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AN ARCHITECTURE DESIGN FOR SMART E-WASTE MANAGEMENT SYSTEM

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Abstract: *E-waste is an uncommon topic to be discussed nowadays due to the need for more awareness regarding this topic among people. Although there are already several establishments of e-waste collection centers, there still needs to be more awareness among the public on proper e-waste handling. Based on this urgency, this study aims to propose a model of an architecture design for designing a Smart E-waste Management System using the Haversine algorithm. This system will work as a medium to disseminate information, create awareness, and educate the public about e-waste and how it would bring harm to humans and the environment if not handled properly. The proposed model was further implemented with the development of a mobile application software called E-Waste System (EWS). This system consists of two types of users: user (the public) and admin. EWS also featured a geolocation function that allows the users to locate any e-waste location nearby them. This function will assist the users in dropping their e-waste in any associated e-waste location to receive points depending on the category of the e-waste. The results of this study present the use case, flowchart, and the final interface of the proposed system. In the future, the proposed system can be improved in terms of the accuracy of the location markers and able to provide real-time updates based on location-based data.*

Keywords: *Smart E-waste Management, Architecture Design, GPS, Haversine*

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Introduction

The Covid-19 pandemic not only causing the world's economic downturn, heaps of deaths, and the world's largest look down, but it also generates another environmental problem which is the staggering of electronic waste (Adejumo & Oluduro, 2021; Ibrahim, 2021). Electronic waste or e-waste is the term used to describe discarded electronics. The restriction of people's mobility causes the need for digitization which increases the consumption of electronic and electrical equipment. This is due to most of the employees switching to the home office and students opting for home-schooling and online learning methods. This in which required them to be equipped with appropriate devices. Thus, they upgraded to new devices, either phones, laptops, tablets, or other electronic and electrical equipment. Although these devices have many benefits, they are also contributing to a huge problem, which is the growing pile of electronic and electrical wastes or e-waste. Baldé and Kuehr (2021), in their study, highlighted as much as 53.6 million metric tonnes of global e-waste generated in the year 2019. However, only 17.4% were appropriately recycled.

A recent report published by the United Nations University (UNU), Sustainable Cycles (SCYCLE), and the United Nations Institute for Training and Research (UNITAR) (2022), which analyses the impact of the Covid-19 pandemic on e-waste in the first quarter of the year 2020. In the first three quarters of 2020, the consumption of game consoles, cell phones, electric ovens, and laptops increased to 0.3 million metric tonnes to the consumption of electronic and electrical equipment, and hence future e-waste generation and this also supported by Baldé and Kuehr (2021) (UNITAR, 2022; Baldé & Kuehr, 2021).

Another interesting study conducted by Adejumo and Oluduro (2021) highlighted the implication of the Covid-19 lockdown on e-waste management in developing countries. The authors few times stressing that the staggering of electronic and electrical equipment due to Covid-19 is like a ticking time bomb that may explode soon if it is not defused in time. Thus, there is a need for developing countries to be cautious when embracing the increased reliance on technological innovations. In addition, they also need to start the conversation and plan for managing the looming increased e-waste situation and start putting measures in place to minimize the generation of e-waste to ensure its proper disposal in an environmentally sound manner (Adejumo & Oluduro, 2021).

Based on the issues addressed earlier, the objective of this study is to propose a model of an architecture design for designing a Smart E-waste Management System using the Haversine algorithm. This system will work as a medium to disseminate information, create awareness, and educate the public about proper e-waste handling and how it would bring harm to humans and the environment if not handled properly.

Literature review

E-Waste in Malaysia

While e-waste generation continues to increase due to rapid technological innovation and changes in human lifestyle on digital technology usage, the lifespan of these electrical and electronic products continues to shorten (BusinessToday, 2023). In Malaysia, nearly 280,000 tonnes, or representing 8.8kg of e-waste per person, were produced (Forti, Baldé, Kuehr, & Bel, 2020). As Malaysia transitions from a middle-high to a high-income country, e-waste production is only expected to increase (Forti, Baldé, Kuehr, & Bel, 2020). Based on research, estimation shows Malaysia will generate 24.5 million units of E-waste in 2025 (Department of

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Environment (DOE), 2023). Currently, it is reported that Malaysia includes only six items of e-waste, which are mobile phones, computers/laptops, television, air-conditioner, refrigerator, and washing machines/dryer (Department of Environment (DOE), 2023). Figure 1 illustrates the prediction statistic for e-waste in Malaysia from 2016 until 2025.

