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IoT-Enabled Cashback-Based Recycling Management System

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Abstract

The IoT-Enabled Cashback-Based Recycling Management System addresses inefficient recycling processes and low participation at Universiti Tun Hussein Onn Malaysia (UTHM). Integrating IoT technology with incentive mechanisms like cashback and deposit return schemes, the system encourages students and staff to recycle by offering financial rewards based on the volume of recyclables disposed of. Research highlights that reward, such as cashback or recognition, significantly enhance recycling behavior, making it a pivotal factor in the system's success. The project combines IoT with behavioral science to track, reward, and provide data-driven insights into recycling activities. Personalized incentives and transparent feedback aim to foster a culture of sustainability on campus. This innovative approach is designed to improve recycling rates, minimize waste contamination, and enhance waste management efficiency at UTHM, contributing to broader environmental goals and promoting active engagement in sustainable practices.

1. Introduction

Recycling is essential for sustainability and environmental preservation. At Universiti Tun Hussein Onn Malaysia (UTHM), current recycling efforts face significant challenges, including limited accessibility to a single recycling bin, poor waste segregation, and minimal engagement from students and staff due to a lack of incentives. These issues result in the contamination of recyclable materials, reducing their quality and reusability. Neglecting this critical separation can greatly diminish the overall efficiency of recycling efforts [1]. An effective recycling system must address these limitations to promote resource conservation, reduce pollution, and encourage sustainable behaviors within the university community.

To overcome these challenges, this study proposes an IoT-Enabled Cashback-Based Recycling Management System that combines Internet of Things (IoT) technology with a cashback incentive model. The system features smart recycling bins for real-time monitoring and waste segregation, alongside a reward mechanism to enhance participation. This initiative aims to increase recycling rates, improve waste segregation, and foster long-term environmentally conscious habits among the campus community. The objectives include designing, developing, and testing the system to create an accessible and efficient solution that aligns with UTHM's sustainability goals.

The objectives of the project are:

1. To design an IoT-Enabled Cashback-Based Recycling Management System using object-oriented approach.
2. To develop a web-based IoT-Enabled Cashback-Based Recycling Management System for logging recycling transactions.
3. To test the IoT-Enabled Cashback-Based Recycling Management System with the smart recycling bins to monitor recyclables and track participation.

Table 1 outlines the core functional modules of the proposed recycling management system. Each module is designed to support efficient user management, recycling tracking, and incentive distribution through IoT integration and role-based system access.

Table 1 *System Function Module*

System Module	Description
Register User Account	A module that allows creation of new user accounts for student and staff.
Login	A secure login for students, staff and administrators, allowing role – based access to system features.
Manage User Profiles	A module that allows user to update their profile in the system and allow administrators to manage user profiles and permissions for secure system access.
Manage Recycling Activities	A module that allows system to automatically record all recycling activities conducted by students and staff through IoT – integrated smart bins.
Manage Recycling Bins	A module that allows IoT sensors embedded in the smart bin to monitor and track the usage of bin in real time.
Manage Cashback Rewards	A module that allows users to redeem their cashback and submitting request to cash out the accumulated cashback rewards.
Generate Report	A module that allows administrators to generate reports based on recycling data from user.

The system comprises several key functional modules, including user registration, secure login, profile management, recycling activity tracking, real-time smart bin monitoring, cashback reward handling, and report generation. These modules work together to ensure efficient, secure, and automated management of the recycling process through IoT integration.

2. Literature Review

This section will discuss on literature review on IoT – Enabled Cashback – Based Recycling Management System and the comparison of similar system.

2.1 Domain Background

Universiti Tun Hussein Onn Malaysia (UTHM) is a leading academic institution committed to fostering sustainability and environmental responsibility among its community. The university has introduced various recycling initiatives to reduce waste and promote eco-friendly behaviour among students and staff. Recycling is recognized as a vital practice to conserve natural resources, lower environmental pollution, and encourage long-term sustainable habits. Despite these efforts, UTHM faces notable challenges in implementing effective recycling programs due to limited infrastructure, low participation rates, and a lack of incentives for active engagement. These barriers hinder the university's ability to achieve its environmental goals and cultivate widespread eco-consciousness.

The current recycling system at UTHM relies on a single centralized bin, which restricts accessibility and discourages participation. Recyclable materials are often mixed with non-recyclables, leading to contamination and diminished recycling efficiency. Without real-time monitoring or structured incentives, the system struggles to engage users meaningfully or track progress effectively. Manual waste collection processes further complicate

efforts to optimize waste management. As a result, UTHM's existing approach fails to meet the growing demand for innovative, efficient, and sustainable waste management practices on campus.

2.2 Recycling Behaviour and Incentive Mechanisms

Recent studies emphasize the role of both financial and non – monetary incentives in promoting recycling, especially in urban areas. Financial incentives like cashback and deposit return schemes are effective motivators. Saeedi [2] notes that innovative approaches, such as blockchain – based reward systems, enhance this impact. Similarly, Gibovic and Bikfalvi [3] report that diverse incentive schemes positively influence recycling habits. However, convenience remains a key factor. Kremel [4] found that despite high awareness, many young adults cite inconvenience as a barrier, highlighting the need for accessible recycling options. Combining easy-to-use systems with financial incentives can increase recycling rates. Non-monetary incentives also matter, social recognition and environmental feedback motivate environmentally aware individuals. Phipps et al. [5] argue that blending financial and social incentives addresses both external and intrinsic drivers, offering a comprehensive strategy for sustained recycling engagement.

2.3 IoT Technology and Smart Waste Management System

The integration of the Internet of Things (IoT) in waste management has significantly transformed traditional recycling systems, enhancing both efficiency and transparency. Smart waste management systems equipped with IoT devices allow for real-time monitoring of waste levels, optimizing collection routes and reducing operational costs [6]. These systems also enable waste management authorities to track and analyze recycling activities with greater accuracy, fostering accountability and minimizing system misuse. The use of IoT in waste management not only improves operational efficiency but also plays a crucial role in ensuring that recycling programs are effective and transparent.

Moreover, IoT-enabled tracking systems provide greater transparency in the distribution of rewards for incentive-based recycling programs, which is essential for increasing user trust and engagement. The World Bank highlights that accurate tracking fosters confidence among participants, encouraging their involvement in recycling initiatives [7]. A notable example of such a system is Envirobank in Australia, which uses a points-based rewards system to incentivize responsible recycling and promote social responsibility [4]. This model demonstrates the effectiveness of combining IoT-driven monitoring with flexible reward structures, showcasing the potential of technology-enhanced recycling systems to improve participation and contribute to sustainability.

2.4 Similar System Comparison

Table 2 presents a comparison between existing applications Envirobank, Klean the World, Recircle and the proposed system. Unlike the others, the proposed system is uniquely designed for UTHM students and staff, offering accessible, motivating, and reward-driven recycling features that enhance the overall recycling process.

Table 2 *Comparison of the existing system and proposed system*

Features	Envirobank [13]	Klean the World [14]	Recircle [15]	Proposed System
Recycling Tracking	Yes	Yes	Yes	Yes
Reward Points	Yes	Yes	Yes	Yes
Cashback Incentive	No	No	No	Yes
Integration with IoT	Yes	Yes	No	Yes
Personalized User Accounts	No	Yes	Yes	Yes
Detailed Recycling History	Yes	No	Yes	Yes
Web- Based Access	Yes	No	No	Yes
Simple Data Analytics Dashboard	No	No	No	Yes

In comparison, Envirobank, Klean the World, and Recircle offer core recycling features such as tracking and non-cash rewards to encourage user participation. In contrast, the proposed system introduces a cashback

incentive to provide stronger financial motivation, particularly for students. Furthermore, while Envirobank and Klean the World utilize IoT for tracking, the proposed system enhances this capability by incorporating detailed recycling history and a data analytics dashboard, enabling users to monitor their individual sustainability impact more effectively.

The literature review section reveals that UTHM's current recycling efforts face challenges like limited infrastructure and low participation. Studies support the use of financial and social incentives, with IoT enhancing real-time tracking and system efficiency. Unlike existing systems such as Envirobank or Recircle, the proposed system offers cashback, personalized accounts, detailed recycling history, and a web dashboard, making it more suitable and engaging for UTHM students and staff.

3. Methodology

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

The project uses the System Prototyping model for its iterative and user-centered approach. This model emphasizes early user involvement allowing feedback through functional prototypes to improve usability and reduce risks. It suits the project well by supporting quick issue identification and ensuring the system effectively incentivizes recycling, reduces waste mixtures, and integrates with campus operations. Table 3 illustrates the System Development Workflow of the prototyping model for the proposed IoT – Enabled Cashback – Based Recycling Management System.

