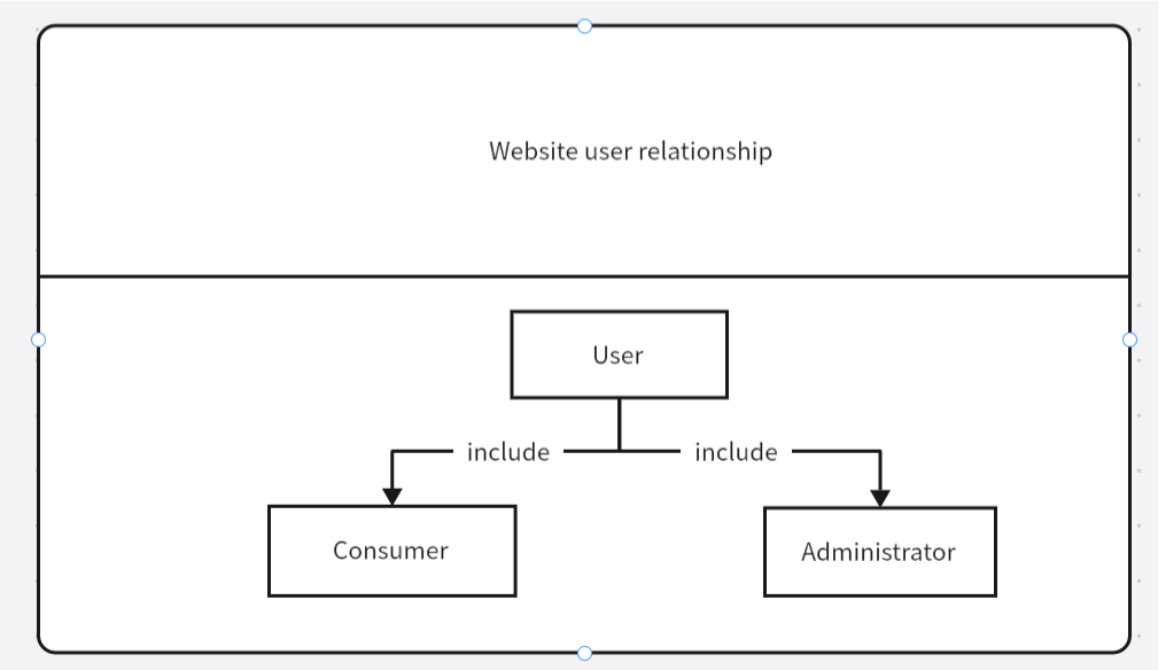


Figure 5: Garbage classification result interface.

5 Design and Implementation

5.1 Function Requirement Implementation – Shared Features for Users, Admins, and Visitors

5.1.1 Chat with AI About Waste Knowledge

User Story: As a user, I want to ask questions about waste classification and recycling to an AI assistant so that I can get immediate and accurate information.

Design and Implementation: The website integrates an AI chatbot that can answer user questions related to waste sorting, recycling procedures, and sustainability tips. The chatbot is powered by chatgpt 3.5 API. Users can interact in natural language, and the system returns concise and informative responses. This feature enhances user engagement by providing personalized, real-time assistance.

