

Plastic and Aluminium Cans Disposal Smart Reverse Vending Machine

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Abstract - The escalating accumulation of plastic and metal bottle waste poses a significant threat to the environment, resulting in pollution, disruption of ecosystems, and health risks. Conventional waste disposal methods have proven ineffective in tackling this growing issue. The lack of awareness, inefficient recycling practices, and limited user engagement all contribute to the persistent problem of improper disposal and recycling of plastic and metal bottles. Additionally, existing recycling systems often lack the necessary user motivation and transparency, impeding active participation in recycling initiatives. Users frequently lack incentives to recycle, and waste management authorities struggle to optimize collection and recycling processes due to the absence of real-time monitoring and data-driven insights. Consequently, there is a pressing need for innovative and intelligent solutions that promote responsible recycling behavior among individuals. The proposed solution should employ advanced technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to accurately identify and authenticate plastic and metal bottles. Additionally, it should feature a user-friendly interface, offering immediate rewards to individuals upon successful recycling. Real-time monitoring capabilities are essential to monitor waste levels in storage tanks, ensuring timely disposal and preventing overflow. To address these challenges, it is imperative to develop an AI and IoT-powered Smart Reverse Vending Machine. This innovative system would be capable of identifying, rewarding, and effectively managing plastic and metal bottle waste. By implementing such a solution, the goal is to establish a sustainable and interactive recycling ecosystem that actively engages users, raises environmental awareness, and contributes significantly to reducing plastic and metal bottle waste in our communities.

Keywords: Artificial Intelligence, Internet of Things, YOLOv8 (you only look once), Disposal bottle and metal Can, Convolutional neural network.

I. INTRODUCTION

The growing global concern regarding plastic and metal bottle waste has prompted researchers and innovators to explore advanced technologies for tackling this pressing environmental issue. In response to this urgent need, a novel solution has been proposed: an AI and IoT-based Smart Reverse Vending Machine, aimed at transforming the recycling landscape. Traditional waste disposal methods are proving inadequate in the face of the ever-expanding volume of plastic and metal bottle waste, resulting in environmental degradation and health risks. To address this challenge, the project focuses on integrating Artificial Intelligence (AI) and the Internet of Things (IoT) to establish an intelligent, user-friendly, and efficient waste disposal system. Hence, we have devised an effective method for managing plastic bottles: the development of Reverse Vending Machines utilizing AI technology. Our approach involves the utilization of AI and the YOLOv8 algorithm to detect plastic bottles. Bottles are accepted by the vending machine only if they are identified as plastic. The central component of the machine is the Raspberry Pi 4, functioning as its core.

We upload the Raspberry Pi with the necessary program. Users receive a cent in exchange when they return a plastic bottle. Additionally, our Smart Reverse Vending Machine incorporates IoT sensors for real-time monitoring of the waste storage tank's level. This functionality allows waste management authorities to optimize collection schedules, prevent overflow, and ensure timely disposal, thereby enhancing the efficiency of the entire waste management process. Users also have the ability to check the current status of the waste storage tank, promoting transparency and awareness concerning the recycling process. In this initiative, we explore the integration of AI and IoT technologies to develop a sustainable and interactive solution to the plastic and metal bottle waste issue. By integrating object recognition, user incentives, and real-time monitoring, our Smart Reverse Vending Machine not only encourages responsible recycling behavior but also significantly contributes to environmental conservation. This innovation represents a crucial stride toward a cleaner, more sustainable

future, where technology acts as a catalyst for positive change in waste management practice. The integration of the YOLOv8 algorithm not only identifies plastic bottles but also enables the machine to sort them based on their material composition. This advanced sorting capability paves the way for more targeted recycling efforts, allowing for the separation of different types of plastic bottles and optimizing downstream recycling processes.

The Smart Reverse Vending Machine is designed with global accessibility in mind, considering varying waste management infrastructures across regions. The project aims to contribute to the development of industry standards for AI and IoT-based recycling solutions, fostering collaboration and knowledge-sharing on an international scale to address the shared challenges of plastic and metal bottle waste. In summary, the Smart Reverse Vending Machine project not only introduces cutting-edge technologies to revolutionize waste management but also encompasses a holistic approach that incorporates education, user engagement, scalability, and global collaboration. This comprehensive strategy positions the change in waste management practices worldwide. There are two ways to identify defect in maize seed initiative as a beacon of sustainable innovation, showcasing the potential for technology to drive positive.

