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Junk Classifier: A Smart Approach to e-Waste Management in India

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Abstract
Combining artificial intelligence, image recognition, and automated systems, the "E-Junk Classifier and Waste Manager" project presents a novel, tech-driven solution to India's ongoing waste management problems. This system is designed to recognize and classify municipal and electronic waste and then automatically direct it to the corresponding waste recycling centers. Its basic components include a simple digital interface that allows custom-ers to schedule waste pickups, an image-based pricing estimator that analyzes the value of scrap materials, and a route optimization tool that utilizes Dijkstra's algorithm to move col-lected waste efficiently. Using robotics in sorting reduces human contact with dangerous chemicals and improves categorization accuracy. Supporting environmental sustainability and in line with Smart City goals, the system aims to significantly reduce landfill buildup and marine pollution, substantially increase recycling efficiency from approximately 20% to over 60%, and generate economic benefits from recovered materials. To ensure a lasting, favorable impact, it also emphasizes public participation, collaboration among stakeholders, and long-term sustainability.

Keywords: *Smart Waste Management; E-Waste, Machine Learning; Robotics; Waste Recycling; Sustainability; Dijkstra's Algorithm.*

INTRODUCTION

Particularly in fast-growing nations like India, the increasing volume of electronic and municipal solid waste (MSW) is a primary environmental and public health concern. Global e-waste is projected to skyrocket to 62 million tons by 2022; forecasts indicate it may reach 82 million tons by 2030, but only just over 22.3% of this waste is correctly recycled (Forti et al., 2023). In India, poor disposal methods continue to pollute groundwater and air, thereby aggravating health concerns (Mishra et al., 2022). A Smart Waste Monetizing System has been suggested to address this problem by motivating people to recycle garbage in return for money properly. Users of this method start by gathering recyclable objects—such as metals, plastics, or paper—and then post pictures via a smartphone app to arrange for pickup. By by-passing intermediaries, this digital model ensures a more transparent and efficient flow. After that, collection vans transport the trash to approved recycling facilities; users are compensated for their contribution to sustainability. Conventional trash management techniques are in effective and pose a serious threat to public health, as they primarily rely on manual labor. Particularly, Deep Convolutional Neural Networks (CNNs) and emerging technologies such as artificial intelligence (AI) and machine learning (ML) have demonstrated categorization accuracy of up to 98%, surpassing human sorting techniques (Singh & Thakur, 2023). CNNs are used by solutions such as ConvoWaste to automate segregation, hence enhancing speed and accuracy (Rao et al., 2023). Smart bins equipped with IoT sensors can also track garbage volume, allowing for more effective routing, a 13.35% reduction in operational expenses, and a 36.8% decrease in travel distances (Yadav & Sharma, 2023). AI-enhanced robotic systems aid in the safe handling of hazardous electronic waste, thereby reducing human exposure and enhancing overall waste processing efficiency (Kumar et al., 2024).

