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Group 20

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Revision Control History:

Version Number	Date	Description and Reason of Change
1	15/2/2024	Adjustments to functional requirements
2	29/3/2024	Non-functional properties correction.
	1/4/2024	Methodology adjustments, Formatting.
3	1/4/2024	Updating Component diagram and its description.
3	5/5/2024	Adding methods and attributes to the class diagram.
4	12/5/2024	Final document formatting

Table 1: This figure shows the Revision Control History.

System Glossary:

Abbreviation	Description
AI	Artificial Intelligence is Technology enabling machines to perform tasks requiring human intelligence.
ML	Machine learning is based on the idea that systems can learn from data, identify patterns, and make decisions.[1]
AI-CNNs	Convolutional Neural Networks (CNNs) are widely used for image classification tasks.

Table 2: This figure describes each abbreviation used in this document.

Mustadam | مُستدام

Group 20

Introduction:

Recently, interest has begun in the concept of “waste recycling” in the Kingdom of Saudi Arabia. The Kingdom produces approximately 15 million tons of municipal solid waste annually, at a rate of 1.4 kilograms per person! This number is expected to double by 2033 to 30 million tons annually [2]. We tried to find a suitable solution which can help to encourage the people to recycle their waste, our goal is to increase the recycling rate in the Kingdom of Saudi Arabia.

Mustadam is an innovative system software designed to revolutionize waste management processes in cities and communities. It addresses the global challenge of waste disposal and environmental sustainability by leveraging advanced technologies such as Machine learning (ML), artificial intelligence, and data analytics to optimize waste collection, recycling, and resource utilization.

Problem Domain Analysis:

Mustadam addresses the pressing problem of environmental sustainability and waste management optimization, targeting students and faculty members from universities in Riyadh. The current state of waste management in the region poses significant challenges, including inefficiencies and low recycling rates, leading to a harmful environmental impact. Through the implementation of innovative technologies, Mustadam aims to improve waste management, increase recycling, and promote sustainable resource use. By optimizing waste handling and minimizing its environmental footprint, Mustadam seeks to create a greener future for Riyadh's communities and beyond.

Solution Description:

The Mustadam application addresses several key problems related to waste management and environmental sustainability through its innovative approach and cutting-edge technology. The program implements the following strategies to tackle these challenges:

- **Waste Sorting Technology:**

  The Smart Bin, equipped with advanced algorithms, utilizes waste sorting technology to accurately identify and categorize different types of waste. By employing embedded image recognition technology (AI-CNNs), machine learning (decision tree algorithms), and pattern recognition techniques, the Smart Bin can distinguish materials such as plastic, paper, glass, metal, and organic waste. This technology ensures efficient and effective waste sorting, reducing the number of recyclable materials ending up in landfills.

- **Intelligent Sorting Algorithms:**

  The Smart Bin's advanced algorithms undergo regular training with new data to continuously improve their recognition capabilities over time. By incorporating machine learning (ML) and (AI-CNNs) techniques (decision tree algorithms) and by training a (AI-CNN) model on a large dataset of waste images, it can learn patterns and features indicative of different waste materials, The trained model can then classify images of waste into different categories, the algorithms can enhance their accuracy in waste categorization. This iterative training process allows the system to stay up to date with new waste items and optimize recycling processes. By retraining the algorithms with new data, the system can effectively minimize waste and maximize the recovery of valuable resources, ensuring efficient and accurate waste categorization.

- **Scanning Technology:**

  Scanning technology, such as barcode scanning, enables the Smart Bin to identify specific products or packaging, determining their recyclability. These technologies enhance the Smart Bin's sorting capabilities, ensuring precise waste categorization.

- **Real-time Feedback and User Interface:**

  The Smart Bin provides real-time feedback to users through an intuitive and user-friendly interface. It visually communicates the waste category and provides clear instructions for proper recycling. The interface simplifies the recycling process, enabling users to easily understand and follow the guidance provided. This facilitates effective waste management and reduces contamination, also user can send feedback to report any issues with the Smart bin to the system administrator.

- **Mobile Application and Rewards:**

  The Mustadam application offers a dedicated mobile application that serves as a central hub for users. Through the app, users can track their recycling progress, view their points balance, and redeem rewards. By offering rewards, such as discounts on popular brands and restaurants, the program incentivizes and motivates users to engage in recycling and adopt sustainable practices.

The System Context View:

- **Redeeming Points for Rewards:**

  The user, a staff member at Riyadh University, has accumulated a significant number of points on the Mustadam app through his consistent recycling efforts. He/she decides to redeem his/her points for a reward during his/her lunch break. The user opens the Mustadam app and navigates to the rewards section. He/she browses through the available rewards, which include discounts on local restaurants and cafes. he/she selects a discount voucher for his favorite restaurant and confirms the redemption. The system deducts the appropriate number of points from the user's account and provides him/her with a digital voucher to use at the restaurant. The user is delighted to enjoy a discounted meal as a reward for his sustainable actions, demonstrating the tangible benefits of participating in the recycling program through the Mustadam app.

- **Recycling Contribution:**

  A student at Riyadh University walks by a Smart Bin installed on campus. She/he notices a piece of plastic waste in her bag and decides to dispose of it in the Smart Bin. she/he approaches the Smart Bin and scans its unique ID barcode on the screen. The Smart Bin identifies the type of waste (plastic) using its embedded image recognition technology and automatically deposits it into the appropriate section within the bin. As a result, she/he earns points for her recycling contribution, which are accurately recorded and accumulated in her/his account for future redemption. The student feels good about contributing to recycling efforts on campus while also earning rewards for her eco-conscious behavior.

- **Reporting Bin Issue:**

  The user, a faculty member at Riyadh University, notices that one of the Smart Bins on campus is overflowing with waste, causing litter to accumulate around it. Concerned about the cleanliness of the campus and the efficiency of waste collection, the user decided to report the issue using the Mustadam app. She/he opens the app on her/his smartphone and navigates to the feedback section. The user reports a big issue and provides details about the overflowing bin, including its location and the nature of the problem. She/he submits the feedback, and the system acknowledges the receipt of her/his report. The system administrators receive the user's feedback and promptly address the issue, arranging for the timely collection of waste from the overflowing bin. The user appreciates the responsiveness of the Mustadam app in addressing campus cleanliness concerns, contributing to a cleaner and healthier environment for the university community.

Functions & NFP Of the System:

1. Functional Requirements:

1.1. User Registration:

1.1.1. Users shall be able to register using their first name, last name, email, phone number, and password.

1.2. SMS Gateway:

1.2.1. The system shall send an OTP "One-Time Password" message to the user.

1.3. User Login:

1.3.1. Users shall be able to log in using their phone number and password.

1.3.2. Users shall be able to log in using their email and password.

1.4. Waste Sorting:

1.4.1. The system shall be able to scan the waste materials by using embedded image recognition technology within the smart bins.

1.4.2. The system shall be able to use machine learning algorithm to identify the waste type.

1.4.3. The system shall be able to deposit the classified waste into the appropriate section within the Smart Bin.

1.5. Points Accumulation & User Identification:

1.5.1. The users shall be able to scan the unique ID barcode of the Smart bin on the screen of the Smart bin to earn their points.

1.5.2. The system shall be able to record and accumulate the users' points for future redemption.

1.6. Rewards Redemption:

1.6.1. The users shall be able to redeem their accumulated points for various rewards offered by partner brands and businesses.

1.6.2. The users shall be able to view redemption points.

1.6.3. The users shall be able to browse the available rewards.

1.6.4. The users shall be able to select from available rewards.

1.6.5. The partner brands shall be able to add rewards.

1.6.6. The partner brands shall be able to edit rewards.

1.6.7. The partner brands shall be able to delete rewards.

1.6.8. The admin shall be able to delete rewards.

1.7. Feedback Mechanism:

1.7.1. The users shall be able to give feedback to report any issues with the Smart Bins.

1.7.2. The admin shall be able to view users' Feedback submissions.

1.7.3. The admin shall be able to respond to users' Feedback.

1.7.4. The user can view the admin's response to his/her feedback.

1.8. User Logout :

1.8.1. The user shall be able to log out from his/her account.

2. Non-Functional Requirements:

2.1. Reliability: The system shall be available 98.5% of the time.

2.2. Usability: The users shall be to learn how to use the system within 3 minutes.

2.3. Performance: The system shall be able to recognize the waste materials in less than 0.5 seconds.

2.4. Scalability: the system shall be able to handle more than 20,000 users' requests.

2.5. Correctness: the system shall be able to identify the waste with an accuracy of at least 95%.

2.6. The system shall run on iOS and Android platforms.

Challenges:

The project may face several challenges during its development or even after its launch. One of the challenges that we are likely to face during the development of the project is the use of the Machine Learning (ML) language in it, as the project depends mainly on it, so the accuracy must be very high to avoid any problem that may occur. After its launch, we must raise awareness and motivate the community to use the application. Contracting with entities that cooperate in giving rewards to users may initially face difficulty due to the lack of guarantee on the profit resulting from this partnership.

Projection:

The project covers the development and implementation of the Mustadam waste management application system, including software development, hardware deployment, and infrastructure setup.

