**Towards a Greener Future: Addressing Infrastructural Challenges in e-Waste Management**

**Abstract:** E-Waste Management system (Scrapmanager) represents a crucial step toward addressing the escalating global crisis of electronic waste (e-waste). As technology advances at an unprecedented pace, the rapid obsolescence of electronic devices poses significant environmental and health risks. We are facing issues in e-waste management at three levels. Firts this sector is diminated by informal infrastructure like kbarialas. Second there is not enough authorized recycling facilities in proportion with the amount of e-waste generated. Latly people are not much aware about the e-waste recycling recycling. Also the policies about the e-waste management are not strategically placed. Our proposed model the scrapmanager is a step to create a sustainable ecosystem by bridging the gap between responsible disposal and environmental preservation. Key features of this system are clean UI design which makes it accessible to all, connects users with certified e-waste collectors across cities. Our proposed system (Scrapmanager) educates users about impact of e-waste through informative articles, infographics, and FAQs. This system contributes to economic growth and sustainable development of the earth. Aim of this system is to protect the environment from the hazardous element used in electronic devices. This system is a platform to connect e-waste sources with the right recycling facilities. Scrapmanager isn’t just a system, it’s a promise—to our planet, future generations, and collective responsibility.

**Keywords***: scrap, e-waste, recycling, environment, dispose, sustainability, awareness, Circular Economy (CE), Extended Producer Responsibility (EPR)*

**1 Introduction**

### Electronic-waste is continuously growing, at a progress rate of 20-25% annually[1]. E-waste termed electronic waste is discarded electronic products that have extended its valuable life. With the fast pace of technological advancements, e-waste accumulates at an astonishing rate[2] as shown in Figure 1. This category of waste includes a wide range of items like computers, entertainment devices, mobile phones, refrigerators and televisions. E-waste may be destined for various fates, such as reuse, resale, salvage, recycling, or disposal. Proper handling and recycling of e-waste is essential to prevent environmental pollution and to recover appreciated materials[3].

In today’s global business landscape, green initiatives play a crucial role in shaping our economy. Among these, waste recycling stands out as a powerful driver (Figure 2) for positive environmental impact. Electronic waste is a critical area of concern due to its unique characteristics:

* Fastest Growing Segment: E-waste is the world's widest-growing category of waste.
* Inherent Value: It holds valuable resources which includes rare earth elements, and reusable components.
* Environmental Hazzard: E-waste can be highly hazardous due to toxic substances like lead, mercury, and cadmium if not handled properly.

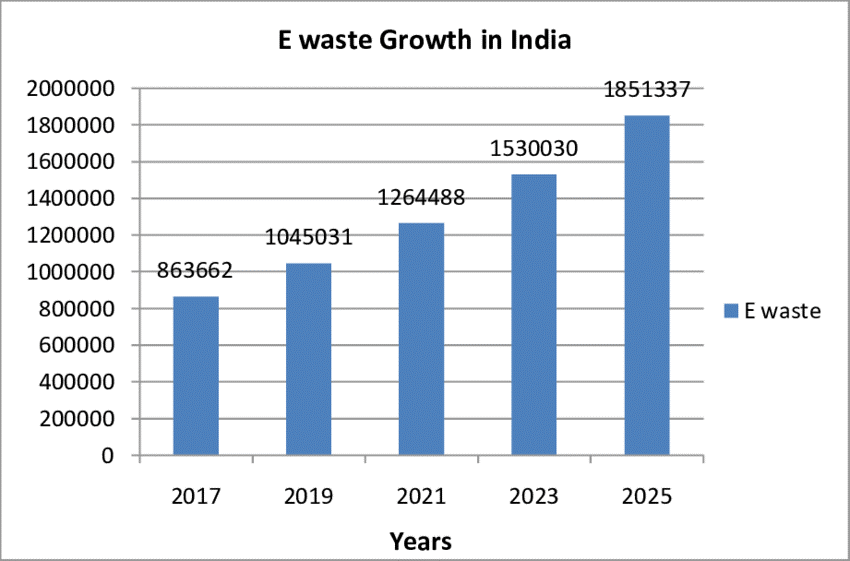


Fig-1 e-waste growth

According to data presented by the Union Ministry of Housing and Urban Affairs, fig -1 shows the trend in the rise of e-waste in last few years

Despite its potential, the e-waste management sector remains largely unorganized and labour intensive. In India and globally, much of e-waste fall under the purview of the unorganized and informal sector. Lack of awareness, skills, and proper processes has hindered the sector’s growth [4]. Some plans for maintaining electronic waste, offers the new evaluation methods for e-waste recycling [5].

