Abstract: The smart bin project aims to revolutionize waste management by promoting the proper disposal of non-biodegradable waste, such as plastic, glass, and e-waste, through an intelligent waste collection and reward system. This innovative system uses a combination of sensors, image processing, and machine learning to automatically detect waste, categorize it, and reward users for their contribution to environmental sustainability. The bin is equipped with a pressure sensor to detect human presence, a camera for image recognition, a load cell for weighing the waste, and motors for sorting. The user is rewarded via a QR code for tech-savvy individuals or a token for those unfamiliar with technology, ensuring inclusivity for all age groups. The project leverages a Raspberry Pi as the control unit, SQLite as the database, and a web interface for user interaction. By combining modern technology with user incentives, the system encourages sustainable waste management practices and aims to reduce the impact of non-biodegradable waste on the environment.

Index terms: Smart Bin, Waste Segregation, Smart Recycling, Reward System, Waste Classification.

1. INTRODUCTION

Waste management is a critical global issue, with improper disposal of non-biodegradable materials such as plastics and electronic waste contributing significantly to environmental pollution. Traditional waste disposal methods are inefficient and lack the user engagement needed to encourage proper recycling practices. To address this, our smart bin project introduces an automated and interactive system designed to promote sustainable waste disposal.

The smart bin uses advanced hardware and software components to simplify the disposal process while educating users on the importance of recycling. By integrating sensors, a camera, and machine learning models, the bin can accurately detect, categorize, and process waste. The user interaction is enhanced by offering rewards in the form of points, which can be redeemed via a QR code or collected as tokens. This system not only encourages proper waste segregation but also provides an engaging platform that motivates users to actively participate in recycling efforts.

The project is built on a Raspberry Pi, with Python as the core programming language, TensorFlow Lite for machine learning, and SQLite for database management. A web interface built using Flask allows users to track their progress and rewards. Through the combination of smart technology and user incentives, the smart bin aims to reduce non-biodegradable waste and promote eco-friendly habits in communities and institutions.

2. IMPLEMENTATION DETAILS:

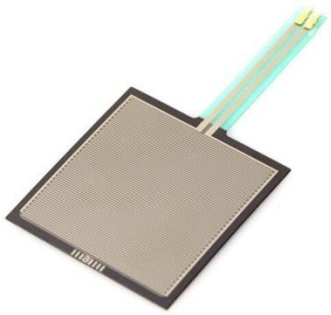
2.1 Hardware Setup:

i. Raspberry Pi 4 Model B (Control Unit):

- **Purpose**: The Raspberry Pi 4 Model B is the central control unit of the smart bin. It processes sensor data, controls motors, handles image recognition tasks, and manages communication with the database and web interface.
- **Setup**: Install the Raspbian OS (or any other supported OS) on the Raspberry Pi.Connect the Raspberry Pi to a power supply and establish a network connection (Wi-Fi or Ethernet) for web communication.Install necessary software packages like Python, OpenCV, TensorFlow Lite, Flask, and SQLite.
- **Connection**:Connect sensors, motors, and peripherals (like the camera and LCD display) to the Raspberry Pi's GPIO pins.Use I2C, SPI, or UART protocols for interfacing specific components, such as the LCD, HX711 weight sensor, and ultrasonic sensor..

ii. Pressure Sensor:

- **Purpose:** The pressure sensor detects when a person approaches the smart bin by sensing their footprint, triggering the system to open the bin lid.
- **Setup:** Place the pressure sensor on the ground near the bin, ideally in the area where a user would stand.Calibrate the sensor to detect the weight of a person.
- **Connection:**Connect the pressure sensor to the Raspberry Pi GPIO pins for reading digital or analog data.



iii. HC-SR04 Ultrasonic Sensor:

- **Purpose:**The ultrasonic sensor helps in detecting the proximity of objects (or waste) and is responsible for determining when to open or close the bin lid.
- **Setup:** Mount the sensor on the lid of the bin to detect the presence of waste or objects near the bin opening.
- **Connection:**Connect the sensor's trigger and echo pins to the Raspberry Pi GPIO pins for input/output functionality.Provide power and ground connections from the Raspberry Pi.

iv. OV 5647 5MP 1080P IR-Cut Camera for Raspberry Pi 3/4 with Automatic Day Night Mode

- **Purpose:**The **OV5647 IR-Cut Camera** is used for capturing images of the waste inside the smart bin to assist in waste classification. The camera has an automatic day-night mode, meaning it can function effectively in both bright and low-light conditions, making it ideal for around-the-clock operation. The **IR-Cut filter** ensures that images are clear and accurate regardless of lighting conditions.