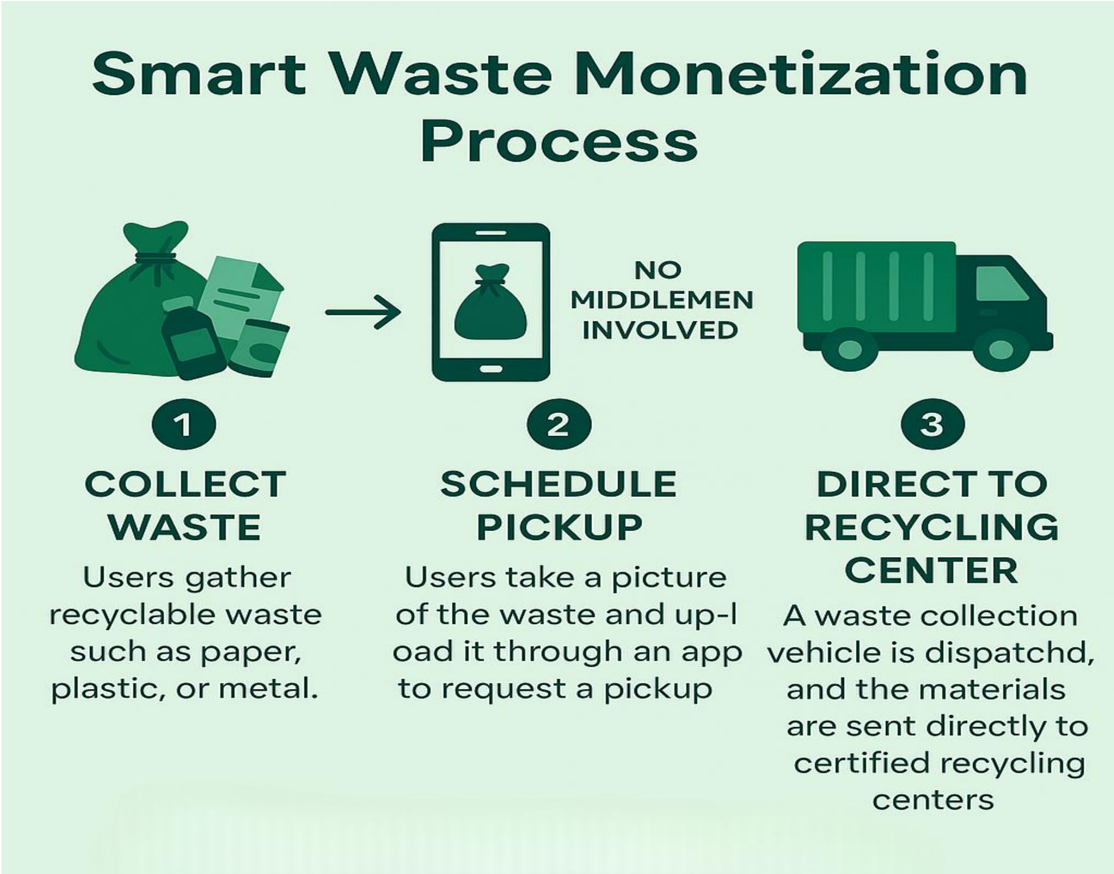

Fig 1: Three-step smart waste monetization—collect, schedule, recycle

Background and Literature Review

In India, the mismanagement of municipal and industrial waste presents a serious threat to public health and the environment. Although fewer than 25% of the 62 million tons of e-waste produced worldwide in 2022 were formally recycled, India ranked third with over 1.6 million tons generated (Forti et al., 2023). Over 90% of e-waste is handled informally, despite laws such as the E-Waste (Management) Rules, which pose pollution and health hazards (Down To Earth, 2023). In comparison, less than 20% of India's 150,000 daily municipal garbage is scientifically processed, and only 70% is collected (CPCB, 2023). , The techniques used to process e-waste are showing to be unsustainable, endangering the health of the earth (Mir et .al.,2024). Emerging technologies, such as artificial intelligence, machine learning, robots, and the Internet of Things (IoT), provide a practical and efficient solution; IoT bins can maximize waste collection, while AI can sort waste (Sharma & Patel, 2023). In line with India's Smart Cities Mission, which supports SDG 11 and 12, the "E-Junk Classifier and Waste Manager" project utilizes technologies for automated e-waste sorting, price estimation, and logistics (Kumar et al., 2024).

Table 1: Summary of Important Waste Management Technologies and Practices

Author(s)	Year	Study/Title	Highlights and Key Contributions
Forti et al. [1]	2023	Global E-Waste Monitor 2023	Reported 62 million tons of global e-waste; less than 25% recycled; India ranks 3rd in e-waste output.

Down To Earth [7]	2023	Article on e-waste in India	Stated 90% of India's e-waste is handled informally, causing major health and environmental hazards.
CPCB [8]	2023	Municipal Solid Waste Statistics	Only 70% of MSW is collected and less than 20% is scientifically processed.
Mishra et al. [2]	2022	Health Impacts of Unregulated Waste Disposal in Urban India	Linked improper disposal to respiratory and gastrointestinal illnesses in urban areas.
Singh & Thakur [3]	2023	Deep Learning for Waste Classification	Demonstrated CNNs can achieve up to 98% classification accuracy for waste sorting.
Rao et al. [4]	2023	ConvoWaste: A CNN-Based Model	Proposed an AI-based waste segregation system improving speed and accuracy.
Wong, C., & Chan, E. (2023). [10]	2023	IoT-Enabled Smart Bins	Predictive analytics and public engagement for increasing recycling efficiency.
Al-Saleh, M., & Park, J. (2024). [11]	2023	AI and IoT in Urban Waste Management	Explores how deep reinforcement learning (DRL) is improving robotic precision in waste segregation systems across the Middle East and South Korea, leading to over 90% classification accuracy.
Garcia, R., & Lemoine, S. (2022). [12]	2024	Autonomous Robotic Systems for Hazardous Waste Management	Examine how smart bins and IoT networks in countries like Chile and Brazil have led to a 25% increase in urban recycling rates and significant reductions in collection-related emissions.
Qiu et al. [13]	2025	Improved EfficientNetV2 for Garbage Classification	Achieved 95.4% classification accuracy using CE-Attention and multi-scale features.
Spyridis et al. [14]	2024	AI-Enabled Sorting Pipeline for Textile Recycling	Combines robotics and AI with digital twins for industrial-scale waste sorting.
dos Santos et al.[15]	2024	Ferrous Scrap Classification via Vision Transformers	Used conformal prediction with ViT to achieve high classification accuracy and model confidence.
Kanani [16]	2024	Pixel Distribution Learning for Garbage Recognition	Proposed novel image recognition method beyond CNNs.
Guo et al. [17]	2023	Machine Vision for Garbage Sorting	Developed a deep learning-based real-time system using MobileNetV2; 90.7% accuracy.
Mandal et al. [18]	2023	Smart Garbage Classification for Sustainable Development	Tested various DL models; proposed Xception_CutLayer model (89.72% accuracy)

Uddin et al. [19]	2023	Recyclable Product Classification Using ResNet50V2	Achieved 98.95% accuracy with ResNet50V2 on recyclable waste data.

