# E-Waste Segregation

**First Author*1, Second Author2, Third Author2, Fourth Author3**

*[1]Department, University/Institute/Company, City, State, Country
Example@ijsrset.com[1]
[2]Department, University/Institute/Company, City, State, Country
Example@ijsrset.com[2]
[3]Department, University/Institute/Company, City, State, Country
Example@ijsrset.com[3]

## ABSTRACT

he rapid growth of electronic waste (e-waste) has substantial environmental and health risks due to hazardous materials like lead and mercury, as well as the loss of valuable metals such as gold, silver, and copper. Manual sorting methods not only affects human health but often involve child labour. Efficient segregation of printed circuit boards (PCBs) is therefore critical for recovery and safe disposal. In this study, we propose an AI-driven, continuous-flow conveyor system that combines computer vision and mechanical design for real-time PCB detection and separation. YOLO an object detection model is trained on a custom dataset of annotated e-waste images, achieved high accuracy in identifying PCB's. To meet industry requirements and minimize dependence on expensive robotic arms which are currently being used for e-waste sorting, the proposed setup employs a conveyor belt, stepper motor, and motorized flap for automatic PCB redirection. Early evaluations reveal notable gains in speed, precision, and scalability, suggesting that this method surpasses manual alternatives for large-scale e-waste management. Along with cutting labour expenses and safety risks, the prototype also allows for versatile integration in various waste-handling scenarios.

## INTRODUCTION

Electronic waste (e-waste) is one of the fastest-growing waste streams globally, driven by rapid technological advancements, increasing consumer demand, and shorter product life cycles. According to the Global E-Waste Monitor (2020), over 53.6 million metric tonnes (Mt) of e-waste were generated in 2019, with projections indicating a continuous rise due to the frequent upgrading of electronic devices and planned obsolescence in modern electronics manufacturing (Forti et al., 2020). Only 17% of e-waste is formally recycled, leaving vast amounts of hazardous and valuable materials improperly handled.

Among the various components of e-waste, printed circuit boards (PCBs) stand out as both highly valuable and highly hazardous. PCBs are essential components in almost all electronic devices, containing a mix of precious metals such as gold, silver, palladium, and copper, along with hazardous substances like lead, mercury, and brominated flame retardants (Cui & Forssberg, 2003).

While 3-5% of e-waste by weight consists of PCBs, they contribute to both recoverable metals and toxic emissions when handled improperly (Bernardes et al., 1997). Traditional PCB recycling methods, particularly in developing countries, involve manual dismantling, acid leaching, and open-air incineration, which not only expose workers to dangerous toxins but also contribute to environmental pollution through airborne heavy metals and persistent organic pollutants (Chatterjee & Kumar, 2009). Because of the hazardous nature of these processes, along with the inefficiencies of manual sorting, underscores the urgent need for automated, AI-driven solutions that can streamline PCB segregation while protecting workers from direct exposure to toxic materials.

This paper proposes an AI-powered, continuous-flow conveyor system designed to automate the detection and segregation of PCBs from e-waste, eliminating hazardous manual labor while significantly improving sorting accuracy and efficiency. The system integrates a YOLO object detection model, trained on a custom dataset of annotated PCB images, with a mechanized conveyor belt, stepper motor, and motorized flap to automatically divert PCB-containing components into a separate collection bin. By replacing manual sorting with computer vision-based classification and real-time mechanical separation, this setup not only accelerates the recycling process but also minimizes human exposure to dangerous substances.

A key advantage of this AI-integrated approach is its ability to mitigate hazardous material exposure at multiple stages of the recycling process. In traditional setups, workers handle and dismantle PCBs using basic tools and unregulated techniques, leading to direct inhalation of toxic fumes during solder extraction or dermal absorption of heavy metals through prolonged contact with circuit boards (Liu et al., 2006).

In contrast, our system processes e-waste in a fully automated environment, ensuring that:

1. Workers do not need to touch PCBs directly, as the conveyor and AI detection module classify and separate them without human intervention.
2. Toxic dust and metal fumes are contained, preventing respiratory hazards commonly associated with traditional sorting methods.

Current e-waste segregation methods rely on manual labor, shredding, and density-based separation, which are often inefficient for handling mixed waste streams (Nowakowski & Pamuła, 2019). Traditional methods such as eddy current separation and magnetic sorting have limitations in identifying complex PCB structures, leading to lower recovery rates (Becker et al., 2023). In contrast, our AI-driven system offers real-time classification of PCBs based on component-level detection, ensuring higher precision and minimal sorting errors compared to traditional mechanical separation techniques. Studies have shown that AI-based waste classification can reduce sorting errors from 20% (manual sorting) to less than 5% (AI-powered methods) (Madhav et al., 2021).

## System Design [ Mechanical Setup ]

The system is designed to automate the segregation of printed circuit boards (PCBs) from electronic waste (e-waste) using a computer vision-based approach. The setup consists of two primary stages: initial PCB concentration assessment and final PCB segregation. A conveyor-based mechanism integrated with an Arduino-controlled system and YOLOv8-based computer vision model is used to detect and separate PCB components efficiently.

The primary structure of the system is built using mild steel rods with pre-drilled holes, which are cut and assembled into a table-like frame. The joints are secured using nuts, bolts, and L-section brackets for stability. On this frame, a conveyor belt is mounted, which is supported by wooden rollers and driven by a stepper motor. The entire conveyor operation is controlled by an Arduino setup, including a motor driver, a power supply, and a microcontroller. The e-waste is loaded onto this conveyor in batches, where a camera mounted on an overhead wooden attachment captures real-time images for analysis. The YOLOv8 computer vision model processes these images to detect and quantify the PCB concentration within the batch. If the PCB concentration exceeds 40%, the entire batch is forwarded to the next stage. If the concentration is below this threshold, a motorized flap controlled by a DC motor, made of an acrylic sheet, redirects the batch to a rejection zone. To transfer the PCB-rich batches to the second stage, a sliding mechanism is incorporated into the design. The second stage is dedicated to finer segregation, where individual PCB pieces are separated from non-PCB components. This stage is structured similarly to the first, using a conveyor system supported by plastic rollers and mild steel stands. The conveyor moves the e-waste batch forward while another camera, integrated with the YOLOv8 model, identifies individual PCB pieces. A servo motor controls a flap mechanism positioned at the end of the conveyor belt. If a PCB piece is detected, the flap moves to direct it toward the right side collection bin; otherwise, the non-PCB waste is directed to the left side.

This two-stage system ensures efficient PCB segregation from e-waste, reducing manual effort and improving accuracy. The integration of the YOLOv8 computer vision model enables real-time detection, while the combination of stepper and servo motors ensures smooth and automated sorting. The modular design allows for scalability and adaptability for different types of e-waste processing. This setup not only streamlines PCB recovery but also contributes to sustainable e-waste management by facilitating efficient recycling.