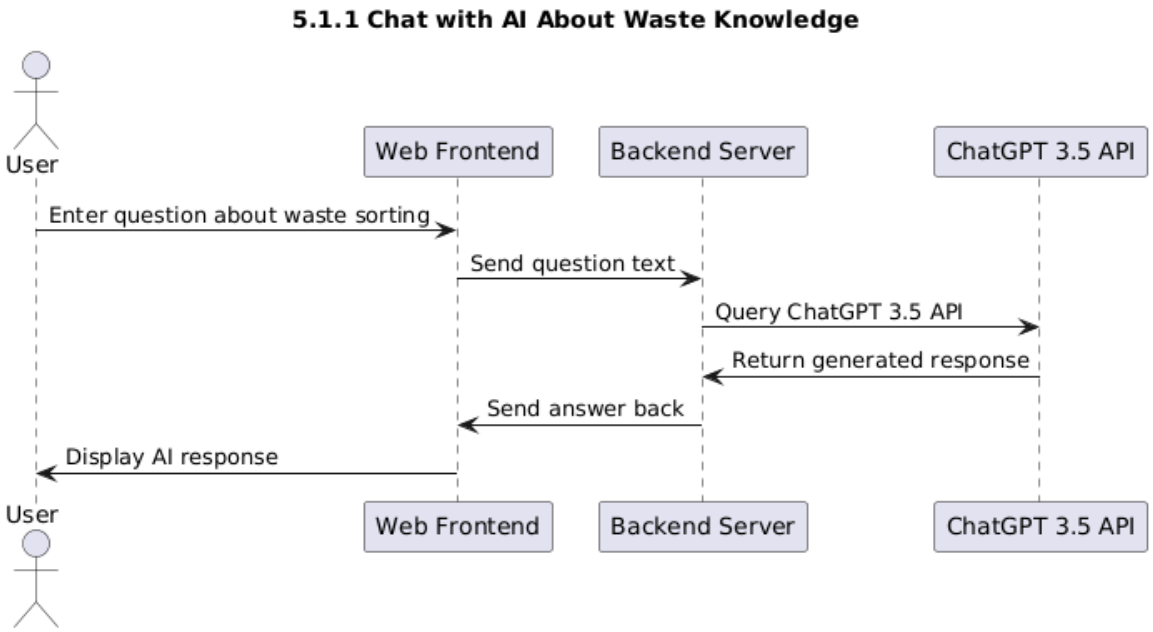


Figure 6: Chat with AI About Waste Knowledge

5.1.2 view main page

User Story: As a user, I want to view the main page of the website so that I can access all the key features and information related to waste management.

Design and Implementation: The main page serves as a visual and functional entry point to the Campus Purge platform. It features a welcoming banner with the slogan "Smart Waste Sorting with AI!", and a navigation bar linking to key sections like About, SDG, Team, and Contact. Users can access waste bin locations, AI garbage classification, educational games, and a reward system. The page also introduces the project background, showcases alignment with SDGs, and displays user feedback and team profiles—all within a clean, responsive layout that loads content efficiently.

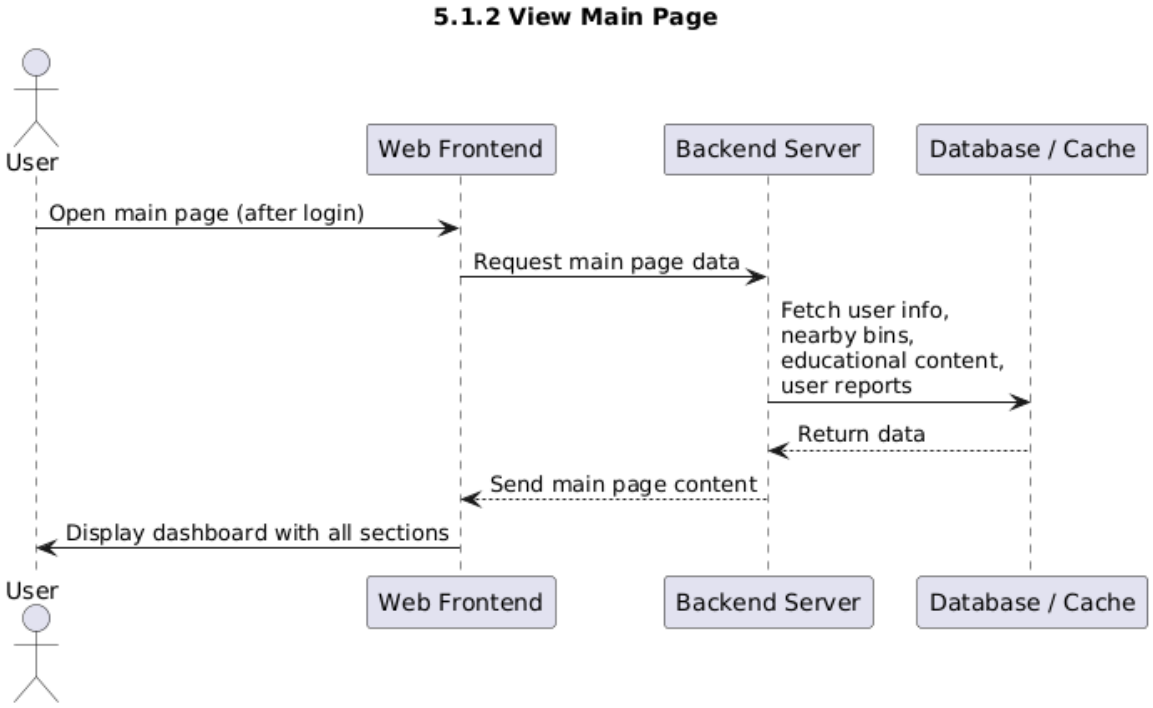


Figure 7: View Main Page

5.1.3 locate user

User Story:As a user, I want the platform to locate my position so that I can easily find nearby waste bins or relevant waste management services.

Design and Implementation: The Locate User feature utilizes the user's device GPS to retrieve their current location, or alternatively, users can manually enter an address. The platform then displays nearby waste bins and relevant information on a map interface. This is achieved through the integration of a mapping API, which takes the user's location and overlays it with waste bin markers on a map. In actual application, the system fetches real-time data on waste bin statuses and updates the map accordingly. This functionality allows users to efficiently locate waste bins that need attention or that are nearby, facilitating quick and convenient waste disposal.