Objectives and Methodology

The primary objective of the "E-Junk Classifier and Waste Manager" project is to design an innovative, technologically enabled system that significantly enhances the handling of elec-tronic and municipal solid waste (MSW) across India. This initiative supports the nation's growing commitment to sustainable urban development, as well as the pressing need for im-proved treatment of increasing e-waste volumes. The system aims to establish a more effec-tive, safe, and environmentally friendly waste processing framework by incorporating intelli-gent automation and aligning with India's legislative developments in waste manage-ment. Figure 1 shows clearly the main goals of the project.

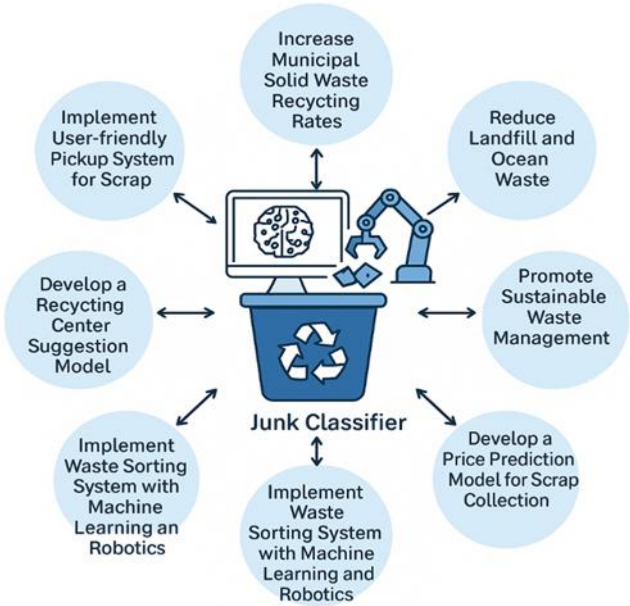

Fig 2: Key Features of an E-Junk Classifier System

This project features intelligently developed hardware and software components that work together to efficiently manage e-waste collection, sorting, and transportation, thereby achieving the goal of automating and enhancing waste management procedures. Built to identify and classify various types of waste precisely, the hardware system minimizes physical handling, thereby reducing worker health hazards. Additionally, a software architecture is employed to support user involvement, machine learning-driven classification, and optimal scheduling of waste collection. Users of a browser-based platform created using HTML, CSS, and JavaScript can interact with the system by posting photographs of recyclable waste, obtaining estimated scrap values, and organizing collection services. Using a trained machine learning model, the backend analyzes these inputs to determine the type of waste and its projected market value. A structured database controls user-profiles and logistics data; image data is kept on a file system. Using a GeoCoder API and Haversine formula to determine proximity, the system assigns pickups quickly. By linking every user's position with the closest accessible collector via a hash map-based architecture, the system may provide real-time alarms. Apart from simplifying waste management, this combined strategy immediately sup-ports automation, reduces human involvement, improves recycling rates, and aligns with the broader goals of innovative city development.