The final product is estimated to cost 110,000 Saudi Riyals in total. The project team consists of 6 software engineering members. One project manager, one mobile application database administrator, one system analyst, and 3 frontend/backend developers. The project is expected to be created in 8 months and 2 weeks. 2 weeks for the project planning, 1 month for analysis, 1 month for designing, and 6 months for implementation and further deployment.

The anticipated outcomes from this project include improved waste management efficiency and effectiveness, increased recycling rates, reduction in environmental pollution, and positive social and economic impact on the community.

The possible skills and knowledge our team will gain by the end of the semester are project and time management, applying the best software architecture for our system, and improving our problem-solving skills.

Methodology:

The decision to adopt an Agile methodology for Mustadam arises from a comprehensive analysis of project objectives, risk assessment, team dynamics, and resource constraints.
Agile is chosen due to its flexibility, adaptability, and iterative approach, which align with the project's need for continuous refinement and improvement.

The project's complexity, coupled with evolving requirements and the integration of ML (machine learning) technology, makes Agile's iterative and adaptive approach more suitable for mitigating risks and addressing challenges.

We decided to divide Mustdam development into several iterations.
Starting with the first iteration we will implement Sign-up, Login, Log out. Then we will start with the riskiest part Waste Sorting with image recognition and Points Accumulation and User Identification modules. Then we will implement the Rewards Redemption and Feedback Mechanism modules. After that, we will integrate the Identifier, Scanner, SMS gateway, and Partner brands subsystems.

Number of iterations	Module/ subsystems	Duration
1	Sign up, and Login, Logout.	8 days
2	Waste Sorting with image recognition, Points Accumulation, and User Identification	12 days
3	Rewards Redemption, Feedback Mechanism	10 days
4	Identifier, Scanner, SMS gateway Partner brands	14 days

Table 3: Mustadam iterations modules /subsystems plan along estimated durations.

The Gantt chart below describes the estimation plan for Mustadam development. based on Agile methodology. Mustadam testing plan is provided in the quality assurance section.

	Task	Resource	Duration	Start	Finish	Work
1	Sing-up	Asma	3 days	Sun 4/2/24 8:00 AM	Thu 4/4/24 5:00 PM	25 hrs
2	Login	Asma	3 days	Sun 4/2/24 8:00 AM	Thu 4/4/24 5:00 PM	25 hrs
3	Logout	Saadiya	2 days	Wed 4/3/24 8:00 AM	Thu 4/4/24 5:00 PM	15 hrs
4	Waste Sorting with Image Recognition	shahad,sara osaimi	7 days	Wed 4/3/24 8:00 AM	Fri 4/12/24 5:00 PM	85 hrs
5	Points Accumulation and User Identificatior	Saadiya,Deem	5 days	Mon 4/8/24 8:00 AM	Fri 4/12/24 5:00 PM	45 hrs
6	Rewards Redemption	Sara Alkanhal,Asma	5 days	Mon 4/15/24 8:00 AM	Fri 4/19/24 5:00 PM	45 hrs
7	Feedback Mechanism	Deem ,shahad	5 days	Mon 4/15/24 8:00 AM	Fri 4/19/24 5:00 PM	45 hrs
8	identifier	Sara Alkanhal	4 days	Mon 4/22/24 8:00 AM	Thu 4/25/24 5:00 PM	44 hrs
9	Scanner	sara osaimi	4 days	Mon 4/22/24 8:00 AM	Thu 4/25/24 5:00 PM	44 hrs
10	SMS getway	shahad,Asma	3 days	Wed 4/24/24 8:00 AM	Fri 4/26/24 5:00 PM	36 hrs
11	Partner brands	Deem, Saadia	3 days	Wed 4/24/24 8:00 AM	Fri 4/26/24 5:00 PM	36 hrs

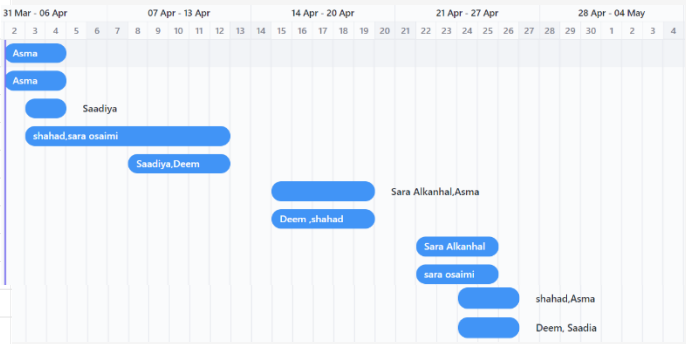

Figure 1: Mustadam Gannt Chart .

The riskiest part is Waste Sorting with Image Recognition.
Image recognition technology can be complex, especially when applied to real-world scenarios like waste sorting where the appearance of items can vary significantly. Ensuring accurate classification of various types of waste materials requires sophisticated algorithms and extensive training data.

System Architecture:

a. Design Decisions:

- **What database management strategies are employed in Mustadam to efficiently store ?**

  In Mustadam, waste-type data collected from smart bins is stored using a database management system (DBMS) with a carefully designed schema, encompassing tables for different waste types and relevant attributes. Utilizing appropriate data types and indexing strategies ensures efficient storage and retrieval of data, while normalization techniques minimize redundancy and maintain data consistency. The chosen DBMS is MySQL, which aligns with system requirements, offering scalability and security features.

- **How does Mustadam support the Smart bins?**

  Our system facilitates smart bins by seamlessly collecting and analyzing waste data, utilizing machine learning algorithms to categorize materials, and offering user-friendly interfaces for engagement. Through incentivization mechanisms, we encourage proper waste disposal and community involvement.

- **How will we deal with the challenges of training the machine learning model?**

  We will ensure that our team members are well trained to achieve continuous skill development leading to higher quality processes and results. All while ensuring that our provided training data will be of high quality, properly labeled using accurate annotation tools, and duplicate-free, diverse, consistent, and relevant. We will provide a vast amount of training data, along with considerable amounts of test data to validate the accuracy and precision of the results provided by the ML model.

- **How will Mustadam authenticate users while logging in?**

  During the login process of the Mustadam, the program confirms users' ownership of the registered phone number by requesting the right OTP. The software creates a one-of-a-kind, time-limited OTP and sends it to the user's registered phone number whenever they attempt to log in. This choice is essential for protecting user accounts and limiting illegal access, ensuring the safety of the app throughout the authentication process.

- **How does our waste sorting module prioritize accuracy and ensure its effectiveness in promoting recycling and environmental sustainability?**

  To ensure that our waste sorting system achieves high accuracy, we prioritize gathering diverse and high-quality data, developing robust machine learning models tailored to our specific needs, and implementing a continuous training and evaluation process. We augment our training data, balance the dataset, and incorporate a feedback mechanism to refine our models over time based on user input. We regularly maintain and update our models to adapt to changing conditions and monitor their performance in real time to detect and address any issues promptly. By following these steps, we ensure that our system achieves and maintains high accuracy levels in waste sorting, contributing to its effectiveness in promoting recycling and environmental sustainability.

b. Domain Model:

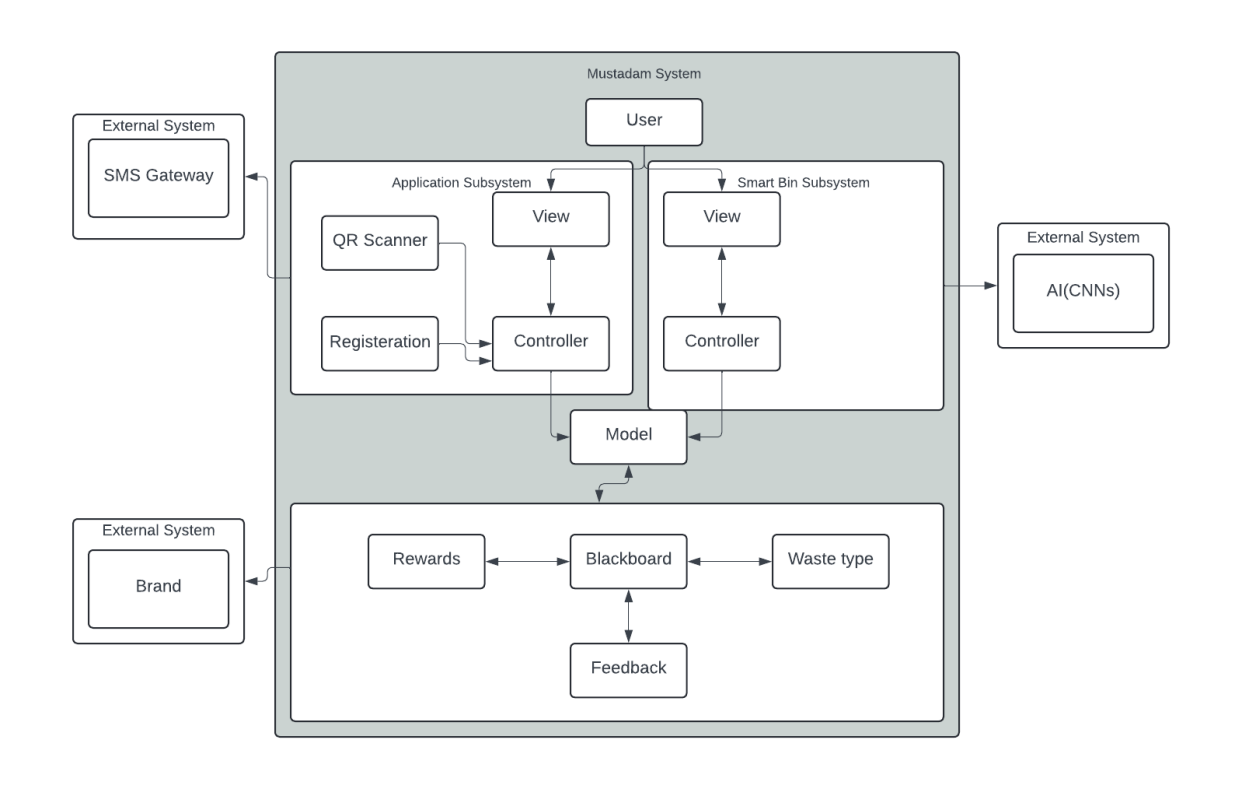

Figure 2: This figure shows domain model of Mustdam system.