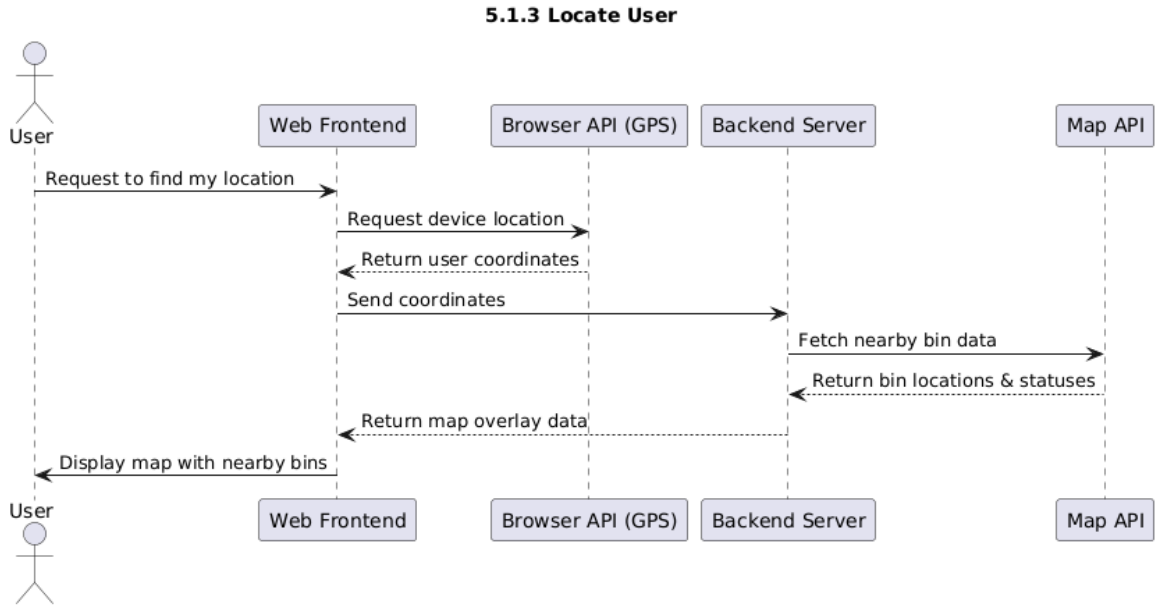


Figure 8: Locate User

5.2 Function Requirement Implementation - User (Common Function)

5.2.1 Login and Register

User Story: As a user, I need to have an account to access personalized features on the website.

Design and Implementation: To use the platform, users must first register by providing basic information such as a username and password. Upon successful registration, users can log in to access personalized functions including submitting waste bin reports or participating in classification quizzes. The login system incorporates encryption and verification mechanisms to ensure user data security and session integrity.

5.2.2 Browse

User Story: As a user, I want to navigate and browse various sections of the homepage so that I can easily access the content or features that interest me.

Design and Implementation: The homepage is designed to provide a clean, user-friendly layout for easy navigation. The layout organizes key sections, including waste bin location reports, waste classification tools, and other relevant features. For returning users, key data such as recent reports or ongoing challenges is preloaded from browser cache, reducing load times and minimizing data usage.

5.2.3 Submit Feedback

User Story: As a consumer, I want to be able to submit feedback about my experience using the platform so that the development team can improve the service and address any issues I encounter.

Design and Implementation: The Submit Feedback feature enables users to share their thoughts, report problems, or suggest improvements regarding the platform. After logging in, users can access a feedback form

from their profile page. The form allows them to select a rating (e.g., 1–5 stars), and then write comments.

Once submitted, feedback entries are stored in a dedicated feedback table in the database, associated with the submitting user's ID and timestamp. Admins can view all feedback through the admin panel to prioritize common issues or implement improvements. The design emphasizes simplicity and encourages open communication to enhance user satisfaction and system refinement.

5.2.4 Play Waste Classification Game

User Story: As a user, I want to play a simple and fun game to practice waste classification so that I can learn the concepts in an engaging and interactive way.

Design and Implementation: The platform provides a gamified module where users drag and drop virtual waste items into the correct bins (e.g., recyclable, hazardous, kitchen, other). Each round presents random items, and users receive instant feedback on whether their choice was correct. The system tracks the user's performance and provides a final score after each session. This feature is designed using responsive graphics and intuitive controls to promote learning through active engagement.

5.2.5 Learn and Take Quiz on Waste Classification

User Story: As a user, I want to access educational content about waste classification and test my knowledge so that I can become more environmentally responsible.