* 1. **Key Features of Smart e-waste Management**

This is a waste management app which offers users a number of functionalities. It simplifies numerous repetitive tasks within the system, Below are few key features of a Smart Waste Management app:

* Bin Inventory: Through the bin inventory feature, users can view and track bins across various locations. The app allows users to see waste containers on a map and access detailed information about each bin, such as its capacity, waste type, location, fill level, and collection schedule.
* Real-time Data: By utilizing sensors, users can gather real-time data from the bins, providing insights into whether a waste container is empty or full. Additionally, the app enables users to predict when the bin is likely to fill up, helping them track the last waste collection time. This functionality ensures that the smart waste management app prevents waste overflow by offering timely information.
* Bin Filling Cycle: This feature enables users to track the filling cycle of the garbage bin. It provides filling graphs that inform users of the optimal times to collect waste. This ultimately helps save both collection time and costs.

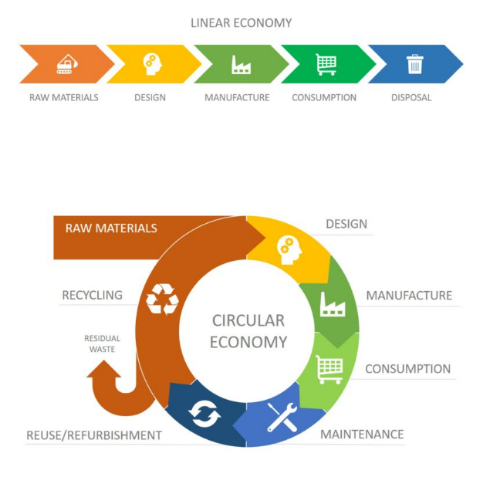


Fig -2: Linear economy to circular economy

As shown in the Fig 2, the scrapmanager presented here is key to a consumption model. Here the disposal stage in the life cycle of a product is replaced with refurbishment stage. The model keeps the product into the ecosystem for an optimal usage.

* Pick Evaluation: Pick evaluation tracks the number of bins collected and missed during each cycle. Using sensors, users can identify which waste containers were overlooked during collection. This feature also helps users create an efficient collection schedule, ensuring that no bins are left half-empty.
* •Bin Distribution: This feature enables users to optimize bin distribution by identifying areas with too few or too many bins. Smart waste management apps help balance the allocation, allowing users to adjust the placement of containers based on the specific needs of each location.
* Waste Collection: Route: Users can determine the most efficient routes for garbage collection and schedule waste pickups accordingly.
* Cost Estimation :Users can estimate the cost of waste management services by using various variables to calculate overall collection expenses. Some apps allow users to set costs based on factors such as the number of bins, vehicles, depots, and waste disposal.
* Real-time Analytics and Reporting: Citizens can report any issues or complaints related to the bins by providing photos and location details. This feature helps service providers address and resolve the issues promptly.

The foremost purpose of Scrapmanager is to provide another method for the client to dispose the electronic waste material. E-Waste Management System (Scrapmanager) is a web-based system that can be opened from anywhere using internet by anyone. It is an automatic system, where we will automate the vending of waste material and the enquiries about the waste equipment for collection. By adopting organized practices, we can transform e-waste management into a non-profitable recycling sector which is used for creating awareness for saving environment. Through Scrapmanager, we envision:

* Sustainable Practices: Implementing sustainable practices that minimize environmental impact.
* Awareness: Raising awareness about responsible e-waste disposal among businesses and individuals.
* Profitability: Demonstrating e-waste management can be both environmentally responsible and highly profitable.
* To offer customers convenient, on-demand services anytime, anywhere.
* To promote the recycling and reuse of electronic waste materials.
* To minimize the buildup of electronic waste in homes.
* To spread awareness about the destructive effects of electronic waste.

**2. Literature Survey**

The inclusive literature review on e-waste management methods is essential part of every research and provides an extensive understanding of the current state and ongoing developments in this field. It finds the research gaps, support to understand the background and recognize the importance of technological innovations in modifying the environmental and health impacts of e-waste[6]. A complete literature review is given in Table 1.

