

Efficient Fill-Level Monitoring for Smart E-waste Recycling

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Abstracts: Proper electronic waste management is compulsory nowadays because, with improper management, the harmful substances in electronic waste will put humans and the environment at risk. The production of e-waste differs from domestic waste as it is not regular. It is vital to improve the e-waste management process. This paper presents a smart e-waste bin fill level monitoring system. This paper proposes a module for identifying fill level, display, and communication systems integrated with a mobile application. Different sensors are implemented to monitor the bin status in real-time. The system will alert the collection party on various scenarios through a mobile application, including the full bin and a fire in the container.

Keywords: E-Waste, Electronic Waste Management, Smart E-Waste Recycle Bin, Bin Fill Level Monitoring System, Mobile Application.

1. INTRODUCTION

Recycling has been familiar in Malaysia since its publication and promotion in a big way by the government and NGOs. The public is aware of the rubbish recycling system, but not all know that electronic gadgets should not be considered ordinary rubbish. Electronic waste, also known as e-waste, is a common name for electronic products that have ceased to exist of quality to users or no longer fulfill their first intent as the consequence of either repetition, breakage, or replacement. E-waste consists of computers, televisions, power banks, and mobile phones.

However, e-waste differs from conventional domestic material because it contains a complicated combination of harmful substances such as mercury, lead, and cadmium. With improper management, this substance will put human health and the environment at risk, jeopardizing the human quality of life in the long run. Therefore, e-waste should be treated as a dangerous material regarding their disposal management, but most e-waste can be reused, recycled, and refurbished.

Although e-waste recycling is not that popular in Malaysia, some NGOs and government organizations still provide e-waste recycling bins and schedule pick-up services for the public. However, the production of e-waste is unpredictable as it will only be produced sometimes. Consequently, the collection task for e-waste might not be as efficient as domestic waste collection.

2. LITERATURE REVIEW

2.1. Existing Smart Waste Management System

Ramson, Vishnu, and Kirubaraj (2022) developed an effective LoRaWAN network-based waste bin level monitoring system to measure the filling levels of solid waste garbage bins. This system implemented an ultrasonic sensor for measuring the fill level for the bin and Atmel ATmega 2560 microcontroller to control all the processes in measuring the trash bin level. Different bins are in different locations; thus, the global positioning system (GPS) module is also implemented. The network technology used is the LaRo module.

LoRaWAN is suitable for applications that require long-range connectivity. The user of this system can view and analyze the fill level and keep track of the location for each bin in real-time through a smart graphical user interface (GUI) developed by C# programming language, as shown in Fig. 1.



Fig. 1: Smart Graphical User Interface (GUI) by Ramson et al., 2022

Fig. 1 shows the three GUIs in the system. The first is the main interface showing the overall fill level for all the bins in the system, and the second interface is the overall fill level based on region. The last interface shows each bin fill level for the selected area. The red color represents that the bin is almost filled, while the yellow color is partially filled.

Abba and Light (2020) designed a smart waste monitoring and control system with the implementation of an Internet of Things (IoT) based Arduino Uno microcontroller, Wi-Fi module, LED light with the ultrasonic sensor to get the bin to fill level information, 'filled,' 'half-filled' and 'empty' then display on a liquid crystal display (LCD) screen. The information about the bin will be transmitted to a web application then the user can view the status of the bin in a bar chart. This website is developed in PHP programming language to send and retrieve from the database and show on the website. Users can access the website through electronic gadgets such as laptops, mobile phones, and desktops. This bin monitoring and control system also provides users with a data log that will be updated continuously. The system allows users to access websites through any device if connected to the Internet.