Design and Implementation: Users can access a structured learning module that explains how different types of waste should be categorized and disposed of. After studying the material, users can take quizzes to test their understanding. The quiz includes multiple-choice questions, and users receive immediate feedback. Administrators can update the quiz content regularly to ensure its accuracy and relevance. This feature encourages self-directed learning and reinforces awareness of eco-friendly practices.

5.2.6 Modify User Profile

User Story: As a user, I want to be able to modify my personal information, such as my username and profile detail.

Design and Implementation: Once logged in, users can access their profile settings and modify personal details, such as their username, email address, and gender. This feature ensures that users have control over their account information and can update it at any time. The system securely saves the changes and notifies users of successful updates.

5.2.7 View recognition history

User Story: As a user, I want to view my past garbage recognition results so that I can track my progress and review previously identified waste items.

Design and Implementation: The View Recognition History feature allows users to access and view a history of their previous interactions with the garbage recognition tool. After the user uploads an image for classification, the system records the classification results, including the waste type. This information is stored in the user's profile and can be accessed through a dedicated "History" section. The history displays a list of all previously recognized items, organized by date, with details such as waste category, classification accuracy score, and the recommended trash bin. The data is retrieved in real-time from the backend database, ensuring that users can always see their most up-to-date history. For privacy and security, access to this history is restricted to the user who submitted the recognition.

5.3 Function Requirement Implementation - User (Core Function)

5.3.1 Garbage Classifier

User Story: As a consumer, I want to upload an image of waste to the platform, so that I can receive a classification of the waste type and know which trash bin to dispose it in.

Design and Implementation: The Garbage Recognition API leverages Alibaba Cloud's AI-powered image classification service to identify waste types from user-uploaded images. Once an image is submitted, the system sends it to the Alibaba API, which processes the image using advanced deep learning models. Based on the returned classification result, the system advises users on the correct disposal category according to China's four-category waste classification standard: Recyclables, Kitchen Waste, Hazardous Waste, and Residual Waste. This ensures accurate sorting and promotes environmentally responsible waste management.

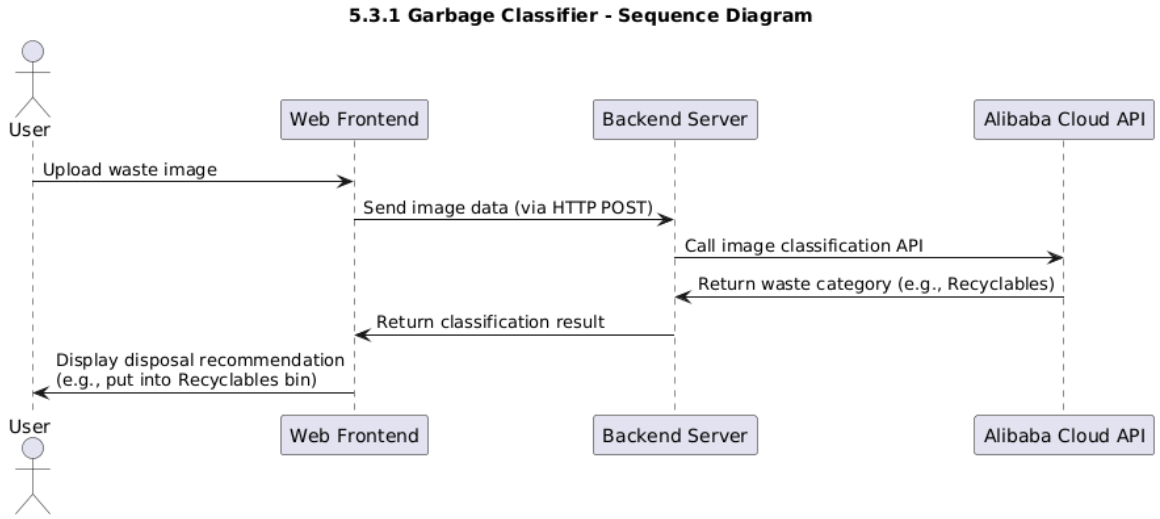


Figure 9: Garbage classification result interface.

5.4 Function Requirement Implementation - Administrator

5.4.1 Garbage map management

User Story: As an Administrator, I need the ability to manage the garbage map, including adding, editing, or removing locations of waste bins, so that the platform remains accurate and up-to-date.