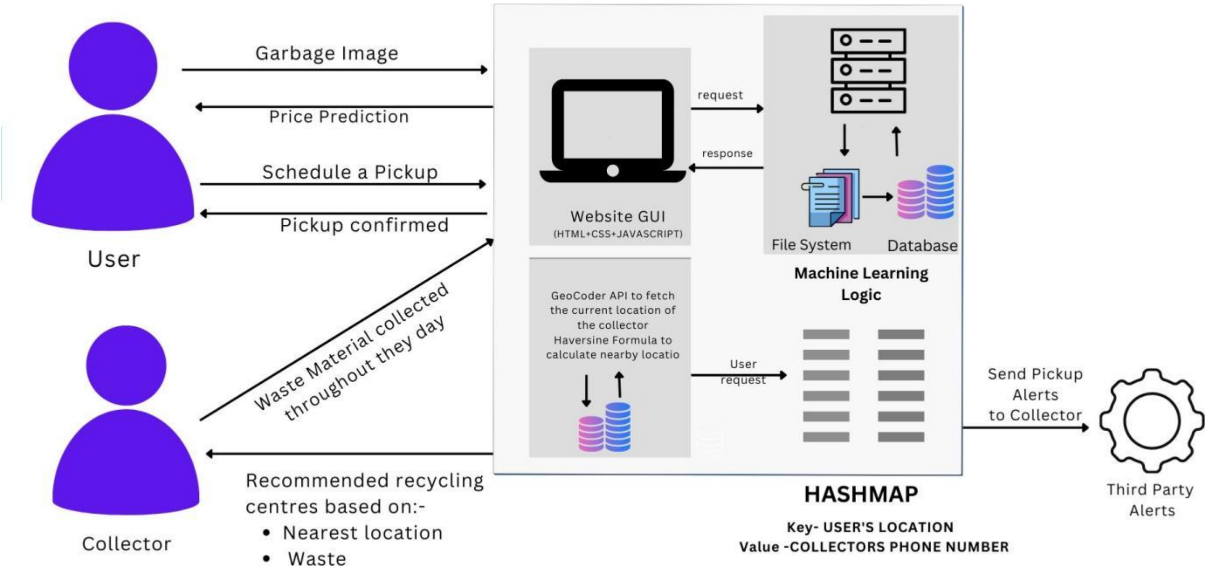

Fig 3: Overview of the Project

Through a web-based interface enhanced by machine learning and geolocation technology, the system diagram illustrates a fully automated framework for waste collection and recycling, where users and collectors are seamlessly connected. Users post pictures of their waste products using a graphical interface built from HTML, CSS, and JavaScript. A machine learning model assesses the potential value of waste based on its type and quality using these images. Users can easily schedule a pickup on the platform after completing the analysis. The system utilizes a GeoCoder API to determine user coordinates and then applies the Haversine formula to identify the closest accessible collectors, thereby enabling effective routing. Stored in a HashMap structure, this location data associates every user's location with the corresponding collector's contact information. Using an outside messaging system, notifications are sent to collectors, guaranteeing prompt pickup coordination. Based on the type of garbage and its location, collectors also receive personalized recommendations for nearby recycling centers. Waste collected during the day is routed to the most suitable recy-cling facilities, therefore encouraging operational efficiency and environmental responsibility.

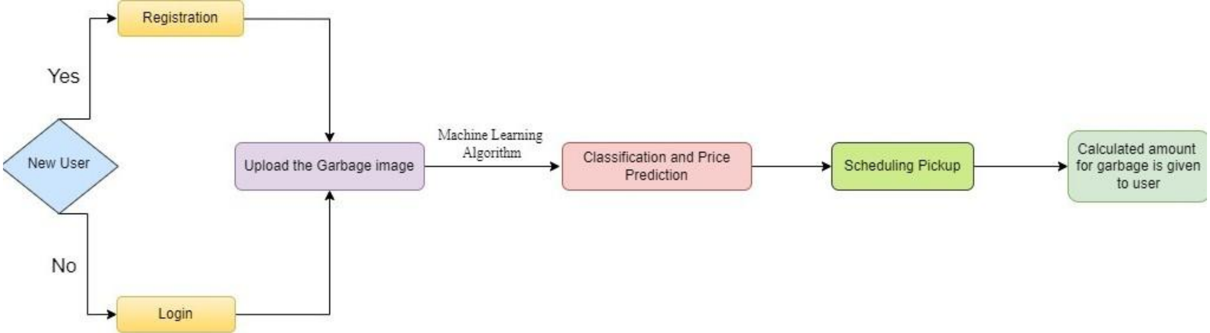

Fig 4: User side workflow of the Software Application

The flowchart illustrates how an innovative waste-selling platform utilizing machine learning to identify waste categories and estimate value works. Starting with an authentication check, new users are guided through a registration process while returning users' logs are updated. Users upload a picture of the waste item through the interface once it has been verified. After that, a machine learning model analyzes this picture and forecasts its approximate value depending on both its category and expected volume by classifying the kind of garbage. Users are allowed to arrange a pickup following the value. Confirmed, the site displays the computed financial worth to the user. By providing financial incentives, this organized and intelligent workflow not only simplifies the entire disposal process but also encourages users to actively engage, thereby improving waste management efficiency through AI-driven automation.