Table 1: Interface of the tool

|  |  |  |
| --- | --- | --- |
| S. No. | Objective of Study | Findings |
| 1. | The study employed a range of methods to assess stakeholders and factors impacting waste management performance, including literature reviews, database analysis, field observations, and structured interviews with professionals, workshop exercises, and stakeholder questionnaires. | The research results provide a detailed list of key stakeholders and identify critical factors contributing to the failure of waste management systems[5]. |
| 2. | This research investigates public awareness about the disposal of outdated electronic devices and proposes a sustainable framework for e-waste management. | It also examines the contribution of Extended Producer Duty (EPD) in addressing e-waste and underscores the importance of green manufacturing practices The article list the approaches to develop effective solutions for electronic waste. |
|  | Environmental consequences of improper e-waste disposal (19) | This article states India's current e-waste challenges, along with the setbacks in recycling and disposal |
|  | A comparison of the disposal of waste electrical and electronic equipment in the EU and India (17) | Understanding waste electronic equipment (WEEE or e-waste) is crucial for actual e-waste management. |
|  | This review examines the global e-waste issue concerning health of Indian public and referring for improving electronic waste management practices. | The review highlights that e-waste represents a severe threat to public health, with noteworthy environmental and health risks. Developing countries like India, are struggling with inadequate implementation of formal recycling processes. To address this, India should adopt more effective life cycle assessment models that have proven successful in other developing countries [16]. |
|  | This paper explores e-waste management practices within the informal sector, focusing on the working and living conditions at various dismantling sites in Delhi. Through unstructured interviews with e-waste workers, it delves into their views on risks and the economic dynamics of recycling in this sector. | Given the significant health hazards linked to e-waste and the large number of individuals involved, the paper emphasizes the urgent need for legal reforms to protect workers' rights and enhance safety measures. |
|  | Awareness and understanding of public on e-waste in urban areas of India. | The urban context for understanding people's awareness of the origins of e-waste issues and its management. |
|  | The study highlights ten major barriers to waste managing, drawing on existing literature and expert insights. Using informative structural modeling (ISM) with Decision Making Trial methodologies, examine the hierarchical and contextual relationships among these obstacles. | Findings of this study reveal that no barrier functions independently. Notably, insufficient civic alertness about e-waste reusing and weak strategies related to e-waste are identified as key root causes. |
|  | Author examines recent advancements in e-waste production and management, as well as current recycling technologies. | Paper evaluated the impacts of recycling processes and materials on human health and the our environment too. |
|  | In this paper author explores recent advancements in e-waste generation and management, with current recycling technologies[13]. | The paper also highlighted the challenges in e-waste management, especially in India, and recommends essential policy interventions. |
|  | This paper collects comprehensive data on e-waste management strategies, policies, and standards to provide a detailed review of the current electronic waste and detect its challenges. | This survey will establish a basis for sharing information and best practices related to e-waste, serving as an essential resource for promoting future collaborative efforts in the field [18] |
|  | The author aimed to tackle the challenges associated with casual reprocessing applies prevalent in many emerging countries. These methods are often rudimentary, resulting in a substantial amount of electronic-waste components being discarded in unhygienic, abandoned landfills and open dump sites[5]. | Author proposed a systematic approach to e-waste management called Integrated E-Waste Management (IEWM). This method provides a robust framework to integrate public solid waste with e-waste management systems. |
|  | Author’s goal was to identify a feasible approach for implementing a simplified version of extended producer responsibility in developing countries. | Essential elements for operative e-waste management in developing countries include shifts in government perspectives, the development of specific e-waste legislation, and improved control over e-waste disposal [8]. |
|  | It aims to present a summary of different technologies used for recovering valuable metals from e-waste, highlighting the significant advancements in recycling methods in recent years[11]. | This discussion explores the benefits and environmental effects of these recycling methods, while also addressing the challenges that must be overcome for their future development and broader implementation. |
|  | Impact of e-waste in Indian econimical system [22] | Formal sectors are working toward E-waste management. but bacause of the lack of competent infrastructure to manage E-waste, informal sectors have rapidly evolved in India and about 95% of the E-waste generated in India is handled by informal sectors. |
|  | This book has objective to elaborate the challenges and opportunities in the strategies and practices to handle with e-waste. [22] | It includes a survey on pan-India initiatives for effective e-waste management through Extended Producer Responsibility (EPR) along with the responses collected from producers. |
|  | This chapter discovers the possibilities of Circular Economy implementation in our country for e-waste details the issues and challenges evolved though the proposed solution architecture [23] | Paper states two importatnt terms in this diretion which are, e-waste management rules 2016 (amended in 2018) emphasis on [extended producer responsibility](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/extended-producer-responsibility), and the national resource efficiency policy 2019 to emphasise on [circular economy](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/circular-economy) (CE) ideology. |
|  | This article pinpoint the factors which can contribute to set up an environmrnt to recycling initiative. [24] | Paper comes out with the conclusion that implementing promising financial incentives is critical for fostering recycling initiatives in India. |
|  | Paper aim to display te challenges tackled by the formal sector in e-waste collection which are either due to the lack awareness among people or very few collection centers throughout the country. Quantification of e-waste in India is very difficult as imported or second-hand electronic gadgets are difficult to be put in electronic waste. [25] | Paper concludes that There is no formal channel or mechanism for collecting data regarding e-waste generation in Indian states or at central Government level. The extimated quantification of it is solely based on the indigenous production and import of electronic goods. |

