E-Waste Facility Locator: A Web-Based Platform for Sustainable Electronic Waste Management

Dr. Thrimoorthy N
Presidency University, Bengaluru, India
thrimoorthy.n@presidencyuniversity.in

Thejas C
Presidency University, Bengaluru, India
thejasaw@gmail.com

T M Tejashwini
Presidency University, Bengaluru, India
tmtejashwini64@gmail.com

Vinay K Hiremath
Presidency University, Bengaluru, India
vinaykhiremath2003@gmail.com

Abstract - The world has been experiencing a large production of electronic waste (e-waste) due to the high rate of consumer electronics use that poses great environmental and human-health problems. The project introduces an E-Waste Facility Locator and Awareness Platform (a web-based tool) that seeks to combine geolocation services, educational information and incentives to respond to responsible disposal practices. The website relies on Google Map APIs to find certified recycling facilities and has an awareness dashboard that explains the risks of e-waste and the safety of handling e-waste. Further improvements, such as the credit-based system of reward on confirmed disposal and a chatbot assistant as well as a pickup-scheduling system (with approximate pickup dates and updates on the status) are offered to the users of the website (household and industrial). The system is coded with HTML, CSS, JavaScript, Node.js and MySQL and was designed following the V-Model development method that focuses on the three aspects of accessibility, awareness and engagement with a user. The platform is in line with the E-Waste (Management) Rules 2022 in India and can be applied to achieve several UN Sustainable Development Goals by integrating the principles of digital access and awareness-based participation with the principles of the circular-economy. The system architecture and the implemented modules show great prospect of scalable user-focused e-waste management although full experimental assessment is not yet taken.

Index Terms - E-waste management, awareness systems, recycling, incentive mechanisms, web technologies.

INTRODUCTION

I. Background and Motivation

Use of digital devices has greatly contributed to the generation of e-wastes all over the world. As stated by the Global E-Waste Monitor 2020, the volume of the e-waste produced worldwide was 53.6 million metric tons, of which 17.4% were channeled to formalised recycling systems. It is forecasted that the overall figure can exceed 74 million metric tons by 2030. India is at the third largest producer with over 1.6 million metric tons every year. Although e-waste has precious materials, it contains toxic elements like lead, cadmium and mercury, which are very dangerous to the environment and health as they are handled in an informal manner. These trends indicate that there is a necessity of available digital solutions that can help facilitate appropriate disposal and raise awareness of the users.

II. Problem Statement

Although the regulatory policies include the E-Waste (Management) Rules 2022, there is still a lack of participation in formal recycling by the population. Users do not usually know where to take their waste to an authorized collection centre, how to safely dispose, and what is dangerous to the environment. Solutions that are in place are either fragmented, geographically confined or they are not motivational. As a result, the old electronics end up either lying around in the houses or going through the informal recycling systems where they end up being handled in an unsafe and unregulated manner. It needs a single, consumer-centric platform that will increase awareness, access, and behavioural stimulation.

III. Proposed Solution

It is a proposal of an integrated web platform that will enhance e-waste disposal in a responsible manner, in the following ways:

1. Discovery of certified recycling centres using geolocation.
2. An awareness dashboard that is interactive;
3. A credit-based reward system of certified disposal.
4. Pickup of the household and industrial.
5. Pickup-status tracking that has approximate pickup dates and time windows.
6. An intelligence chat assistant.
7. A repair-reuse marketplace in favor of circular-economy.

Facility verification, submission approvals and allocation of rewards are handled by an administrator module.

IV. Research Objectives

The purposes of this system are to:

1. Create an interface that is easy to use to find authorized recycling centres.
2. Increase the awareness of the populations via organized educational materials.
3. Combine an incentive system to facilitate behavioural change.
4. Offer pick-up booking and approximated arrival timings and progress reports.
5. Lengthen process of device lifecycle through repair and reuse.
6. Checking of support facilities and administration using administrative tools.
7. Design a scalable system that can be used in the institutions and municipal systems.

Literature Review

Electronic waste management has been extensively studied in the fields of environmental science, digital systems and sustainable technologies. The literature of the past indicates the technical, infrastructural and behavioural difficulties linked to increasing amount of e-waste stream and the necessity of integrated and accessible solutions.

Pont et al. [1] conducted a general research of the global challenges of e-waste, including the hazardous components, the lack of recycling infrastructure, and a lack of knowledge. Their examination supports the urgency of the systems that should offer unambiguous disposal instructions and offer more people access to certified recyclers.

A framework to monitor e-waste in smart cities was suggested by Khan and Ahmad [2], which is a blockchain- and IoT-based system. As their work shows, a safe online verification can contribute to more transparency but the computational cost of a full-scale implementation of blockchain makes its adoption in lightweight consumer-facing systems too soon.