Table 3 *System Development Workflow*

Phase	Activity	Work Product	Tools
Planning	Define Project Objectives	Project Scope Document	MS Word
Analysis	Analyze current recycling challenges. Conduct interviews with stakeholders. Identify functional and non – functional requirements.	Proposal User Requirement	Interview
Design	Create UML diagrams. Develop wireframes and user interface. Design database schema.	UML Diagram Wireframes Database Schema	Canva Draw.io PhpMyAdmin
Implementation	Develop core features. Integrate system with database. Build early prototype	Initial Codebase Database Structure	Visual Studio Code PhpMyAdmin Arduino
Testing	Conduct comprehensive testing Connect to the prototype to the database for data operations	Functional System Functional Database System	Visual Studio Code PhpMyAdmin Arduino

This project uses the System Prototyping model to develop the IoT-Enabled Cashback-Based Recycling Management System. The model supports iterative development and early user feedback, helping to refine system features and ensure alignment with user needs. The methodology includes five key phases which are

planning, analysis, design, implementation, and testing. Each phase contributes to building a functional and user-friendly system by addressing project objectives, understanding user requirements, designing interfaces and databases, developing core features, and testing system functionality using tools like Visual Studio Code, Arduino, and PhpMyAdmin.

4. Analysis and Design

This section discusses about the analysis and design that have been conducted as part of the development process for IoT – Enabled Cashback – Based Recycling Management System.

4.1 System Requirement Analysis

The requirement analysis phase ensures the IoT – Enabled Cashback – Based Recycling Management System aligns with stakeholder expectations and operational constraints, enabling a systematic and efficient design. Functional requirements center on key features such as weights as well as good integration of cashback incentive mechanisms. Non – functional requirements address critical system quality attributes, including performance reliability to handle concurrent user interactions and user – friendly interfaces to enhance accessibility and engagement.

4.1.1 Use Case Diagram

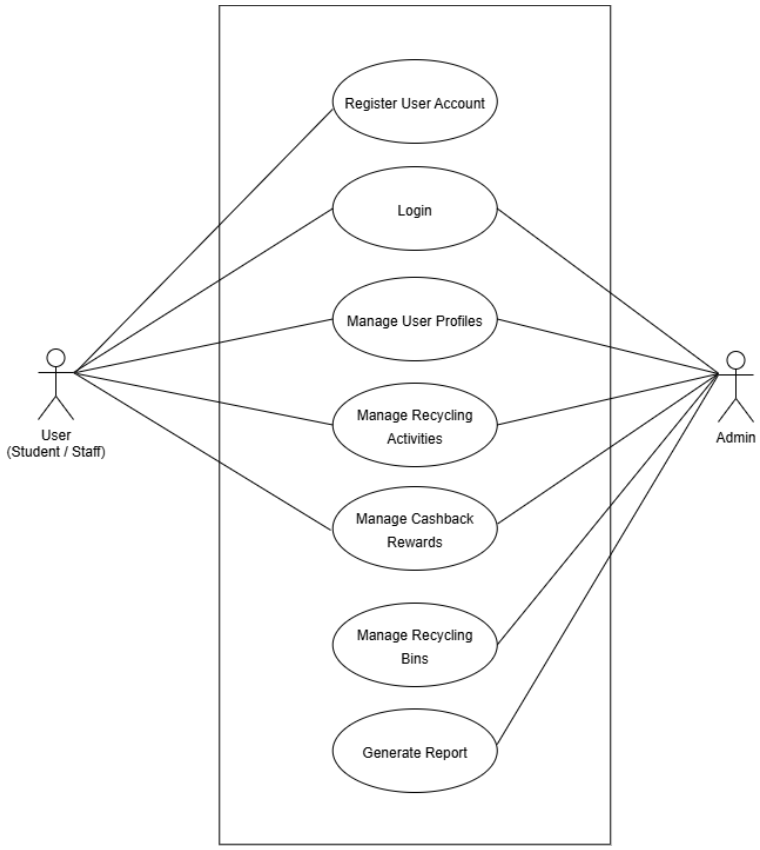

Figure 1 *Use Case Diagram of IoT-Enabled Cashback-Based Recycling Management System*

4.1.2 Functional and Non-Functional Requirements

The functional and non-functional requirements define what the system should do and how it should perform. Figure 1 illustrates the use case diagram of the IoT-Enabled Cashback-Based Recycling Management System, highlighting the interactions between users (students and staff) and administrators with the system's core modules. The diagram provides a clear overview of key functionalities such as user registration, login, recycling activity tracking, reward management, and report generation. Table 4 further outlines the functional requirements of the IoT – Enabled Cashback – Based Recycling Management System where the table describes the system expected behaviour for both users and administrators to ensure effective recycling tracking, reward management and system interaction

Table 4 *Table of Requirements of IoT-Enabled Cashback-Based Recycling Management System*

Modules	Functionalities
Register user account	The system shall allow users (students and staff) and administrators to register using their email address and create a secure password.
	The system shall ensure password complexity to maintain security.
	The system shall validate the entered credential format to ensure it is valid.
	The system shall display error message if the registration details is invalid.
Login	The system shall allow users to log in securely using their registered email and password.
	The system shall validate the entered credentials before granting access into the account.
	The system shall display an error message if the login fails, indicating invalid credentials.
	The system shall allow administrators to log in securely using their admin credentials.
	The system shall ensure separate access levels for users and administrators.
Manage User Profiles	The system shall allow users (students and staff) to update their personal information through their profile page.
	The system shall allow administrators to view, add, update or delete admin accounts from the system.
	The system shall save all changes made to user and admin profiles in the database securely.
Manage Recycling Activities	The system shall log each recycling transaction, including weight, timestamp, and cashback amounts.
	The system shall maintain a transaction history for users, including dates, weight and rewards earned.
	The system shall notify users of successful transactions and display their updated cashback balance.
Manage Recycling Bins	The system shall monitor IoT- enabled bins in real – time to capture fill levels.
	The system shall allow admins to update the bin status.
	The system shall display bin status to users.
Manage Cashback Rewards	The system shall require users to fill in all necessary fields for cashback redemption.
	The system shall validate user input.
	The system shall enable cashback redemption only when the user's balance meets or exceed the predefined level.
	The system shall deduct redeemed cashback from the user's balance after a successful redemption.

Table 4 (cont) *Table of Requirements of IoT-Enabled Cashback-Based Recycling Management System*

Generate Report	The system shall generate a monthly report showing the total amount of recyclables collected across all users. The system shall allow administrators to filter reports by date range and user group. The system shall allow administrators to view, download and print the generated reports.

In addition to the core functionalities, the system must meet several non-functional requirements to ensure usability, performance, and reliability. Table 5 lists these non-functional aspects, including operational compatibility, performance benchmarks, security measures, and data integrity features, which collectively contribute to a smooth and dependable user experience.

Table 5 *Non-Functional Requirement of IoT-Enabled Cashback-Based Recycling Management System*

Requirement	Description
Operational	The system shall be able to work with any web browser. The system shall be easy to use.
Performance	The loading time for the website is no more than 15 seconds. The system shall respond to user requests within 5 seconds under normal operating conditions.
Security	The system shall authenticate and authorize user. The system shall deny access to any user if the credentials are incorrect.
Usability	The system shall support mobile and desktop browsers, ensuring accessibility from a wide range of devices.
Integrity	The system shall back up critical data to prevent data loss in case of failure.

4.1.3 Domain Class Diagram

The class diagram illustrates the conceptual model in database of the system. It includes admin, user, withdrawal, load_data and bin.