Mustdam system components:

- **User:** a registered user who can access the system and all its functionalities.
- **Model:** manages data and business logic, ensuring data integrity and efficient processing.
- **Waste type:** it represents the technology and algorithms used to accurately identify and categorize different types of waste by using (AI-CNNs).

- **Mustdam Application subsystem:**

  - **Registration:** a component responsible for registering/signing in users.
  - **SMS Gateway: "External System":** sends an OTP via SMS to the user.
  - **View:** The view component which will display the GUI.
  - **Controller:** The controller component controls how the user interacts with the system.

- **Smart bin subsystem:**
  - **View**: The view component which will display the GUI.
  - **Controller:** The controller component controls how the user interacts with the system.

- **AI (CNNs)"External System":** enhance the waste sorting capabilities of the Mustadam system by accurately identifying and categorizing different types of waste through image recognition techniques**.**
- **Database :**
  - **Blackboard:** Stores relevant information, facts and data used by the Mustdam system.
  - **Rewards:** Represents the rewards offered to users for their accumulated points. Its offers users the opportunity to redeem accumulated points for discounts and incentives from partner brands and businesses.
  - **Waste types :** Contains information about different types of waste.
  - **Feedback :** user feedback and related data for analysis and system improvement.
  - **Brand "External System":** Partner brands that offer rewards to users.

c. Architectural Style:

In Mustadam, the combination of the Model-View-Controller (MVC) architectural pattern with a Blackboard architecture forms the backbone of its software infrastructure, ensuring efficient waste management and user interaction. The smart bin and the application acting as a knowledge source for the blackboard, both (smart bin and application) structured using MVC style to organize the user interface, separating the visual elements (View) from the logic that handles user interactions (Controller). The Model component within the MVC architecture encapsulates the underlying data and business logic of the system, including waste sorting algorithms, user authentication mechanisms, rewards management systems, and database operations. This separation allows for the development of intuitive and responsive interfaces across different platforms, such as the Smart Bin interface and mobile applications. For example, the View component focuses solely on presenting data to users, while the Controller component handles user input and interacts with the server to retrieve or update data.
Meanwhile, The Blackboard architecture provides the system with a centralized data allowing

the knowledge sources to update the data and retrieve it . The first style (MVC) helps us to develop an interactive system with multiple views for the same data, and using blackboard to develop system that works with AI and image recognition.

While Service-Oriented Architecture (SOA) offers several benefits, it was not chosen for Mustadam due to its potential complexity and overhead for the specific requirements of the waste management system. SOA typically involves designing and managing many individual services, each with its interfaces, protocols, and dependencies. In the case of Mustadam, the relatively focused scope of functionalities, such as waste sorting algorithms, user authentication, and rewards management, did not warrant the overhead of implementing and managing a full-fledged SOA. Instead, a more streamlined approach was preferred to meet the project's needs efficiently while ensuring scalability, flexibility, and maintainability.

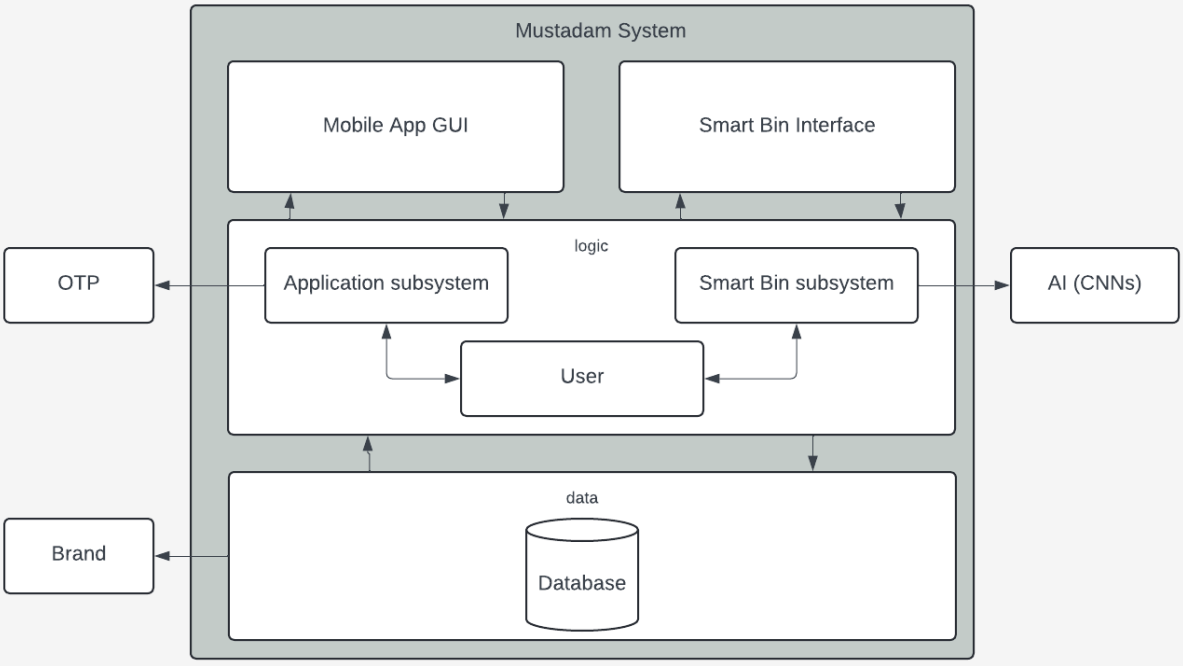

Figure 3: Architectural Style figure(Application subsystem and Smart bin subsystem are both clarified in the domain model)

d. Structural Model:

(1) Class diagram:

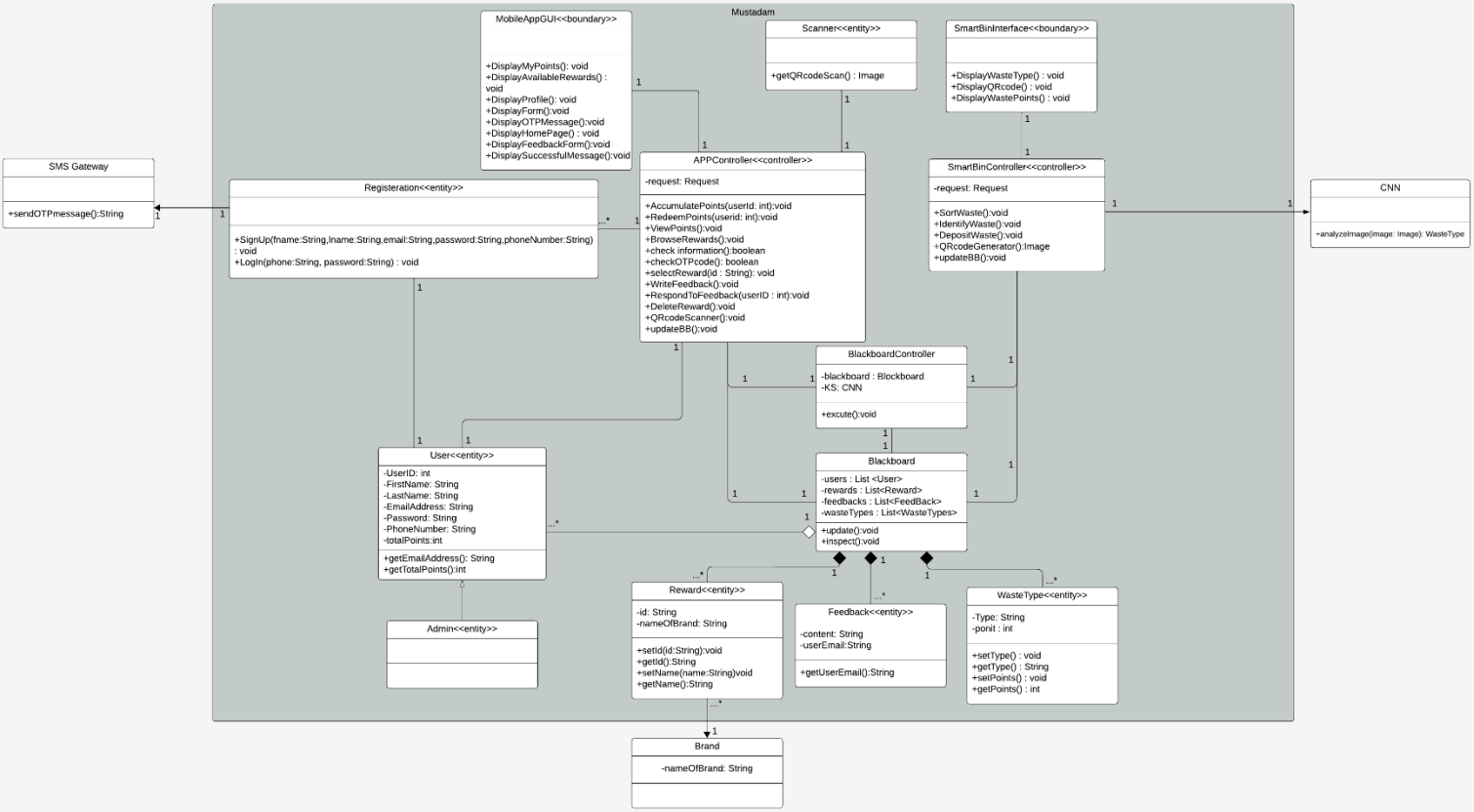

Figure 4: Mustadam's system class diagram.

(2) Component diagram:

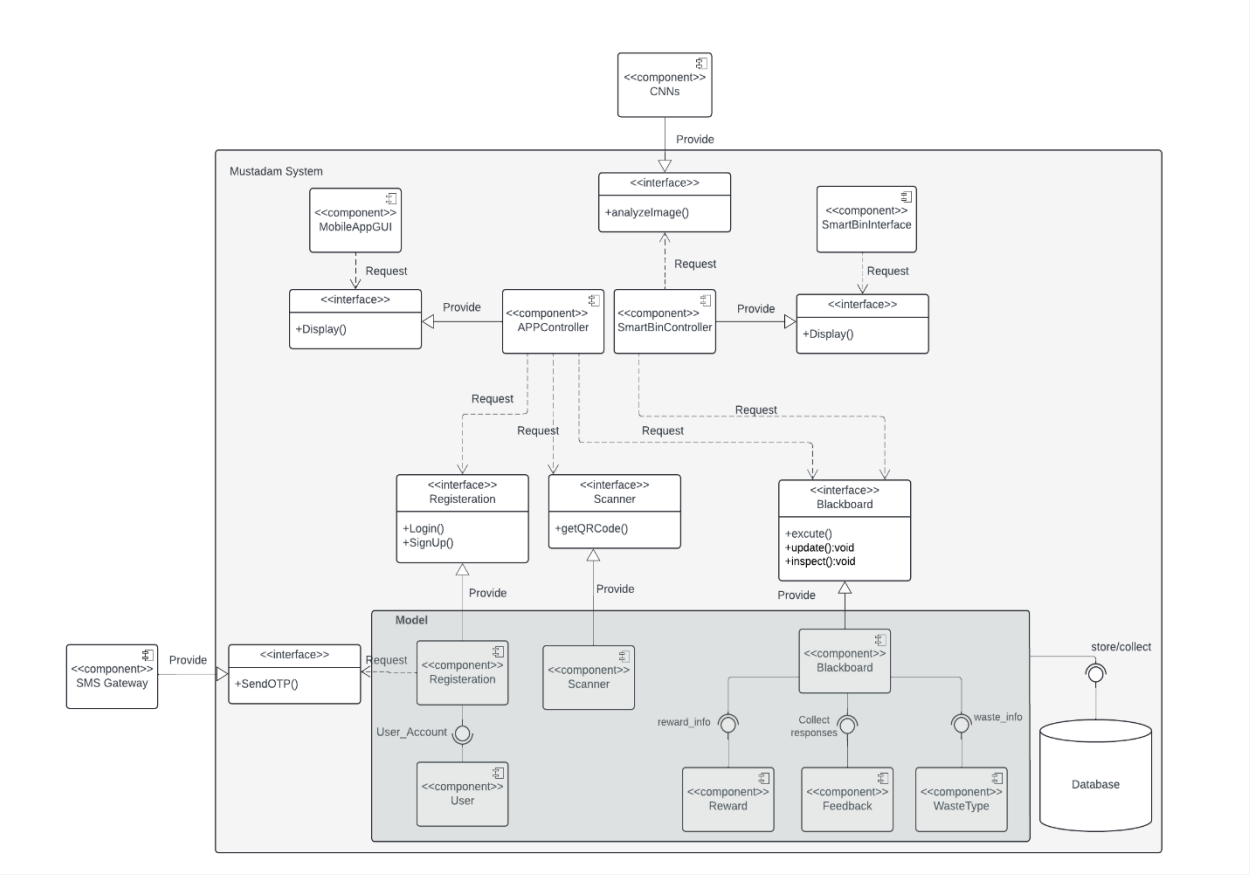

Figure 5:Mustadam's component diagram.

Component Name	SMS Gateway
Description	External system for confirming user login using OTP
Behavior/Functionality	Sends SMS containing OTP for user login
Connectors and Interfaces	Provides an interface for sending OTPs.
class	SMS

Component Name	Registration
Description	Provides sign up and log in functions
Behavior/Functionality	Manages user registration, login
Connectors and Interfaces	Provided interfaces: provide Registration info for app controller, provide user Account info for user, Require SMS Gateway to send the OTP
class	Registration

Component Name	User
Description	Registered user with access to system functionalities
Behavior/Functionality	Interacts with the system and utilizes its features
Connectors and Interfaces	Require Account info for the user.
class	User

Component Name	MobileAppGUI
Description	Graphical user interface for the Mustadam mobile application.
Behavior/Functionality	Provides intuitive navigation for users interacting with the Mustadam app.
Connectors and Interfaces	Required interface: require APP Controller to display
class	MobileAppGUI

Component Name	Scanner
Description	Responsible for QR code scanning functionality
Behavior/Functionality	Enables users to scan QR codes
Connectors and Interfaces	**Provided interface: provide QR code for APP Controller**
class	**Scanner**

Component Name	SmartBinController
Description	Manages smart bin functionalities
Behavior/Functionality	Controls smart bin operations such as waste identification and point allocation
Connectors and Interfaces	Required interfaces: Require Blackboard interface and Require from CNNs the result of Recognition the image. Provided interface: provide Display for Smart bin Interface.
class	SmartBinController

Component Name	SmartBinInterface
Description	User interface for smart bin interaction.
Behavior/Functionality	Displays waste sorting options and points accumulation status.
Connectors and Interfaces	Required interface: require SmartBinController to Display.
class	SmartBinInterface

Component Name	Reward
Description	Manages reward system
Behavior/Functionality	Handles reward distribution and redemption
Connectors and Interfaces	**Provided interface: provide reward info for Blackboard**
class	**Reward**

Component Name	Feedback
Description	Manages user feedback
Behavior/Functionality	Collects and manages user feedback submissions
Connectors and Interfaces	Provided interface: provide the Collected responses for Blackboard
class	Feedback

Component Name	APP Controller
Description	Controls application flow and logic
Behavior/Functionality	Manages interactions between different components of the application
Connectors and Interfaces	Required interfaces: require from Registration interface the Registration info, require from Scanner interface the QR code, require from blackboard interface the updated info of the reward, Feedback responses and WasteType info Provided interface: provide the interface for Mobile App GUI
class	APP Controller

Component Name	WasteType
Description	Manages information about waste types
Behavior/Functionality	Categorizes waste materials for sorting and identification.
Connectors and Interfaces	Provided interface: provide waste info for Blackboard
class	WasteType

Component Name	Blackboard
Description	Centralized data repository in Mustadam.
Behavior/Functionality	Facilitates data exchange between Mustadam components.
Connectors and Interfaces	Required interfaces: Require from Reward the reward_info, Require from Feedback the Collected responses, Require from WasteType the waste info Provide interface: provide the updated info and inspection for the Smart Bin Controller
class	Blackboard

Component Name	CNNs
Description	Convolutional Neural Networks (CNNs) Handles image recognition
Behavior/Functionality	Performs image recognition by Utilizing convolutional neural networks for waste identification
Connectors and Interfaces	**Provided interface: provide the result of Recognition the image to the Smart Bin Controller**
class	**CNN**

(3) Deployment diagram :