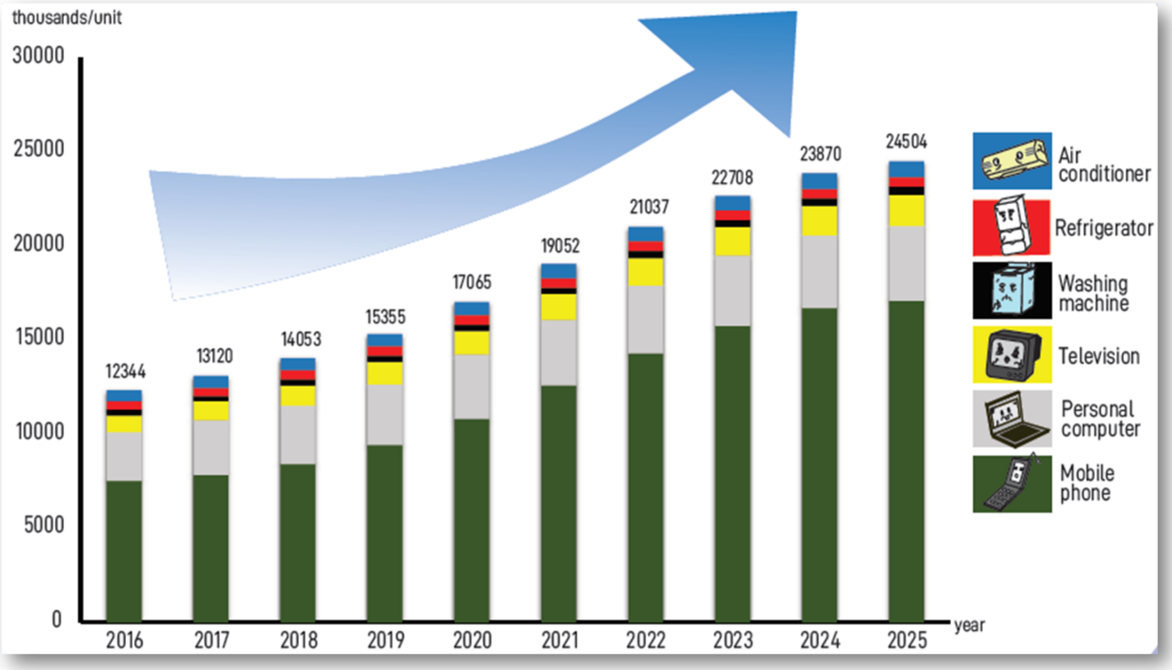

Figure 1: Statistic of e-waste in Malaysia from 2016 until 2025

Awareness and education dissemination about e-waste is still lacking. A study by Mahat et al. (2019) conducted a survey across nine (9) districts in Malaysia to measure the level of awareness of e-waste among Malaysian. The results revealed that the respondents' e-waste disposal knowledge and e-waste disposal attitudes were at a high and medium level; however, their e-waste disposal practice was still in the range of low levels.

This finding was aligned with a study conducted by Hamzah et al. (2020) that found a lack of awareness among the public community in handling proper e-waste. They emphasized that most people out there are not aware of the difference between e-waste and organic waste; hence just throw them out into the trash without knowing the hazardous effect that it could cause on the environment. A local and latest survey in Shah Alam also found that 43% of respondents did not know what e-waste was, and the majority of respondents were not aware of any proper disposal channels for electronics (BusinessToday, 2023). Due to this, studies suggested that required knowledge on e-waste must be delivered through different channels of information sources, and more e-waste collection centers should be established to minimize these effects (Baldé & Kuehr, 2021; BusinessToday, 2023).