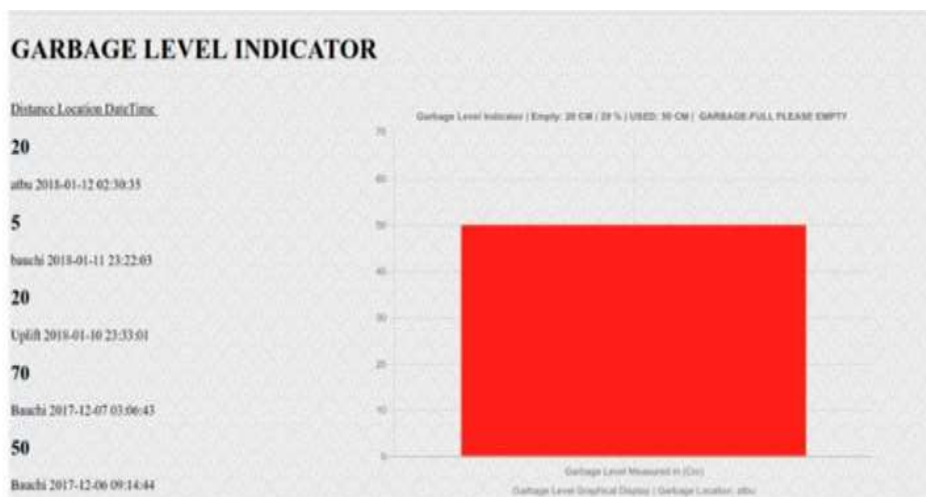


Fig. 2: Garbage Bin is Almost Full and Due for Collection by Abba & Light, 2020

Fig. 2 shows the webpage from Abba and Light, which perform analysis and visualization. The webpage includes a bar chart showing the garbage waste level; because the fill level is almost full, the bar color is red. On the left of the website is a list showing the garbage height and distance in the bin in real-time with DateTime.

Sohag and Podder (2020) proposed a smart garbage management system for the urban area to carry out a proper waste management approach. Similar to the previous system, the authors also used an ultrasonic sensor to measure the tallness of the volume of the waste in the bin and then show the percentage of filling on an LCD screen. Arduino Uno is the microcontroller used to control the whole process of the system. When the bin is full, implementing the mobile communication (GSM) module system will inform the corresponding agency to clear the bin by sending a short message service (SMS). The developed smart bin can control the lid to open or close by using a servo motor. The lid will not be opened as the bin is filled up because the personnel detected it in the detection range. This proposed system can eliminate the overflow of waste with the automated lid.

The technology applied by Chen (2022) and Kang, Kang, and Chong (2020), except for the automated lid, is the same as the smart waste bin management system produced by Sohag and Podder (2020), Chen (2022) and Kang et al., 2020. Both utilized the GPS module to guide the user to the bin. For the system developed by Chen (2022), the bin's status will be transmitted to a central cloud server, and the user can view the current location and condition on the web-based application in real time. The user will also get a notification to clear the bin and deliver a notification to the user through a mobile application.

Kang, Kang, and Chong (2020) used Google Firebase as the cloud-based database system to correct and store data because Firebase is efficient and free to use for the concurrency control features. As mentioned by the authors, Firebase allows the admin to navigate and monitor all the related data online effortlessly, even though multiple data have been pushed and pulled simultaneously. Besides using the GSM module, this system implements an automated email alert system by utilizing Gmail's simple mail transfer protocol (SMTP) server. When the collection box reaches a certain level, the Arduino board is configured to send an alert email to the related company to correct the e-waste.

The main interface between the user who wants to dispose of their waste and the administration server is a mobile application (Kang et al., 2020). A mobile application will show and take the user to the nearest smart e-waste collection box with the implementation of Google Maps and display the disposal

history of the user. (Kang et al., 2020) use battery-powered supply, not a stable power source for the system. Thus, the smart e-waste system is set to sleep mode when not in use to improve battery efficiency. To wake up the system, the user must scan the QR code on the collection box for registration and the location code for the package. The backend server will send the wake-up signal to the system, ensuring the user disposes of e-waste in the correct box.

The IoT-based application to monitor the smart wastes bin proposed by Sirisha, Nallapaneni, Parimala, and Jyothi (2018) to measure and monitor the bin fill level continuously are similar to the smart waste bin developed by Sohag and Podder (2020). Both use ultrasonic sensors, Arduino Uno as a microcontroller, an LCD screen to display the bin status, and a GSM module to send alert messages. For this system (Sirisha Yerraboina et al., 2018), users can also acquire bin information by accessing a web-based application using the registered login details. The web portal enables authorized users to monitor the smart waste bin status. Registration and login functions ensure that the smart waste bin web-based application only can be accessed by authorized users.