Setup: Mounting:

- Install the camera inside or on top of the smart bin, ensuring it has a clear view of the waste as it enters the bin. The automatic day-night feature allows it to

function even in dim lighting conditions, such as during the night.

- Ensure the IR-cut filter is positioned correctly to switch modes based on lighting conditions automatically.
  Power and Cooling:The camera may require additional power and cooling if used extensively. Make sure the Raspberry Pi can supply sufficient power through the GPIO pins. The camera itself is energy efficient, but proper ventilation in the bin setup is important to prevent overheating.
- **Connection:**connect the camera to the **Raspberry Pi** using the **CSI (Camera Serial Interface)** port with the provided ribbon cable. Ensure the metal connectors on the ribbon cable are facing the correct direction when inserting into the CSI port. Power the Raspberry Pi, and install camera libraries like **picamera** or **opencv** to interface with the camera. Use the camera in your software pipeline for capturing waste images and classification.

v. Depth Sensor:

- **Purpose:** The depth sensor measures the distance between the waste and the bin, helping to differentiate between valid waste and other materials such as sand or small particles.
- **Setup:** Install the depth sensor above the waste compartment to accurately measure the depth of the waste placed in the bin.
- **Connection:**Connect the depth sensor to the GPIO pins or via I2C/SPI interface to the Raspberry Pi for distance measurement readings.

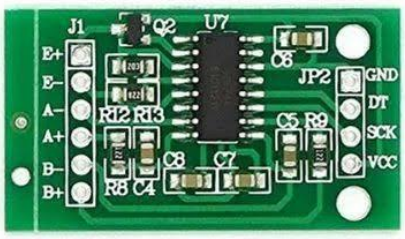
vi. Load Cells (4 × 50 kg):

- **Purpose:** The load cells measure the weight of the waste in the bin, helping to determine how much waste is being disposed of and triggering the reward system accordingly.
- **Setup:** Install the load cells at the bottom of the waste compartment to measure the combined weight of the waste.Ensure the load cells are properly calibrated for accurate weight measurements.
- **Connection:**Connect the load cells to the HX711 amplifier, which is then connected to the Raspberry Pi GPIO pins for reading the weight data.

vii. HX711 Weight Sensor:

- **Purpose:** The HX711 is an amplifier and A/D converter used to process the small electrical signals generated by the load cells and send them to the Raspberry Pi for weight calculation.

- **Setup:** Place the HX711 close to the load cells to minimize signal noise.Calibrate the HX711 to ensure accurate weight measurements from the load cells.
- **Connection:**Connect the HX711 to the load cells and interface the amplifier with the Raspberry Pi using the GPIO pins.



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viii. 2-inch LCD Display Module for Raspberry Pi Pico (65K Colors, 320×240, SPI)

Purpose: The 2-inch color LCD display provides a more interactive and visually rich user interface. It can display the weight of the waste, QR code information, and reward points.

Setup: Mount the display on the front panel of the bin for easy visibility to the user. Install the necessary libraries to control the display, such as the Pillow and spidev Python libraries, which support SPI-based screens.
Connection: The display uses the SPI (Serial Peripheral Interface) protocol for communication. Connect the SPI pins (MOSI, MISO, SCK) from the Raspberry Pi Pico **to** the corresponding pins on the display.
Additionally, connect the power and ground pins, and the chip select (CS) and data/command (DC) pins for controlling the display's operation. Configure the display in your code using the SPI interface, specifying the resolution and color depth. The display will communicate with the Raspberry Pi Pico via SPI to show text and images.