Design and Implementation: The Garbage Map Management feature enables administrators to manage waste bin data through an interactive map interface. Administrators can add new bin locations by directly clicking on the map, which automatically captures the selected coordinates—manual input is not required. They can also remove outdated or incorrect entries to maintain data accuracy; however, the status of each bin (e.g., full, emptied, or damaged) is automatically updated in real time through camera monitoring and therefore cannot be manually modified by administrators. The map is powered by a mapping API, such as Google Maps, and in real-world application, provides a real-time view of bin locations and statuses, helping users easily locate the nearest available waste bin. Although there is no dedicated search or edit panel, administrators can manage bin data directly on the map interface in an intuitive and efficient manner.

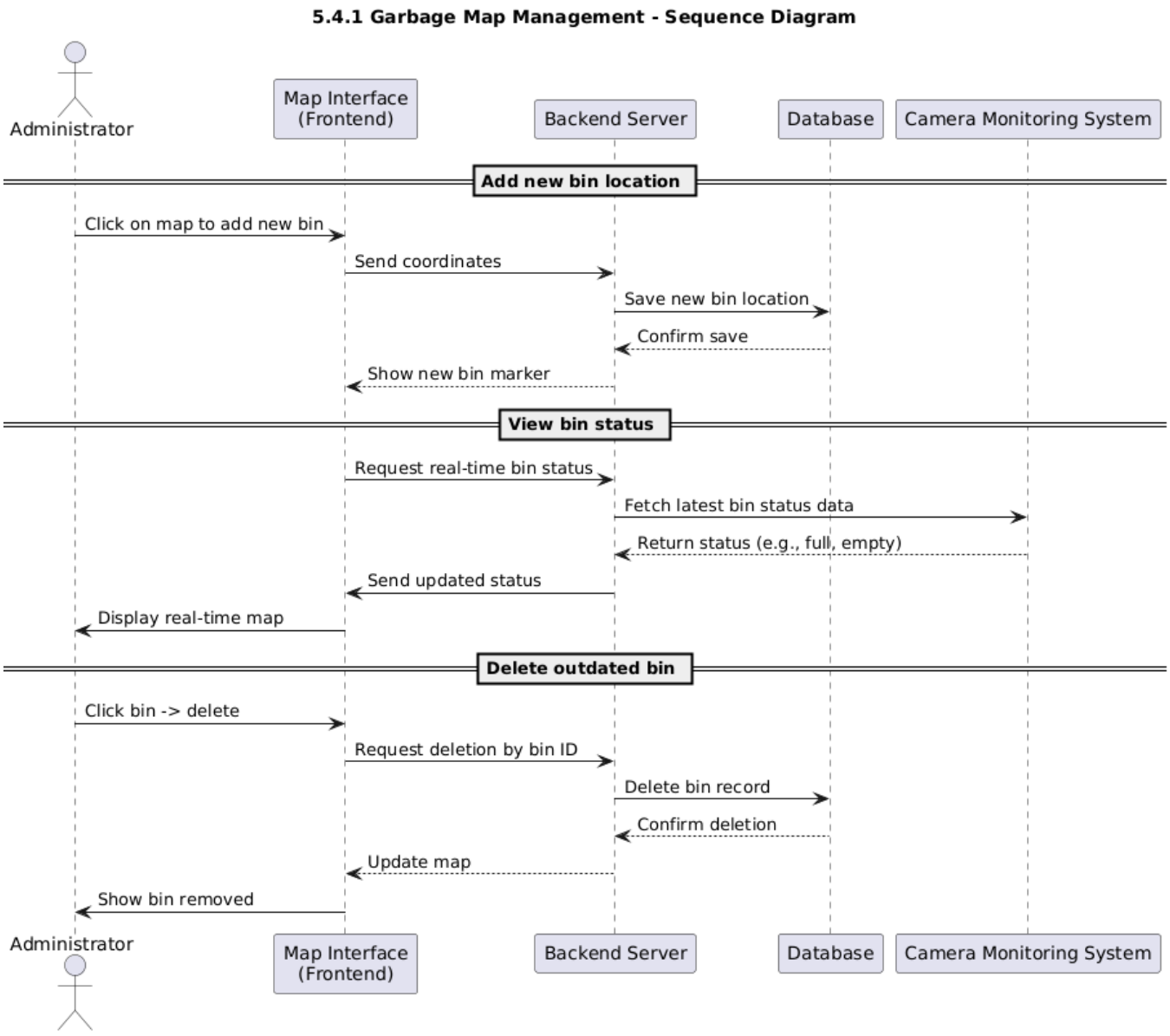


Figure 10: Garbage Map Management

5.4.2 View User Feedback

User Story: Administrator needs to have the ability to review and manage user feedback submitted regarding the website's functionality so that continuous improvements can be made based on user suggestions and issues.

Design and Implementation: When users submit feedback about their experience, the input is stored in a centralized database. While the system does not currently support automatic categorization or filtering, administrators can view all submitted feedback entries through a management interface. This interface allows them to manually review user input, such as bug reports, suggestions, or general comments. Although direct responses to users are not supported within the system, the collected feedback helps administrators understand user sentiment, identify areas for improvement, and guide future platform enhancements.