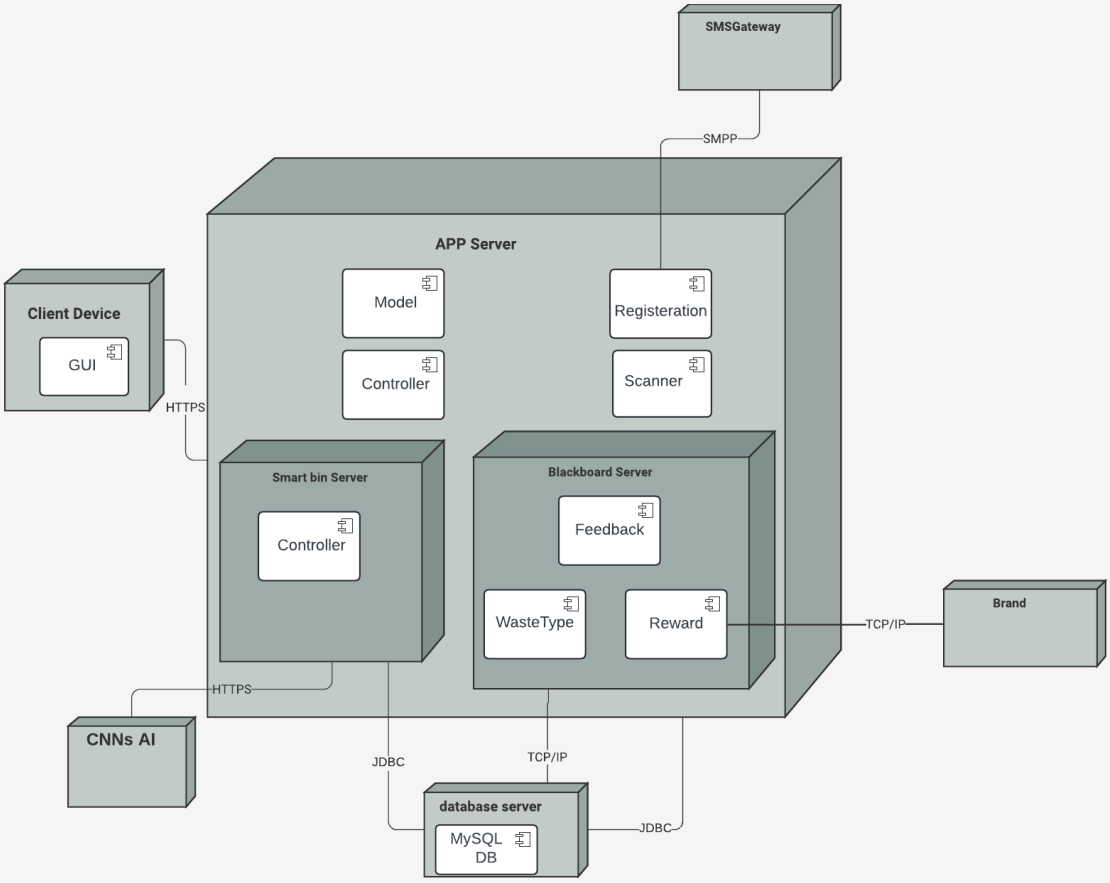

Figure 6: Mustadam system deployment diagram

(4) State Machine diagram :

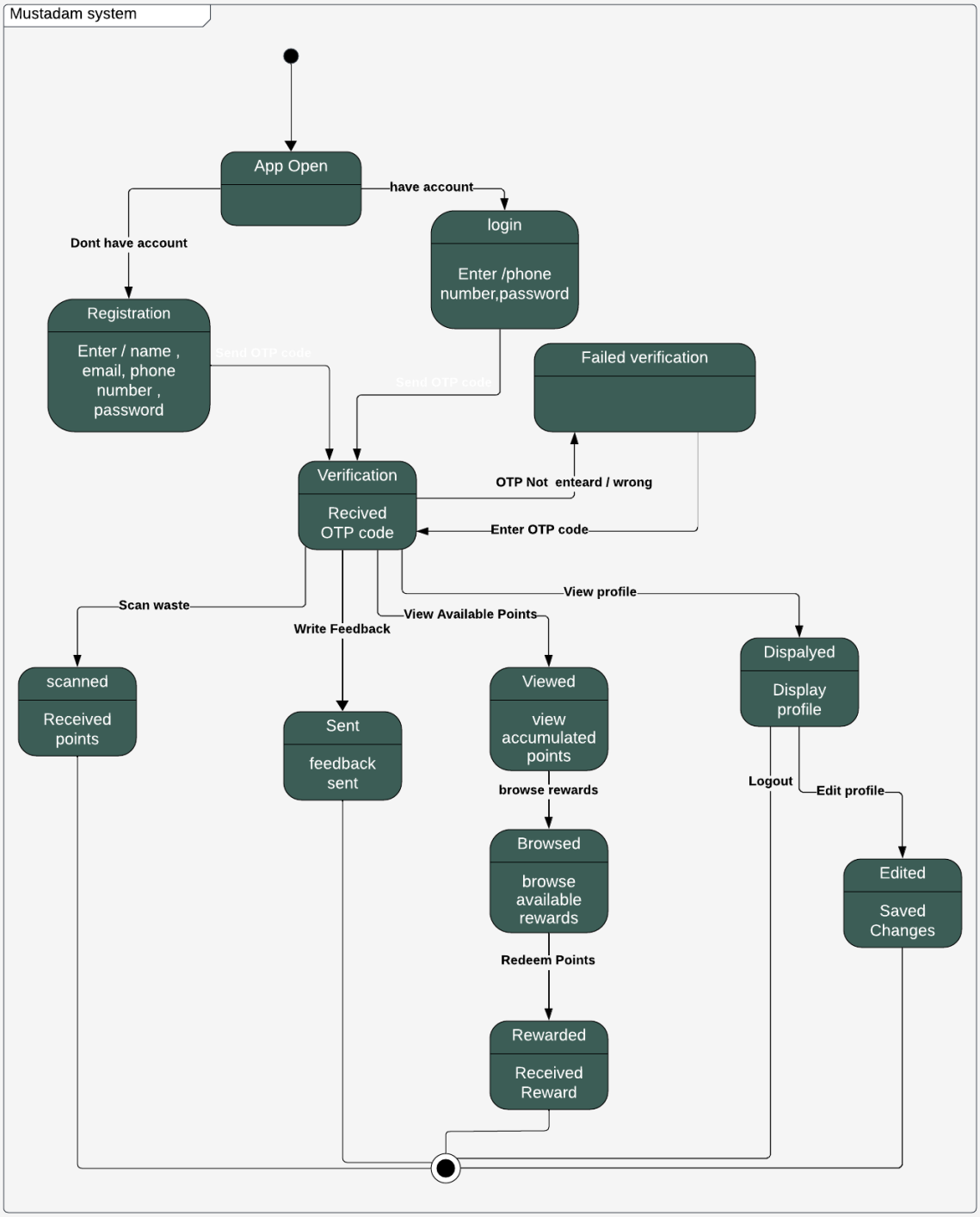

Figure 7: Mustadam system state machine diagram

(5) use case diagram :