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ix. Gear Motor

Purpose: The gear motor is used to control mechanical movements inside the smart bin, such as opening and closing the lid or moving waste between compartments. Unlike a servo motor, the gear motor provides continuous rotation, which is better suited for heavy-duty and extended operations.

Setup: Install the gear motor at the designated area where mechanical motion is required, such as for operating the bin lid or moving waste.Choose the appropriate gear ratio depending on the required torque and speed for the operation.

Connection: Connect the gear motor to a motor driver, which is essential for controlling its operation from the Raspberry Pi. Use an H-bridge motor driver like the L298N for directional control. The motor driver should be connected to the Raspberry Pi GPIO pins for controlling power and direction using Pulse Width Modulation (PWM).

x. Ebike MY6812 120W 12V 3350RPM DC Electric Motor

- **Purpose:** The **Ebike MY6812 DC Electric Motor** is used to perform tasks such as moving the waste between compartments or driving mechanical systems in the smart bin. This motor is suitable for high-torque applications and can handle heavier loads compared to the BLDC motor.
- **Setup: Mounting**: Secure the motor in the designated location in your smart bin where mechanical movement is required. This motor is larger and more powerful, so ensure it is mounted securely to prevent vibration or movement during operation.
- **Power Supply**: Ensure that you use a 12V power supply that can provide adequate current to the motor (approximately 10A depending on the load). Use a separate power source if

necessary to avoid overloading the Raspberry Pi's power supply.

- **Connection:**Connect the motor to an appropriate DC motor driver or controller, such as the L298N or another suitable H-bridge motor driver. This will allow you to control the direction and speed of the motor through the Raspberry Pi.

xi. Motor Driver Circuit:

- **Purpose:** The motor driver controls the operation of the motors , allowing the Raspberry Pi to manage the bin's mechanical movements.
- **Setup:** Install the motor driver close to the motors and ensure proper cooling for extended operation.
- **Connection:**Connect the motor driver to the Raspberry Pi GPIO pins and power supply. It acts as an intermediary between the control unit and the motors.

3. PROPOSED SOLUTION:

3.1 Introduction:

i. Problem Statement:

Improper waste disposal and inadequate recycling systems contribute to severe environmental issues, such as pollution and resource depletion. Traditional waste management methods often fail to ensure efficient segregation of non-biodegradable waste. This paper presents a Smart Bin system designed to address these challenges through automation and user incentives.

ii. Solution Overview:

The proposed Smart Bin system integrates advanced technologies including sensors, machine learning, and user rewards to enhance waste segregation and management. The system aims to automate the waste sorting process, encourage proper disposal through rewards, and provide real-time monitoring for improved waste management.

3.2 Objectives:

i. Automated Waste Segregation:

The Smart Bin system's primary objective is to automatically sort non-biodegradable waste into predefined categories such as plastics, glass, and e-waste. By leveraging various sensors and machine learning algorithms, the system aims to achieve high accuracy in waste classification and segregation.

ii. Incentivization:

To promote correct waste disposal, the system incorporates a reward

mechanism. Users are incentivized through a dual reward system that provides either QR codes or physical tokens, depending on their technological proficiency. This approach is designed to maximize user participation and compliance with waste disposal guidelines.

iii. **Real-Time Monitoring:**
The system includes real-time monitoring capabilities that track waste disposal activities and user interactions. Data is collected and analyzed to provide insights into waste management patterns, system performance, and areas for improvement.