The IoT-based smart waste bin monitoring system to detect overflow developed by Kanade, Alva, Prasad, and Kanade (2021) and Roy, Manna, Kim, and Moon (2022) both implement the same technology, such as an ultrasonic sensor to measure the fill level of the bin, LCD screen to display the status of the bin, Arduino Uno as a microcontroller, GPS module to obtain the location of the bin, GSM module, and Wi-Fi module. The smart bin proposed by (Roy et al., 2022) will send the bin information, including the geolocation and fill level, to the central monitoring system (CMS). Then if the bin is full, CMS will send a vehicle to collect the trash. The radio-frequency identification (RFID) reader is implemented in this system to authenticate the user.

The smart waste bin of Kanade et al., 2021 implemented an infrared (IR) sensor to trigger the ultrasonic sensor after the bin is closed by individuals to detect any changes in the fill level of the bin. The status and location of the bin will be sent to an Android cell phone application using Firebase in JSON data. Users must register and log in to view bin information, for example, the receptacle's state and area. The application will gather information from all the remembered sites and measure bin fill levels. Fig. 3 shows the mobile application with a picture of a dustbin to inform the user whether the bin is full or empty.

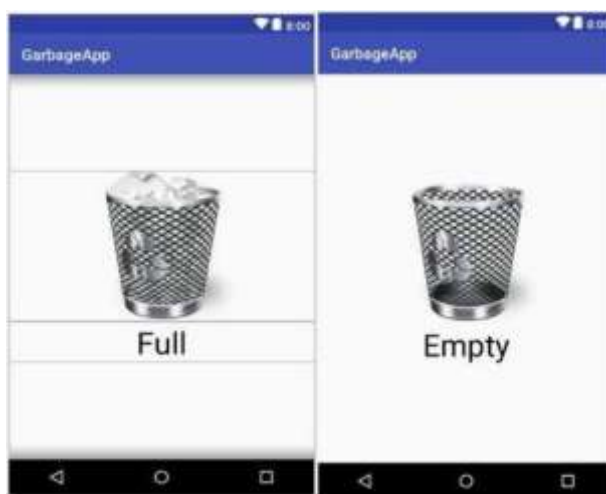


Fig. 3: Bin Full or Empty by Kanade et al., 2021

An IoT-based smart waste system using ZigBee as the wireless technology had proposed by Raaju, Mappillai, Sasidharan, Premkumar, and Tech (2019) to check the dustbin in the urban area. Same as other systems, use ultrasonic sensors to identify the fill level of the bin and Arduino Pro mini as the microcontroller. The power source of this system is solar panels, a renewable energy resource. Next, the bin data will be collected by ZigBee, and the NodeMCU will send all the data to the Firebase. The status of the bin will be updated frequently and uploaded to the cloud. The cloud service can be accessed from anywhere, anytime, with an internet connection. Then, an Android application will retrieve and display the data to the user. When the bin is full, the application will notify the driver to collect the waste. Google Maps, the GPS module in this system, will be used to track the correct location. Contrary to other systems, this system is not implemented with a GSM module. According to the authors, without the GSM module can reduce the maintenance fee.

The system has three sensors developed by Joshi, Bharti, Singh, and Malik (2022). First, the ultrasonic sensor will measure the level of the waste in the bin, and an IR sensor to detect an object which will help open the lid. The third sensor is a temperature sensor to measure the bin's temperature. The system implements WPAN and cloud-based architecture via XBee communication and the Internet to monitor waste from any remote location. XBee is a hassle-free communication channel between the cloud server and the microcontroller. The LCD screen will display the level of waste in percentage. LED lights as a level indicator has three colors: green, yellow, and red, which will glow according to the fill level of the bin. All the corrected data will be visualized on the cloud server through an internet connection and WPA.

Based on the earlier findings, we postulated that the system must have at least three fundamental requirements. Firstly, network technology such as Wi-Fi enables seamless data transmission and retrieval within cloud servers and systems. Additionally, a microcontroller must be implemented to monitor all bin activities, necessitating the integration of multiple sensors on and within the bin to accurately determine its fill level.

Besides the basic features, a smart e-waste bin must include a GPS module to provide the user with information about the location of the bin for efficient waste collection. An external LCD screen outside the bin displays the fill level of waste in percentage, enabling the user to observe easily. Furthermore, considering the potential fire risk, a temperature sensor is a must. As the temperature sensor detects the temperature inside the bin is too high, the system must alert the user through the mobile application's notification or email to prevent grave consequences.