Location-Based Services and E-Waste Awareness

Research by Jang and Lee (2018) suggested cooperating with the use of location-based services (LBS) as one of the solutions taken by countries and companies around the world in dealing with natural issues such as e-waste. This approach is environmental preservation, environmentally friendly, and sustainable technology solutions (Jang & Lee, 2018). LBS plays an important role in eco-friendly business activities of the technology industry and continuously

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strives to gain added value and competitive advantage by developing energy-saving techniques and responding to the addressed climate change (Chang et al., 2021).

LBS is a general term indicating software services that use geographic data and information to provide services or information to users or also known as a global positioning system (GPS) (Schiller & Voisard, 2004). LBS commonly used examples include navigation software, social networking services, location-based advertising, and tracking system (Gartner & Huang, 2017). The implementation of LBS across a variety of contexts, such as in healthcare approachability search (Ganesan & Chamundeeswari, 2020), entertainment (Mihale-Wilson, Felka, Hinz, & Spann, 2021; Chen, Lu, & Luor, 2018), indoor object search (Huh & Seo, 2017), smart transportation (Lin, Niu, Li, & Atiquzzaman, 2019), personal life (Xu, Chen, Zhou, Fang, & Liu, 2019), disaster and emergency (Rohman, 2020), as well as education (Huang & Gartner, 2018). LBS also includes personalized weather services (Chen, Gong, Yang, Ma, & Kan, 2020) and even location-based games (Lee, Chiang, & Hsiao, 2018; Tefera & Yang, 2019).

Therefore, underpinning the variety of applications of LBS, its environmentally friendly and sustainable technology solutions, and being combined with the Haversine technique, this study aimed to present an e-waste management mobile application that embeds location-based services as the navigation and tracking system to assist the users in locating the nearest e-waste location centers around them using the Haversine algorithm. The proposed system is known as E-Waste System (after this will be addressed as EWS). EWS also works as a platform to disseminate information and to create awareness in the local community on current e-waste issues.

Material and Method

This section further discusses the LBS technique used, which is the Haversine formula and EWS system design and development.

Geolocation and Haversine Technique

Geolocation is a technology with the capability to locate the exact location of a person or object, including their longitude and latitude, through the GPS of the devices that are being used (Djuknic & Richton, 2001). In the context of the proposed system, geolocation allows the user to locate any e-waste collection center near them, including the distance between the collection center and the current user location. The distance between one location to another location can be calculated using the flat earth formula. However, according to (Swara, 2017), the result of this calculation will become more accurate only when the distance reaches more than 20 kilometers. Thus, Swara (2017) suggested that the Haversine formula is a perfect choice to get the distance between the two locations considering the earth's shape. Figure 2 shows the Haversine formula in the form of a diagram and trig ratio.

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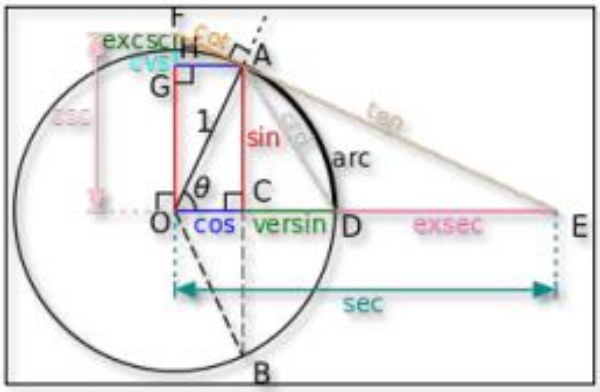