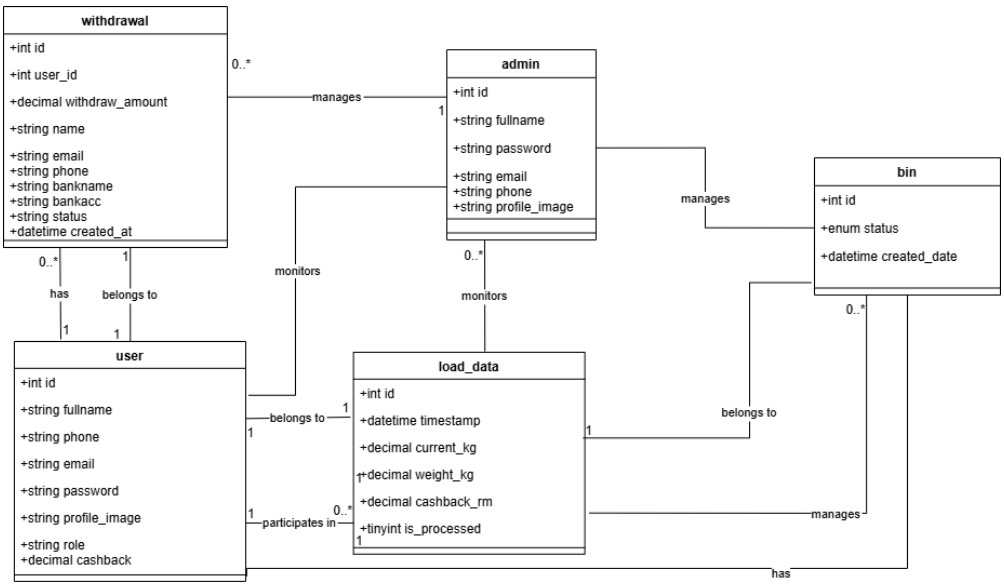

Figure 2 *Domain Class Diagram of IoT – Enabled Cashback – Based Recycling Management System*

4.2 Design

Following the comprehensive analysis of user requirements, the project transitions into the design phase. This phase involves the systematic development of both the user interface and database architecture, providing a detailed visual and structural blueprint of the system prior to implementation.

4.2.1 System Architecture

The IoT – Enabled Cashback – Based Recycling Management System follows a client – server architecture as shown in Figure 3. Users including students, staff and admin interact with a centralized MySQL server through user interfaces. Each role can access specific modules as the system provides secure, role-based access while maintaining efficient communication between frontend interfaces and backend databases.

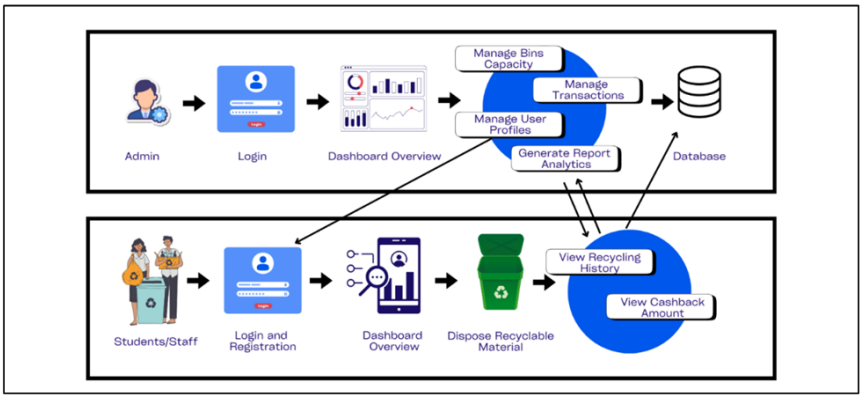

Figure 3 *System Architecture for IoT – Enabled Cashback – Based Recycling Management System*

4.2.2 Hardware and Software Requirement Analysis

This section outlines the essential hardware and software components required to develop and operate the proposed IoT-enabled recycling management system. Table 6 shows the hardware requirements of the IoT – Enabled Cashback – Based Recycling Management System.

Table 6 *Hardware Requirements*

Requirement	Description
Load Cell Sensor (0-5kg)	Devices to accurately measure the weight of recyclable materials.
NodeMCU ESP32 (30-pin)	Microcontroller with built-in Wi-Fi and Bluetooth for real – time communications.
HX711 Load Cell Amplifier Module	Converts analog signals from the load cell into digital data for the ESP32.
SG90 Micro Servo Motor	Rotates 0-180 ° to control physical actions like opening and closing compartments.
MB102 Solderless Breadboard (170 holes)	Compact breadboard for prototyping and connecting components without soldering.
Female-to-Female Jumper Wires (20 cm)	Used for connecting components on the breadboard to the ESP32.
LCD	Display output such as total weight and total cashback of recycling items.

Table 7 shows the software requirements of the IoT – Enabled Cashback – Based Recycling Management System that include several key software tools such as Arduino, Spring Boot Framework, PhpMyAdmin, and XAMPP.

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Table 7 *Software Requirements*

Requirement	Description
MySQL Database	Manage structured data, including user profiles and recycling activities.
Arduino IDE	Platform for developing and deploying firmware for microcontrollers.
GitHub	Version control system for tracking code changes and facilitating collaboration.
Spring Boot Framework	Java – based framework for backend development, managing APIs and server – side logic.
Visual Studio Code	Platform to edit code and debug the system.
PhpMyAdmin	Database Management tool for managing proposed system database.
Draw.io	Design tool for designing UML diagram such as use case, sequence diagram, activity diagram and class diagram.
XAMPP	Server for hosting and testing the system locally.

4.2.3 User Interface Design

This section shows the user interface of the system module for the IoT – Enabled Cashback – Based Recycling Management System. The user interfaces of the system were designed using Visual Studio Code. Figure 4 to Figure 10 display several essential interfaces of the proposed system that are aligned with modules in use case such as Register User Account, Login, Manage User Profile, Manage Recycling Activities, Manage Cashback Rewards, Manage Recycling Bin, Manage Cashback Rewards and Generate Report.

