Applied Mathematics and Computational Intelligence
Volume 14, No. 2, 2025 [82-94]

Development of E-Waste Management Mobile Application Using Location-based Service

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Received: 26 August 2024
Revised: 13 December 2024
Accepted: 16 April 2025

ABSTRACT

The technological revolution has significantly transformed the global landscape. As awareness of the detrimental impacts of e-waste has grown, people have begun to take this issue seriously. Nevertheless, several barriers hinder active participation in e-waste recycling, including challenges in accessing collection points and limited awareness about proper recycling procedures. Addressing these challenges and improving e-waste recycling practices is of paramount importance. This study aims to examine a suitable system for managing electronic waste by developing a mobile application utilizing location-based services to assist users in recycling e-waste. The project employed the Rapid Application Development (RAD) model, which emphasizes fast iterations in developing the final product of an e-waste management application. The results reveal the mobile application user interface for e-waste management guides users in managing e-waste properly in terms of finding nearby drop-off location points. Potential future updates could encompass the integration of points and badge elements, which has the potential to attract a larger user base. Introducing a feedback and rating mechanism would also allow users to promptly share their insights and contribute to a continuous cycle of enhancement and user engagement.

Keywords: e-waste, location-based service, mobile application, recycling.

1 INTRODUCTION

Since the technological revolution first began, the world has come a long way. Once people realize the true extent of the dangers caused by e-waste, they take the issue more seriously, and e-waste management cannot be carried out if there is no cooperation from all parties. Previously, this e-waste is either thrown into the landfill or burned. It has taken some time before people realized the adverse impact that such actions would have on the environment and their health [1].

Electronics is a fraction of technology that continues to evolve daily. The use of electronics has spread throughout the world. Today, the availability of electronic devices (i.e. laptops and tablets) has made our daily routines more convenient. However, this convenience comes with a downside: it is crucial to find proper methods for disposing of electronic devices once they are no longer in use. One of the

major issues with e-waste recycling is that there are not enough official recycling centres around the community [2][3]. Studies have shown that one of the reasons people do not recycle their electronic waste is the collection places are difficult to reach, and the hassle does not seem worth it [4].

According to [5], the study in Malaysia shows that people would rather store broken or unused electric and electronic equipment rather than try to fix it or recycle it. The results showed 48% of respondents kept their unused electronic equipment in the store at home, and only 22% took their e-waste to the recycling centre. Moreover, [6] stated that about 50% of consumers are unaware that e-waste electronics contain harmful and hazardous substances. Since they are unaware of the potential hazards, it is not surprising that they might simply keep unused electronic equipment rather than disposing of it properly.

If individuals choose to buy new products instead of recycling, it can contribute to increasing climate change and global warming which by opting for recycled products, we can help lower the demand for materials that generate greenhouse gases and mitigate their impact on the environment [7]. This project is essential for providing people with easy access to transport their e-waste to formal collection points using an online platform [8][9], hence contributing to efforts to combat global warming as a whole.

In order to manage e-waste effectively, it is plausible to increase the number of easily accessible drop-off points for the local community. Thus, this study aims to enhance e-waste access, starting with users in Kelantan, which the primary goal is to simplify the process of disposing of e-waste, such as broken laptops, printers, or cables, by facilitating easy drop-off at recycling centres.

1.1 Type of E-Waste

Electronic equipment includes devices such as LCD monitors, televisions, laptops, computers, printers, mobile phones, and many more. The United Nations (UN) defines e-waste as any discarded product with a battery or plug that can cause a high impact on human health and the environment because it contains toxic and dangerous substances such as mercury [10]. As a result, e-waste requires a specific disposal process, and only the responsible parties need to manage it [11].

However, e-waste is becoming a growing global issue due to the increasing reliance on electronic devices. Most individuals own at least two electronic devices, and these devices typically have a short lifespan of just 3 to 5 years. As mentioned by [12], the approximate lifetimes of various electronic devices are as follows: 2 to 5 years for a PC and 1 to 2 years for a mobile phone, with smartphones often lasting no more than 18 months to 2 years. Consequently, as these devices become damaged, the volume of discarded electronics rises because people are more likely to purchase new equipment rather than repair or recycle their old ones.