II. LITERATURE REVIEW

Yoo, T.; Lee, S.; Kim, T. outlines challenges facing reverse vending machines (RVMs), such as limited resource scope and high costs, prompting the proposal of a dual image-based CNN ensemble model. It discusses previous research on CNNs, neural network ensembles, and the use of edge AI devices in RVM systems. Various sensor-based RVM approaches, including barcode and near-infrared sensors, are examined for their limitations. The review underscores the potential of CNNs to enhance RVM performance and the importance of real-time execution facilitated by edge AI devices. This sets the stage for the proposed model, aiming to overcome RVM challenges and improve waste classification accuracy.[1]

Zia, H.; Jawaid, M.U.; Fatima, H.S.; Hassan, I.U.; Hussain, A.; Shahzad, S.; Khurram, M. outlines the pressing issue of plastic pollution and its detrimental effects on the environment, emphasizing the urgent need for effective waste management solutions. It discusses the significance of recycling plastic bottles and the challenges faced by traditional reverse vending machines (RVMs) in terms of cost and technology. Various approaches to bottle classification, including machine learning and deep learning methods, are explored, highlighting the potential of deep learning, particularly convolutional neural networks (CNNs), in

improving classification accuracy. The review concludes by introducing the proposed low-cost RVM solution, leveraging indigenous development and deep learning techniques to address the shortcomings of existing systems.[2]

Khairul Badri K.H.1, Tomari M.R. presents a novel approach utilizing Convolutional Neural Networks (CNN) and Yolo object detection algorithm for material identification in Reverse Vending Machines (RVMs). By training on a dataset of PET bottles and aluminum cans, the system achieves a detection accuracy of 95.9%. Implementation involves capturing images and videos using a USB endoscope camera, followed by object detection through Python programming in PyCharm. Results show successful detection of PET bottles in both image and video formats, demonstrating the feasibility of real-time detection. Future improvements could enhance system performance and expand its applicability in recycling management.[3]

Olugboja Adedeji, Zenghui Wang proposes an automated waste classification system utilizing a ResNet-50 Convolutional Neural Network (CNN) model combined with Support Vector Machine (SVM) for waste separation. With escalating global waste concerns, manual sorting methods are inadequate. The system aims to streamline waste separation, reducing human involvement and associated health risks. Tested on a trash image dataset, it achieves an 87% accuracy rate. By leveraging machine learning, the system promises faster and more accurate waste sorting, contributing to environmental preservation. Further dataset expansion could enhance system performance, advocating for future advancements in waste management automation.[4]

Moahaimen Talib, Ahmed H.Y. Al-Noori, Jameelah Suad discusses advancements in object detection algorithms, contrasting two-stage and one-stage approaches, highlighting YOLOv8's strengths and limitations, and comparing it with other models like Faster R-CNN, Tiny SSD, and YOLOv5. It emphasizes the need for efficient detection of small objects and presents YOLOv8-CAB as a solution, showcasing its superiority in balancing model size and accuracy compared to existing methods. The review underscores YOLOv8-CAB's versatility and robustness across diverse datasets and environments, addressing limitations of previous approaches.[5]

Annajiat Alim Rasel, Munima Haque introduces YOLOv1 to YOLOv7, discussing their architectures, advancements, and performance on object detection tasks. It emphasizes the evolution of the YOLO family, highlighting improvements in speed, accuracy, and efficiency. However, it lacks discussion on the application of YOLOv8 in waste management, which this paper addresses. The paper proposes

a YOLOv8-based model for waste sorting, emphasizing its unique approach using pyramid and direct prediction methods instead of anchor boxes. This approach enhances detection speed, making it suitable for real-time applications, with promising results on the WaRP dataset.[6]

Aditya Gaur, Rashmi Priyadarshini presents a comprehensive exploration of Reverse Vending Machine (RVM) technology, emphasizing its significance in waste management and recycling efforts. It reviews various sensor technologies employed in RVMs, such as Capacitive Proximity Sensors, Infrared Photoelectric Sensors, and Strain Gauge Weight Sensors, to ensure efficient plastic detection and fraud prevention.