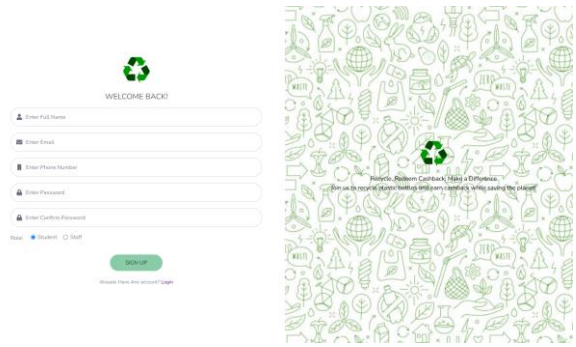

Figure 4 *Register User Account Interface for User*

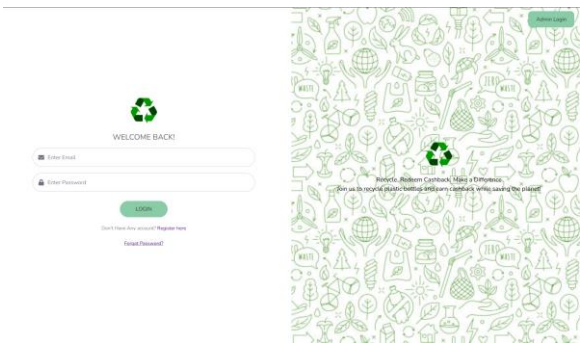

Figure 5 *Login Interface for Admin*

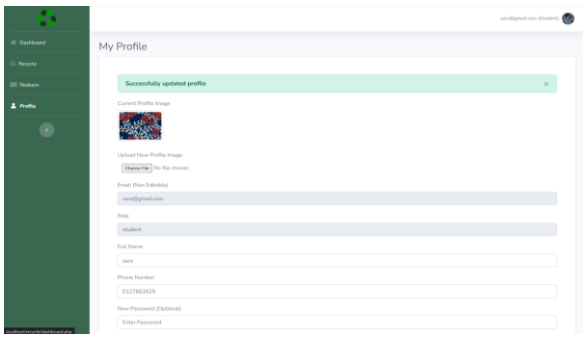

Figure 6 *Manage User Profile Interface*

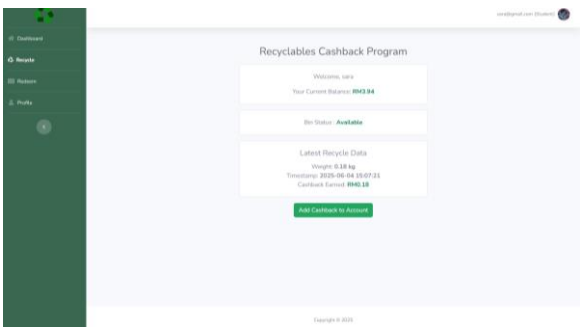

Figure 7 *Manage Recycling Activities Interface*

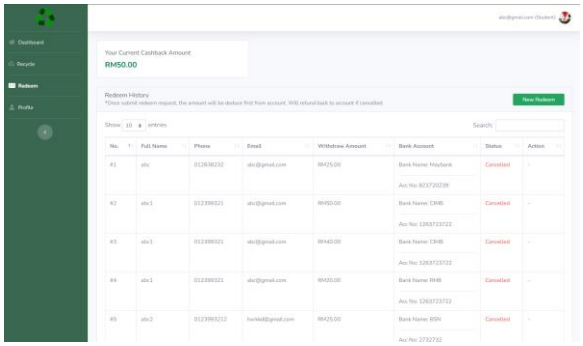

Figure 8 *Manage Cashback Rewards Interface*

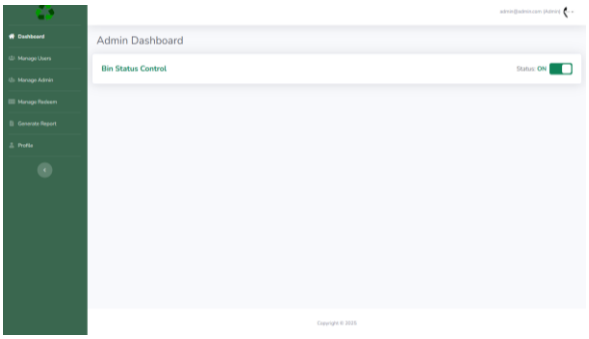

Figure 9 *Manage Recyling Bin Interface*

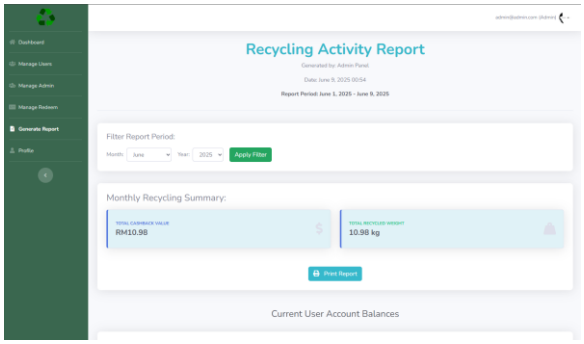

Figure 10 *Generate Report Interface*

4.2.4 Database

The database schema derived from the class diagram are listed as follows, highlighting the structure of each table with its attributes:

I. Admin (id, fullname, email, password, phone, profile_image)
II. User (id, fullname, phone, email, password, profile_image, role, cashback)
III. Load_data (id, timestamp, current_kg, weight_kg, cashback_rm, is_processed)
IV. Withdrawal (id, user_id, withdraw_amount, name, email, phone, bankname, bankacc, status, created_at)
V. Bin (id, bin_status, created_date)

This section presents the analysis and design of the IoT-Enabled Cashback-Based Recycling Management System. It starts by defining functional and non-functional requirements, ensuring the system supports secure login, recycling tracking, and cashback features. Use case and class diagrams are used to visualize system operations and data structure. The design includes a client-server architecture with role-based access for users and admins. Hardware and software requirements are specified to support IoT integration and system functionality. User interface designs are provided for key modules such as registration, recycling activities, and reward management. Lastly, the database schema outlines tables for managing users, transactions, bins, and cashback withdrawals.

5. Result and Discussion

5.1 Implementation

The Register User Account module in the IoT-Enabled Cashback-Based Recycling Management System is built using PHP and MySQL, with HTML and CSS for the interface design. It allows students to sign up by entering their name, email, phone number, role and password. User details are stored securely in the database, and the email and password are used for future logins. Basic validation ensures all fields are completed and prevents duplicate email entries. Upon successful registration, users receive a confirmation and are redirected to the login page. The Register User Account interface is illustrated in Figure 11, and the User Registration Code Segment is shown in Figure 12.

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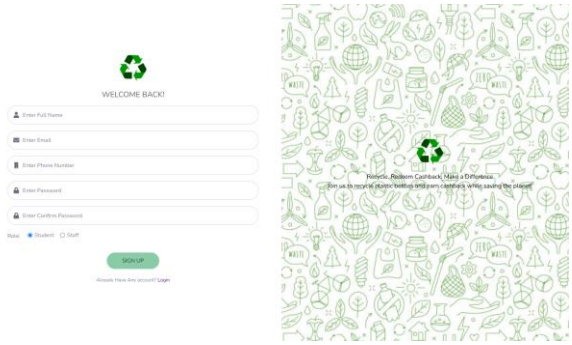

Figure 11 *Register User Account Interface*

Figure 12 *Register User Account Code Segment*

The Login module enables registered users to securely access the IoT-Enabled Cashback-Based Recycling Management System by entering their email and password. The system validates these credentials against the MySQL database. If the login is successful, users are directed to their respective dashboards either the admin interface or the student/staff interface based on their assigned role. Incorrect login attempts trigger an error message prompting the user to re-enter valid credentials. Figure 13 and Figure 14 displays the Login Interface for both user types, while Figure 15 and Figure 16 presents the associated code segment.

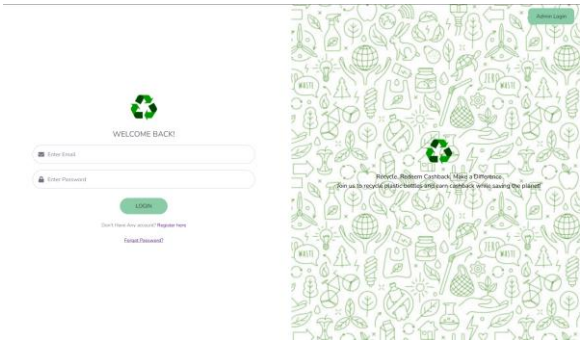

Figure 13 *Login Interface for User*

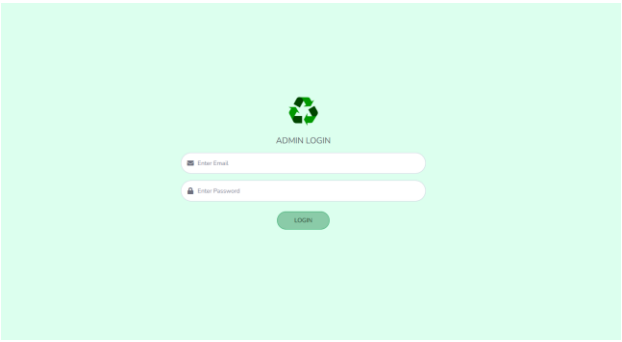

Figure 14 *Login Interface for Admin*

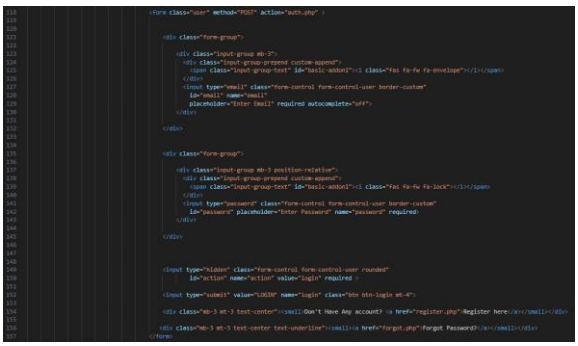

Figure 15 *Login Interface for User Code Segment*

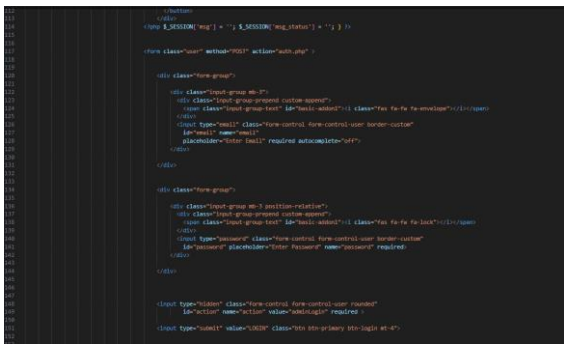

Figure 16 *Login Interface for Admin Code Segment*

The Manage User Profiles Module provides profile management features for both students/staff and administrators. Users can update their personal information such as name, contact details, password through their dedicated profile page. Administrators have additional privileges, allowing them to view, add, update, or delete admin accounts within the system. All modifications made to user or admin profiles are securely stored in the MySQL database, ensuring data integrity and protection. Figure 17 and Figure 18 displays the Manage User Profiles interface for both user types, while Figure 19 and Figure 20 presents the associated code segment.