Electronic waste can be categorized into different groups based on its source and intended use. [13] said that the average percentage of each type of e-waste can change based on many things, such as the economy, consumer habits, population size, and how much businesses and homes rely on electronic and electrical equipment (EEE). The major group comes from bulky household items, at 42.1% of e-waste. This was followed by Information Technology (IT) and telecommunications (33.9%), consumer devices (13.7%), small home appliances (4.7%), electricity and electronics have a smaller share (2%) and 1% for toys and sports equipment.

The focus of this study is IT and telecommunications (i.e., laptop/desktop computers, cameras, modems, printers, mobile phones) only. This choice was made in response to the frequent use of electronic devices in daily routines. Hence, when a computer, printer, or other electronic device ceases to function, this application will simplify the recycling process.

2 RELATED WORK

Previous studies found that while Malaysia has made progress in managing e-waste, significant gaps remain, particularly in enforcement and infrastructure, which need to be addressed to improve overall e-waste management practices [14] and Malaysia's e-waste management system also needs further development and refinement [15]. Although Malaysia still faces several challenges in e-waste management, there are significant opportunities to improve the system through targeted actions [16].

2.1 E-Waste Management in Malaysia

By addressing identified challenges and implementing recommended strategies such as refined regulatory, infrastructural, and public engagement issues, Malaysia can improve its e-waste management practices and develop a more effective and sustainable e-waste management approach [15][16].

Malaysia has implemented several policies to regulate e-waste, including the Environmental Quality (Scheduled Wastes) Regulations 2005 and the Scheduled Waste Management Guidelines [17]. However, enforcement remains inconsistent, and informal recycling practices persist. The introduction of Extended Producer Responsibility (EPR) policies [18], mandating manufacturers to manage end-of-life products, is a positive step but requires more robust implementation.

The management of e-waste in Malaysia involves various initiatives and collaborations to address the collection and recycling of both industrial and household e-waste. The Department of Environment (DOE) regulates e-waste management activities, and transporters with permits issued by DOE are responsible for collecting industrial e-waste. Formal collectors, under DOE regulations, handle a portion of household electronic waste, while informal collectors also collect some household electronic waste. Efforts have been made to improve household e-waste collection, including pilot programs and guidelines developed by DOE [16].

Furthermore, the Malaysian Communications and Multimedia Commission (MCMC) started the "Mobile e-waste: Old Phone, New Life" initiative in collaboration with the Malaysian Technical and Standards Forum Bhd (MTSFB) and industry members to collect and recycle end-of-life mobile devices. Collection boxes were set up at various locations, and the collected mobile e-waste was transported to licensed full recovery facilities for urban mining operations. The National Solid Waste Management Department (JPSPN) is responsible for non-hazardous solid waste management tasks and collaborates with DOE to collect household e-waste during local municipal waste collections. Non-governmental organizations (NGOs), such as the Tzu Chi Foundation and Islamic Relief, have also participated in household e-waste management projects [15].

While efforts have been made to improve household e-waste management in Malaysia, specific collection volumes and statistics for certain initiatives are yet to be reported. The participation of NGOs is encouraged to strengthen existing household e-waste collection systems. Figure 1

summarized the operation of e-waste management in Malaysia including through formal and informal sector.

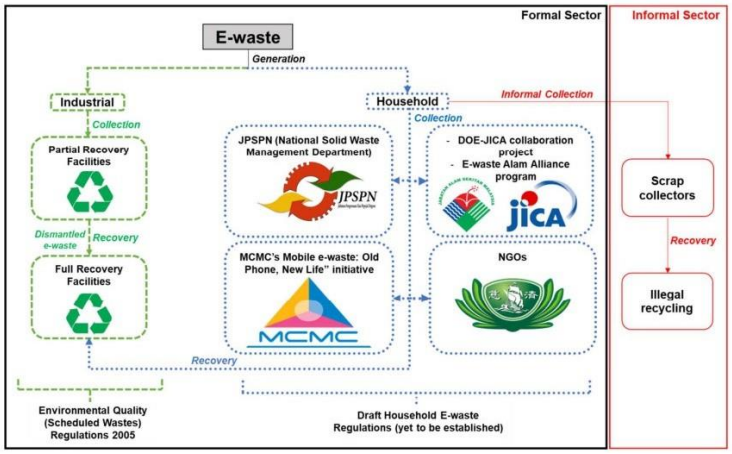

Figure 1: Operation of E-Waste Management in Malaysia [19]