3.3 Features of the Smart Bin:

i. **Sensor Integration:**
The Smart Bin utilizes multiple sensors to facilitate the waste management process:
   - **Pressure Sensor**: Detects user presence to activate the bin's lid.
   - **Ultrasonic Sensor:** Measures the distance to control the lid opening mechanism.
   - **Depth Sensor:** Assists in verifying the waste type and ensuring accuracy in segregation.
   - **Load Cells and HX711:** Measures the weight of the waste to support proper categorization.

ii. **Machine Learning:**
TensorFlow Lite is employed to develop a machine learning model that classifies waste based on images captured by the Raspberry Pi Camera Module. The model processes visual data to distinguish between different types of waste and facilitates accurate sorting.

iii. **Reward Mechanism:**
The system features a reward mechanism designed to encourage user participation:
   - **QR Code Rewards:** Users receive QR codes that can be scanned to earn rewards. This method is suitable for tech-savvy users who prefer digital interactions.
   - **Token Dispenser**: For users less familiar with technology, physical tokens are issued as rewards. This method ensures inclusivity and accessibility.

iv. **Web Interface:**
A web interface, developed using Flask, allows users and administrators to monitor the system's performance, view waste disposal data, and manage user rewards. The interface provides a user-friendly platform for interacting with the Smart Bin system.

3.4 Benefits:

i. **Environmental Impact:**
The Smart Bin system contributes to environmental conservation by improving waste segregation and recycling processes. Proper segregation reduces the volume of waste sent to landfills and enhances the efficiency of recycling operations.

ii. **User Engagement:**

The dual reward system motivates users to participate actively in proper waste disposal. By providing tangible rewards, the system encourages compliance with waste management practices and fosters a culture of environmental responsibility.

iii. **Data Insights:**
Real-time monitoring and data collection offer valuable insights into waste management patterns. The data can be analyzed to identify trends, evaluate system performance, and make informed decisions for future improvements.

3.5 Challenges and Solutions:

i. **Technical Challenges:**

Sensor Accuracy: Ensuring accurate readings from sensors can be challenging. Calibration and testing procedures are implemented to address this issue.

Integration: Integrating various hardware components and software systems requires careful planning and execution. Modular design and thorough testing are used to ensure seamless integration.

ii. **User Acceptance:**
   - Technology Familiarity: Some users may be unfamiliar with the reward system or the technology used. Educational outreach and user-friendly design are employed to overcome this barrier.
   - Reward System Participation: Ensuring that the reward system is appealing to all users is crucial. The dual reward approach aims to cater to different user preferences and technological proficiency levels.

3.6 Implementation Strategy:

i. **Development Phases:**
The development of the Smart Bin system is divided into distinct phases:
   - **Design and Planning:** Defining system requirements, selecting components, and creating system designs.
   - **Hardware Setup:** Assembling and configuring hardware components, including sensors, motors, and the control unit.
   - **Software Development:** Developing and integrating software for sensor data processing, machine learning, and web interface.
   - **Testing:** Conducting thorough testing of hardware and software to ensure system functionality and reliability.
   - **Deployment:** Installing the Smart Bin system in real-world settings and monitoring its performance.

ii. **Testing and Evaluation:**
   - **Prototype Testing**: Initial testing is conducted with prototype units to validate system functionality and performance. This phase involves assessing sensor accuracy, motor operations, and waste classification accuracy.
   - **User Trials:** Deploying the Smart Bin in a controlled

environment to gather user feedback and identify any usability issues. This feedback is used to make necessary adjustments before full-scale deployment.

- **Performance Monitoring:** Continuous monitoring of the system's performance in real-world settings to ensure it meets design specifications and user expectations.

3.7 Conclusion:

i. **Summary of Contributions:**
The Smart Bin system represents a significant advancement in waste management technology. By integrating automation, machine learning, and user rewards, the system enhances waste segregation efficiency, encourages proper disposal practices, and provides valuable data insights.

ii. **Future Work:**
Future enhancements to the Smart Bin system may include:
- Advanced Waste Classification: Improving the machine learning model to classify a wider range of waste types with higher accuracy.
- Scalability: Expanding the system to handle larger volumes of waste and integrate with municipal waste management infrastructure.
- User Engagement Features: Introducing additional features to further engage users and promote recycling, such as gamification elements or community challenges.

iii. **Final Thoughts:**
The Smart Bin system addresses critical challenges in modern waste management and offers a practical solution for enhancing recycling and waste segregation. Through continuous improvement and adaptation, the system has the potential to make a substantial impact on environmental conservation and sustainability.