Gaur et al. [3] also examined the e-waste ecosystem in India in the perspective of Producer Responsibility Organizations (PROs) which found insufficient cooperation, poor technology acceptance and disjointed recycling systems as persistent obstacles. These results highlight the relevance of digital centralized platforms that can bridge the information gap and provide the user with certified facilities.

Qadir et al. [4] developed a prolonged TOPSIS-based decision model in the assessment of recycling partners in multifaceted fuzzy environments. Though the algorithm is mathematically sophisticated, it helps the concept of algorithmic ranking of facilities, which may be implemented in our system in the future.

The review of blockchain applications in waste management by Ahmad et al. [5] identified their capability in enhancing accountability and lowering the incidences of fraud in the recycling process. Their results indicate possibilities of verifiable digital records integration in e-waste collection procedures in the future.

Chakraborty et al. [6] highlighted the circular-product design and its contribution to the reduced generation of e-waste in the long run. They share the view of the repair-and-reuse marketplace that will be applied within the presented system to encourage the durability of the devices.

Chen and Yee [7] carried out awareness-based research among the students and reported that there was scanty knowledge on safe disposal practices. This observation is a direct result of the necessity of embedded awareness tools, e.g., dashboards and chatbots, in online e-waste systems.

Malagati *et al.* [8] came up with E-Sangrahan, which is an e-waste management system in India. Although the system also featured digital disposal, it did not have incentive measures and scheduling tools, which made it possible to consider increased user engagement strategies.

Chaturvedi et al. [9] came up with SAFA-E which combines Android and web based interfaces in the discovery of facilities and data gathering. Their solution proves the functionality of hybrid systems but lacks behavioural incentive and awareness-based design.

The system in Roy et al. [10] is an automated e-waste segregation and recycling. Though they work in the sphere of mechanical and operational elements of recycling, they emphasize the necessity to introduce digital collection systems to the checked physical recyclers.

In general, the available literature shows:

1. limited public awareness
2. disjointed digital platforms.
3. inadequate participation processes.
4. poor disposal guidance-facility access integration.

These gaps are filled by the proposed system which integrates geolocation, spread-of-awareness, incentive-based participation, and pickup schedule into one digital system. System architecture and methodology.

METHODOLOGY AND SYSTEM ARCHITECTURE

I. Development Approach

The system is created on the basis of the V-Model software development methodology that focuses on the structured flow with the parallel verification and validation stages. This model can be used in applications that need reliability, modularity and guarantees of consistency in quality. Each phase of requirements specification, architectural design, module-level planning, and implementation has a specific test phase that will guarantee systematic validation throughout the development cycle.

II. System Overview

The suggested platform will have three key functional modules:

1. Facility Locator Module, a discovery of approved recycling centres using geolocation.

2. Awareness Module which spreads the environmental safety information concerning e-waste management.

3. Digital credits are granted through Credit and Reward Module that gives credit on verified events of disposal.

The modules work as a coordinated workflow allowing the user to find the disposal facilities, learn safe practices, as well as engage in incentivized recycling. recycling.

III. Architecture Layers

The system is controlled by a multilayered architecture that consists of:

1. Presentation Layer - This layer was developed based on HTML, CSS, JavaScript and Bootstrap and offers an interactive and responsive interface that can be accessed by desktop and mobile devices.

2. Application Layer-Node.js and Express.js are implemented in this layer and it deals with server-side applications, user authentication, API communication, scheduling of operations, chatbot interaction, and reward processing.

3. Data Layer- MySQL relational database is used to store the user accounts, facility records, pickup request data, reward logs, and administrative data. The schema has been made to facilitate efficient queries and role based access.

4. Integration Layer - This layer interacts with external services such as using Google Maps API to find location, JWT to perform secure authentication, and using third-party NLP models to provide assistance to the chatbot.

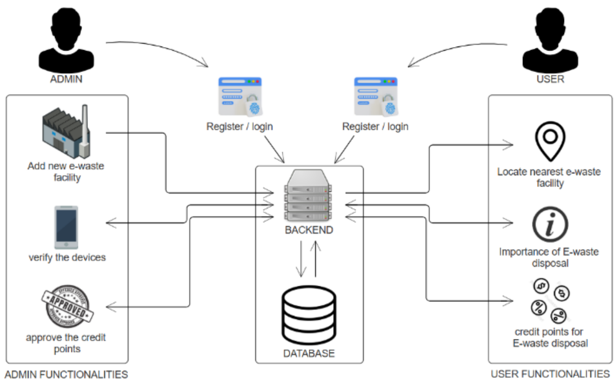

FIGURE 1: Architecture

IV. Workflow

The working process of the system is as follows:

1. The user enters the category of device and where it is found.

2. The Facility Locator uses the geolocation information to locate the closest certified recycling centres.

3. The Awareness Module provides the relevant information about hazards, disposal instructions and safety measures.

4. The user can also make an appointment to pick up the e-waste at their place of residence or industries.

5. This system assigns pickup slot, displays the approximate pickup date/time and status messages (e.g. Scheduled, Assigned, Pending Verification).