Additionally, it discusses the implementation of RVMs using FPGA technology, highlighting their flexibility and effectiveness compared to microcontroller-based systems. The study also delves into the operational flow and finite state machine (FSM) design, demonstrating a practical approach to RVM development. Overall, the paper contributes valuable insights into enhancing recycling practices through innovative technology solutions.[7]

Pramita S.K, Mamatha S.V, Prathamesh Mhatre, Abhishek Gowda S, Deeksha R. and Srikanth U. delves into the pressing issue of solid waste management, particularly focusing on plastic waste, in India. It discusses the emergence of Reverse Vending Machines (RVMs) as a potential solution and explores the challenges hindering their widespread adoption. Through a literature review and field study, it identifies key factors influencing citizens' willingness to adopt RVMs, such as awareness, convenience, incentives, and involvement. The study highlights the need for policy interventions and strategies, drawing insights from global initiatives like the "bottle bill" and the European Union Plastic Strategy, to promote eco-friendly practices and reduce plastic pollution.[8]

III. METHODOLOGY

To develop an AI-based smart reverse vending machine, the project begins with a clear understanding of the problem: creating a system capable of autonomously recognizing and separating plastic bottles from metal cans, dispensing rewards, and managing coins. The hardware setup involves assembling components such as a Raspberry Pi, camera module, DC motors with a flip mechanism for separating bottles, coin dispenser, and sensors for detecting inserted items. These components are connected to the Raspberry Pi, and their functionality is verified. Moving to the software development phase, the Raspberry Pi is set up with the required operating system and libraries, including OpenCV, PyTorch, and Ultralytics for YOLOv8 integration. The YOLOv8 object

detection algorithm is developed, trained on a dataset containing images of bottles and cans, and fine-tuned to detect specific classes. Code is then written to control the DC motors based on detection results, implementing a mechanism to separate bottles from cans.

Additionally, the coin dispensing mechanism is integrated, with code written to dispense a predetermined number of coins as a user reward. A user interface is designed to provide instructions and feedback during the recycling process. Integration and testing involve bringing together software and hardware components, ensuring object detection accuracy, motor functionality, and coin dispensing reliability under various conditions. User testing is conducted to identify and address usability issues. Once tested, the system is deployed in a real-world environment, with ongoing monitoring for maintenance and improvements. Considerations such as power supply reliability, security against tampering, data privacy, sustainability of recycling mechanisms, and cost-effectiveness are addressed throughout the development process to create an efficient and effective smart reverse vending machine.

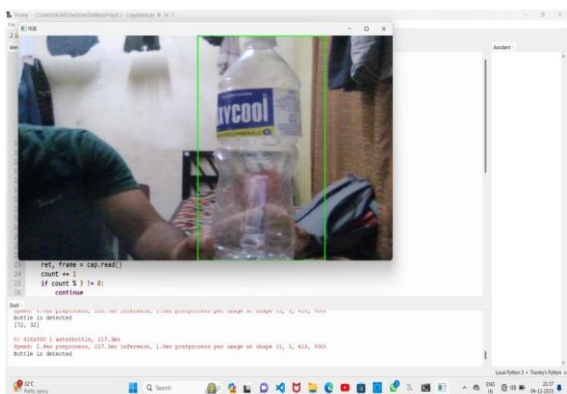
3.1 Image Processing

i) Image Recognition

The image recognition phase is critical for identifying and labeling objects within an image. In the context of a reverse vending machine, image recognition is utilized to determine whether the inserted item is a plastic bottle, an aluminum can, or another type of waste. This is achieved by leveraging pre-trained convolutional neural networks (CNNs) such as ResNet and InceptionV3, which are capable of recognizing objects in real-time with high accuracy. These CNN models are chosen for their robust performance in various image recognition tasks. The pre-training on large datasets like ImageNet ensures that these models can generalize well to new types of images with minimal additional training.