Figure 2: Haversine formula in trig ratio form

In getting the distance between the two locations considering the earth's shape (which is a sphere), the Haversine formula has been applied. Figure 3 shows the Haversine formula applied in the EWS development. The formula requires four important inputs which are:

i. latitude of location A (assumed to be location-from or user current location)
ii. longitude of location A (assumed to be location-from or user current location)
iii. latitude of location B (assumed to be location-to or e-waste drop-off point)
iv. longitude of location B (assumed to be location-to or e-waste drop-off point)

```
public static double GetDistanceFromCurrentPosition(double lat1,double lng1, double lat2, double lng2)
{
    double earthRadius = 3958.75;

    double dLat = Math.toRadians(lat2 - lat1);

    double dLng = Math.toRadians(lng2 - lng1);

    double a = Math.sin(dLat / 2) * Math.sin(dLat / 2)
            + Math.cos(Math.toRadians(lat1))
            * Math.cos(Math.toRadians(lat2)) * Math.sin(dLng / 2)
            * Math.sin(dLng / 2);

    double c = 2 * Math.atan2(Math.sqrt(a), Math.sqrt(1 - a));

    double dist = earthRadius * c;

    int meterConversion = 1609;

    return (int) (dist * meterConversion);
}
```

Figure 3: Haversine formula applied in EWS

In determining the nearest e-waste drop-off location from the user's current location, the logic shown in Figure 4 has been applied. By using for loop, EWS will calculate each of the e-waste drop-off location's latitude and longitude and compare it with the user's current location using the Haversine formula. The return results for each of the calculated distances will be compared using if conditions to determine which of the e-waste drop-off location is the nearest to the current user's location. As a result, the formula and logic applied above can provide the suggested system interface, as shown in Figure 5.

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```
double minimumValue = 0;
double currentValue = 0;

for (DataSnapshot ds : snapshot.getChildren())
{
    EWasteLocationModel EWLM = ds.getValue(EWasteLocationModel.class);

    assert EWLM != null;
    latLngMarkerLoc = new LatLng(EWLM.getLatitude(), EWLM.getLongitude());

    currentValue = GetDistanceFromCurrentPosition(lat1,lng1, EWLM.getLatitude(), EWLM.getLongitude());