4. SYSTEM DESIGN AND ARCHITECTURE:

4.1 Hardware Architecture:

4.1.1 Control Unit:

i. **Raspberry Pi 4 Model B:**
- Specifications: The central processing unit of the system, equipped with 4 GB RAM and a quad-core processor.
- Role: Manages all computational tasks, including sensor data processing, machine learning inference, and web interface operations.
- Connectivity: Interfaces with sensors, motors, and display units through GPIO, USB, and I2C connections.

4.1.2 Sensors:

i. **Pressure Sensor**:
- Function: Detects user presence by measuring applied pressure.
- Integration: Connected to GPIO pins to provide digital

input signals indicating when a user approaches the bin.

ii. **Ultrasonic Sensor:**
- Function: Measures distance to control the lid's opening mechanism.
- Integration: Connected to GPIO pins for sending trigger signals and receiving echo signals to determine distance.

iii. **Depth Sensor:**
- Function: Assesses the depth of waste to verify its type and ensure accurate segregation.
- Integration: Connected via I2C to provide depth measurements that help distinguish between different waste types.

iv. **Load Cells and HX711:**
- Function: Measures the weight of the waste to assist in proper categorization.
- Integration: Connected through an HX711 module to GPIO pins, transmitting weight data to the Raspberry Pi.

4.1.3 Camera Module:

i. **Raspberry Pi Camera Module V2:**
- Function: Captures images of waste for classification.
- Integration: Connects to the CSI port on the Raspberry Pi to provide high-resolution image data for processing

4.1.4 Motors:

i. **SG90 Micro Servo:**
- Function: Controls the lid's opening and closing mechanism.
- Integration: Connected via PWM control to manage lid operation based on sensor inputs.

ii. **BLDC 2212 KV100**:
- Function: Sorts waste into different compartments.
- Integration: Controlled by an Electronic Speed Controller (ESC) connected to GPIO pins for precise sorting operations.

4.1.5 Display:

i. **LCD Display (20x4 I2C):**
- Function: Displays weight and reward points to users.
- Integration: Connected via I2C to show real-time data on the bin's status.

4.1.6 QR Code Reader and Token Dispenser:

i. **QR Code Reader**:
- Function: Scans QR codes for user identification and reward processing.
- Integration: Connects to the Raspberry Pi via USB to enable QR code scanning functionality.

ii. **Token Dispenser:**
- Function: Issues tokens as rewards for users.
- Integration: Controlled by GPIO pins to dispense physical tokens based on user interactions.

4.2 Software Architecture:

4.2.1 Programming Language:

i. **Python:**
   - Role: Primary language used for scripting and controlling the Smart Bin system.
   - Libraries: Utilizes libraries such as RPi.GPIO for hardware control, OpenCV for image processing, and Flask for web development.

4.2.2 Machine Learning:

i. **TensorFlow Lite:**
   - Role: Provides lightweight machine learning models for waste classification.
   - Implementation: The model is trained to recognize different types of waste from images and is deployed on the Raspberry Pi for real-time classification.

4.2.3 Database Management:

i. **SQLite:**
   - Role: Manages user data, waste records, and reward points.
   - Implementation: The database schema includes tables for storing user information, waste types, and transaction records. Python scripts interact with the SQLite database to perform CRUD operations.

4.2.4 Image Processing:

i. **OpenCV:**
   - Role: Processes images captured by the camera module.
   - Implementation: Includes preprocessing steps like resizing and normalization, followed by classification using the TensorFlow Lite model.

4.2.5 Web Framework:

i. **Flask:**
   - Role: Develops the web interface for system monitoring and user interaction.
   - Implementation: Provides endpoints for accessing system data, viewing waste disposal records, and managing user rewards. Flask interacts with the SQLite database and presents data through a web-based dashboard.

4.2.6 Integration:

4.2.6.1 Hardware Integration:

i. **Wiring and Connections:**
   - Procedure: Detailed steps for connecting sensors, motors, and other components to the Raspberry Pi. Includes wiring diagrams and connection tables.

ii. **Calibration and Testing:**
   - Procedure: Methods for calibrating sensors and ensuring accurate readings. Includes testing procedures for verifying hardware functionality and performance.