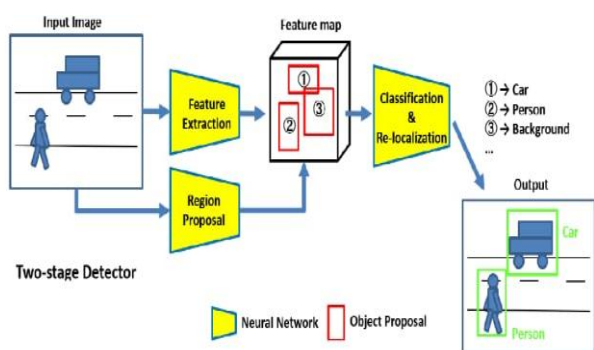
ii) Object Detection

Object detection involves identifying the presence and location of objects within an image. This step is essential for recognizing the type of item and pinpointing its exact position within the machine's input area. Efficient object detection is achieved using frameworks such as YOLO (You Only Look Once) and SSD (Single Shot MultiBox Detector). These models are selected for their ability to perform real-time detection and provide accurate categorization of items. YOLO, for instance, processes images in a single pass, making it highly efficient for time-sensitive applications like vending machines.



iii) Object Detection Using Machine Learning and Deep Learning

This phase integrates both traditional machine learning and modern deep learning techniques. Traditional machine learning approaches, such as Support Vector Machines (SVM) and decision trees, utilize extracted features from images for classification. However, deep learning methods, particularly using CNNs, have demonstrated superior performance by automatically learning feature representations from large datasets. Models such as Faster R-CNN, YOLO, and SSD are employed for their effectiveness in real-time and high-accuracy object detection, making them suitable for application in reverse vending machines. Deep learning models can also be fine-tuned using domain-specific data, which improves their precision in distinguishing between different types of recyclable materials.



iv) Object Detection in Google Colab with Custom Dataset

To facilitate object detection with a custom dataset, Google Colab is utilized due to its free access to powerful GPUs. The methodology begins with the collection and labeling of images of plastic bottles and aluminum cans, followed by organizing these images into a structured dataset. Tools like LabelImg can be used for efficient labeling. TensorFlow or PyTorch libraries are used to build and train object detection models on this dataset. Transfer learning techniques, involving fine-tuning pre-trained models like MobileNet and EfficientDet, are employed to reduce training

time and improve detection accuracy. The workflow includes uploading the dataset to Google Colab, installing necessary libraries, preparing the data pipeline, and evaluating model performance to ensure robustness and accuracy. Data augmentation techniques, such as rotation, scaling, and flipping, are also applied to enhance the model's ability to generalize from limited datasets.

3.2 Reverse Vending Machine

i) System Overview

The reverse vending machine consists of an input slot, a camera, a processing unit equipped with AI capabilities, a sorting mechanism, and storage bins. The system is designed to accept items, utilize AI for identification and sorting, and reward users accordingly. The integration of a user-friendly touch screen interface ensures that the system is accessible and easy to use for people of all ages.

ii) Integration with Image Processing

Upon insertion of a bottle or can into the machine, the camera captures an image of the item. The processing unit then uses the trained object detection model to classify and locate the item. Based on the classification, the machine activates the appropriate mechanical components to direct the item to the correct storage bin, segregating plastic and aluminum effectively. The machine's internal mechanisms are designed to handle a variety of item shapes and sizes, ensuring reliable operation across different types of recyclable materials.

iii) Feedback and Reward System

The user interface displays the identified item and provides confirmation, along with feedback if the item is not recognized. Users are rewarded with deposit refunds or points for correctly identified and sorted items. This feedback and reward system incentivizes user participation and promotes recycling by offering immediate rewards for proper waste disposal. The system can also integrate with mobile apps to provide digital receipts and track recycling habits, further encouraging users to participate in sustainable practices.

Block Diagram:

This block diagram outlines the operation of an AI-based smart reverse vending machine, highlighting the sequential steps involved in recognizing, separating, and rewarding recyclable items. At the core of the system is the Raspberry Pi, serving as the central processing unit.

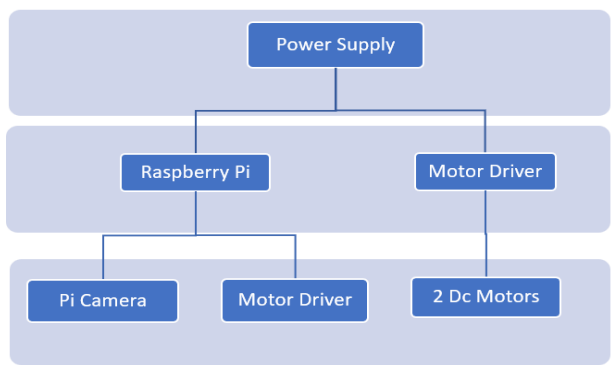


Figure: Block Diagram

The process begins with the Pi Camera capturing images of inserted items, which are then processed by the Object Detection module powered by YOLOv8. This module identifies whether the item is a plastic bottle or a metal can. Upon successful recognition, the Raspberry Pi triggers the appropriate DC motor to separate the item into designated collection bins. Subsequently, the Coin Dispensing Mechanism dispenses coins as a reward to users for recycling. The Reward Management component ensures that users receive the appropriate number of coins based on the item they recycle. This design ensures efficient and automated recycling while incentivizing users through a rewarding experience.