An effective smart e-waste recycling bin fill level monitoring system must have a mobile application or a webpage that can provide the visualization and analysis function for users to monitor the e-waste bin. The mobile application or webpage should display the bin's location, making it convenient for the user. Moreover, the fill level of the e-waste bin should be presented through visualizations, accompanied by a detailed list of the bin's status, including temperature and fill level based on date and time, allowing the user to track the e-waste bin in real time.

In this paper, we propose a mobile application that ensures real-time notifications related to the bin. Two sensors are deployed for bin fill level monitoring: an ultrasonic sensor as the primary sensor for measuring fill level and a temperature sensor for monitoring the bin's temperature. Additionally, since the bin's location will remain fixed, the admin can manage any changes to the location. The implementation of a GPS module on the e-waste bin is unnecessary. Admin can change and update the bin location, and the updated location will display on the mobile phone. A Wi-Fi module will control bin data uploading to the server, which the mobile application will retrieve and display to the user. Consequently, there is no need to incorporate an LCD screen on the bin, as users can conveniently view the bin's fill level through their

mobile phones. Using LCD screens also can reduce the cost.

By incorporating these features and technologies into the e-waste bin fill level monitoring system, the purpose is to enhance waste management practices, improve efficiency in waste collection, and promote awareness and responsibility in e-waste recycling.

3. METHODOLOGY

3.1. Overview of System Architecture

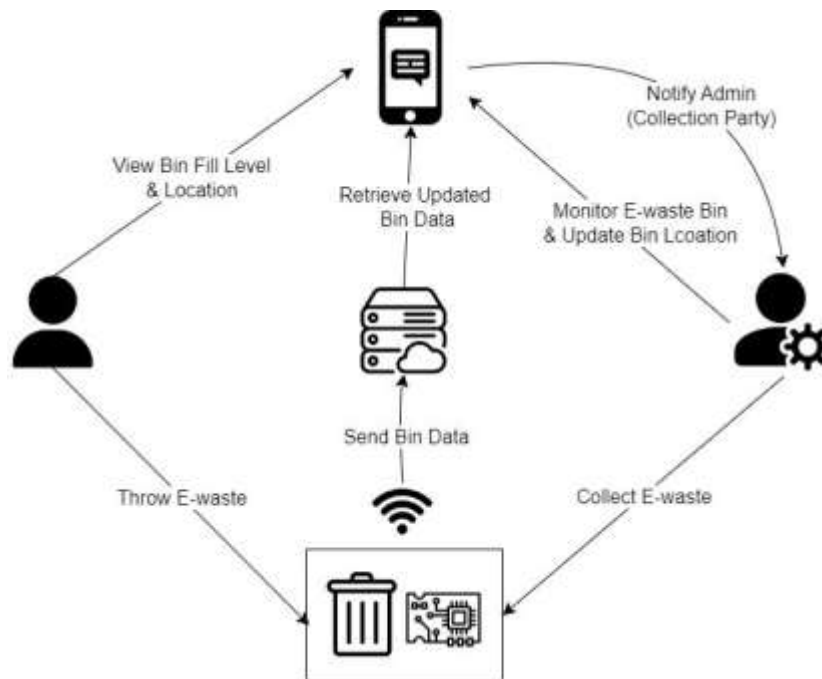


Fig. 4: System Architecture

Fig. 4 illustrates the system's architecture, including a mobile application, cloud database server, and e-waste bin. The system has two user roles: admin and user. The admin serves as the collection party responsible for monitoring the e-waste bin, while the user is the party that disposes of the e-waste. A mobile application is developed to enhance user convenience and adherence to waste disposal regulations. Users can use this application to check the e-waste bin's fill level, which enables them to decide if they can dispose of their e-waste or if the bin is full. Additionally, the location of the bin will be shown on the mobile application so that the user can quickly find it when required.

The mobile application is a monitoring tool for the admin role of the e-waste bin. The application will display details such as fill level, temperature, and the most recent update timestamp. Additionally, the admin can update the bin's location through the mobile application, ensuring accurate tracking and accessibility. The e-waste bin is equipped with sensors and a Wi-Fi module to have seamless data transmission and retrieval that allow the bin to send data to the cloud server, and the mobile application can retrieve the information and show the data to the user. This seamless data transmission and retrieval ensures real-time data availability and enhances the system's overall efficiency.