Overall, previous research has predominantly concentrated on examining e-waste management regulations, including policies, legal frameworks, and compliance requirements. While these studies provide valuable insights into the regulatory landscape, there has been relatively little focus on the practical development and implementation of e-waste management systems, particularly within the context of Malaysia. This lack of emphasis on system development highlights a gap in addressing the growing challenges of e-waste handling and disposal. Consequently, there is a pressing need for further research to explore innovative approaches, such as the design and deployment of mobile applications, which can facilitate more efficient and user-friendly e-waste management solutions.

2.2 Mobile Application Using Location-based Services

Mobile communication has become integral to daily life, to the point where many individuals feeling a sense of discomfort or disconnection when separated from their mobile phones. Initially, mobile phones were primarily designed for basic functions, such as making calls and sending text messages to family and friends. Today, however, their capabilities have expanded significantly, transforming them into multifunctional tools that cater to a wide range of needs. Beyond their traditional role in communication, mobile phones are now extensively used for various purposes, including navigating and identifying specific locations.

One of the key advancements in mobile technology is the integration of location-based services (LBS), which allow users to determine their real-world position in real-time [20]. This functionality is closely tied to the concept of geocoding, which involves converting geographic coordinates into meaningful address data. Reverse geocoding translates latitude and longitude into a recognizable street address, while forward geocoding performs the opposite task by converting a street address into global coordinates [21]. These processes enable seamless navigation and location-based functionalities, making them essential components of modern mobile applications.

The Android operating system, known for its heftiness and versatility, has emerged as a powerful platform for developing a wide array of LBS applications. With the support of Google Maps, Android provides fully automated geocoding capabilities and an extensive suite of APIs, along with rich graphical features [22]. These tools empower developers to create innovative and user-friendly map-based applications.

In line with this technological evolution, this project aims to incorporate location-based services as a core feature in a mobile application. Leveraging the Android operating system, the application will utilize geocoding and mapping functionalities to assist users in locating recycling centers nearby. By integrating these advanced features, the application will enhance user convenience and contribute to environmentally conscious practices by promoting accessible recycling solutions.

3 METHODOLOGY

This study employed Rapid Application Development (RAD) as RAD is the best approach for developers working in a fast-paced environment [23]. The development process is dynamic, and things frequently change as it goes. RAD provides a framework where intermediate adjustments can be carried out and it is even encouraged during the development phase. The detailed process is highlighted below.

3.1 Requirement Planning

At the outset, researchers set project goals, establish expectations, and devise solutions for potential development issues. During this phase, an online survey via Google Forms was conducted to assess awareness and practices regarding e-waste. The survey also identified key challenges faced by users in recycling personal e-waste. Based on these insights, ideas for features to include in the mobile application were developed, aimed at addressing these challenges.

3.1.1 User Requirements

To launch this application, the target users primarily include 22 university students and lecturers in Kelantan with ages ranged from 21 years old to 30 years old. This demographic is well-suited as the audience since they frequently engage with multiple electronic devices, making them potential contributors to e-waste. Another key user group is the collectors, who are the owners or operators of recycling centers. Collectors play role in managing user registrations, overseeing requests made through the application, and updating the locations of their recycling centers.

Through this application, users can access a list of recycling centers available in Kelantan, with detailed information about each center. Additionally, users can search for nearby recycling centers using location-based features and submit requests to collectors for recycling their personal e-waste. The application also allows users to manage and update their profiles as needed to ensure accurate information. Meanwhile, collectors can view and manage requests submitted by users who require their recycling services.