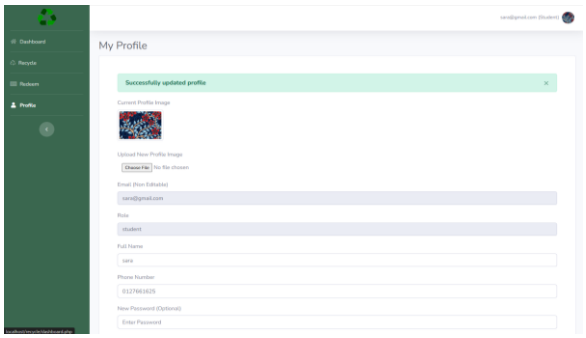

Figure 17 *Manage User Profiles Interface for User*

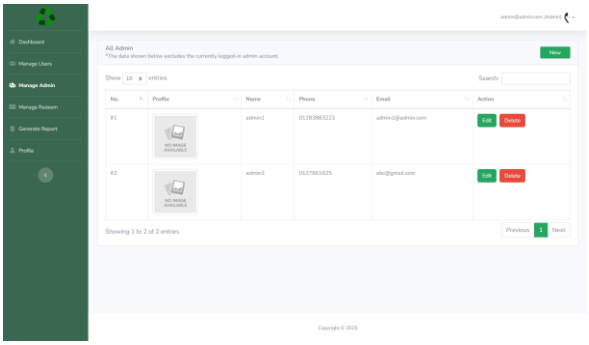

Figure 18 *Manage User Profiles Interface for Admin*

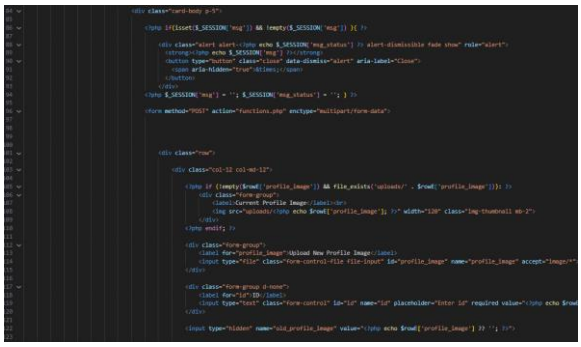

Figure 19 *Manage User Profiles Code Segment*

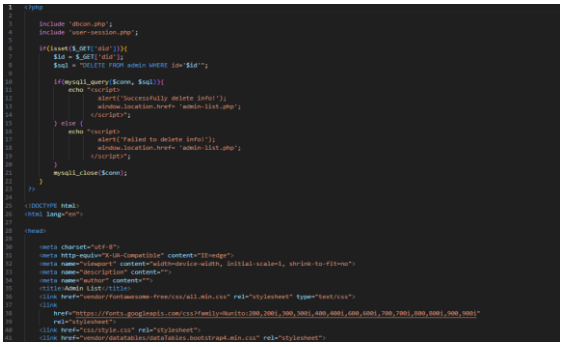

Figure 20 *Manage User Profiles Admin Code Segment*

The Manage Recycling Activities Module provides features to record each recycling transaction by capturing key details such as the weight of recyclable materials, timestamp, and the corresponding cashback amount. A transaction history is maintained for every user, allowing them to view past recycling activities along with dates, weights, and rewards earned. Upon successful completion of a transaction, the system notifies the user and updates their cashback balance accordingly. Figure 21 displays the Manage Recycling Activities interface for user, while Figure 22 presents the associated code segment.

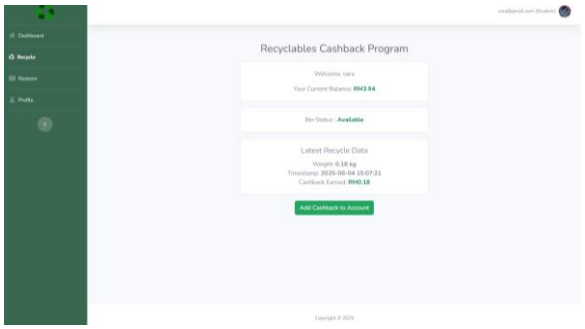

Figure 21 *Manage Recycling Activities Interface*

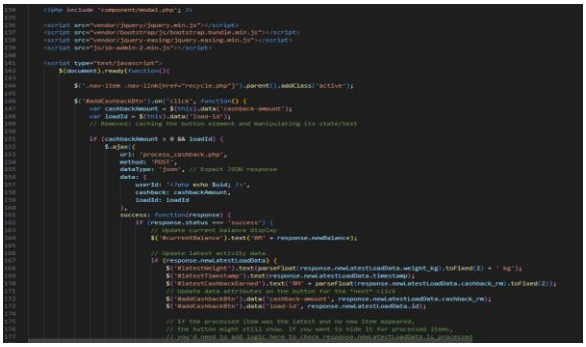

Figure 22 *Manage Recycling Activities Code Segment*

The Manage Recycling Bins Module provides monitoring by IoT-enabled recycling bins in real time to capture and report their fill levels. This data helps ensure timely collection and efficient bin usage. Administrators are granted the ability to update bin statuses as needed. Current bin statuses are also displayed to users, allowing them to locate available bins and avoid overfilled ones. Figure 23 displays the Manage Recycling Bins interface for admin, while Figure 24 presents the associated code segment.

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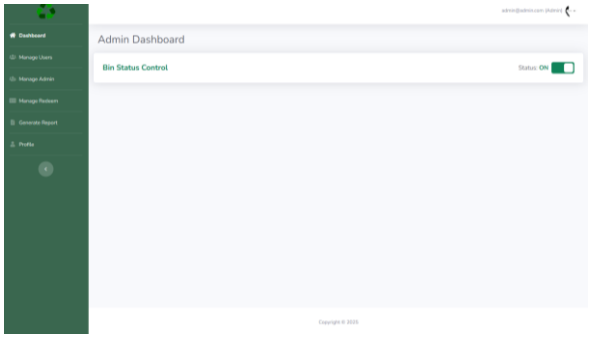

Figure 23 *Manage Recycling Bins Interface*

Figure 24 *Manage Recycling Bins Code Segment*

The Manage Cashback Reward Module facilitates cashback redemption by requiring users to complete all necessary fields during the redemption process. Input validation is implemented to ensure the accuracy and completeness of submitted information. Redemption is only allowed when a user's cashback balance meets or exceeds the predefined minimum threshold. Upon successful redemption, the redeemed amount is deducted from the user's balance accordingly. Figure 25 and Figure 26 displays the Manage Cashback Rewards interface for both user and admin, while Figure 27 and Figure 28 presents the associated code segment.

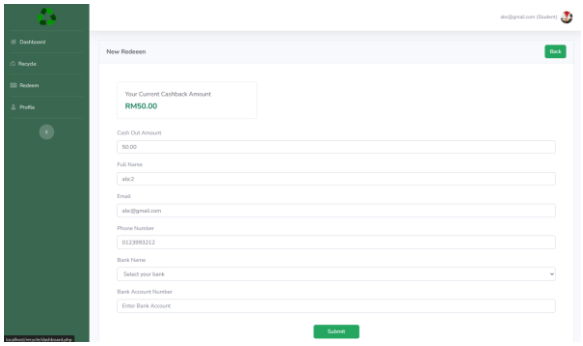

Figure 25 *Manage Cashback Rewards Interface User*

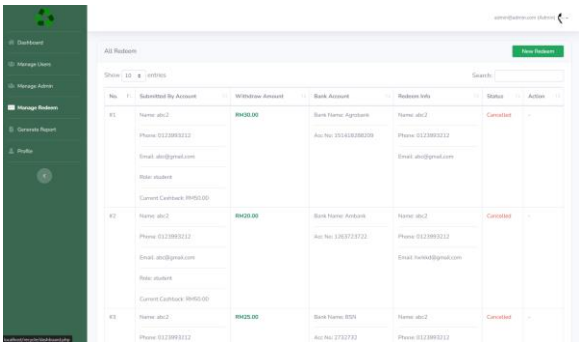

Figure 26 *Manage Cashback Rewards Interface Admin*

Figure 27 *Manage Cashback Rewards User Segment*

Figure 28 *Manage Cashback Rewards Admin Segment*

The Generate Report Module helps to generates monthly reports detailing the total amount of recyclables collected across all users. Administrators can filter these reports by date range and user group to gain more specific insights. Generated reports can be viewed, downloaded, and printed directly through the admin interface, supporting both digital and hard-copy record keeping. Figure 29 displays the Generate Report interface for admin, while Figure 30 presents the associated code segment.