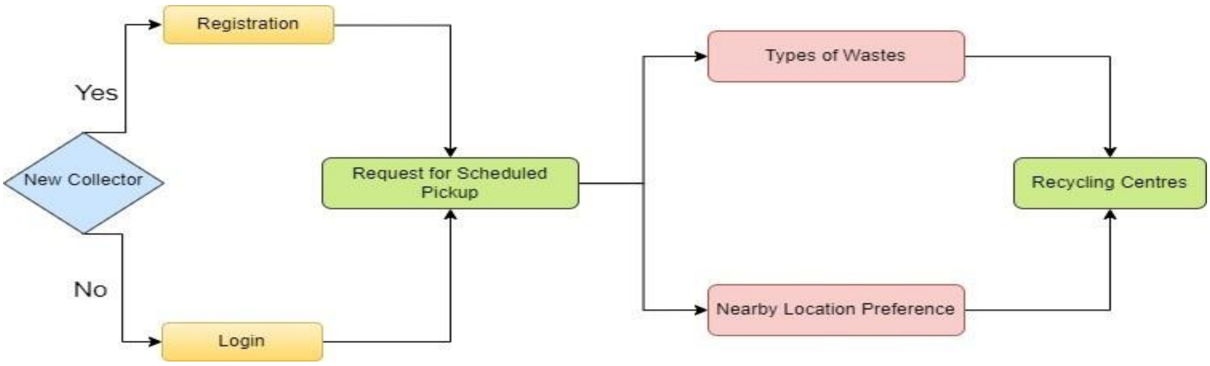

Fig 5: Collector side workflow of the Software Application

The operational actions followed by waste management system collectors are captured on the flowchart. It begins with asking whether a collector is new; whereas current collectors go straight to log in, new users finish a registration process. Collectors who log in gain access to pick up requests, each accompanied by important information, including the types of garbage involved and the recommended collection site. Using this information, the system cleverly recommends suitable recycling facilities, considering both the trash category and proximity to those centers for collection. This method ensures effective pickups and directs collected waste to the appropriate recycling facilities, thereby supporting the system's commitment to environmental standards.

Emphasizing the interaction among users, the front-end interface, backend processing, and col-lection operations, the accompanying system architecture diagram provides a comprehensive view of the intelligent garbage-collecting network. Users of the web-based interface can post photos, receive value estimations, and arrange pickups. A machine learning model housed in the backend handles these queries in tandem with geolocation services and a hash map-based data structure to determine the best collector assignments. Real-time warnings sent to collectors using third-party notification systems help to guide them to users and then to the most suitable recycling facilities. This completely integrated framework supports ecologically friendly results and improves the dependability, speed, and scalability of the garbage collecting process.

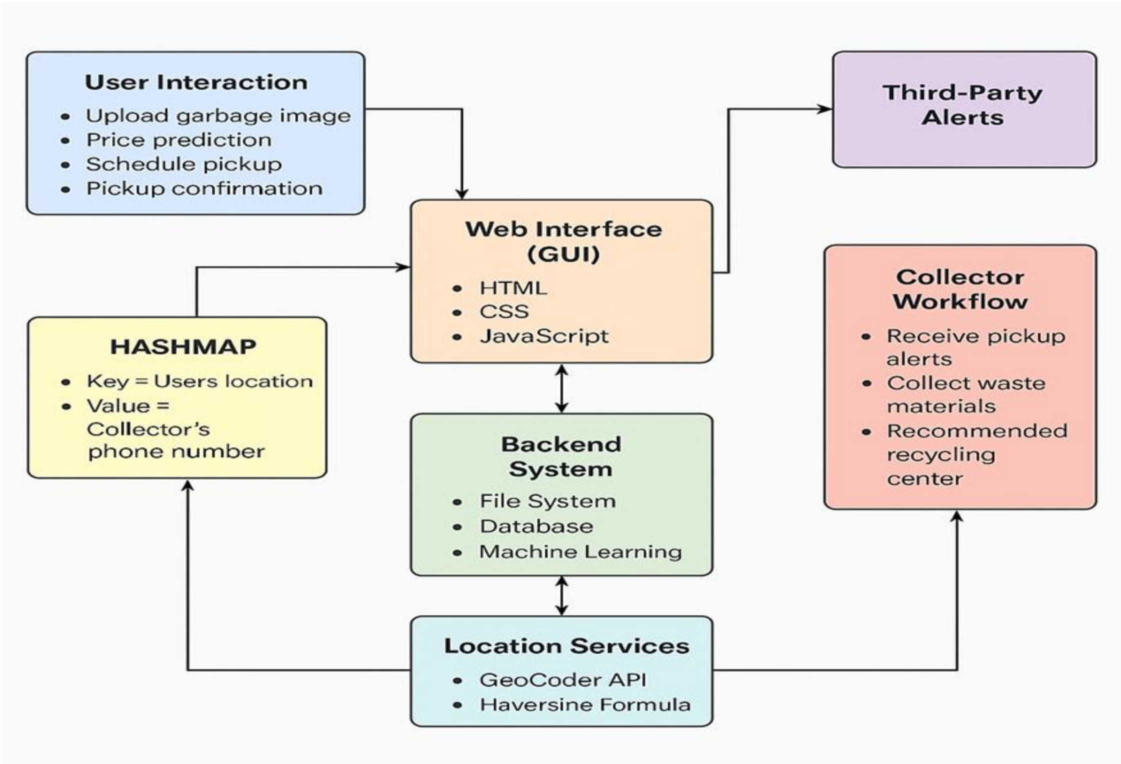

Fig 6: Proposed Intelligent Waste Collection Framework: System Architecture

SMALL-SCALE HARDWARE ARCHITECTURE FOR THE SUGGESTED SYSTEM OF E-WASTE COLLECTING

Using a modular and scalable hardware architecture meant to automate and maximize the waste detection, categorization, and collection. At a small scale, the proposed E-Waste Collection Sys-tem, incorporating essential components of the Internet of Things (IoT), edge computing, and embedded robotics, provides a fundamental paradigm for the next central installations.