    if (minimumValue == 0)
    {
        minimumValue = currentValue;
    }
    if (minimumValue >= currentValue)
    {
        minimumValue = currentValue;
        tvLocationName.setText(EWLM.getLocationName());
        tvFullAddress.setText(EWLM.getFullAddress());
        tvDistance.setText("Nearest E-Waste Drop Point : " + String.format("%.2f", currentValue/1000) + " KM");
        tvNavigateLocName.setText(EWLM.getLocationName());
    }
}
```

Figure 4: Algorithm applied to calculate the nearest e-waste drop-off locations

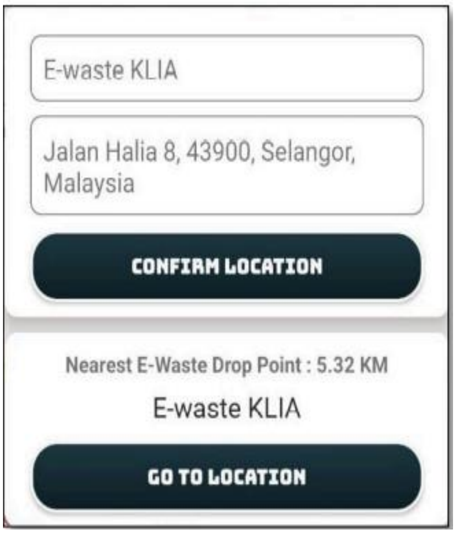

Figure 5: Distance output of nearest e-waste drop-off location presented in EWS

EWS System Design

This section explains the system design of EWS, which consists of the system use case, the overall system flow chart from the admin and user perspective, and the system development. Figure 6 illustrates the use case of the proposed system, while Figure 7 illustrates the overall flowchart of EWS from the admin perspective. Among the functionalities performed by the EWS admin are in charge in managing the 'E-Waste Info' for the purpose to aware and educating the public on e-waste-related issues, the ability to update the e-waste drop-off locations, managing the e-waste items dropped by the users, and handling the e-waste vouchers (as the reward given to the user who donates their e-waste).