When the e-waste bin's fill level has reached 80%, an email notification will be sent to the admin, serving as a reminder to collect the e-waste. Overall, this system architecture with a mobile application,

cloud server, and different sensors on e-waste bins can provide a comprehensive and user-friendly solution for efficient e-waste management and facilitate the admin and user's responsibility to dispose and collect e-waste.

3.2. Hardware

A smart e-waste recycle bin monitoring the bin's fill level must integrate hardware and software. This system's hardware components include a Wi-Fi module, an ultrasonic sensor, and a temperature sensor. All of them are integrated to monitor the status of the smart e-waste bin, such as fill level and temperature, and send or retrieve data from the bin. The sensors' circuit board and Wi-Fi module must be connected to a power bank with 10000MAH.

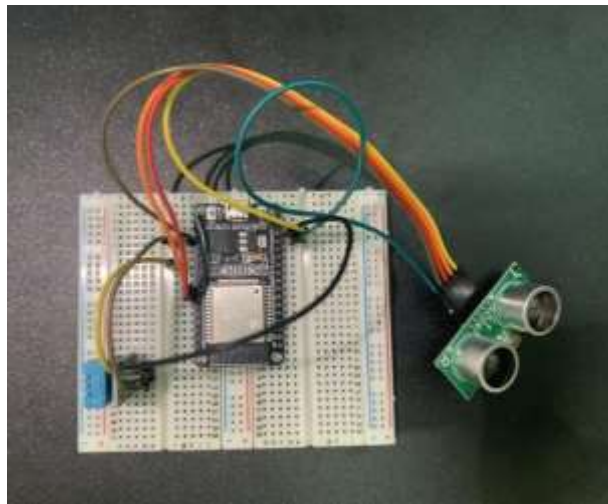


Fig. 5: Deployed Wi-Fi module, temperature sensor, and ultrasonic sensor

3.2.1 Ultrasonic Sensor Ultrasonic Sensor

As Rahman, Bappy, Komol, and Podder (2019) mentioned, an ultrasonic sensor is good for measuring height because the reflection of the soundwave does not depend on the object's shape. Utilizing the ultrasonic sensor can produce error-free measurements. This type of sensor is preferred to detect the waste level. This ultrasonic sensor is placed inside the e-waste bin at the bin's lid to measure the waste level. This sensor will transmit an ultrasonic sound, and e-waste in the bin will reflect the sound wave—the time gap between transmitting ultrasonic sound and the sensor receiving the reflected sound wave will be recorded. The level of e-waste in the bin will then be calculated using the time gap.

The ultrasonic sensor deployed in this research (see Fig. 5) is US-100 Ultrasonic Sonar Distance Sensor which is like the popular sensor HC-SR04; however, it can run 3V to 5V and does not require any logic level shifters and can be used in HC-SR04 mode or Serial UART mode (Adafruit Industries, n.d.). This sensor is commonly used in robotic research and accurately measures the distance between e-waste and the sensor inside the bin. It can work between 2cm and 450cm, but working between 10cm and 250cm can get the best result.

In this system, the ultrasonic sensor will get the time gap in microseconds. After that, the time gap will be converted from microseconds to centimeters. Our deployed e-waste bin height is 250cm. Then, 250cm minus the time gap in centimeters will obtain the value of the e-waste fill level in the e-waste bin.

3.2.2. Temperature Sensor

A temperature sensor is an electronic device used to measure the environment's temperature. This sensor is also implemented inside the bin to measure the temperature and detect the temperature inside the bin. The temperature of the bin will be shown in degree Celsius. Exposure to extreme temperatures, such as more than sixty degrees Celsius must be avoided (Herrerias-Martínez et al., 2021). Therefore, when the temperature inside the bin is higher than fifty degrees Celsius, the system will notify the user through email to have a check for the bin.

The temperature sensor selected is DHT11 Temperature and Humidity Sensor. This sensor is commonly used to measure the temperature of surroundings and can measure temperatures up to 50 degrees Celsius (DHT11 Temperature and Humidity Sensor Module Breakout, n.d.). This information is important for assessing the environmental conditions inside the bin and ensuring the temperature remains within safe limits. When the sensor detects any unusual temperature increases could indicate the possibility of a fire. By monitoring the temperature, the system can generate a notification to avoid potential hazards, and then the admin can take quick action.