6. The digital credits are provided to the account of the user after the administrators or licensed recyclers validate the disposal.

This workflow makes the process of disposal streamlined and awareness based with the help of behavioural incentives.

V. Tools and Technologies Used

Component	Technology Used
Frontend	HTML, CSS, JavaScript, Bootstrap
Backend	Node.js, Express.js
Database	MySQL
APIs	Google Maps API
Authentication	JWT (JSON Web Tokens)
Hosting	AWS / Firebase Cloud
Chatbot	NLP-based AI Model
Development Model	V-Model SDLC

IMPLEMENTATION AND MODULE DESCRIPTION

I. System Implementation

The E-Waste Facility Locator is developed as a modular web-based application, which is extensively designed to support extensions, maintainability and secure multi-user interactions. The system combines a web frontend, a Node.js-based server, and a MySQL relational database, which are made on scalable cloud infrastructure. The front is designed on HTML, CSS, JavaScript, and bootstrap to provide a responsive user interface comprising of facility discovery, pickup schedule, awareness content, and digital credit management dashboards.

The backend is developed using Node.js and Express.js; it carries out server-side business logic, request processing, authentication, job scheduling, chatbot, and administrative tasks. MySQL database schema contains facility logs, user description logs, pickup logs, credit logs and administration logs. The schema assists in role-based access control and it guarantees efficient execution of queries.

The cloud implementation (AWS / Firebase) is highly available and has load balancing and automated backups to be available.

System security is applied in the form of an HTTPS-based communication, authentication, and encrypted data processing, as well as adherence to the E-Waste (Management) Rules 2022 and the Digital Personal Data Protection Act (DPDPA) 2023.

II. Module Description

1. User Registration and Login: This module allows onboarding and access of users safely. Encrypted credentials and JWT-based sessions are used in registration and authentication. Users have access to the history of their disposal, scheduled pick-ups, credit earned, and the profile settings.
2. Facility Locator Module: The module is the one that uses Google Maps API to show the certified e-waste recycling centres after the location of the user. It contains information on the facilities including address, contact, wastes accepted, and opening hours.

3. Pickup Scheduling Module: The scheduling module is of two types:

   a. Doorstep Pickup: Customers may make pickup orders of household electronics. The system allocates a slot according to the availability and gives an approximation of pickup dates as well as the statuses which include Scheduled, Pending Assignment, and Completed.

   b. Industrial Pickup: Companies may make a demand of the bulk or large scale e-waste collection. The system maintains adherence to the regulatory principles and sends automatic alerts to licensed recyclers and administrators.
4. Awareness Dashboard: This module is designed to offer a systematic educational experience such as hazard details, disposal, infographics, eco-tips, and interactivity. The dashboard will be developed in a way that makes the user learn more and adopt sustainable disposal behaviour.
5. Credit and Reward System: This module will bring in an engagement system modeled as gamification where credits are earned due to verified e-waste disposals. Credits are also awarded according to the category of device and confirmation of the recycler and may be exchanged in terms of vouchers, discounts or eco-friendly products.
6. Admin Panel: Administrators are able to control the listing of facilities, to validate the pickup submissions, to verify the disposal claims, to control the assigning of rewards. Analytical summaries are also available on the panel and help in policy evaluation through showing aggregated disposal data.
7. Chatbot Assistant: A chatbot is a chatbot based on NLP and does not have any particular specialty, but it offers real-time assistance in all the areas of the facility, system navigation, information scheduling and environmental consciousness. It minimizes the workload of manual services and increases accessibility by the user.
8. Repair and Reuse Marketplace: This module facilitates practices of a circular-economy because it links users with certified technicians, refurbishers, and second-hand buyers. It gives a second life to functional devices through repair, refurbishment, and re-use of used devices responsibly to increase their lifecycle, and minimize waste production.

RESULTS AND DISCUSSION

I. System Evaluation

Evaluation of the system was done by conducting functional validation, interface-testing, and workflow verification that would help in confirming that the implemented modules functioned appropriately. Functional tests ensured that the main features were performed properly as the facility discovery, awareness content delivery, pickup scheduling with estimated pickup dates, and credit allocation after the validation. Authentication and form-handling procedures were checked to make sure that the input is reliable and the sessions can be managed. Performance tests revealed that the platform can react predictably when used in normal conditions, and all modules can communicate effectively in a clearly defined API.