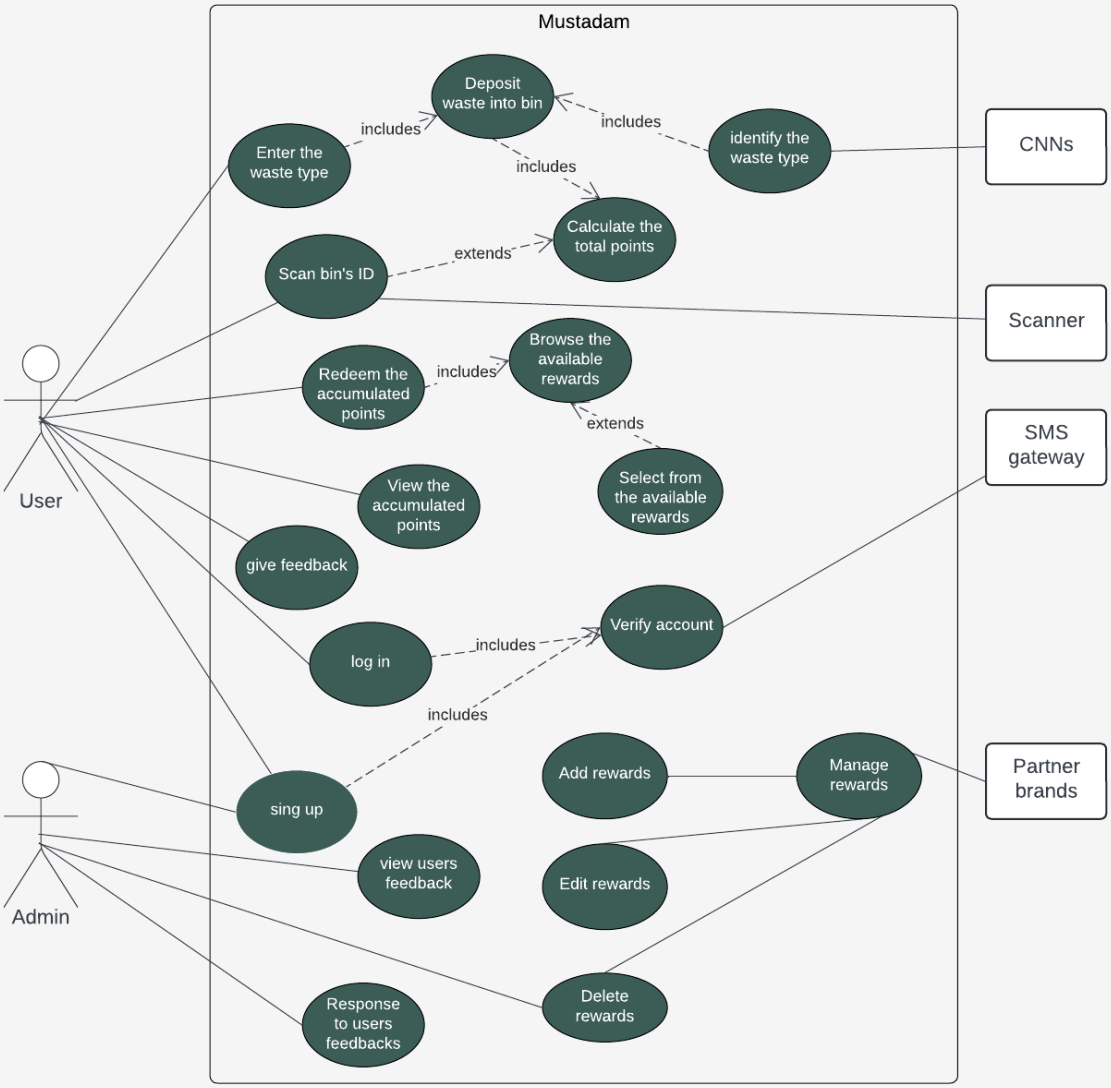

Figure 8: Mustadam system use case diagram

(1) Use case descriptions & Sequence diagrams:

(a) Give feedback use case description**:**

System: Mustadam	
Use case name: Give feedback	
Primary actor: user	**Secondary actor: -**
Description: This use case allows the user to give feedback in the app	
Relationships : **Includes: none** **Extends: none** **Generalization: none**	
Pre-conditions: -	
Steps	
Primary actor(s) (user)	**System (Mustadam)**
1. The user clicks on the give feedback option on the home page. 3. The user enters his/her email in the blank. 4. The user writes his/her feedback in the blank. 5. The user clicks on the send button to send his/her feedback.	2. The system displays the give feedback page. 6. The system displays a message that indicates successful feedback sending
Alternative and exceptional flows: • **Wrong email address:** If in step 3, the user enters wrong email address then: 1. The system displays a message indicating an email address is wrong. 2. Step 3 is resumed.	
Post-conditions: • **Success:** successful feedback sending message is shown. • **Failed:** fail feedback sending message is shown.	

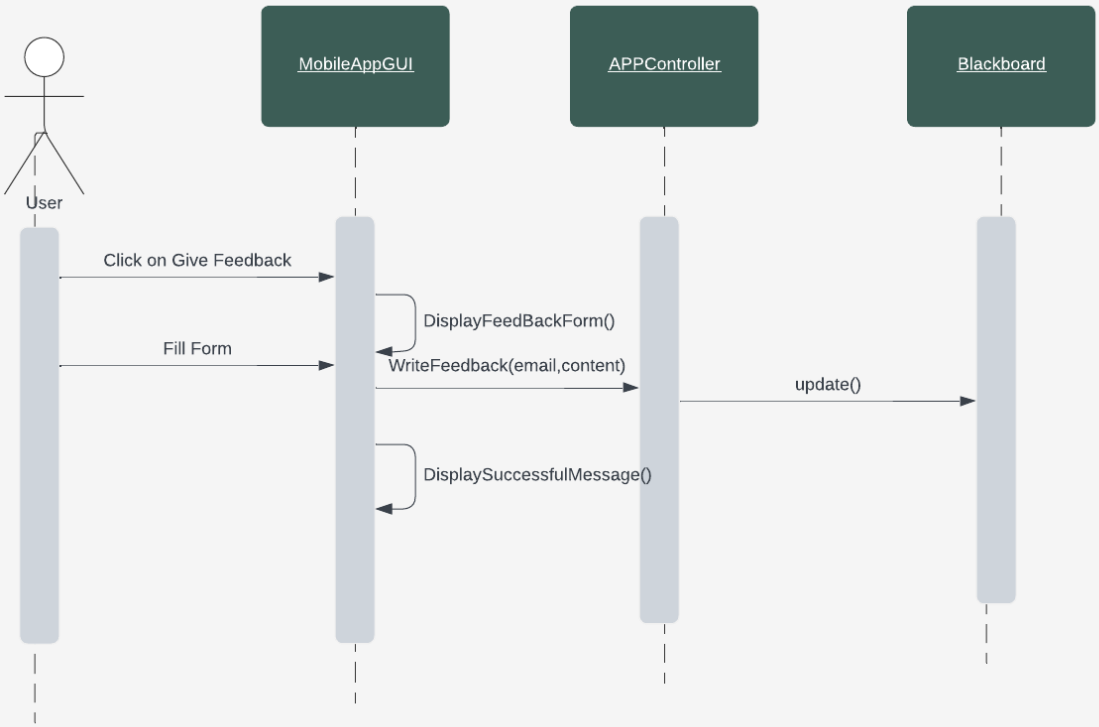

Figure 9: give feedback sequence diagram.

(b) Redeem the accumulated points use case description:

<table>
<tr><td colspan="2">System: Mustadam</td></tr>
<tr><td colspan="2">Use case name: Redeem the accumulated points.</td></tr>
<tr><td>Primary actor: user</td><td>Secondary actor: -</td></tr>
<tr><td colspan="2">Description: This use case allows the user to redeem the accumulated points</td></tr>
<tr><td colspan="2">Relationships :
Includes: Browse the available rewards.
Extends: none
Generalization: none</td></tr>
<tr><td colspan="2">Pre-conditions: -</td></tr>
<tr><td colspan="2">Steps</td></tr>
<tr><td>Primary actor(s) (user)</td><td>System (Mustadam)</td></tr>
<tr><td>1. The user clicks on the 'redeem points' option on the home page.
3. The user browses through the list of rewards.
5. The user selects the desired reward
7. The user receives confirmation of the selected reward after system validation.</td><td>2. The system displays the available rewards page.
4. The system displays the available rewards After browsing, based on step 3

6. The system validates the user's accumulated points against the required points for the selected reward and confirms the redemption.
8. The system displays a message that indicates successful reward sending</td></tr>
<tr><td colspan="2">Alternative and exceptional flows:
• The selected reward becomes unavailable or out of stock :
If in step 5, the user doesn't find the desired reward :
1. The system notifies the user by displaying a message.
2. Step 4 is resumed</td></tr>
<tr><td colspan="2">Post-conditions:
• Success: The user gets the reward with the redemption of the accumulated points.
• Failed: If the user's accumulated points do not meet the required points for the selected reward.</td></tr>
</table>

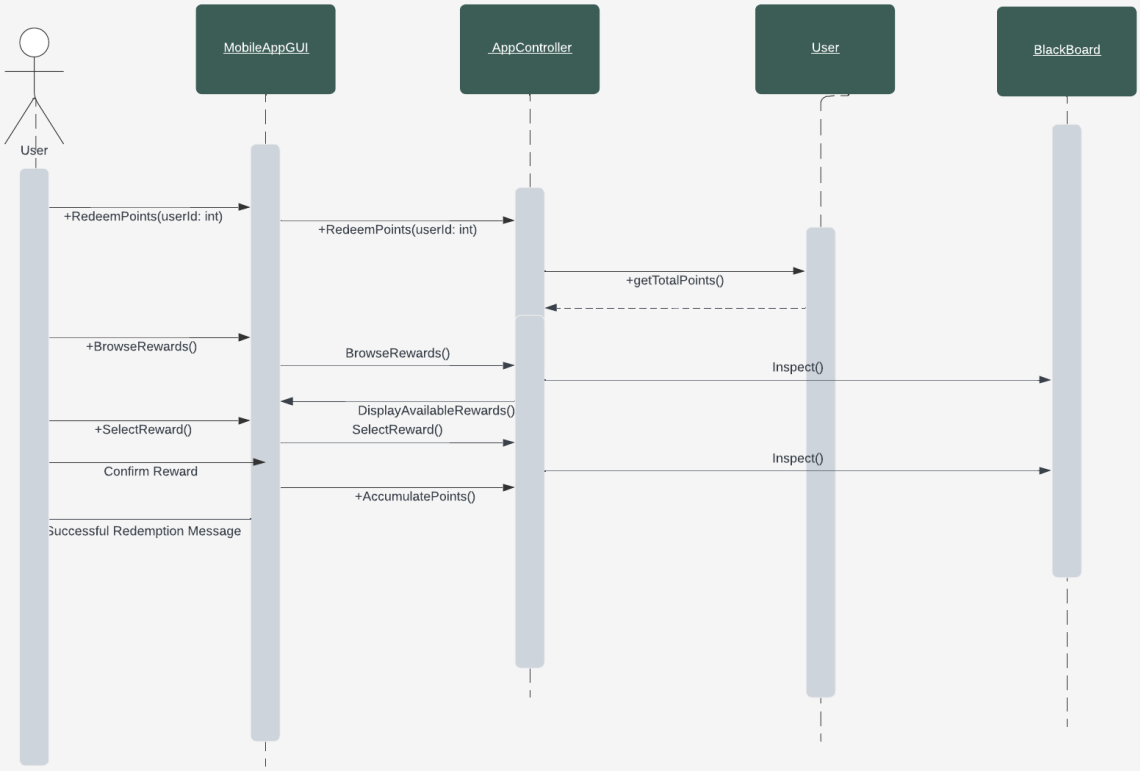

Figure 10: Redeem points sequence diagram.