3.1.2 Technical Requirements

The hardware requirements for this project include a smartphone and a laptop. The smartphone serves as a replacement for the emulator in Android Studio, enabling users to conduct real-world testing of the application. Unlike emulators, smartphones differ in screen size, performance characteristics, and hardware capabilities, making them essential for accurate testing. The laptop, on the other hand, is used to facilitate the development process and ensure seamless execution while also enabling the documentation of the project report.

In terms of software requirements, the project utilizes Android Studio, a web browser, and Firebase Database. Android Studio is a dedicated programming software for Android mobile application development. As Google's official integrated development environment (IDE) for Android, it is built on the IntelliJ IDEA platform from JetBrains and includes numerous advanced features that restructure the development process. The Firebase Database is employed to record and manage all data involved in the application, ensuring reliable and efficient data handling throughout the project.

3.2 User Design

Next, a case diagram and an Entity Relationship Diagram (ERD) were developed for this study. From the ERD perspective, as illustrated in Figure 2, a user can recycle one or more e-waste items. Each user can submit one or multiple e-waste items as part of a single recycling request. Afterwards, a recycling center can process one or multiple recycling requests and manage a corresponding number of e-waste items. Also, each recycling center is managed by an owner, who may oversee one or multiple recycling centers simultaneously.

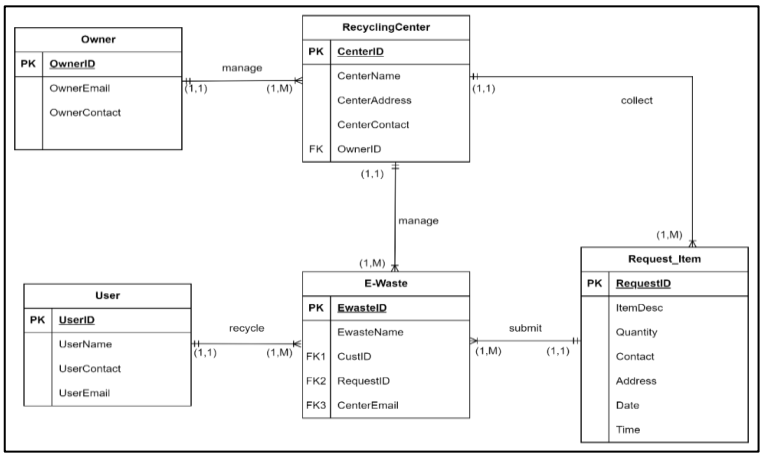

Figure 2: Entity Relationship Diagram of Project Application

The use case diagram, as shown in Figure 3, involves two primary actors: users and recycling centre owners. Initially, users are required to create an account to access the system. After successfully

logging in, users can select the type of e-waste they wish to recycle and submit a request to a recycling centre managed by an owner. Users can utilize the "Find Nearby Collector" feature to locate a recycling facility in their area. Users also have full control over their profiles, with the ability to view, edit, and delete their information as needed. In conjunction, recycling centre owners can oversee users, process recycling requests, and manage the details and locations of their centres. This includes adding new entries, updating existing ones, deleting records, searching for specific data, and viewing relevant information, ensuring efficient operation and service delivery.