4.2.6.2 Software Integration:

i. **Sensor Data Processing:**
   - Procedure: Code snippets and algorithms for processing data from sensors. Includes integration of sensor inputs into the main control loop.

ii. **Machine Learning Model Integration:**
   - Procedure: Steps for deploying and using the TensorFlow Lite model for waste classification. Includes code examples for loading the model and making predictions.

iii. **Web Interface Development:**
   - Procedure: Design and implementation of the web interface using Flask. Includes code examples for creating endpoints and rendering data on the web page.

4.2.7 System Workflow:

i. **Data Flow Diagram:**
   - Description: A diagram illustrating the flow of data between hardware components, the Raspberry Pi, and the software modules. Shows how sensor data is processed, waste is classified, and user interactions are managed.

ii. **Interaction Diagram:**
   - Description: A diagram showing the interactions between users, the Smart Bin system, and the web interface. Includes user actions, system responses, and reward mechanisms.

4.2.8 Summary:

i. **Key Design Considerations:**
   - Reliability: Ensuring the system operates consistently under various conditions.
   - Scalability: Designing the system to handle different volumes of waste and user interactions.
   - User Experience: Creating an intuitive interface and reward system to engage users effectively.

ii. **Future Enhancements:**
   - Advanced Features: Exploring additional features such as remote monitoring and integration with municipal waste management systems.
   - Performance Improvements: Optimizing hardware and software for better efficiency and accuracy.

5. SOFTWARE DEVELOPMENT PHASE:

i. **Programming Language (Python):**
   - Python is chosen as the primary programming language for this project due to its simplicity and flexibility. Python is ideal for interacting with the Raspberry Pi and controlling sensors, motors, and other hardware components. Additionally, Python is used to develop the machine learning models that

help the smart bin classify waste.

ii. **Machine Learning Integration (TensorFlow Lite):**
   - In this project, we use TensorFlow Lite, a lightweight version of TensorFlow, to classify different types of waste (plastic, glass, e-waste) based on the images captured by the camera. The model is trained to recognize these waste categories and provide a real-time response when new waste is detected. TensorFlow Lite is optimized for running on the Raspberry Pi, making it a perfect fit for this project.

iii. **Image Processing (OpenCV):**
OpenCV is a popular library for image processing. It is used to process images captured by the Raspberry Pi camera, which helps detect and classify the waste. OpenCV allows us to:
   - Preprocess the captured images (e.g., resizing, noise reduction).
   - Detect the shape, color, or other features that help in classifying the waste.

iv. **Sensor Data Processing:**
Several sensors are integrated into the smart bin (e.g., ultrasonic sensor, depth sensor, pressure sensor). The software reads the data from these sensors to automate various tasks, such as:
   - Detecting when a person approaches (via the pressure sensor) and opening the bin lid.
   - Measuring the weight of the waste using load cells and calculating the total amount of waste.
   - Ensuring that the waste has been properly classified and processed before it is sorted into the respective container.

v. **User Interface and LCD Display:**
The smart bin uses an LCD display to show information such as:
   - The weight of the waste disposed of.
   - User instructions and system status.

vi. **Database Management (SQLite):**
   - The software interacts with the SQLite database to store and manage data about users, their reward points, and waste disposal history. The database helps keep track of each user's contribution to recycling and the points they've earned through proper waste disposal. This database is lightweight and perfect for a small-scale project like this.

vii. **Web Interface (Flask):**
The smart bin's system is also connected to a web interface developed using Flask, a web framework in Python. The web interface allows users to:
   - View their disposal history.
   - Check how many reward points they've accumulated.
   - Access the status of the bin (e.g., when it needs to be emptied).

viii. **System Integration:**
All the software components (machine learning model, sensor data processing, database management, and web interface) are integrated to work as a single system. This involves:

- Connecting the sensors, camera, and motors with the Raspberry Pi.
- Using Python scripts to automate tasks like opening the bin lid, classifying waste, and sorting it into containers.
- Running background processes to handle user inputs, data storage, and reward generation.