1. **System Reviewed**:

The proposed system aims to automate the selling of waste material and facilitate inquiries related to waste equipment collection, specifically focusing on e-waste. E-waste refers to discarded electrical or electronic devices, including computers, phones, televisions, and other gadgets. The rise in the usage of electronic products has led to a significant increase in the volume of e-waste, making it a pressing environmental issue. However, by implementing an automated system, this challenge can be transformed into a sustainable and non-profit-driven solution that promotes recycling and environmental awareness.

Components of the System as shown in Fig 3:

* Automated Waste Selling Platform: This component allows individuals and businesses to sell their e-waste materials online through an easy-to-use platform. The system automatically evaluates the type, quantity, and value of the waste materials being sold, ensuring fair pricing and offering a streamlined process. Sellers can simply upload details of their e-waste, and the system handles the transaction, making it easy for everyone to participate in recycling.
* Automated Inquiries for Waste Collection Equipment: The main barrier to effective e-waste recycling is the lack of access to proper collection equipment. This automated system would allow users to make inquiries regarding the availability of waste collection tools, like bins or large containers to gather e-waste in bulk. By automating this process, we ensure that those who wish to recycle can easily find the resources they need to store and dispose of their e-waste properly.
* Non-Profit Recycling Model: The system operates on a non-profit basis, where the primary objective is not to make a profit but to promote environmental sustainability. Funds raised through the sale of recycled materials are reinvested into the system, helping cover operational costs and funding awareness campaigns. This approach ensures that all actions taken are in the interest of environmental conservation and public education.
* Raising Awareness for E-Waste Management: One of the system’s main goals is to raise awareness about the significance of proper e-waste management. By offering an automated, user-friendly platform, the system will engage more individuals in the recycling process. Additionally, it will include educational resources, such as articles, guides, and infographics, to make users aware about the dangers of inappropriate disposal and the uses of recycling electronic devices. This educational component is key to inspiring long-term changes in consumer behavior.
* Environmental Impact: The e-waste recycling system emphasizes on reducing the harmful effects of electronic waste on the environment. Improper disposal of e-waste leads to toxic substances like lead, mercury, and cadmium leaching into the ground and water systems. By automating the collection and recycling process, this initiative aims to reduce e-waste landfills, recover valuable materials, and ensure that the disposal is done in an environmentally responsible way.

This automated system represents a proactive, organized approach to e-waste managing. By automating both the selling of waste material and the inquiry process for collection equipment, it makes recycling easier, more efficient, and accessible. Furthermore, by operating on a non-profit model, the system is driven by the mission of creating environmental awareness and contributing to a cleaner planet. Through such initiatives, the system can not only manage e-waste but also drive broader social change by educating the public on the significance of recycling and its role in preserving the environment.

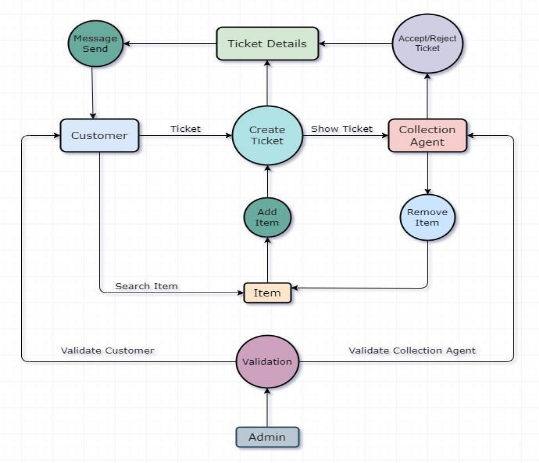


Fig. 3: Components of proposed System

As per fig 3, the system manages entities customer and collection agents. Items accepted for e-waste by the collection agent are maintained. Although the price list of e-waste items are not publicized to the customers. The customer can be subsidized for e-waste deposit to some collection agents. The ticket has the collection agent, customer, item type and the price agreed for collection by the agent.

Figure 4 represents the dynamic aspects of a system, business process, or workflow. They depict the steps involved in the execution of a proposed system.