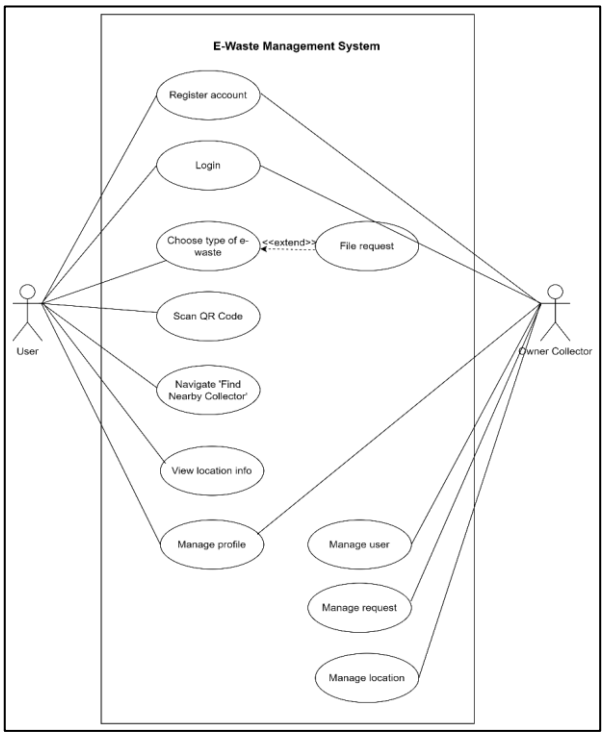

Figure 3: Use Case Diagram of Project Application

3.3 Rapid Construction

At this phase, application coding, system testing, and unit integration took place. Converting prototypes and migrating beta systems to working models also happened in this phase. This step could also be repeated as needed to support new requirements and changes. To develop applications quickly, low-code or rapid application development tools were used.

Due to the iterative prototyping phase, the problems faced and every change made by the users were well addressed and controlled. The final working model was able to be built faster than the traditional approach. Here, the application was tested using System Usability Scale (SUS) technique, and researchers collected feedback from end users regarding improvements that could be made towards the functionality of the application.

3.4 Cutover

The developer resolved any issues that arose during early prototyping in the final phase of project development. To make the final product better and easier to maintain, developers can perform optimal implementation. Each component was deployed to the live production environment for bug resolution and underwent comprehensive testing. Finally, detailed documentation, maintenance, and final testing were completed before handing the finished product over to the users.

4 RESULTS AND DISCUSSION

The application was designed with a focus on simplicity in the user interface, while also prioritizing an aesthetically pleasing experience. To achieve this, green was chosen as the primary color theme, symbolizing environmental sustainability. The goal is to guide users in effectively managing their e-waste and providing them with easy access to information about nearby e-waste drop-off locations. This section offers a detailed overview of the application, which is named "Recycle E-waste." Figure 4 displays the initial interfaces of the e-waste application.

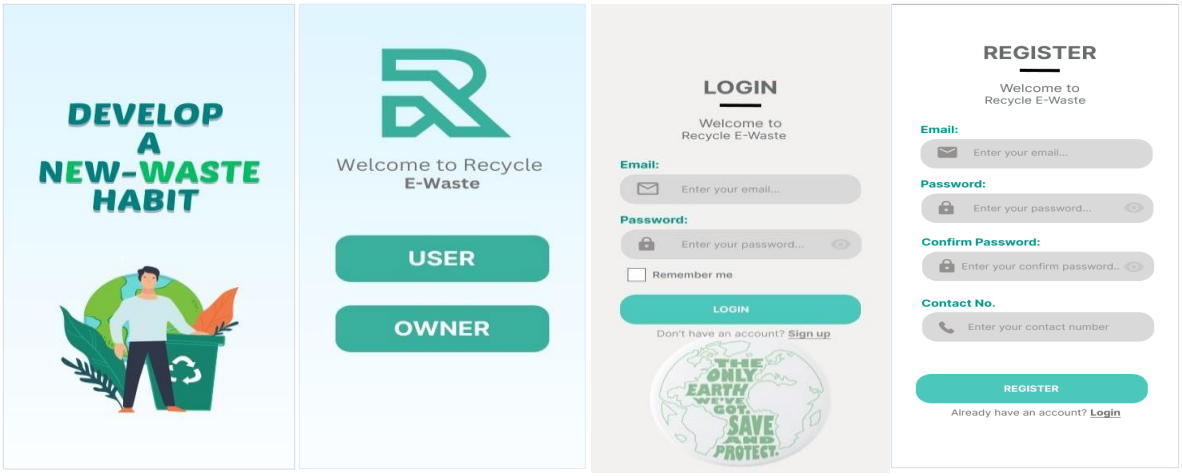

Figure 4: Initial Interfaces of Recycle E-Waste Application

The splash screen is the first visual interface that appears when users launch the mobile application. It provides an engaging introduction while the application loads its main components. The inclusion of the splash screen is designed to enhance the visual appeal for users. The application is primarily intended for two types of users: the user and the owner, as indicated by the two buttons on the screen. Both users and owners are required to create an account before accessing the application's features. If they already have an existing account, they can log in directly. Figure 5 shows the interface from the owner's perspective.