5.4.3 Manage User Accounts

User Story: Administrator needs to have the ability to modify user types, suspend or activate accounts, and manage user roles as needed to maintain a safe and smooth-running platform.

Design and Implementation: Administrators have access to an account management panel where they can reset user passwords, update user information, and add or remove user accounts. These functions help ensure that user access remains up-to-date and the platform operates securely and efficiently.

5.4.4 Manage Educational Content

User Story: Administrator needs the ability to add new questions to the waste classification quiz, modify existing ones, and remove outdated questions.

Design and Implementation: To keep the quiz content up to date, administrators can manage quiz questions through a dedicated interface. This includes creating new questions, editing existing ones, updating answer options, and removing outdated content to ensure continued relevance. All approved changes are instantly reflected in the quiz module, ensuring users always access accurate and current learning material. This functionality supports the platform's educational objectives and helps maintain user engagement.

5.4.5 View User Recognition Reports

User Story: As an administrator, I want to view users' waste recognition records so that I can monitor their classification behavior and system usage. By analyzing the most frequently recognized items, I can further refine and expand the educational content to better match user needs.

Design and Implementation: This feature displays a list of user recognition records, including waste type, predicted category, and timestamp. A bar chart shows the top 10 most frequently recognized waste types based on user data. This visualization helps administrators adjust educational materials to better reflect user interaction patterns.

5.4.6 View Garbage Reports

User Story: As an administrator, I want to view daily and monthly statistics of waste volume so that I can monitor campus waste disposal trends over time.

Design and Implementation: In real-world application, this module displays bar charts showing the number of waste items detected each day and each month. The data is collected in real time from the smart waste bin cameras and automatically aggregated by date. This visualization helps administrators identify peak disposal periods and evaluate the effectiveness of waste management strategies.

5.5 Non-functional Requirements Implementation

5.5.1 Security

User Story: The user's goal is to use the website safely and protect their personal information.

Design and Implementation: To ensure a secure user experience, the platform implements multiple layers of protection:

- **Authentication of Different Identities:** Users must log in to access most website features. Before authentication, they are treated as guests with limited access (e.g., no commenting or transactions). Role-based access control ensures that only authorized users can view or modify sensitive content.
- **Data Encryption:** Sensitive user data, including passwords and personal information, is encrypted using industry-standard protocols. This ensures data confidentiality and integrity during transmission and while stored on the server.
- **Use of Secure Frameworks and Libraries:** The platform is built on trusted development frameworks and libraries to prevent common vulnerabilities. This minimizes exposure to exploits from outdated or insecure dependencies.
- **Input Verification:** All user inputs are strictly validated to prevent injection attacks, such as SQL injection or cross-site scripting (XSS). This guards against malicious data and strengthens the platform's defense against unauthorized manipulation.

5.5.2 Reliability

User Story: The user's goal is to use the website safely and protect their personal information.

Design and Implementation: To enhance the reliability of the system and minimize service disruptions, the following measures are in place:

- **Unit Testing:** All system components undergo thorough unit testing before integration. This early validation ensures component-level correctness and prevents propagation of bugs into the production environment.

- **System Dependency Management:** Active coordination among development teams helps reduce complex interdependencies between modules. This alignment lowers the risk of cascading failures and supports smoother implementation workflows.
- **Prevention of Data Loss:** Regular database and file backups are conducted to safeguard critical data. Backup mechanisms ensure recovery capability in case of system crashes or hardware malfunctions, preserving data integrity and platform stability.