3.2.3. Wi-Fi Module

Network technology is a must for a system to achieve a wireless connection to the Internet. With the Wi-Fi module, the system can send and retrieve data over Wi-Fi with the cloud server. Then the data on the server will be retrieved and displayed on the mobile application for the user to keep track of the status of the e-waste bin. The Wi-Fi module used in this system is ESP32 which Espressif System produces (ESP32, n.d.). ESP32 has built-in Wi-Fi to enable seamless wireless communication between the e-waste bin and the cloud server, mainly used to ensure real-time data transmission and monitor the e-waste bin. Besides that, ESP32 is low power consumption and is suitable for battery-powered applications. Therefore, ESP32 can operate longer without draining the battery quickly, reducing the need for battery replacement.

3.3. Software

In this system, a mobile application will alert the user or collection party about the fill level of the recycle bin, and a dashboard to show the user for the smart bin fill level. Besides that, the mobile application will also show the user's location and the bin's temperature. The mobile application will keep a log of the fill level of the bin every fifteen minutes. Then, the system will notify the user when the collection is required through email, as the bin status will be updated in real-time.

3.3.1. Meteor

The mobile application of this system is developed by using Meteor. Meteor is a full-stack JavaScript framework that supports real-time data updates (Meteor Software: A Platform to Build, Host, Deploy, and Scale Full-Stack JavaScript Applications, n.d.). It enables seamless data synchronization and quick changes across networked devices when paired with MongoDB, a NoSQL database, making it possible to track the level of e-waste bin fill in real time, giving users and administrators access to precise and current information. Meteor uses single language development (Introduction | Meteor Guide, n.d.). It simplifies the development process by enabling developers to use JavaScript on a program's server and client. Due to the shortened learning curve and accelerated development cycle, the fill level monitoring system can be deployed more quickly.

3.3.2. MongoDB

The cloud database server used in this research is MongoDB. MongoDB is a document-oriented database that provides reliable data storage and retrieval (Advantages of MongoDB, n.d.). It can provide a flexible schema to change the data requirement and ensures that data captured from the bin fill level monitoring system is securely stored and readily accessible. It also ensures the integrity and reliability of the system's data, even during power outages or other interruptions. Besides that, MongoDB has a change-friendly design because it enables users to upload new data at any time and from any location without affecting the database's normal operations (Top Advantages of MongoDB, n.d.).

3.3.3. NoSQLBooster

NoSQLBooster is a user-friendly cross-platform GUI tool for MongoDB. It provides an intuitive interface that simplifies database management, querying, and administration tasks. NoSQLBooster also offers server monitoring tools and a debugger for MongoDB scripts. All the provided services make it easier to work with MongoDB databases (The Smartest GUI Tool and IDE for MongoDB, n.d.). MongoDB and NoSQLBooster work together to provide developers and administrators a robust environment for efficiently working with NoSQL data and optimizing database operations.

4. DEPLOYED USER INTERFACES

4.1. User Interface and Program Usage

The bin fill level system's user interface can provide users with a user-friendly platform to interact with the system. In the mobile application, the user can easily view the bin fill level and location before disposing of the e-waste. Besides monitoring the bin, the admin can update the bin location and view the previous bin record.

4.1.1. Home Screen



Fig. 6: Home Screen with Different Bin Fill Level

As shown in Fig. 6, the user will see the Home screen with a rubbish bin picture showing the e-waste bin fill level. On top of the bin will be the updated bin status date and time in the 24-hour system, bin level in percentage, and temperature of the bin in Celsius. The bin fill level text will show in different colors based on the bin fill level. When the fill level of the bin is under fifty percent of the color, the fill level percent of the bin will be green; when the fill level is between fifty percent to seventy percent, the color will be orange; then the bin fill level more than seventy percent the color will be in red.