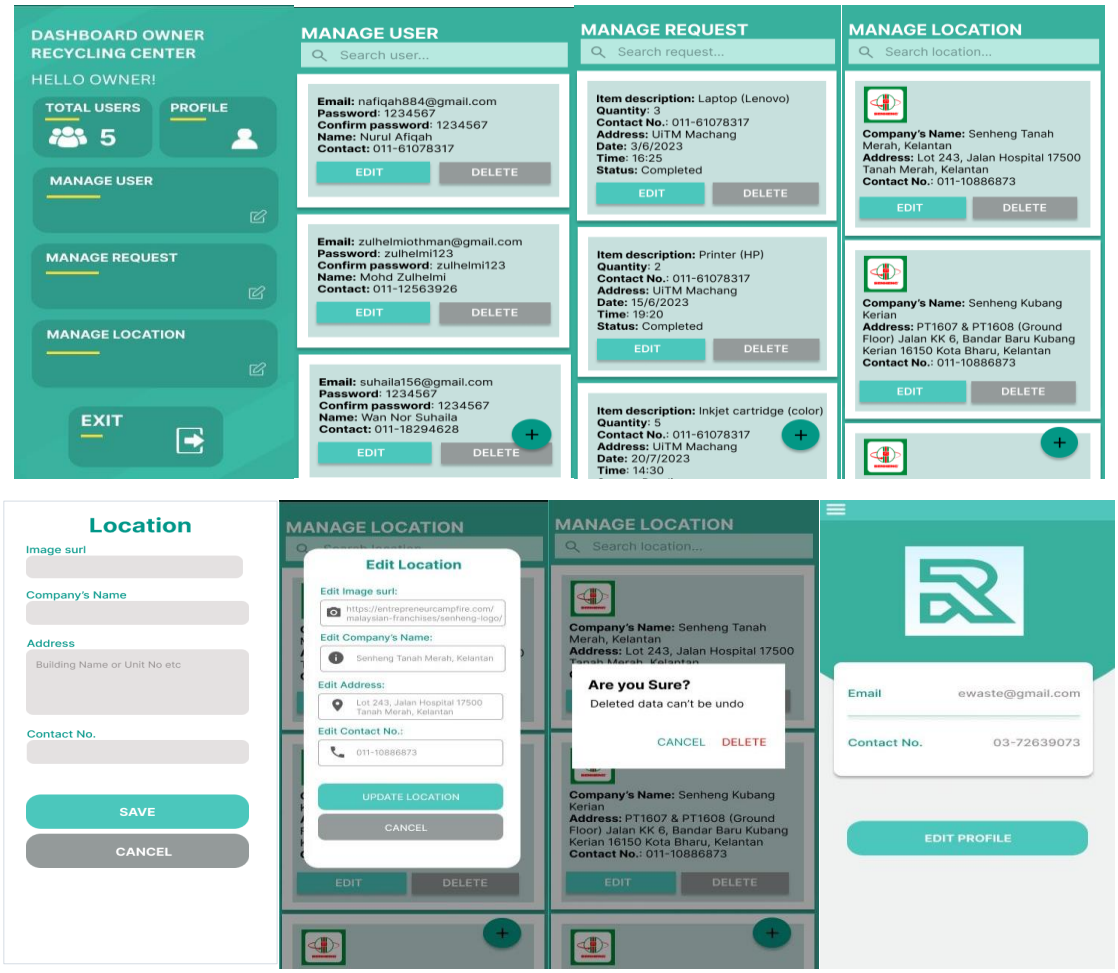

Figure 5: Owner's Interfaces of Recycle E-Waste Application

The owner's page shows a dashboard for the recycling centre, allowing owners to track the number of users who have registered on the application. From this page, owners can manage their profile information and oversee user data, handle requests, and update the latest details about nearby recycling centre locations. Owners are responsible for managing user requests, which include item descriptions, quantities, contact numbers, addresses, dates, times, and request statuses (either completed or pending).