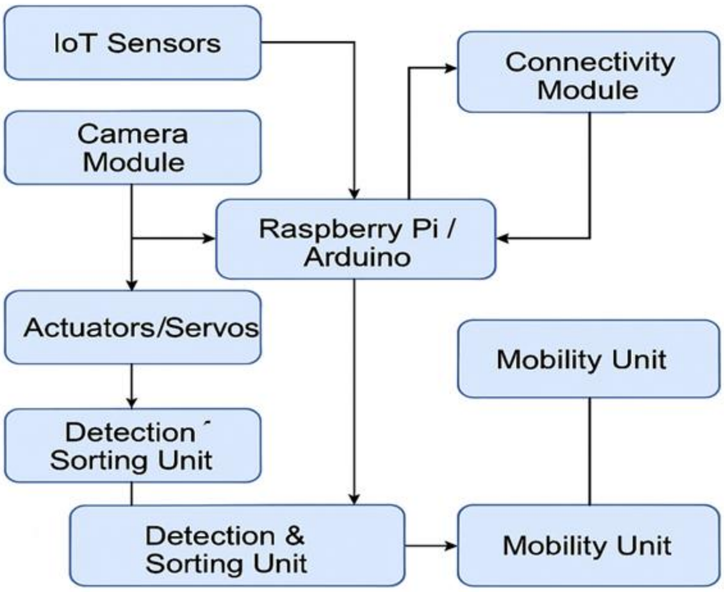

Fig 7 : Small scale hardware Architecture of the system

The diagram labeled "Small-Scale Hardware Architecture for E-Waste" depicts a modular and scalable system engineered for the intelligent detection, categorization, and collection of e-waste at a prototype stage. The system's core comprises a Raspberry Pi or Arduino microcontroller, serving as the central processing unit. Following the analysis, the controller transmits commands to actuators or servo motors that operate a mechanical sorting unit to categorize garbage into specified classifications physically. The system incorporates a networking module (Wi-Fi, LTE, or Bluetooth), facilitating communication with cloud platforms, databases, or user interfaces for real-time monitoring and remote coordination.

Proposed and projected e-waste management system revenue model

A neat numerical structure supports the E-Junk Classifier and Waste Manager system's profit es-timate. The system produces a gross daily income of ₹10,000, or ₹3,00,000 per month, with a daily intake of 100 kg of scrap and an average income of ₹100 per kg. Estimated monthly operational expenses—including personnel, electricity, logistics, maintenance, and miscellaneous costs—are ₹60,000. The net monthly profit is thus ₹2,40,000. The system maintains a net profit of ₹1,00,000 per month, even under a conservative scenario that includes rising operational expenses of up to ₹2,00,000. These numbers confirm the financial viability of the system, as they not only cover their expenses but also generate a significant profit, thereby providing a workable and scalable solution for efficient and practical intelligent waste management.