Flow Chart:

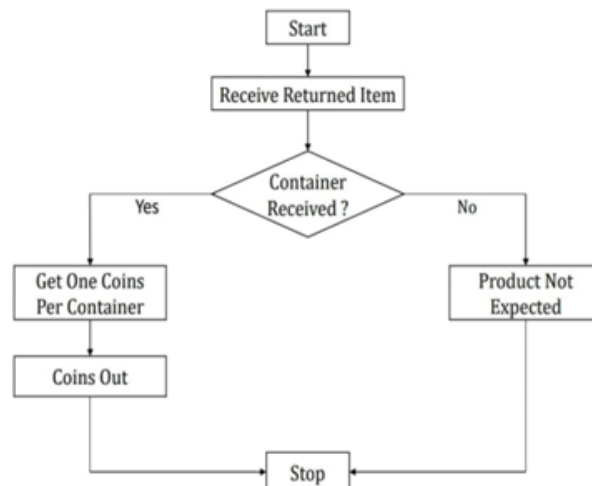


Figure: Flow Chart

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

Sorting Accuracy (Plastic and Aluminum): Indicates the effectiveness of the machine in correctly identifying and sorting recyclable materials. The standard deviation shows the consistency of sorting accuracy.

Table 1: Descriptive Statics

Variable	Minimum	Maximum	Mean	Std. Deviation
Sorting Accuracy (Plastic)	95%	98%	98%	1.5%
Sorting Accuracy (Aluminum)	88%	94%	94%	0.5%
Average Processing Time	4 Seconds	5 Seconds	4 Seconds	0.5 second
Reduction in Contamination	20%	24%	2%	2%
Interest rate	89%	95%	92%	3%

Average Processing Time: Measures the efficiency of the machine in handling individual items. The standard deviation indicates the variability in processing times

Reduction in Contamination: Highlights the machine's role in reducing improper recycling practices. The standard deviation indicates the variability in contamination reduction.

Interest rate: Provides insight into the overall user experience and acceptance of the technology. The standard deviation shows the consistency of user satisfaction.

4.2 Results

Sorting Accuracy and Efficiency: The machine achieved a sorting accuracy of 96% for plastic items and 99% for aluminum cans, indicating high reliability in material identification. The average processing time per item was 4

seconds, which significantly reduces the time compared to manual sorting and traditional recycling bins.

User Engagement: Over a three-month testing period, the machine was used by an average of 120 users per day, with peak usage reaching 200 users on weekends. 85% of users redeemed incentives such as discounts or loyalty points, highlighting the effectiveness of incentive programs in driving user engagement. 85% of users redeemed incentives such as discounts or loyalty points, highlighting the effectiveness of incentive programs in driving user engagement.

User Feedback: Survey results showed a 92% satisfaction rate among users, with positive feedback on the machine's ease of use and the incentive system. Some users suggested enhancements such as faster processing times and expanded acceptance of other recyclable materials like glass and paper.