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In addition, the main functionalities as the EWS users such as they are able to easily locate the nearest e-waste drop-off locations around them, donate their e-waste at any of the e-waste drop-off locations, can claim or redeem a voucher based on their e-waste donation, and easily manage the e-waste items which they have donated. Figure 8 illustrates the overall flowchart of EWS from the public user perspective.

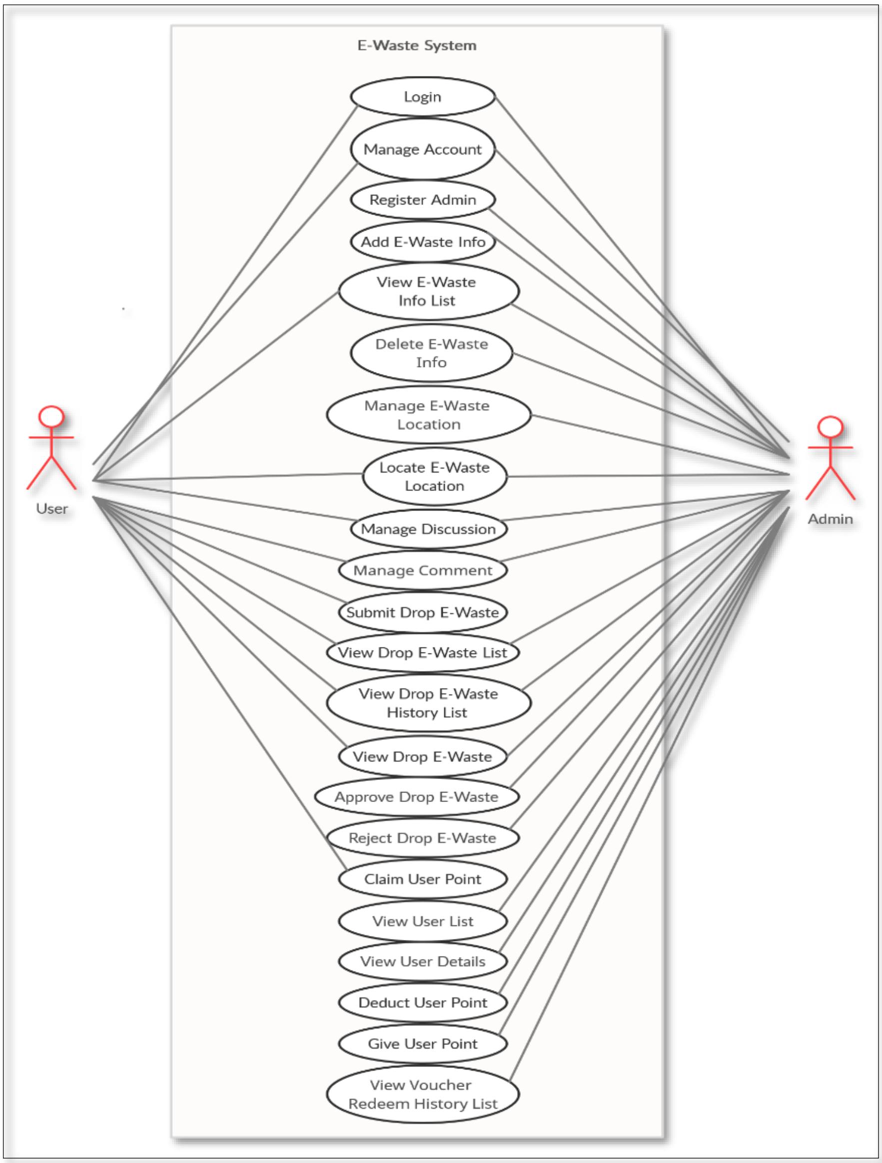

Figure 6: Use Case Diagram for E-Waste System

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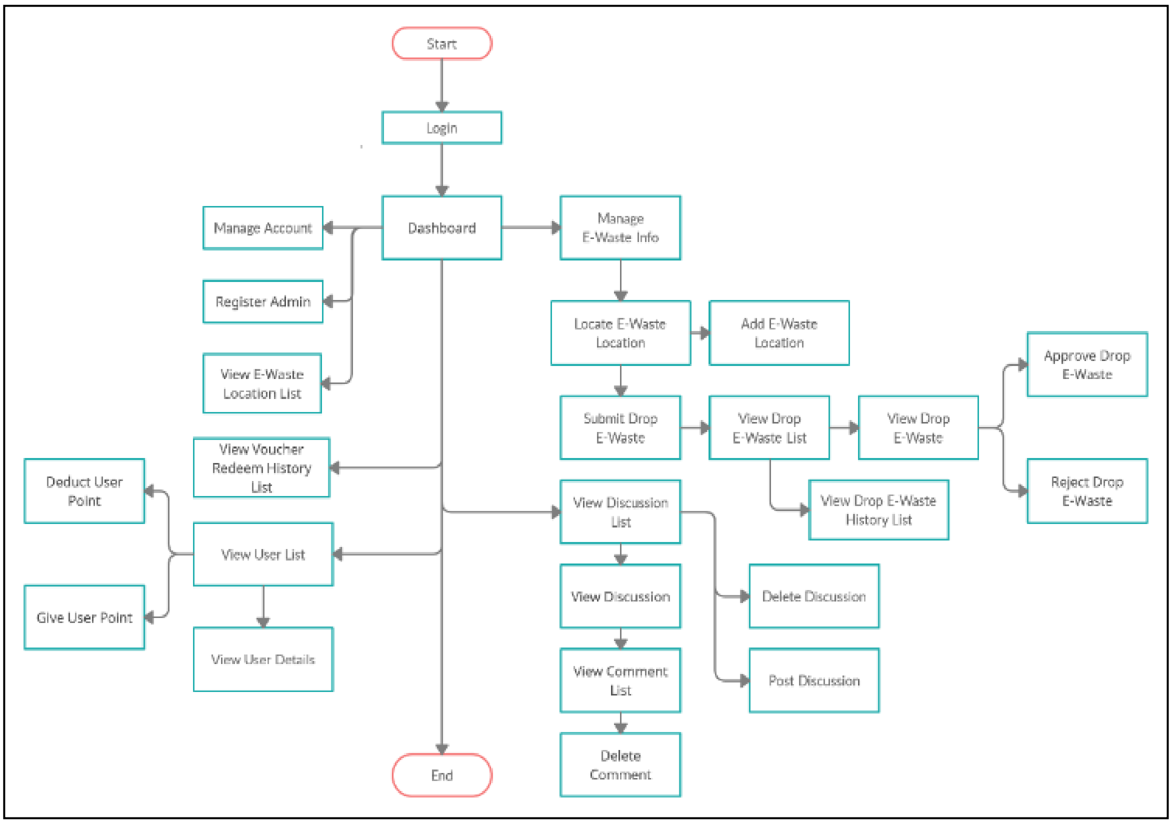

Figure 7: Overall system flowchart of EWS from admin perspective

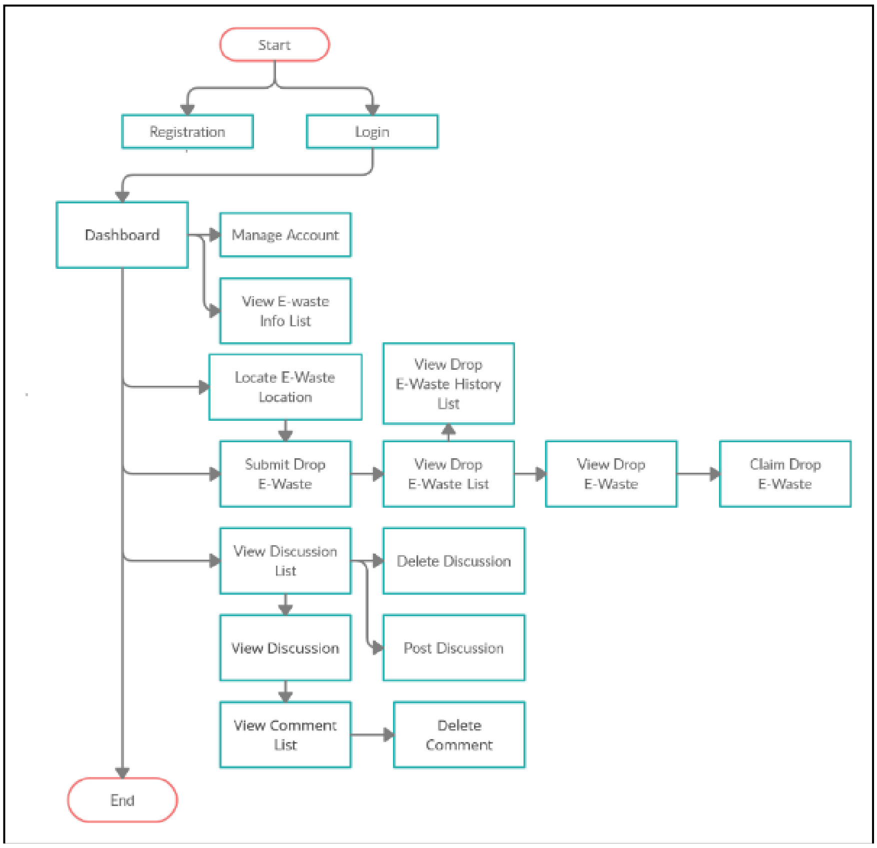

Figure 8: Overall system flowchart of EWS from user perspective

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EWS System Development

Table 1 shows interfaces of the proposed EWS for admin and user functions.

Table 1: EWS Proposed Interfaces

Interface		Name
		Splash screen and start activity of EWS
		Login activity and forget password activity
		User profile and admin profile

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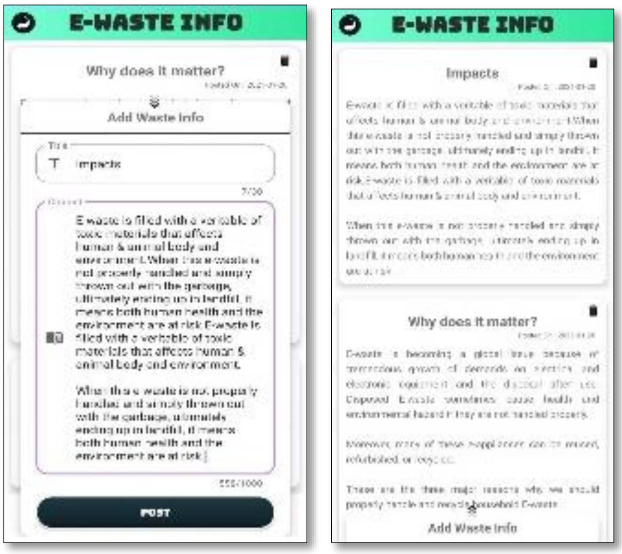
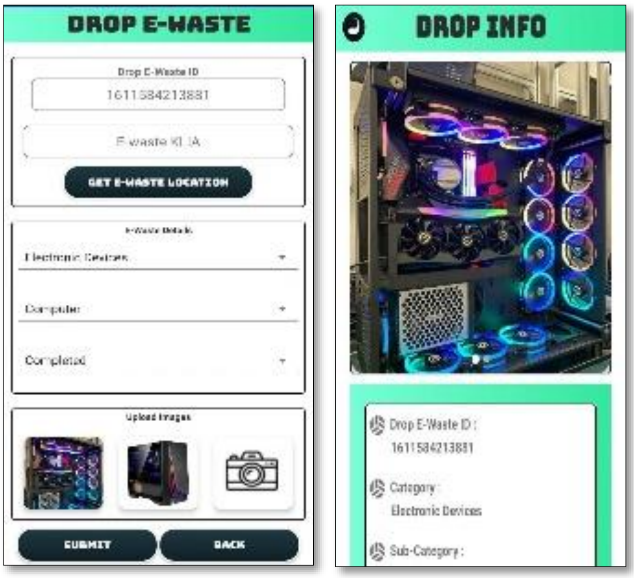
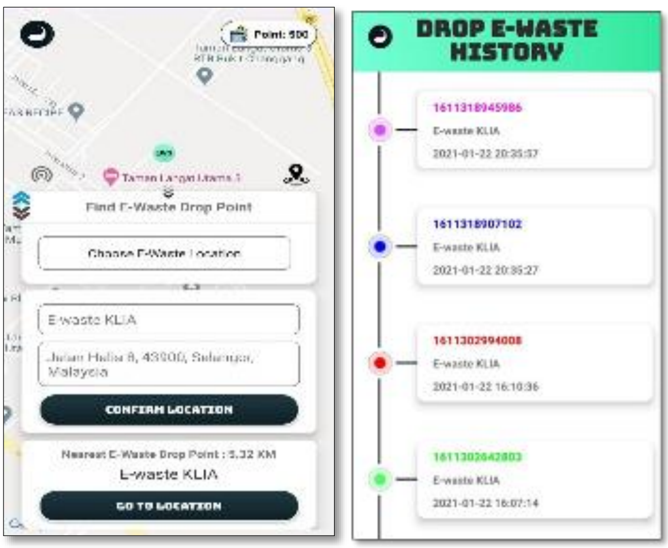


Add e-waste info activity and view e-waste info activity



Drop e-waste activity and view drop e-waste activity



Locate e-waste location activity and view drop e-waste history list

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Result and Discussion