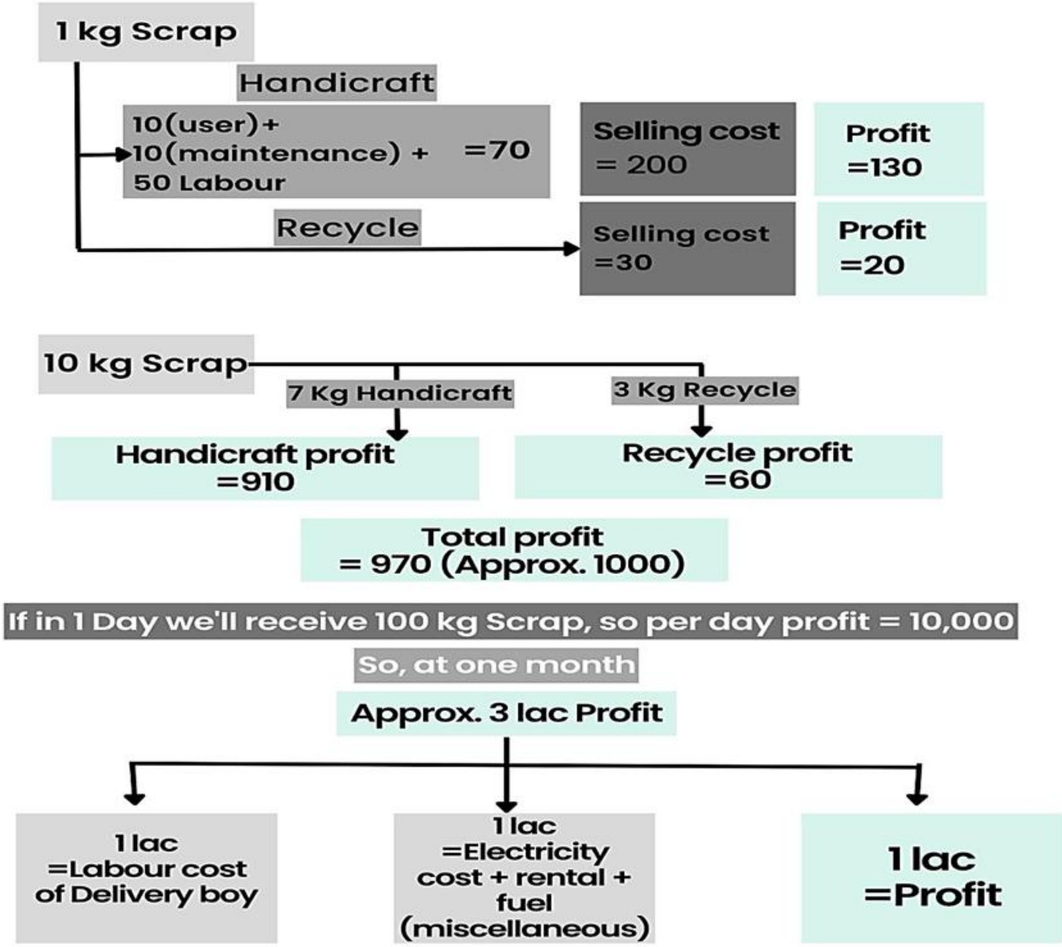

Fig 8: Revenue Model Validation for System for E-Waste Management

The E-Junk Classifier and Garbage Manager project employs a diverse and sustainable income strategy to convert municipal and electronic waste into financial value. The project generates revenue by upcycling non-toxic components into handcrafted items and selling valuable resources like plastics and metals, thereby promoting environmental responsibility. Offering subscription-based waste management solutions, licensing its technologies to third parties, and developing alliances with companies and governments generates other income. While organizing sponsored educational initiatives to increase awareness and foster community involvement, the project also gets income via CSR partnerships and environmental grants. This combined solution ensures long-term scalability and financial sustainability. Processing one kilogram of scrap initiates the revenue-generating process; it can either be recycled or transformed into handicrafts. Under the handicraft model, the cost breakdown comes out to be ₹10 for user incentives, ₹10 for maintenance, and ₹50 for labor, or ₹70 for every unit. With the finished handicraft sold at ₹200, a profit margin of ₹130 per kilogram results. On the other hand, if the same 1 kg is recycled straightforwardly, the product generates a profit of ₹20 per kg and a selling price of ₹30. Applying this technique to 10 kg of scrap results in a suggested distribution whereby 3 kg for recycling and 7 kg for handcraft manufacture. With 10 kg of scrap, this produces a handicraft profit of ₹910 and a recycling profit of ₹60, thereby generating almost ₹970 (rounded to ₹1,000) in income. Scaling this to 100 kg of daily scrap input, the system is capable of producing ₹10,000 per day. Monthly income over a normal 30-day operational month comes to ₹3,00,000. The approach projects the following cost distribution:

1. ₹ 1,00,000 for labor expenses—especially for delivery staff—especially ₹ 1,00,000 for rental, fuel and Miscellaneous overheads, electricity, ending with a monthly net profit of ₹1,00,000.

2. This income model not only supports the potential employment generation, resource recovery, and promotion of the circular economy suggested by the system but also confirms its economic feasibility. It demonstrates the significant financial and environmental benefits that a well-integrated technology and operational framework can yield.

RESULTS

Positioned to have significant influence across technical, operational, financial, environmental, and social spheres, the E-Junk Classifier and Waste Manager system's method reduces human involvement by utilizing robotic sorting with 95% mechanical accuracy and a deep CNN model with up to 98% accuracy, thereby optimizing efficiency. By using Dijkstra's algorithm, smart bins are projected to maximize collecting paths, thereby reducing fuel consumption by up to 20% and enhancing scheduling by over 30%. The project may bring a daily income of ₹10,000, escalating to a monthly profit of ₹1,00,000. Environmentally, it aims to increase recycling rates by 40–60%, thereby reducing landfill and ocean waste. Socially, it enhances job stability, income, and safety, thereby empowering informal waste workers. These results, taken together, highlight the potential of the idea as a scalable, intelligent, socially conscious waste management solution.

CONCLUSION

Although The E-Junk Classifier and Waste Manager system's practical feasibility is yet to be verified at huge commercial level, yet it promises to shows that environmental impact and financial feasibility may coexist in trash management driven by technology. The system promises to significantly increases efficiency using the combination of machine learning, robots, IoT, and sophisticated optimization strategies, therefore encouraging social inclusion and sustainable practices as well as efficiency. Its innovative design and scalability help it to be a viable choice for tackling the challenging waste issues current metropolitan environments provide.