6. WEB INTERFACE PHASE:

i. **Purpose of the Web Interface:**
The web interface is designed to:

- Provide a user-friendly experience: Users can easily access their disposal data and rewards.
- Display real-time information: The interface shows data such as the current status of the bin, how much waste has been disposed of, and the user's accumulated points.
- Manage rewards: Users can see how many points they've earned for proper waste disposal and claim rewards (either digital or physical, depending on the system setup).

ii. **How the Web Interface Works:**

- User Log-in: Each user can log in to their account to see personal disposal history and the number of points earned.
- Waste Disposal History: The web interface shows the user's past waste disposal activities, including the types of waste they've thrown (plastic, glass, e-waste) and the corresponding reward points.
- Rewards Section: Users can view the total reward points they've earned from proper waste disposal. There could be options to redeem these points for prizes or services.
- Bin Status: The interface also shows the bin's current status, such as if it's full and needs to be emptied.

iii. **Key Features of the Web Interface:**

- Dashboard: The web interface will have a dashboard summarizing all important details, such as user points, disposal history, and bin status.
- Real-time updates: The system provides up-to-date information as soon as a user interacts with the bin.
- User-friendly navigation: Simple navigation helps users quickly find the information they need, such as their points balance or waste history.

iv. **Connection with the Smart Bin:**

- Backend communication: The smart bin sends data (such as

user details, waste type, and points) to the backend server. The server processes this data and updates the web interface in real-time.

- Database management: All the information about waste disposal and rewards is stored in a database (SQLite in this case), and the web interface fetches this data whenever required.

v. **Importance of the Web Interface:**
The web interface adds value to the smart bin project by allowing users to:

- Keep track of their environmental contributions.
- Earn and monitor reward points for proper waste disposal.
- Access important information without physically interacting with the bin.

7. DATABASE MANAGAEMENT PHASE:

i. **Purpose of Database Management:**
The database stores all the important data related to:

- User information: Each user's details, including their unique ID, login credentials, and reward points.
- Waste disposal records: Information about each disposal event, such as the type of waste (plastic, glass, or e-waste), weight of the waste, and the user who disposed of it.
- Rewards tracking: The database keeps track of the points earned by each user and updates them every time they dispose of waste properly.

ii. **How the Database Works:**

- Storing data: The database saves details of every user and their activities, such as the amount of waste disposed of and the points earned.
- Organizing data: Data is structured into tables and records. For example, one table might store user details, another might store disposal records, and yet another table might keep track of rewards.
- Retrieving data: Whenever the system or a user needs specific information, the database retrieves it. For example, when a user checks their reward points on the web interface, the database provides the current points total.

iii. **Database Used(SQLite):**
In this project, SQLite is used as the database management system. It is lightweight, easy to set up, and ideal for small projects like this one. SQLite stores all the data in a single file, making it simple to manage on the Raspberry Pi.

iv. **Types of Data Managed:**
The database handles different kinds of data, including:

- User Data: This includes usernames, passwords, and

unique IDs for identifying each user.

- Waste Data: Information about the waste disposed of, such as the type of waste (plastic, glass, e-waste) and its weight.
- Rewards Data: The points earned by users are stored and updated in the database whenever waste is disposed of properly

v. **. Interaction Between the Database and the System:**

- Data collection: Sensors and cameras collect information (e.g., type of waste, weight), and the system sends this data to the database.
- Storage: The database organizes this data and stores it for future use.
- Retrieval: When users check their points or disposal history, the system retrieves the required information from the database and presents it on the web interface or LCD display.

vi. **Key Features of Database Management:**

- Real-time updates: Every time a user interacts with the bin, the database is updated in real-time to ensure the most accurate data is available.
- Data security: The database ensures that user data is kept safe, using encryption or other security methods to protect personal information.
- Data consistency: The system ensures that the data remains consistent, meaning that reward points, waste records, and other information are always up-to-date and accurate.

vii. **Importance of Database Management:**

The database is the backbone of the entire smart bin system, as it:

- Tracks user activities: It keeps a detailed record of all waste disposal actions and reward points, making it easier to track and analyze user participation.
- Manages rewards: By keeping an accurate log of user contributions, it ensures that the reward system functions properly, encouraging users to continue recycling.
- Supports system functions: All the data needed to make the smart bin system work (like waste type and weight) is stored and managed efficiently in the database.