In addition, owners can manage the location information for their recycling centre, including the name, address, and phone number of their facility. If needed, owners can update this information. If a registered recycling centre has ceased operations, the owner can remove the location from the system. New recycling centres in Kelantan can be added by the owner, ensuring that users have access to the most up-to-date information. When adding a new location, the owner can also include a company logo via an image website address, along with the company name, address, and contact number. Figure 6 highlights the user interfaces of the application.

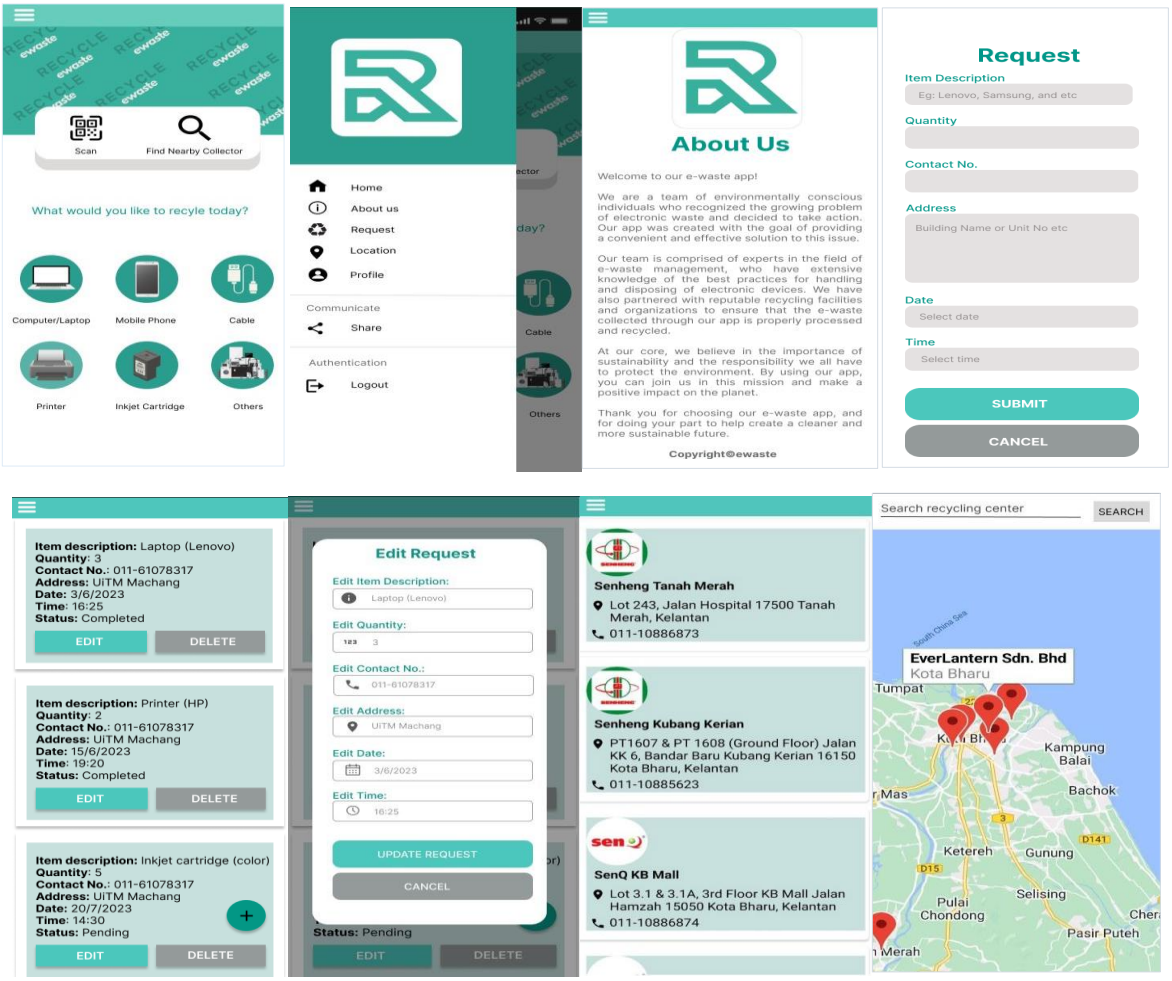

Figure 6: User's Interfaces of Recycle E-Waste Application

On the user's side, the application includes features such as a "Find Nearby Collector" function, and a variety of e-waste categories, including mobile phones, laptops, batteries, and other electronic devices. The sidebar menu offers an "About Us" page and a "Request" page, which allows users to conveniently submit pickup requests for their personal e-waste to be collected by a recycling centre owner. Additionally, there is a "Location" page that provides information on nearby recycling centres where users can drop off their e-waste. When submitting a new request, the user is required to provide details such as the item description, quantity, contact number, address, date, and time for pickup. The user can also view a list of nearby recycling centres, with their address and phone number displayed, making it easier to locate and contact the facility.

The application integrates Google Maps as a Location-Based Service (LBS) system to assist users in selecting a drop-off location. Upon first use, an access permission prompt will appear, requesting the user's consent to allow the app to access their location. The "Find Nearby Collector" feature utilizes location-based services to provide a map view of nearby collectors and recycling centres, enabling users to easily locate the nearest options. This feature helps users choose the most convenient recycling centre based on their current location.

Towards the end of the study, the System Usability Scale (SUS) technique was employed to gather valuable insights into users' perceptions of the overall usability of the mobile-based e-waste management application. The results revealed that the majority of users expressed a high likelihood of using the application frequently, with 15 respondents (68.2%) strongly agreeing with this statement. Besides, 12 respondents (54.5%) strongly disagreed with the assertion that the application is unnecessarily complex and 15 respondents (68.2%) also strongly disagreed with the idea that they would need to learn a considerable amount before being able to use the application.