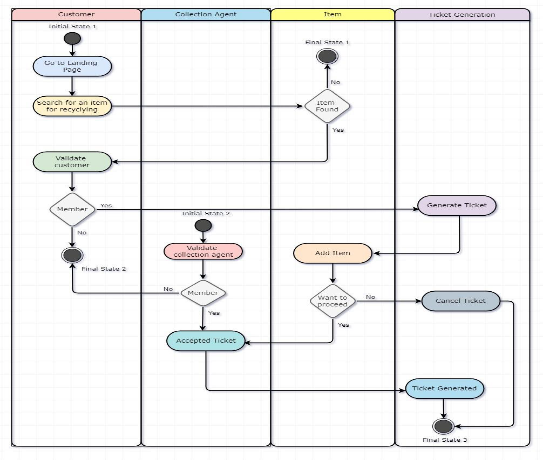


Figure 4: workflow of proposed system

The realization of e-waste management pivots on the incorporation of formal recycling process adopted and the informal e- waste management system.

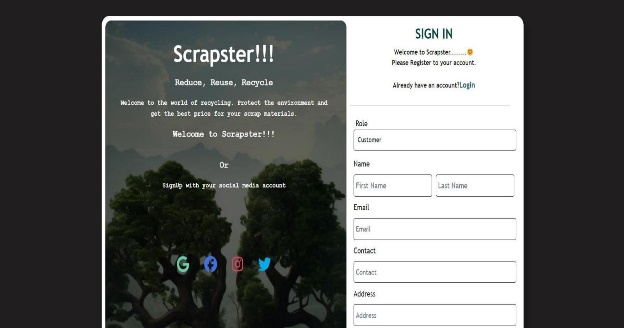
1. **Tool Test Results**

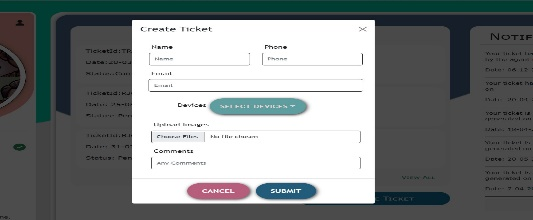
Following table 1: Displays the output screens of our proposed e-waste management system:

##### Table 1: Deails User Dashboards

##### Fig 5.Sign up to the tool

##### Fig 6.Sign up page for customer or the collection agent



Fig 7. Sign in page

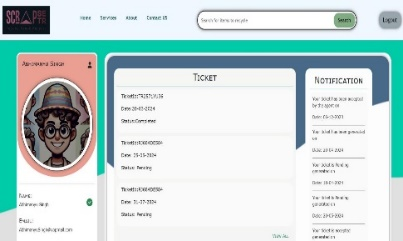




Fig 8. Ticket generate page

The dashboard shows the status of the ticket generated by the customer. Once the collection agent joins the app the tickets generated by the customer are presented (state) to the collection agent. The collection agents once approves the item mentioned in the ticket, the ticket comes to the Accept (state). The ticket remains in the Pending state after the pick update till the item is picked.

1. **Conclusion**

E-waste management is a crucial environmental and community health concern, driven by the rapid advancement of technology and increase in consumer demand for new electronic gadgets. The literature highlights the urgent need for effective recycling systems, stringent regulations, and greater public awareness to mitigate the harmful effects of electronic waste. Despite ongoing efforts, challenges such as improper disposal, lack of awareness, and inefficient recycling infrastructure persist. E-waste, the rejected electronic equipment that accumulates in landfills, poses a significant risk to our environmental conditions and health. The rapid pace of technological advancement intensifies this problem, as consumers frequently upgrade their devices. Our mission was clear: create a platform that bridges the gap between responsible disposal and environmental preservation. Scrapmanager is a digital ecosystem where users could seamlessly recycle their old gadgets. Scrapmanager allows users to register, log in, and submit e-waste pickup requests effortlessly. The clean layout ensures that even non-tech- savvy individuals can participate. It connects users with certified e-waste collectors.

1. **Suggestions**

We have e-waste management regulations. One of them is e-waste management and handling rule in 2011 which talks about the extended producer responsibility in four different ways. The incentives are given to the producers by the local government. This rule comes to a challenge where a product has multiple components or have a complex supply chain. Smartphones too comes to this category.ERP stategy is not diretly applicable here. The sustainability of such a model of e-waste management is critical in lieu of the factor like the current strategies are not motivating customers for sustainable consumption of electronic goods. The concept of lean manufacturing is a move to sustainable production but due to the lack of the awareness customer are motivated to the usage of the product which has a longer life span.

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# [Varsha Bhagat-Ganguly](https://www.taylorfrancis.com/search?contributorName=Varsha%20Bhagat-Ganguly&contributorRole=author&redirectFromPDP=true&context=ubx), E-Waste Management

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