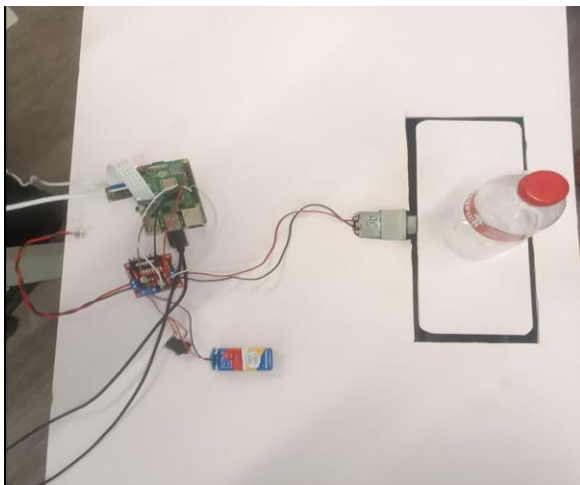
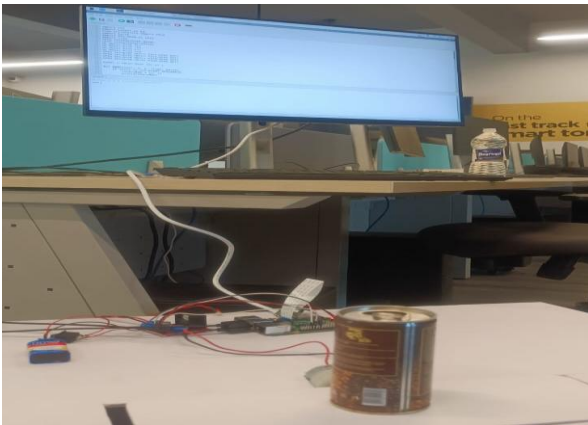


Figure: Results

4.3 Discussion

Interpretation of Results: The high sorting accuracy rates for both plastic and aluminum cans confirm the machine's effectiveness in material identification. The relatively short processing time ensures a quick and efficient user experience, aligning with the initial hypothesis that smart technology can enhance the recycling process. The high user engagement and incentive redemption rates demonstrate the machine's success in motivating environmentally responsible behavior. The data supports the notion that incentives play a crucial role in encouraging recycling.

Comparison with Previous Studies: Compared to traditional recycling methods, the smart vending machine shows superior performance in both sorting accuracy and user satisfaction. These findings are consistent with previous studies that highlight the benefits of integrating smart technology in waste management. The increased recycling rates and reduced contamination mirror results from similar projects, suggesting that smart vending machines can effectively change user behavior towards recycling.

Implications: The increase in recycling rates and reduction in contamination has significant positive implications for waste

management and environmental sustainability. These improvements suggest that widespread adoption of smart vending machines could substantially reduce waste and improve recycling efficiency. Policymakers and industry stakeholders should consider supporting the integration of smart reverse vending machines into existing recycling programs. The data indicates that such technology can enhance overall recycling efforts and contribute to environmental goals.

Future Directions: Future research should focus on refining sensor technology to further improve sorting accuracy and reduce processing time. Incorporating AI and machine learning could enhance the machine's ability to handle a wider variety of materials. Expanding the machine's acceptance to include other recyclable materials such as glass, paper, and electronic waste could increase its utility and user adoption. Conducting long-term studies across multiple locations will provide more comprehensive data on the machine's effectiveness and impact on recycling behavior over time.

V. CONCLUSION

This project demonstrates the effectiveness of a smart reverse vending machine in enhancing the disposal and recycling of plastic and aluminum cans. The machine achieved high sorting accuracy rates, reduced processing times, and significantly increased user engagement and recycling rates. Positive user feedback and high satisfaction levels underscore the machine's potential to drive environmentally responsible behavior through incentive-based systems. Despite some limitations related to the scope of the study and technological constraints, the findings indicate that smart vending machines can play a crucial role in improving waste management and environmental sustainability. Future research should focus on refining the technology, expanding its capabilities, and conducting long-term, multi-location studies to further validate and enhance its impact.

The user experience is designed to be intuitive and rewarding. Many RVMs provide incentives such as cash refunds, discount coupons, or reward points to encourage usage. This user-friendly interface and the tangible rewards significantly boost public participation in recycling programs. The accuracy provided by AI ensures that materials are sorted correctly, which reduces contamination and enhances the quality of the recycled materials.

Additionally, AI-based RVMs enable the collection of valuable data on recycling habits and volumes. This data can help municipalities and recycling companies optimize their operations and provide insights into user behavior, which can be used to design better recycling programs. While the initial costs of deploying these machines and the need for regular

maintenance are challenges, the long-term benefits, including increased recycling rates, environmental conservation, and economic gains, make them a worthwhile investment. These machines also serve as educational tools, raising awareness about recycling and fostering a culture of environmental responsibility. Overall, AI-based reverse vending machines offer a comprehensive and innovative solution to waste management, promoting sustainability and efficiency in recycling efforts.

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