4.1.2. Bin Location Screen

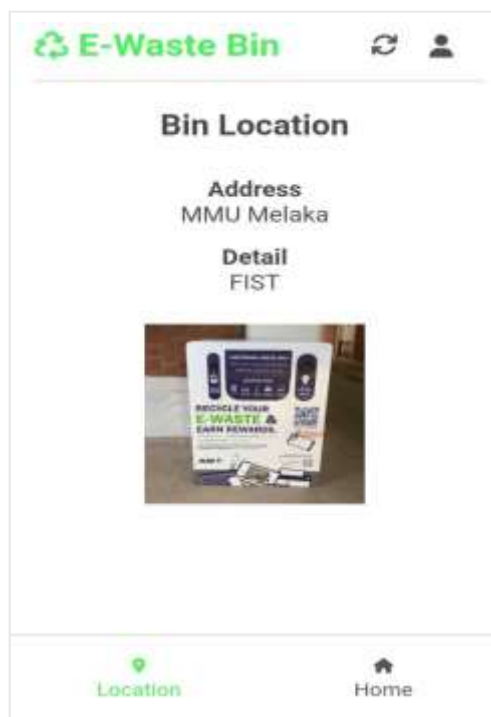


Fig. 7: Bin Location Screen

Fig. 7 shows the bin location with address, detail, and image. According to the location shown on the mobile application, the admin can directly go to the location to collect the e-waste. At the same time, users can dispose of e-waste without mindlessly finding where the bin is and bringing convenience for users to dispose of their e-waste.

4.1.3. Record Screen

Fig. 8 shows the Record Screen, which only can be accessed by admin. The status of the bin will be automatically updated every fifteen minutes. Besides the real-time status on the home screen, the admin can also view the previous status record of the bin on this screen. This screen uses a list view to show all the previous records, including fill level percentage, the temperature in Celsius, and updated date and time in the 24-hour system. Same as the Home screen, the fill level will be displayed in different font colors according to the percentage of bin-fill level.

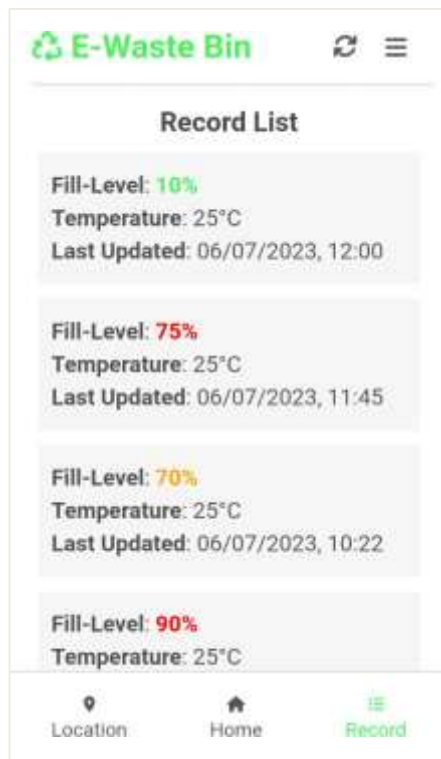


Fig. 8: Record Screen

4.1.4. Change Bin Location Screen

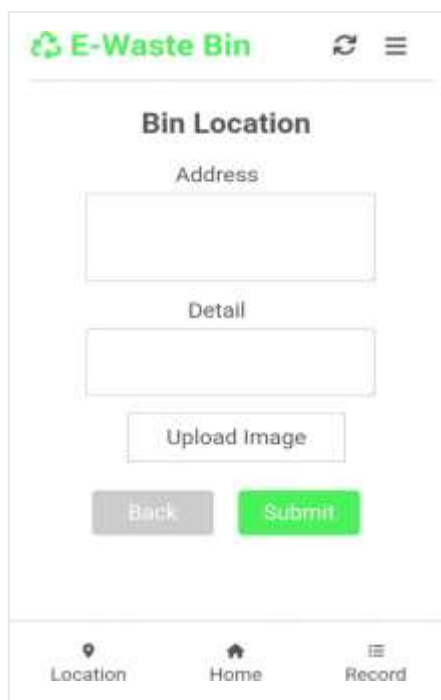


Fig. 9: Change Bin Location Screen

Fig. 9 demonstrates the function which allowed the relocation and new allocation of the bin. The admin is provided the flexibility to remove or shift the old bin and add a new bin to a specific location. All information will be updated automatically and pushed to all app users once the relocation is complete.

5. USER TESTING

5.1. Test Case

Some test cases are conducted to evaluate the functionalities of the mobile application and the bin fill level sensor. Each test case describes the function being tested, the expected outcome, and the actual result. These tests will comprehensively evaluate the system's capabilities and ensure proper functioning.