The majority of respondents demonstrated a strong awareness of the negative impact of e-waste on human health and the environment, regardless of their background. However, the findings reveal that a significant portion of respondents has not yet participated in e-waste recycling or adopted proper disposal methods for electronic waste. Several factors contribute to their lack of involvement, including limited access to transportation, making it difficult for them to transport their personal e-waste to recycling centres. Despite these challenges, the overall feedback from the user experience survey suggests that the application is well-received. Users appreciate its ease of use, and the system has been positively accepted, indicating that it offers a valuable solution for managing e-waste.

5 CONCLUSION

Everyone has an old electronic bag, often referred to as e-waste. As more individuals engage with technology and the internet, the volume of e-waste continues to grow, creating a significant challenge for both environmental sustainability and public health. E-waste management is vital in addressing these issues and helps reduce environmental and health hazards associated with the improper disposal of electronic waste. As the lifespan of electronic equipment shortens, recycling becomes more important. When e-waste is not handled properly, it can pose serious risks, such as the release of toxic chemicals into the environment or harm to human health through unsafe disposal methods.

This application serves as an initial step towards managing e-waste more effectively. Its intention is to raise awareness and offer a practical solution for users to dispose of their electronic waste responsibly. By providing a platform to locate recycling centres and request pickups, the application plays a dynamic role in promoting environmentally friendly practices. Furthermore, it can inspire other developers and researchers to create more solid solutions for e-waste management, encouraging wider participation and engagement from users.

At some point, incorporating a feedback and rating system would be beneficial to enhance the application. This feature would provide users with a direct way to share their experiences, opinions, and suggestions, creating an interactive space for continuous improvement. A rating system could allow users to assess their overall satisfaction with the application, while a comment box or survey could provide more detailed feedback. To encourage active participation, prompts could be incorporated into the app, asking users to rate their experience or offer suggestions after completing specific tasks. This feedback loop would not only help improve the application's features but also foster a sense of involvement and community among users, ultimately contributing to more effective and efficient e-waste management.

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