II. Discussion

The e-waste management tools available in the market mainly aim at finding recycling centres or offering informational materials. The suggested platform goes further than these functions since it incorporates the awareness mechanisms, incentive-driven engagement, and the system-based pickup scheduling. With the combination of the facility mapping, education support and behavioural motivation, the users can actively engage in responsible disposal practices. Though experimental research has not been carried out formally yet, the adopted architecture and modular design suggest great prospects of scalability, community adoption, and integration in the future with regulation or municipal waste-management models.

FUTURE WORK

The existing implementation provides a practical basis of the geolocation-based discovery of facilities, spread of awareness, the presence of incentives to participate, and the organization of pickup schedules. The system can be enhanced further with several improvements that will strengthen the capabilities of the system and its overall impact in the society in the long-term.

1. Mobile Application Development: An Android and iOS native application can be used to increase accessibility, real-time alerts, pick-up scheduling, and offline awareness content.

2. AI-Based Predictive Analytics: ML algorithms can be used to study the disposal patterns and predict the high-

demand pick-up areas, as well as optimization of the scheduling operation and resources distribution.

3. Blockchain-The use of blockchain can be used to enhance validation of disposal, rewarding, and authentication of recyclers to guarantee no one can tamper with the records and enhance trust among the stakeholders.

4. Government/ PRO Co-operation: Co-operation with municipal government and Producer Responsibility Organization (PROs) could allow large-scale implementation, formal certification of facilities, and connection with city-wide or state-wide waste management.

5. IoT-Enabled Smart Bins: Smart collection bins that have sensors can be launched with the ability to automatically alert on the level of the fill, pick up orders, and less manual supervision.

6. Higher Cognition and Gamification: The next generation can involve interactive campaigns, eco-challenges, user-based achievements, and competitions based on rewards that will help maintain a long-term interest and encourage environmental responsibility.

7. Analysis and Dashboards to Guide Policy: Analytical dashboards will be used to give policy makers, recyclers and environmental agencies insights that are actionable based on the aggregation of user activity, disposal patterns and facility demand data.

8. Marketplace Expansion: The repair-and-reuse market may be expanded along with AI-based device condition evaluation, verification indicators of technicians, and eco-labeling campaigns to enforce the principles of the circular-economy.

REFERENCES

[1] A. Pont, A. Robles, and J. A. Gil, "E-WASTE: Everything an ICT Scientist and Developer Should Know," *IEEE Access*, vol. 7, 2019.

[2] A. U. R. Khan and R. W. Ahmad, "A Blockchain-Based IoT-Enabled E-Waste Tracking and Tracing System for Smart Cities," *IEEE Access*, vol. 10, 2022.

[3] T. S. Gaur, V. Yadav, S. Mittal, S. Singh, and M. A. Khan, "E-Waste Management Challenges in India from the Perspective of Producer Responsibility Organizations," *IEEE Access*, vol. 13, 2025.

[4] A. Qadir, S. Abdullah, S. Khan, and F. Khan, "A New Extended TOPSIS Method for E-Waste Recycling Partner Selection Under Complex Pythagorean Fuzzy Rough Dombi Aggregation Operator," *IEEE Access*, vol. 12, 2024.

[5] R. W. Ahmad, K. Salah, R. Jayaraman, I. Yaqoob, and M. Omar, "Blockchain for Waste Management in Smart Cities: A Survey," *IEEE Access*, vol. 9, 2021.

[6] M. Chakraborty, J. Kettle, and R. Dahiya, "Electronic Waste Reduction Through Devices and Printed Circuit Boards Designed for Circularity," *IEEE Access*, vol. 12, 2024.

[7] L. F. Chen and H. W. Yee, "E-Waste Management: Are We Ready for It? — A Study on the Awareness of COIT Students Toward E-Waste Management," in *Proc. IEEE Conf. Sustainable Systems and Technology (ISSST)*, 2011.

[8] N. S. Malagati, M. Rajesh, and B. Sreevidya, "E-Sangrahan: A Sustainable Paradigm and Comprehensive Framework for Efficient E-Waste Management Towards a Greener Future," in *Proc. IEEE Int. Conf. Smart Technologies for Smart Nation (SmartTechCon)*, 2019.

[9] V. Chaturvedi, R. Babbar, I. Arora, D. Varshney, and U. Hariharan, "SAFA-E: The E-Waste Management System," in *Proc. IEEE Int. Conf. Innovation and Technology in Computer Science and Engineering (ITCSE)*, 2021.

[10] M. S. Roy, M. N. I. Lusan, M. A. R. Khan, M. P. Khan, A. Ahmed, and M. S. R. Zishan, "Design and Development of E-Waste Monitoring, Segregation and Recycling System," in *Proc. IEEE Int. Conf. Computer and Information Technology (ICCIT)*, 2021.