5.1.1. Smart E-Waste Bin Fill Level

Here will test the bin fill level system in this research. Table 1 below shows the test case based on different bin fill levels.

Table 1: Test Scenarios of Smart E-waste Bin Fill Level

Test Description	Expected Outcome	Result	Status (Pass/Fail)
No e-waste in the bin	The bin fill level in mobile applications should be 0%	The fill level show correctly	Pass
E-waste fills 25% of the bin.	The bin fill level in the mobile application should be 25%	The fill level show correctly	Pass
E-waste fills 50% of the bin.	The bin fill level in the mobile application should be 50%	The fill level show correctly	Pass
E-waste fills 75% of the bin.	The bin fill level in the mobile application should be 75%	The fill level show correctly	Pass
E-waste fills the bin fully.	The bin fill level in the mobile application should be 100%	The fill level show correctly	Pass

5.1.2. Mobile Application User Account

Table 2 below shows the user account test case, including user registration, login, and password.

Table 2: Test Scenarios of User Account Screen

Test Case	Description	Expected Outcome	Result	Status (Pass/Fail)
Register New Account	Register a new account with valid registration details	After successful registration, a verification email should be sent to the provided email address for confirmation	The registration process is completed, and the verification email is successfully sent	Pass
Login with Valid Credentials	Logging into the mobile application using valid login Credentials	Upon successful login, the user should be redirected to their account screen	The login process is successful, and the user is directed to their account screen	Pass

Change Password	Changing the password by providing the old password and new password and confirming the new password	Upon successful password change, the system should update the user's password to the new one.	The password is successfully changed, and the user can log in with the updated password.	Pass
Forgot Password	Requesting a password reset by entering the registered email address	The system should send a password reset URL to the provided email address	The password reset email is sent, allowing the user to reset their password	Pass
Reset Password	Resetting the password by clicking the password reset URL and entering a new password	After a successful password reset, the user should be redirected to the Login screen to log in with the updated password.	The password is reset, and the user can log in with the new password.	Pass

5.1.3. Smart E-Waste Bin Fill Level

Table 3 below shows the test case of the user action related to the smart e-waste bin information, including clicking the refresh button to get the real-time bin fill level, view the bin location, and record the screen. The admin can change the bin location.

Table 3: Test Scenarios of User Action towards Different Smart E-waste Bin Fill Level

Test Case	Description	Expected Outcome	Result	Status (Pass/Fail)
Refresh Bin Data	Click the refresh icon on the header to retrieve the latest bin data	The system should fetch and display the latest fill-level and other data of the e-waste bin	The bin data is successfully refreshed and updated on the Home screen	Pass
View Bin Location	Accessing the Location screen to view the e-waste bin's location details	The Location screen should display the address, details, and an image of the bin's location	The Location screen is successfully displayed with the relevant bin location information.	Pass
Change Bin Location	Modify and update the bin location address, detail, and image	The bin location is successfully changed to the new address, detail, and image	bin location is successfully updated and displayed on the Location screen with the new address, detail, and image	Pass
Record Screen Display	Navigating to the Record screen to view real-time and previous records of the e-waste bin	The Record screen should show the status and records of the bin, including fill level, temperature, and timestamps.	The record screen displays the real-time and bin previous records correctly	Pass

CONCLUSIONS

Implementing the e-waste bin's fill level system with a mobile application can provide users with an efficient way to monitor the fill level of the e-waste bin and show the bin for e-waste disposal. This proposed system eliminates the need for regularly scheduled e-waste collection, avoiding inefficiencies when bins are not filled. By implementing fill level monitoring, collection parties can significantly reduce expenses such as fuel costs and labor hours by collecting e-waste bins only when required.

The developed mobile application of this system offers a user-friendly interface and various features such as bin fill level monitoring, registration, login, changing bin location, and accessing previous records. Testing has ensured that the system's functionalities are working as expected. This smart system can contribute to effective e-waste management by empowering users with information and promoting responsible disposal practices. It also revolutionizes waste management by providing real-time monitoring to optimize resource allocation and reduce

costs. By embracing innovative technology, it can pave the way for a more efficient, sustainable, and responsible approach to e-waste disposal. Ultimately, it can protect the environment and encourage public engagement in e-waste disposal practices.

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