This section discusses the results and findings obtained from the proposed study for location-based service using the Haversine algorithm for Smart E-Waste Management. The proposed system's functionality was further tested to verify if the system had met the aim objectives. Table 2 summarizes the functionality testing results of the proposed system. Overall, the results revealed that all the functionalities passed the required testing.

Table 2: Functionality testing results

Use Case No	Use Case Name	Result
UC01	Login	PASS
UC02	Sign Up	PASS
UC03	View Account	PASS
UC04	Update Account	PASS
UC05	Register Admin	PASS
UC06	Add E-Waste Info	PASS
UC07	View E-Waste Info List	PASS
UC08	Delete E-Waste Info	PASS
UC09	Add E-Waste Location	PASS
UC10	Delete E-Waste Location	PASS
UC11	Locate E-Waste Location	PASS
UC12	View Discussion List	PASS
UC13	Add Discussion	PASS
UC14	Delete Discussion	PASS
UC15	View Discussion	PASS
UC16	View Comment List	PASS
UC17	Delete Comment	PASS
UC18	Submit Drop E-Waste	PASS
UC19	View Drop E-Waste List	PASS
UC20	View Drop E-Waste History List	PASS
UC21	View Drop E-Waste	PASS
UC22	Approve Drop E-Waste	PASS
UC23	Reject Drop E-Waste	PASS
UC24	Claim User Point	PASS
UC25	View User List	PASS
UC26	View User Details	PASS
UC27	Deduct User Point	PASS
UC28	Give User Point	PASS
UC29	View Voucher Redeem History List	PASS

In conclusion, the development of the Smart E-Waste System is a success due to the system's ability to satisfy every requirement stated by the stakeholder and pass all the functionality testing. EWS has also been able to become a solution for the highlighted problems stated earlier, which are the lack of awareness regarding e-waste among the community; people do not know how and where to dispose of their e-waste. Each function implemented in the EWS is found to be a great solution to each of these problems. Aside from that, the EWS was also able to achieve the objective of this study which indicates the completion and success through the system development.

For the future, this study would like to point out several recommendations that can be improved, such as improving the accuracy of the location mark. The improvement in terms of the accuracy of the location mark for the system will add value to the system. It allows EWS to operate and provide much more accurate information concerning location-based details hence also allowing the system to run with both efficiency and accuracy. Next, the study also plans to provide real-time updates on location-based details. Another improvement that could be made to EWS is to implement a capability for the system to provide real-time updates on location-based details. Therefore, it will allow EWS to run the same as any GPS application, such as Waze and Google Maps, where those applications allow their user to find directions to any specific location. As a result of this implementation, aside from locating nearby or any e-waste location on the map, the user can also find the direction to any of those e-waste locations without relying on any of the GPS applications.

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