6 System Design

6.1 Database Design

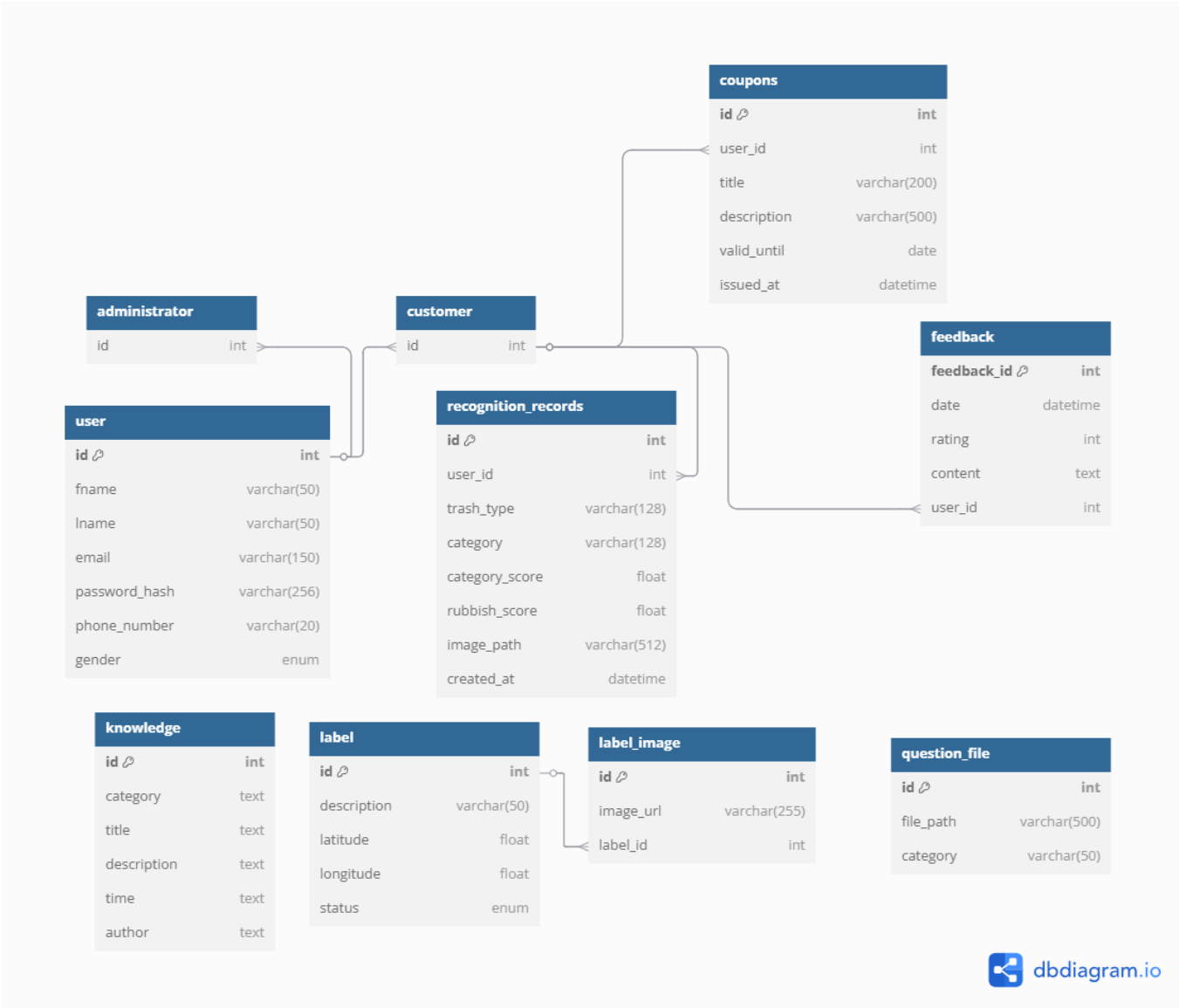


Figure 11: ER Diagram

Our platform adopts a normalized relational database schema to ensure data integrity, scalability, and efficient performance. The design integrates key components including:

- User and role management (user, customer, administrator)
- Waste recognition records (recognition_records)
- Location-based labeling system (label, label_image)

- Educational content and quizzes (knowledge, question_file)
- User feedback and engagement (feedback)
- Incentive tracking (coupons)

The database adheres to normalization principles, eliminating redundancy and maintaining consistent integrity through the use of foreign keys and structured relationships. This supports secure and scalable user operations, efficient querying, granular access control, and future extensibility. Altogether, the architecture provides a robust and responsive foundation for AI-driven waste recognition and promotes sustainable user interaction with the platform.

6.2 Unit Testing

We ensure that each unit is thoroughly tested before being integrated into the system. Inspired by best practices within the open-source community, we have developed comprehensive testing guidelines tailored to our platform's specific needs.

6.2.1 Testing Priorities

- **User Registration and Login**: Fundamental features requiring repeated testing to ensure successful account creation, login, and personalized access.
- **Waste Sorting Quiz**: Core feature requiring rigorous testing for:
  - Response accuracy
  - Question selection
  - Scoring system reliability
- **AI Waste Recognition**: Essential testing for:
  - Classification accuracy
  - System reliability
  - Appropriate disposal advice
- **Waste Bin Reporting**: Thorough testing of reporting features for:
  - Overflow detection
  - Maintenance alerts
  - User submission ease

6.2.2 Testing Methodology

- Used **Apache JMeter** for automated testing
- Conducted performance analysis and bug detection
- Maintained system stability through:
  - Throughput testing
  - Concurrency testing
  - High-load processing tests

Our testing approach achieved:

- 100% unit test coverage in back-end
- Confidence in system stability and quality
- Optimal user experience

7 Risk Analysis

Throughout the development of our waste management platform, we encountered several challenges, primarily related to security, system stability, and limited experience in deploying and maintaining a live website. As this is our first time deploying the platform on a real server, we faced difficulties ensuring smooth operation and addressing issues such as server configuration and performance optimization. Additionally, we ran into technical obstacles due to our team's relatively limited experience with web development, particularly in areas like web design and enhancing site efficiency. Despite these hurdles, we overcame them through collaborative teamwork, ongoing testing, and an intensive review process that helped us analyze relevant information and find effective solutions.