Glimpses of System Prototype Hardware and Software

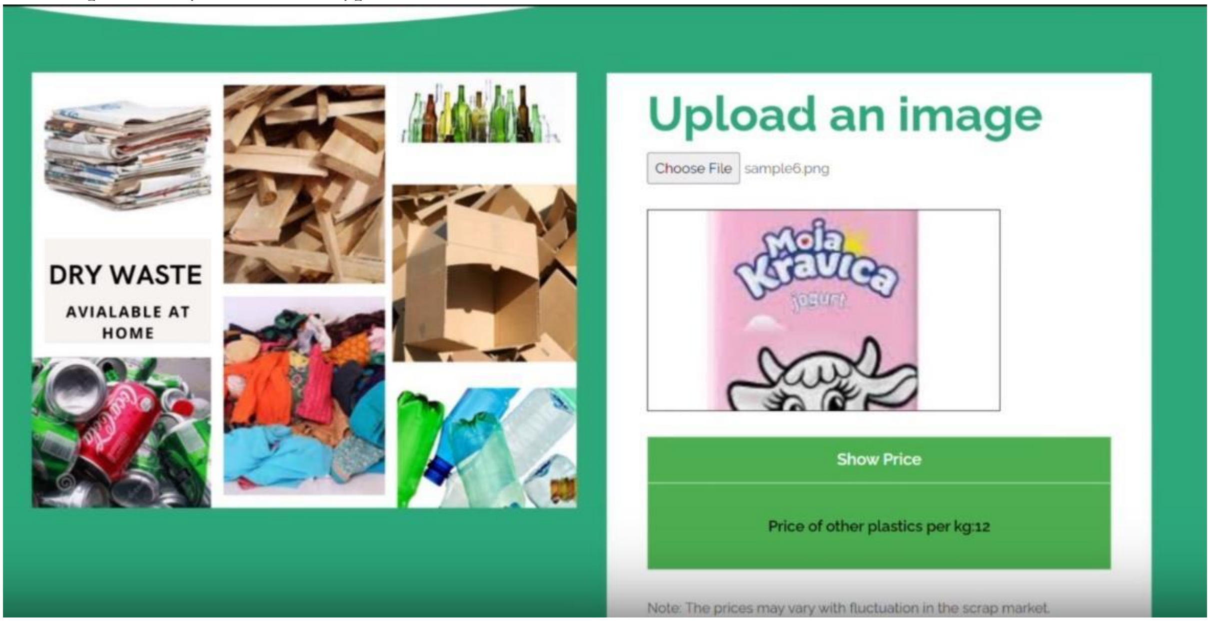

Fig 9 : Set up of the Software

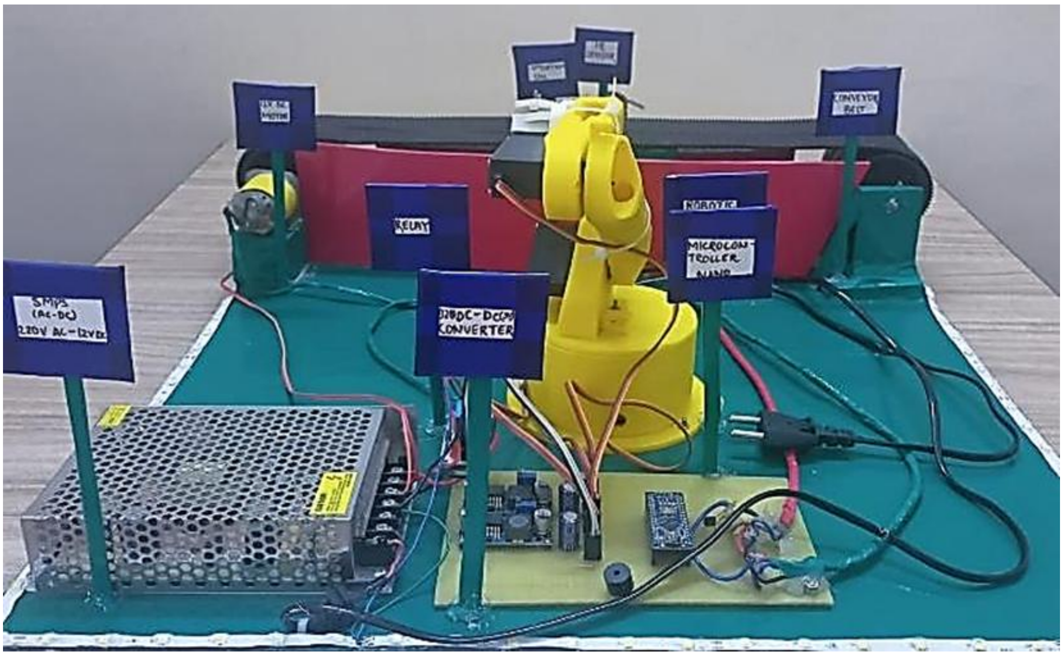

Fig 10: Set up of the Hardware prototype

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