(c) Sign-up use case description:

<table>
<tr><td colspan="3">System: Mustadam</td></tr>
<tr><td colspan="3">Use case name: Sign-up</td></tr>
<tr><td colspan="2">Primary actor: user</td><td>Secondary actor: SMS Gateway</td></tr>
<tr><td colspan="3">Description: This use case allows the user to create an account in the application</td></tr>
<tr><td colspan="3">Relationships :
Includes: verify account
Extends: none
Generalization: none</td></tr>
<tr><td colspan="3">Pre-conditions: -</td></tr>
<tr><td colspan="3">Steps</td></tr>
<tr><td>Primary actor(s) (user)</td><td>System (Mustadam)</td><td>OTP message</td></tr>
<tr><td>1. The user clicks on the get started button.
3. The user fills his/her information:
• First name.
• Last name.
• Email.
• Phone number.
• Password.
7. The user receives the 4-digit code.
8. The user fills the 4-digit code in the blanks.</td><td>2. The system shows the sign-up form.
4. The system checks whether the phone number and email are valid or not.
5. The system displays the verification page to the user.
9. The system verifies whether the entered code matches the sent code.
10. The system displays the home page to the user.</td><td>6. The SMS Gateway sends an OTP message with a 4-digit code to the user’s phone number or email within a short time.</td></tr>
<tr><td colspan="3">Alternative and exceptional flows:
• Empty required field:
If in step 3, the user misses a required field then:
3. The system displays a message indicating a required field is missing.
4. Step 3 is resumed.</td></tr>
<tr><td colspan="3">Post-conditions:
• Success: The home page is shown.
• Failed: The home page is not shown, and the sign-up page is still displayed.</td></tr>
</table>

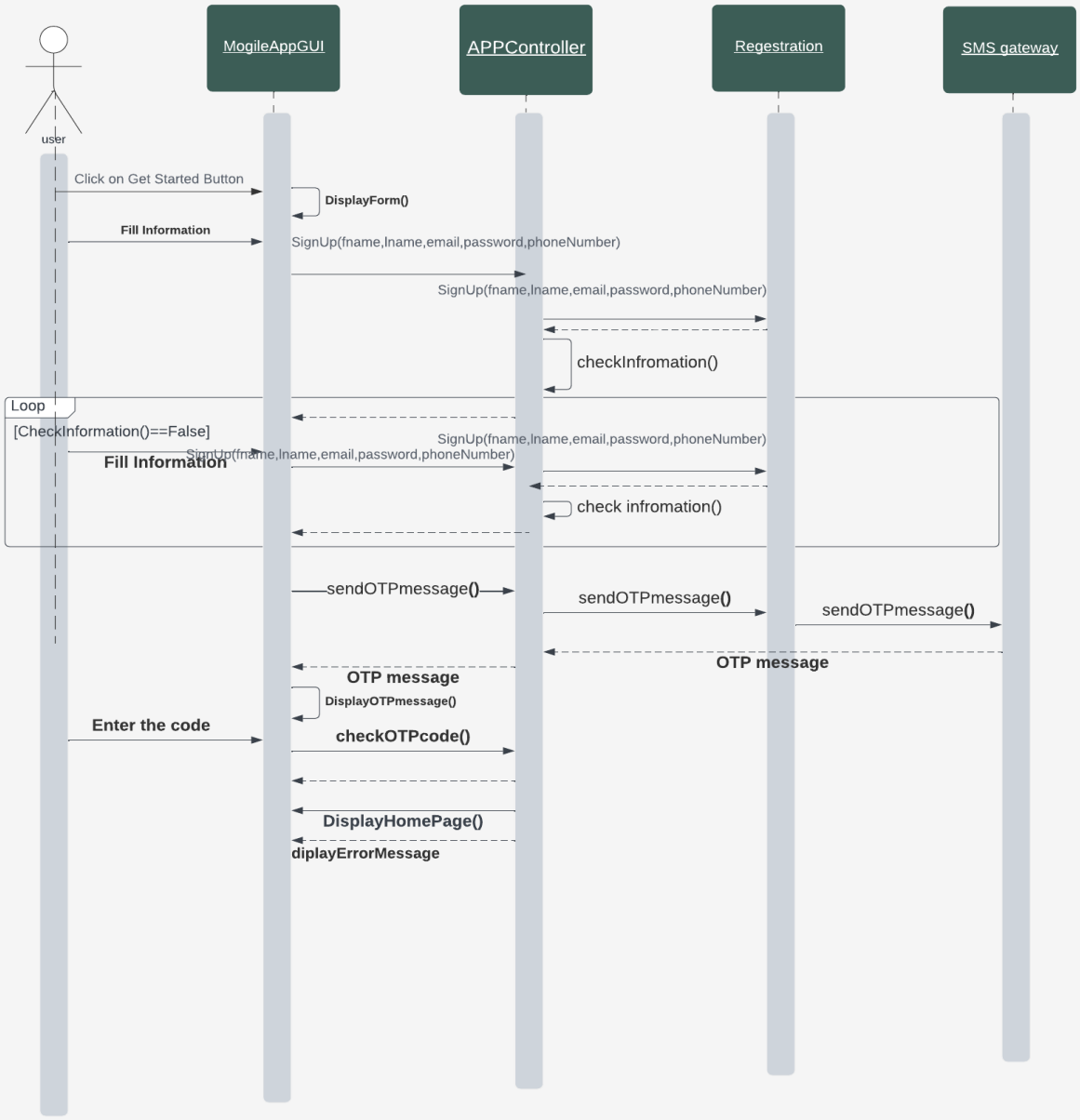

Figure 11: sign up sequence diagram.

e. User Interface:

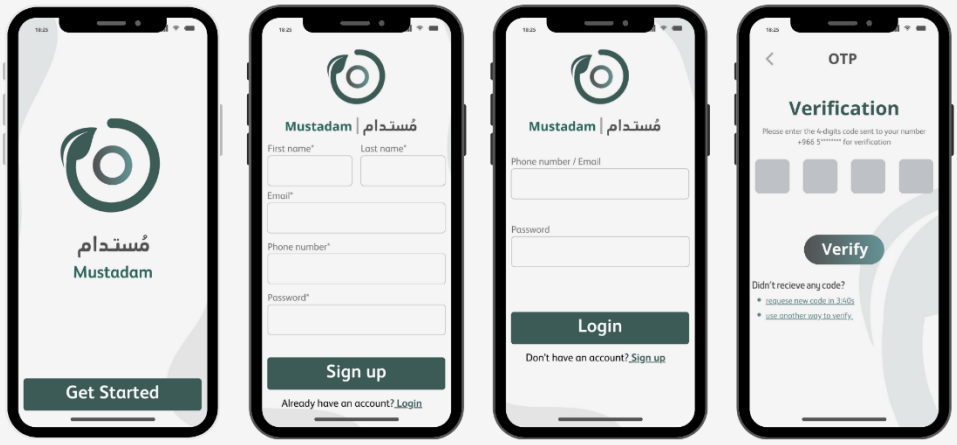

Figure 12: Mustadam's sign-up page, login page, and verification page interfaces.

Figure 13 :Mustadam's home page, smart bin's ID scan page, view accumulated points page, and browse available rewards page interfaces.

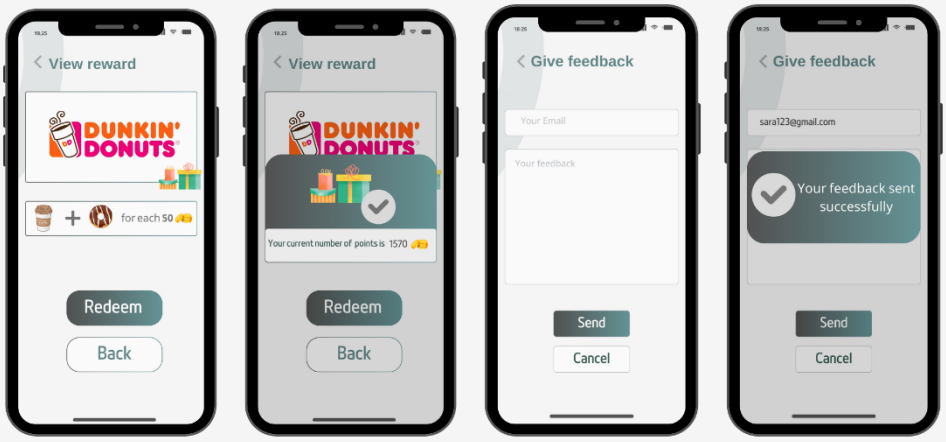

Figure 14: Mustadam's view reward page, successful redemption message page, give feedback page, and successful feedback sending message page interfaces.

Figure15; Mustadam's my profile page, edit profile page, successful profile editing message page, and successful log out message page interfaces.