Another challenge we faced was scheduling conflicts within our team. Many members had other academic and professional commitments, such as preparing for exams or participating in internships. These overlapping schedules created potential delays in the project timeline. However, we mitigated these issues through improved communication, flexible planning, and effective negotiation among team members, which allowed us to keep the project on track.

7.1 Service Stability Risks

Our website is designed to provide users with real-time updates on waste bin locations and garbage collection statuses. However, the platform currently relies on a single server with no backup in place. This lack of redundancy exposes the system to risks related to server failure, which could cause downtime or service disruptions. Additionally, while we have conducted extensive testing, the platform has not yet been deployed in a production environment with real-world traffic. As the website will eventually be used by numerous individuals across various locations, any server instability could be magnified when it handles a larger load. We are aware that this could potentially affect the overall user experience and platform reliability.

7.2 Privacy Risks

Our platform collects and stores personal data from users, including their location information and participation in waste sorting quizzes. While we have implemented strong encryption measures to protect sensitive user data, there is always an inherent risk associated with storing personal information online. We have made efforts to minimize the amount of sensitive data users need to submit, encouraging them to avoid providing unnecessary details. However, despite these precautions, the possibility of data breaches or privacy leaks cannot be entirely ruled out. As we continue to scale the platform, we will remain vigilant in monitoring and improving our security practices to safeguard user privacy.

8 Conclusion

8.1 Future Implementation

Although our platform has successfully integrated core functionalities such as waste recognition, bin location mapping, quiz-based learning, and reward mechanisms, there remains considerable potential for functional enhancement. The following areas are identified as key directions for future improvement:

8.1.1 Optimization of the Waste Recognition Module

The current waste recognition relies on basic classification logic and external APIs, which may result in occasional inaccuracies, especially for unclear or mixed waste images. In future iterations, we aim to develop a custom AI model trained on a dataset collected from real campus scenarios. Furthermore, we plan to incorporate a user feedback system that allows correction of misclassifications. This feedback will help refine the model over time and build a self-improving recognition system.

8.1.2 Enhancement of User Behavior Tracking and Personal Profiles

Currently, users can view only basic recognition history. We propose the development of a comprehensive "Environmental Behavior Dashboard" for each user. This dashboard will display personalized statistics such as trends in classification activity, quiz accuracy rates, point transaction history, and ranking comparisons. These features aim to boost user engagement and encourage long-term participation.

8.1.3 Expansion of the Reward System

The initial reward system is limited in scope. Future plans include integrating real-life campus rewards such as discounts at the cafeteria, campus merchandise, or entry to eco-friendly events. Additionally, we plan to implement a mission-based structure—daily tasks, milestone achievements, and seasonal campaigns—to enhance motivation and build a sustained usage loop.

8.1.4 Advanced Administrator Dashboard

The current admin interface handles basic content management. In future upgrades, we intend to introduce a more comprehensive dashboard with features such as graphical quiz management, review workflows for user-submitted bin issues, and auto-generated analytics reports. These enhancements will improve the platform's utility for campus sustainability administrators and decision-makers.

8.2 Reflection of Problem-based Learning and Cooperation

Throughout this project, we focused on solving real campus waste management issues using a technical approach. Our development process was divided into clear milestones, and each member was responsible for different modules such as AI waste recognition, real-time bin mapping, user interaction, and backend integration.

One key challenge we faced was the coordination between different components—especially when integrating frontend and backend modules. We addressed this through regular discussions and by clearly documenting API interfaces. Although some functions required multiple rounds of testing and adjustment, we learned to debug and collaborate more efficiently over time.

This project helped us not only improve our technical abilities, but also taught us how to work as a team. Each member had a chance to take ownership of a major task while staying aligned with the group's overall direction. We also learned how to prioritize tasks, manage deadlines, and support each other when difficulties arose.

In the end, we are proud of the platform we built together, and we gained a deeper understanding of how problem-based learning and cooperation can lead to meaningful outcomes.

9 Statement

- To enhance the clarity and readability of this manual, we utilized AI tools (such as ChatGPT) to refine grammar, improve phrasing, and polish language expression. All content and ideas remain our own; AI was used solely for language enhancement.