8. REWARD SYSTEM PHASE:

i. **Purpose of the Reward System:**

The reward system serves several purposes:

- Encouraging proper waste disposal: By offering incentives, users are motivated to sort and dispose of their waste correctly.
- Promoting sustainability: The system rewards users for recycling and helps raise

awareness about the importance of responsible waste management.
- Increasing user participation: People are more likely to use the smart bin if they know they will receive something in return, such as points, rewards, or tokens.

ii. How the Reward System Works:
When a user disposes of waste in the smart bin, the system performs the following steps:
- Waste detection: The bin's sensors and camera verify whether the waste is non-biodegradable and falls under one of the allowed categories (plastic, glass, e-waste).
- Weight calculation: The system uses load cells to calculate the weight of the disposed waste. The heavier the waste, the more points the user will earn.
- Reward points generation: Based on the type and weight of the waste, the system calculates the number of reward points the user is entitled to.

iii. Two Methods of Rewarding Users:
The system provides rewards in two ways, depending on the user's familiarity with technology:

❖ **QR Code System (for tech-savvy users):**
- After disposing of the waste, a QR code is generated and displayed on the bin's screen or given through a QR reader.
- The user scans the QR code using their smartphone, which takes them to the web interface, where they can log in to view their earned points.
- The points are accumulated in the user's account, and they can later redeem them for prizes, vouchers, or other benefits.

❖ **Token Dispenser (for non-tech users, elderly people):**
- For users who are not familiar with technology or do not have a smartphone, the system provides rewards in the form of physical tokens.
- After proper waste disposal, a token is dispensed from the bin, which the user can collect.
- These tokens can later be exchanged for rewards at a collection point, making the system inclusive for people of all ages.

iv. Process Flow of the Reward System:
✓ Step 1: The user approaches the smart bin and is detected by the

pressure sensor (using their footprint).

- ✓ Step 2: The lid opens automatically, allowing the user to dispose of the waste.
- ✓ Step 3: The system checks the type and weight of the waste using sensors, a camera, and the load cell.
- ✓ Step 4: Once validated, the system calculates reward points based on the waste type and weight.
- ✓ Step 5: The reward (either in the form of a QR code or a token) is provided to the user.

v. **Importance of the Reward System:**
The reward system plays a crucial role in the success of the smart bin project:

- Motivation: It incentivizes users to correctly dispose of waste, making it fun and rewarding to participate in recycling efforts.
- User engagement: By earning points or tokens, users feel a sense of accomplishment and are more likely to continue using the smart bin.
- Behavior change: The system encourages sustainable habits, as people are more likely to recycle when they receive tangible rewards for their actions.

vi. **Customization of Rewards:**
The reward system can be tailored to suit different scenarios or community needs. For example:

- Community-wide campaigns: Points can be used in neighborhood programs to promote collective recycling efforts.
- School initiatives: Rewards can be given in educational settings, encouraging students to learn about recycling while earning rewards for their school.

9.CONCLUSION:

The smart bin project successfully demonstrates how technology can be leveraged to address environmental challenges, specifically in waste management. By creating an automated waste sorting and reward system, this project encourages users to actively participate in recycling efforts, offering both educational and motivational benefits. The use of sensors, image recognition, machine learning, and a well-designed reward system makes waste disposal more efficient, while also promoting eco-conscious behavior. The QR code and token reward mechanisms ensure that the system is inclusive, accommodating users with varying levels of technological proficiency.

Moving forward, this system has the potential to be implemented in schools, communities, and public spaces, helping to reduce the burden of non-biodegradable waste and promote a cleaner, more sustainable environment. By continuing to refine the technology and expanding its functionality, this smart bin could become a

cornerstone in global efforts to improve waste management practices.