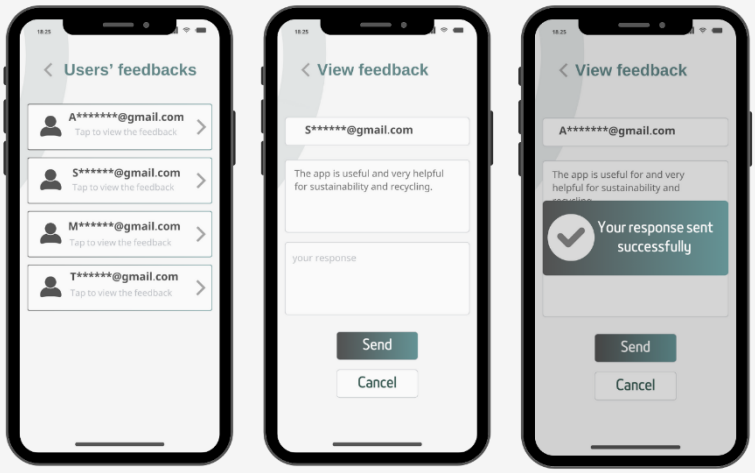

Figure 16: Mustadam's Admin view users' feedback page, response to users' feedback page, and successful response sending message page interfaces.

Non-Functional Properties:

- **Reliability:** The reliability of the system is of utmost importance as it directly affects the users' trust and confidence in the waste management process. To address this, the system should be highly available, ensuring minimal downtime and disruptions. The system shall be available 98.5% of the time, meaning it should be accessible to users for at least 98.5% of the operational hours. This ensures that users can consistently rely on the system for waste disposal and recycling needs.

- **Usability:** Usability is essential to ensure that users can easily and effectively interact with the system. In the case of Mustadam, it is crucial for users to quickly learn how to use the system to encourage widespread adoption and participation. For instance, specifying that users should be able to learn how to use the system within 3 minutes sets a measurable benchmark for the system's ease of use. Intuitive user interfaces, clear instructions, and user-friendly interactions contribute to achieving this usability goal.

- **Performance:** The performance of the system directly impacts the user experience and satisfaction. In the context of waste recognition, the system's ability to identify waste materials in less than 0.5 seconds ensures real-time and efficient waste sorting. This quick response time allows users to dispose of their waste without experiencing delays, enhancing their overall experience, and promoting optimal usage of the system.

- **Scalability:** As the system aims to cater to a significant number of users, scalability is crucial to handle increasing demands without compromising performance. The requirement that the system should be able to handle more than 20,000 users' requests highlights the need for a scalable architecture. This ensures that the system can accommodate a growing user base and handle increased data processing and storage requirements effectively.

- **Correctness**: Ensuring the correctness of the system is essential to avoid errors and inaccuracies in waste management processes. The system should accurately identify and categorize waste materials to facilitate proper recycling and disposal. For example, specifying that the system should achieve at least 95% accuracy in waste recognition ensures a high level of correctness. Regular testing, validation, and calibration of the waste recognition algorithms can help achieve this accuracy level, minimizing the chances of incorrect waste sorting and disposal.

In addition to these quality attributes, there are other constraints to consider. Hardware constraints that involve ensuring compatibility with a variety of devices (smartphones and tablets). Software constraints that include compatibility with different operating (iOS and Android) and, the system shall support Arabic and English languages.

Quality Assurance:

- **Reviews:**
  - **Walkthrough:** Regular walkthrough sessions will be conducted where team members and stakeholders will navigate through the Mustadam mobile application and use the smart bins to identify any issues, inconsistencies, or deviations from design standards. Feedback will be collected to ensure the quality and consistency of the user experience.
  - **Checklist:** A predefined checklist will be utilized to ensure that the Mustadam mobile application adheres to specific criteria and standards. This checklist will cover aspects such as functionality, user interface design, performance, and security to identify and address potential issues or defects.

- **Verification:**

  Formal inspections will be conducted for critical components of the Mustadam system, such as the waste sorting algorithms and user authentication mechanisms. This verification process will involve a group of trained professionals reviewing the code and design to ensure compliance with specified standards and regulations. Peer reviewing will be employed for other components of the application, leveraging the team's domain knowledge and programming skills.

- **Validation:**
  - **Unit Testing:** Each module and feature of the system will undergo unit testing to ensure its proper functionality. Black box testing will be used to test each unit without requiring knowledge of its internal implementation details.
  - **Integration Testing:** Modules and features will be integrated to verify smooth interaction and data flow within the application. Both manual and automated integration testing techniques will be employed to identify and resolve any integration issues.
  - **System Testing:** The entire mobile application will undergo comprehensive testing to evaluate its performance, usability, and overall functionality. Usability testing, performance testing, and regression testing will be conducted to ensure

a seamless user experience and stability across different devices and operating systems.

- **Acceptance Criteria:**
  - **Procedures:** Clear user stories and acceptance criteria will be documented to ensure that stakeholders' requirements are well-defined and understood by the development team.
  - **Installation:** Mustadam will be available for installation via app stores on iOS and Android devices. Clear instructions will be provided to guide users through the installation process.
  - **Testing:** Beta testing will involve selected users testing the application in real-world scenarios to provide feedback and ensure it meets their needs and expectations.
  - **Training:** Instructional tutorials and help guides will be provided within the application to assist users in navigating its functionalities and features.
  - **Documentation:** Comprehensive user manuals and technical documentation will be provided to assist both users and developers in understanding and utilizing the Mustadam mobile application effectively.

Future Considerations:

- **System Flexibility:**

  The architecture of the Mustadam mobile application is designed to accommodate future changes and additions to meet evolving user needs and technological advancements. The modular structure of the application allows for seamless integration of new features, functionalities, and enhancements without disrupting the existing system.

- **Possible Future Changes/Additions:**
  - **Advanced Waste Sorting Algorithms:** Continuously improve and refine waste sorting algorithms using machine learning techniques to enhance the accuracy and efficiency of waste categorization. Integration of advanced image recognition and sensor technologies to identify and sort a wider range of materials with precision.
  - **Personalized Rewards Recommendations:** Implement personalized recommendation algorithms based on user behavior, recycling habits, and preferences to offer tailored reward suggestions. Leverage machine learning and data analytics to analyze user engagement patterns and predict which rewards

are most likely to resonate with individual users, enhancing the relevance and effectiveness of the rewards program.

- **Expansion to New Regions and Waste Streams:** Scale the Mustadam platform to serve additional cities, communities, and waste streams beyond Riyadh, catering to diverse recycling infrastructure and regulatory environments. Adapt the system to accommodate different waste management practices, cultural norms, and user preferences in various regions.
- **Gamification Features:** Introducing gamification elements such as challenges, leaderboards, and rewards to further incentivize and motivate users to participate in recycling activities.
- **Integration with Sustainable Brands and Eco-Friendly Products:** Partner with sustainable brands and eco-friendly product manufacturers to offer rewards that align with Mustadam's mission of promoting environmental sustainability. Showcase environmentally conscious products, organic goods, and eco-friendly alternatives as reward options to encourage users to make sustainable choices in their everyday lives.

- **Architecture Support for Changes:**
  - **Modular Design:** The components of the application are loosely coupled, allowing for independent development, testing, and deployment of new features without affecting existing functionalities.
  - **API Integration:** Integration with external APIs allows for seamless connectivity with third-party services and systems, facilitating the incorporation of new features and functionalities.
  - **Scalability:** The architecture is designed to scale horizontally and vertically to accommodate increased user demand and data processing requirements as the platform grows.

- **Things must be changed in Mustadam architecture:**
  - **Add more waste types:** To add more waste types in the Mustadam architecture, update the database schema to include additional fields for new waste types, and modify the waste identification algorithms and models to accurately recognize and categorize the newly added waste types.

- **Key Parts of the System:**
  - **Waste Sorting Technology:** The core functionality of Mustadam relies on accurate waste sorting algorithms and image recognition technology embedded within the Smart Bin and mobile application.
  - **User Interface and Experience:** The user interface plays a crucial role in ensuring a seamless and intuitive experience for users interacting with the Mustadam application, including waste disposal, reward redemption, and feedback submission.
  - **Backend Infrastructure:** The backend infrastructure, including databases, servers, and APIs, forms the foundation of Mustadam, supporting data storage, processing, and communication between various components of the system.

- **Risk Assessment:**
  While every component of the Mustadam system is essential, the implementation and integration of waste sorting algorithms present a higher level of risk due to the complexity and criticality of accurately identifying and categorizing different types of waste. Continuous testing, validation, and refinement of these algorithms will be essential to mitigate risks and ensure optimal performance.

- **Feasibility Check:**
  - **Prototyping:** Rapid prototyping and proof-of-concept development will be conducted to validate the feasibility and effectiveness of new features and functionalities.
  - **User Feedback:** Soliciting feedback from users and stakeholders through surveys, interviews, and usability testing to gauge interest, usability, and feasibility of proposed changes.
  - **Technical Evaluation:** Conducting technical feasibility studies and assessments to evaluate the scalability, performance, and compatibility of new features with the existing architecture and infrastructure.

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