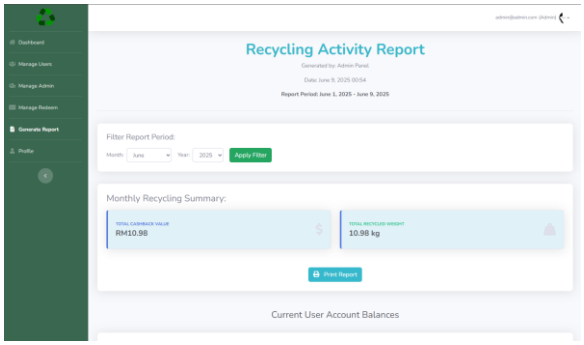

Figure 29 *Generate Report Interface*

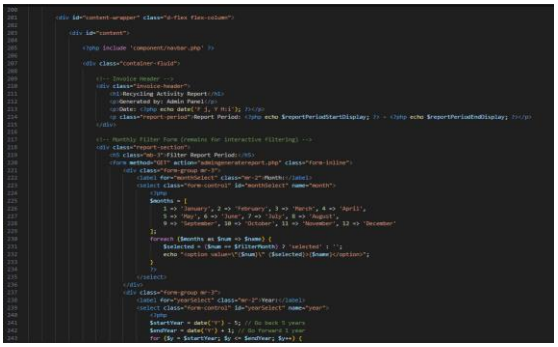

Figure 30 *Generate Report Code Segment*

5.2 Testing

The IoT – Enabled Cashback – Based Recycling Management System undergoes testing to verify whether it fulfills the requirements. Two types of testing are conducted, including functional requirement testing and user acceptance testing.

The overall test results for the functionality testing are shown in Table 8. The total test cases for each module and the number of passed test results are concluded in the Table 8.

Table 8 *Overall Test Case Result*

Test Case ID	Total Test Cases	Total Passed
TEST_100	5	5
TEST_200	6	6
TEST_300	6	6
TEST_400	4	4
TEST_500	4	4
TEST_600	6	6
TEST_700	5	5
Total	36	36

The functional testing of the IoT-Enabled Cashback-Based Recycling Management System involved a total of 36 test cases across all system modules. As shown in Table 8, all 36 test cases passed successfully, indicating that each module functions as intended and meets the specified requirements. This confirms the system's reliability and readiness for user deployment.

User acceptance testing was conducted among university communities including students and staff. A total of ten participants participated in the test. From a scale 1 to 5 representing very unsatisfied to very satisfied, the satisfaction of the users on these aspects are recorded. Table 9 presents the results from user involvement in the IoT - Enabled Cashback – Based Recycling Management System.

Table 9 *User Acceptance Testing*

No.	Question	Scale					Total
		1	2	3	4	5	
1.	How satisfied are you with the overall layout and design of the recycling system interface?	0	0	0	2	8	10
2.	How easy is it to register and manage your user profile?	0	0	0	2	8	10
3.	How intuitive is the recycling submission process (e.g, scanning, weighing recyclable)?	0	0	0	0	10	10

Table 9 (cont) *User Acceptance Testing*

4.	How satisfied are you with the system's performance and speed during usage?	0	0	0	3	7	10
5.	How well does the system notify and confirm successful recycling transactions?	0	0	0	0	10	10
6.	How easy is it to navigate between different sections of the recycling system interface (e.g. dashboard, profile, cashback)?	0	0	2	0	8	10
7.	How satisfied are you with the overall user experience of the recycling system?	0	0	0	2	8	10
8.	How secure do you feel the system is in protecting your data?	0	0	1	2	7	10
9.	How satisfied are you with the visual representation and clarity of recycling history and cashback records?	0	0	0	0	10	10
10.	How easy is it to understand to use the system's features as a new user?	0	0	0	0	10	10

The user acceptance testing showed highly positive feedback from the university community. All ten participants rated most aspects of the system as either "satisfied" or "very satisfied," with a strong majority selecting the highest rating (5) across all questions. Key areas such as the recycling submission process, transaction confirmation, and clarity of cashback records received perfect scores. The results indicate that users found the system intuitive, easy to use, visually clear, and secure, confirming its usability and effectiveness for campus deployment.

The IoT-Enabled Cashback-Based Recycling System was successfully implemented using PHP and MySQL, featuring modules for user registration, login, profile management, recycling tracking, bin monitoring, cashback, and reporting. All 36 functional tests passed, confirming system reliability. User testing showed strong satisfaction, with participants finding the system easy to use, secure, and effective for campus deployment.

6. Conclusion

In conclusion, the IoT-Enabled Cashback-Based Recycling Management System is designed to address the recycling challenges faced by Universiti Tun Hussein Onn Malaysia (UTHM) by introducing a more efficient and engaging approach to waste management. By integrating IoT technology with a cashback incentive structure, the system aims to enhance user participation, track recycling activities in real-time, and provide meaningful rewards for users' efforts. This system is expected to improve recycling processes, improve tracking accuracy, and offer a more user-friendly experience, ultimately encouraging sustainable recycling practices on campus. The successful implementation of this system will not only help UTHM meet its environmental goals but also foster a culture of sustainability, making recycling both accessible and rewarding for students and staff.

Acknowledgement

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Aisyah Binti Abu Bakar, Ruhaya Binti Ab.Aziz;* ***data collection:*** *Aisyah Binti Abu Bakar, Ruhaya Binti Ab.Aziz;* ***analysis and interpretation of results:*** *Aisyah Binti Abu Bakar, Ruhaya Binti Ab.Aziz****;draft manuscript preparation:*** *Aisyah Binti Abu Bakar, Ruhaya Binti Ab.Aziz. All authors reviewed the results and approved the final version of the manuscript.*

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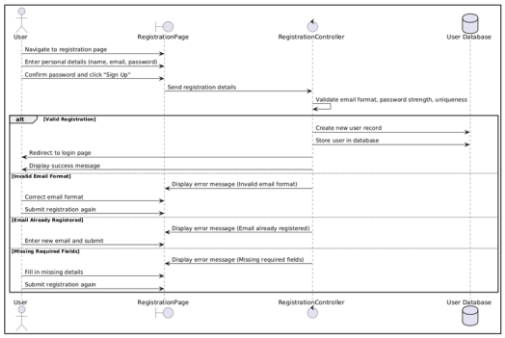
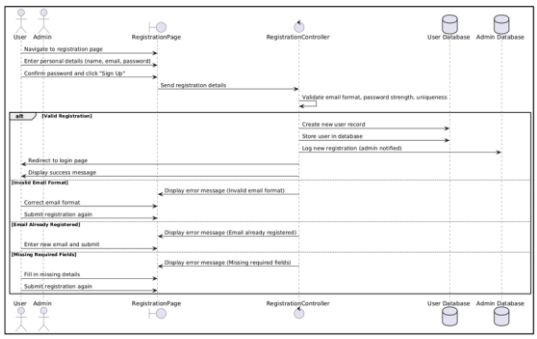
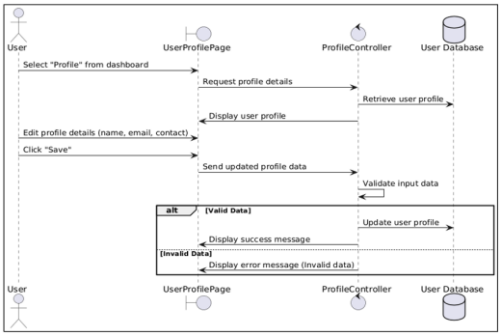
Appendix A: Sequence Diagram



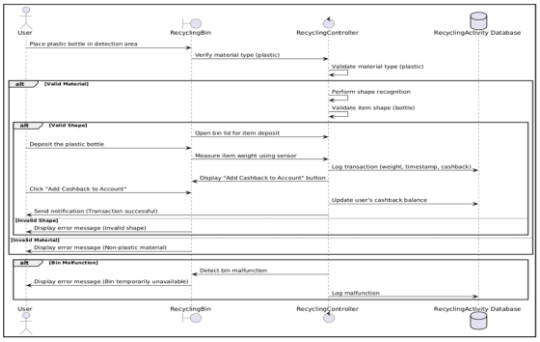
Sequence Diagram of Register Module



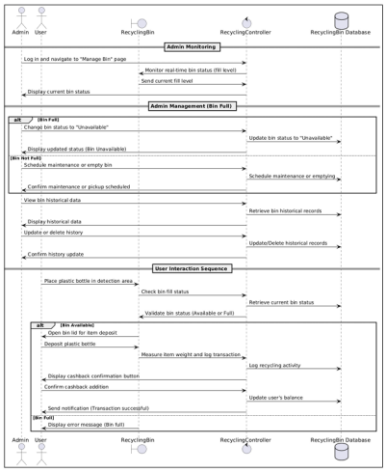
Sequence Diagram of Login Module



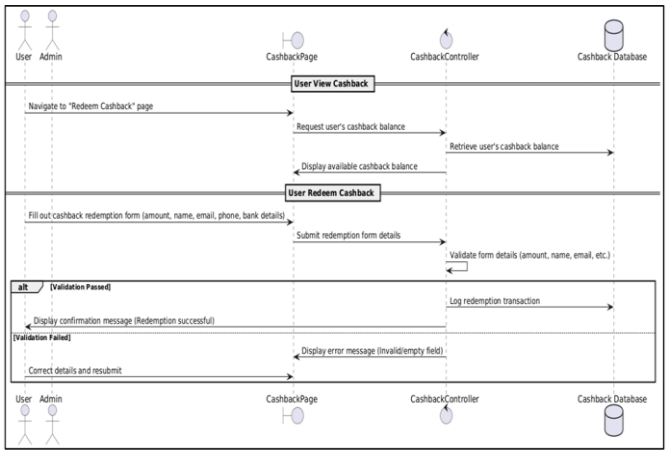
Sequence Diagram of Manage User Profile Module



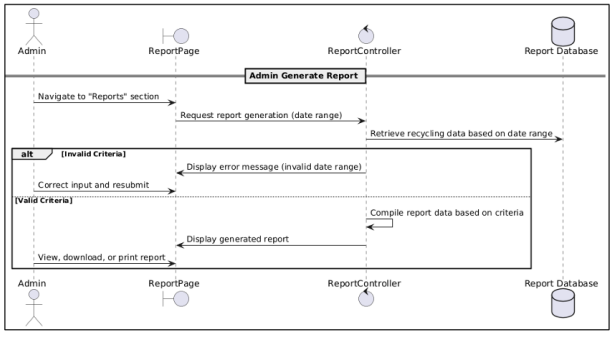
Sequence Diagram of Manage Recycling Activity Module



Sequence Diagram of Manage Recycling Bin Module

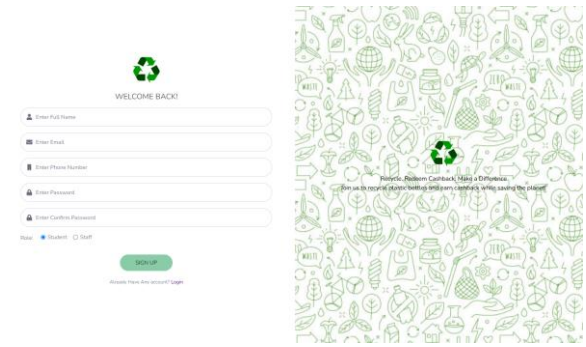


Sequence Diagram of Manage Cashback Module

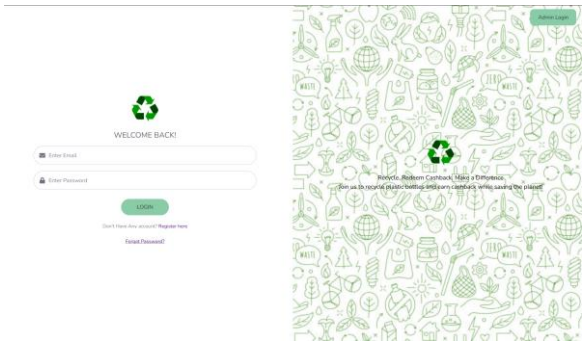


Sequence Diagram of Generate Report Module

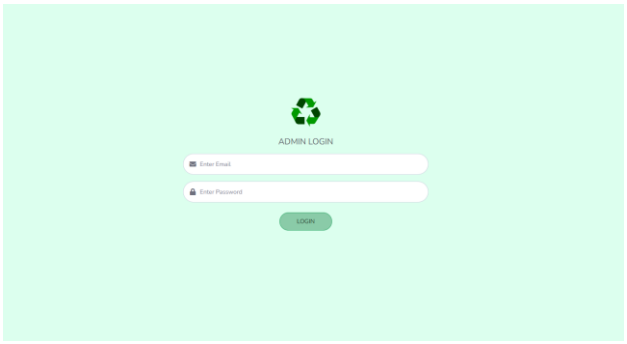
Appendix B: User Interface Design



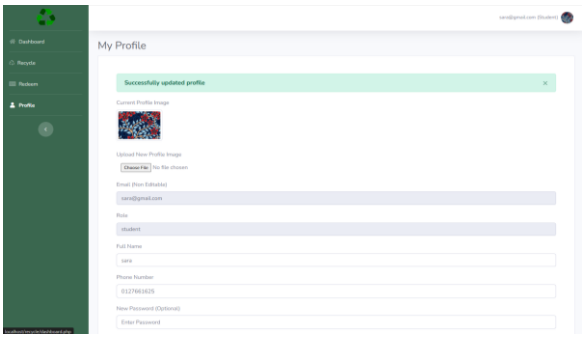
Register Interface for User



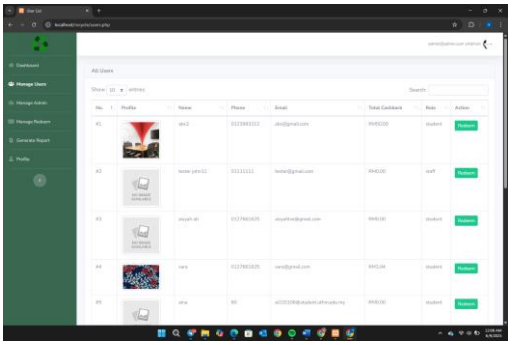
Login Interface for User



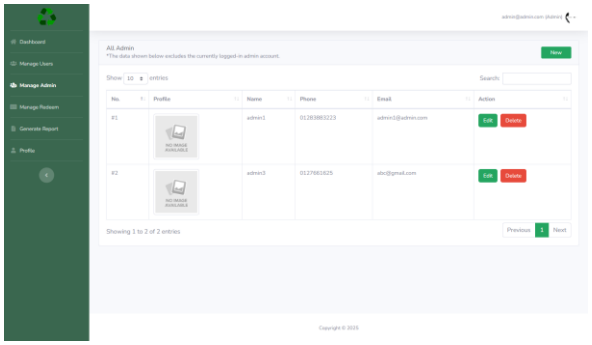
Login Interface for Admin



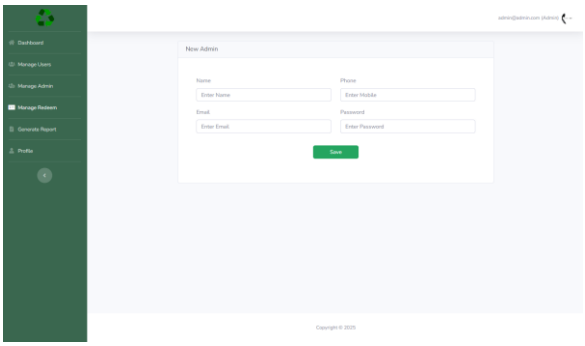
Manage Profile Interface for User



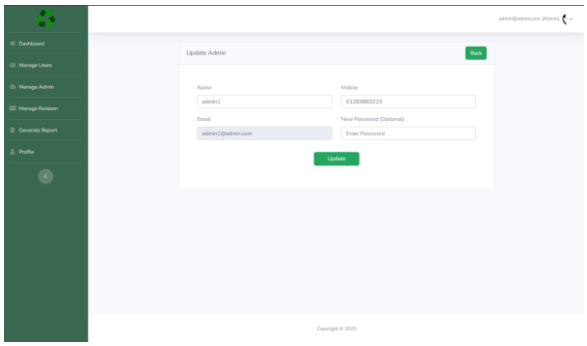
Manage Profile Interface for Admin (1)



Manage Profile Interface for Admin (2)



Manage Profile Interface for Admin (3)



Manage Profile Interface for Admin (4)

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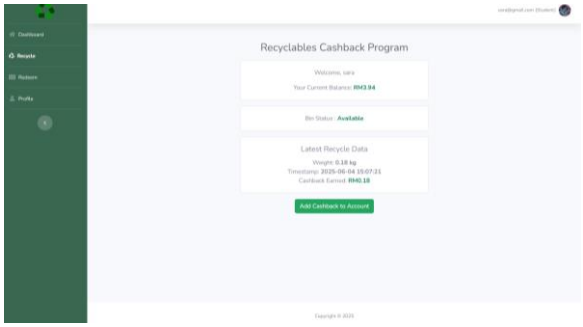
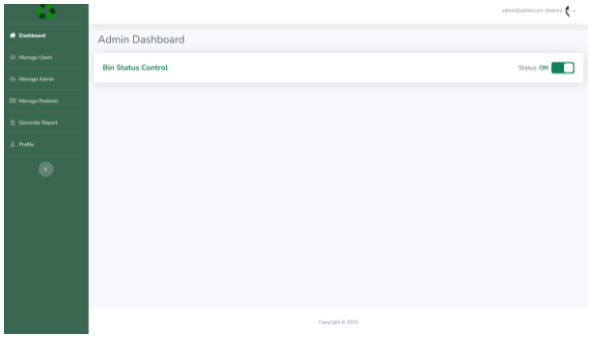
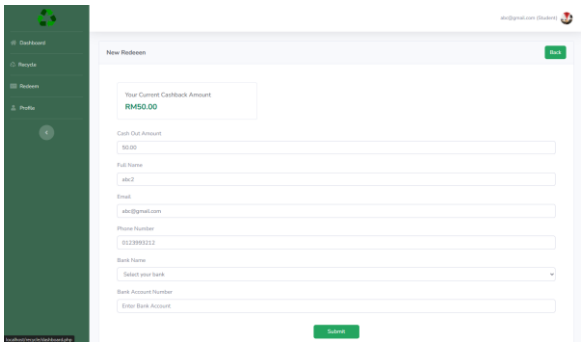


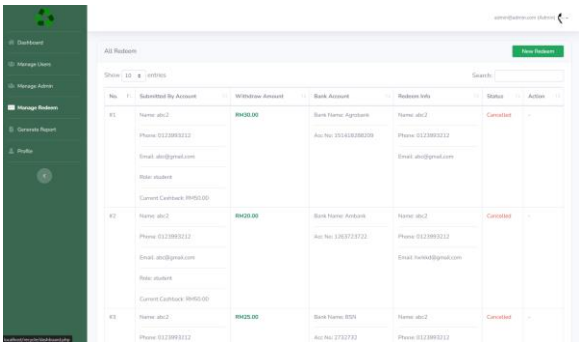
Manage Recycling Activities Interface for User



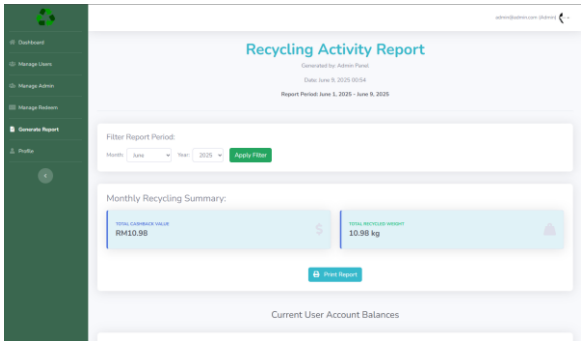
Manage Recycling Bins Interface for Admin



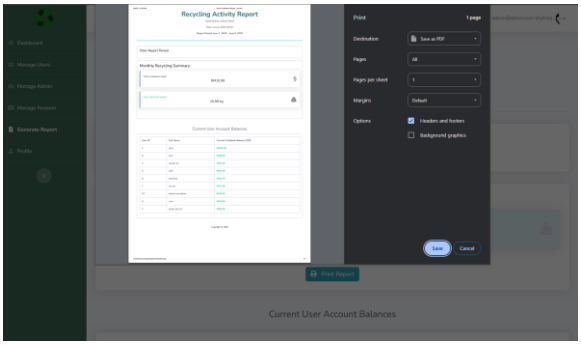
Manage Cashback Interface for User



Manage Cashback Interface for Admin

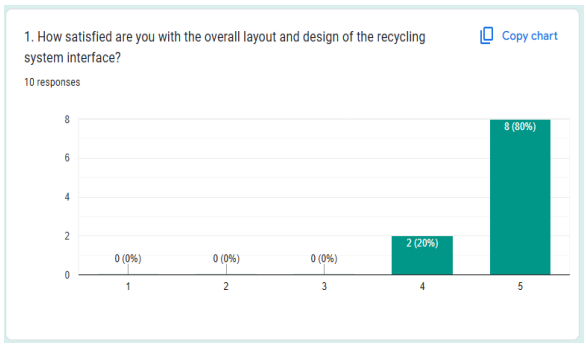


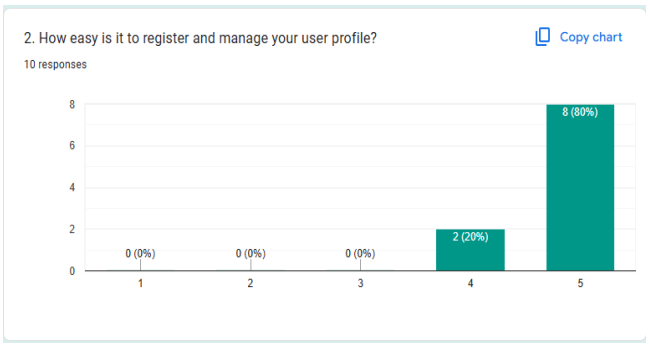
Generate Report Interface for Admin



Generate Report Interface for Admin (2)

Appendix C: Google Form Feedback Respondents

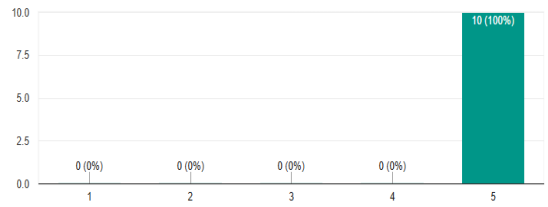




3. How intuitive is the recycling submission process (e.g., scanning, weighing recyclable)?

Copy chart

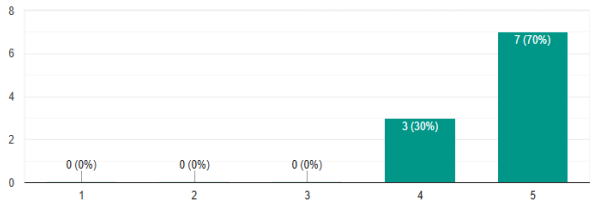
10 responses



4. How satisfied are you with the system's performance and speed during usage?

Copy chart

10 responses



5. How well does the system notify and confirm successful recycling transactions?

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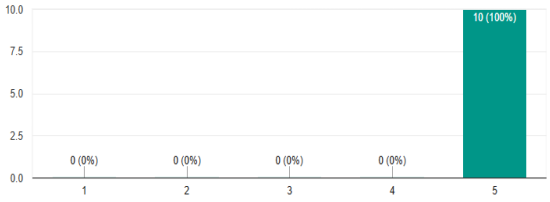
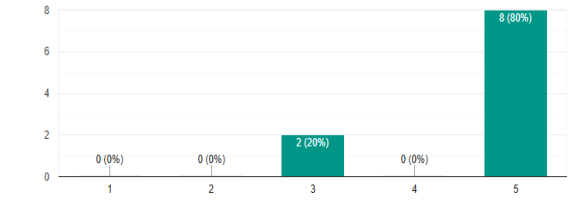
10 responses



6. How easy is it to navigate between different sections of the recycling system interface (e.g., dashboard, profile, cashback)?

Copy chart

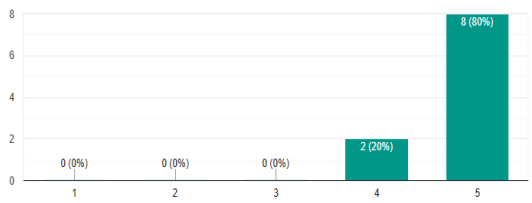
10 responses



7. How satisfied are you with the overall user experience of the recycling system?

Copy chart

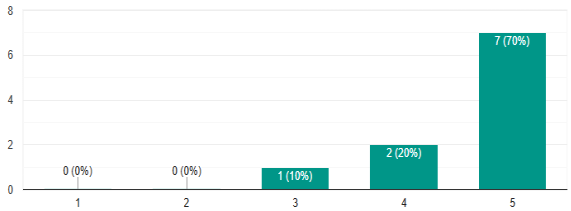
10 responses



8. How secure do you feel the system is in protecting your data?

Copy chart

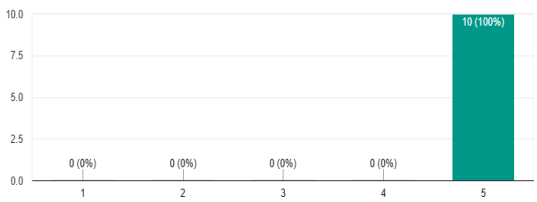
10 responses



9. How satisfied are you with the visual representation and clarity of recycling history and cashback records?

Copy chart

10 responses



10. How easy is it to understand and use the system's features as a new user?

Copy chart

10 responses