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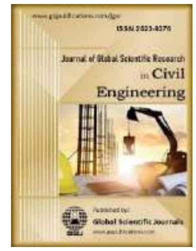

Reducing Environmental Impacts in Developing Regions using AI-Enabled Smart Sorting Systems

Maytham Kadhim Obaid

Water Resources Management Engineering Department, College of Engineering, AL-Qasim Green University, Babylon 51013, Iraq.

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ABSTRACT

Due to deteriorative environmental and social situation in developing countries, waste management systems are changing dynamically. The improper disposal of refuse in open spaces is a disturbing trend, which sustains environmental degradation and heightens health hazards. In this paper, the use of smart systems technologies, and in particular integrated CBSS (sensor-based) and AI (artificial intelligence) applications, to address this phenomenon is introduced. The work concentrates on a smart waste separation and sorting system based on the Arduino UNO R3. The system uses a number of dedicated sensors (moisture and ultrasonic sensors) to distinguish waste into three global categories: moist, plastic and metal. Garbage is sorted into correct bins automatically with a rotating platform and servo, feeding back information through an LCD and beeper once found. The prototype showed great performance on the accuracy and efficiency of classifying waste characteristics, which can help with recycling and reusing resources effectively. Environmental and social problems associated with random dumping in the developing world are also discussed, and smart systems and artificial intelligence (AI) are suggested as solutions to increase efficiency of source sorting in waste and minimize types of environmental pollutants, including toxic gas emissions, water pollution, and soil pollution. Additionally, the paper examines barriers against the adoption of these technologies including poor infrastructure, financial limitations and social opposition. It requests supportive policies, stronger community participation and more consciousness in smart waste management. Lastly, the authors suggest stronger integration of AI techniques and their expansion to support an appropriate reaction to the increasing problem of waste and to foster environmental and public health sustainability.

1. Introduction

As the world population grows and urbanization and industrialization speed up, daily production of solid waste has increased dramatically (David et al., 2024; Chien et al., 2023), aggravating environmental as well as public health problems related to its management. Most establishments have continued to use conventional waste collection and sorting techniques that are inefficient, time consuming and poorly structured; a need now exists for efficient management of

Corresponding author:
E-mail address: maytham@wrec.uoqasim.edu.iq
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wastes through development of smart systems that will limit environmental damage caused by wastes (Athiyapoobalan; Sundaralingam & Ramanathan, 2023; Cheng et al., 2022; Codinhoto et al, 2023).

AI is a qualitative step forward in regards to waste management logistics. Various studies suggest that AI-enabled systems could reduce transportation distance by 36.8% which can lead to fuel savings and lower greenhouse gas emissions." It also results in a 13.35% reduction of the operation costs and a 28.22% reduction of the logistic operation time, which makes it faster response and more efficient use of resources (Fang et al., 2023). At the classification and sorting layer, AI has shown very promising performance in detecting and separating types of waste, with accuracy rates between 72.8% and 99.95% using deep learning or computer vision among other technologies. This improves recycling quality and reduces unrecovered waste (Fang et al., 2023; David et al., 2024).

In such extended processes, the EW separation systems are the most advanced technological solution which uses electronic instruments, including sensors, automated sorting of materials and IoT-systems to properly select waste at source (Naghel et al., 2022). Experimental applications have worked in practice to enhance recycling rates, reduce dumping in landfills and support ecological well-being (Sofiat et al., 2021; Delgado et al., 2021). However, there are significant technical, financial and administrative limitations to the scale deployment of such systems. Simple and inexpensive as they are, such systems save labor, time, and capital in both affluent areas and those with economic restraints (Fang et al., 2023).

In the era of fast developing intelligent systems and embedded applications, Open Source Hardware (OSH) platforms like Arduino Uno have become an affordable and competent tool for developers to quickly prototype advanced designs. Arduino Uno, with open-source architecture and ATmega328P microcontroller, a platform that started as an experimental tool has developed prominent importance in sensing applications, industrial control systems, and contemporary technical education (Tsebesebe et al., 2025; Kaffale & Liu, 2025; Bhushan et al., 2025).

In the present study, contribution of electronic waste separation systems for improving efficiency in management of waste has been presented by analyzing the constituents of technical structures and assessing their environmental, economic as well as social impacts so that a comparison could be carried out with traditional methods adopted for managing wastes. Furthermore, it aims at identifying the challenges of these systems' implementation, especially in low-resource settings.

Problem Statement

One of the greatest difficulties for integrated management systems for waste is found in known sorting systems limited efficiency. Manual sorting is prone to errors, includes higher labor and operational costs, It exposes employees to potential health hazards. Therefore, it is important to evaluate the extent to which modern electronic systems contribute in addressing the challenges and enhancing overall waste management performance.

Research Objectives

The aim of this study is to:

1. Examine the technical and operational features of Waste separation systems.
2. Assess their potential to contribute to the improvement of waste management performance and waste sorting.
3. Discuss their environmental, social and economic consequences.
4. Determine the major problems that prevent their application and recommend proper solutions.

Significance of the Study

This study is significant in that digital transformation of environmental management has been emerging worldwide, and it helps to fill this research gap on the effectiveness of e-waste sorting systems. Moreover, the results of this study are useful for policy-makers, engineers, local governments and researchers working in the sustainable development field to develop a new market opportunity for the adoption and implementation of such systems in Arab countries but particularly Iraq.

2. Literature Review

Basic Concepts

Solid Waste Management

Waste management is the control of waste generation, collection, transportation, sorting, treatment, recycling or disposal in a manner that mitigates against adverse effects on health or the environment (Abedin et al., 2025). Solid waste, because of its magnitude and variety, is one of the most toxic forms of waste and needs solid management systems in the context of sustainable development, especially in developing countries (Chen-Fu et al., 2023).

Iraq has structural issues in the sector, such as poor infrastructure and low levels of community awareness, as is evident from various studies. It has been reported by scholars that the combination of waste management with energy generation may greatly contribute to attaining environmental sustainability (Kareem et al., 2024).

Electronic Waste Separation System

The concept of the electronic waste separation system is employed here, in which smart technologies (e.g., sensors, cameras, actuators), IoT and artificial intelligence are implemented to automatically classify waste type(to name a few: organic waste, plastic and metal (Goh et al., 2022; Olawade et al., 2010). These systems may exist at the site of waste generation; for example, in homes and restaurants or in collection and processing facilities (Alourani et al., 2024).

Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328P. It can be hooked up to the computer via USB or powered by an AC-DC adapter or battery. The microcontroller is the ATmega328P, which runs at 5 volts and 16 MHz with a range of input voltage from 7-20V.

The board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs. Every I/O pin can handle a DC current of 20 mA and the 3.3V line can serve up to 50 mA at most. Memory consists of 32 KB (with 0.5 KB used for the bootloader), 2 KB SRAM, and 1 KB EEPROM. The board has the dimensions of 68.6 mm × 53.4 mm and it weighs 25 g.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. It lacks only a DC power jack and is instead powered through the Mini-B USB connector (see **Table 1**).

Table 1. Shows the comparison between Arduino Uno and existing microcontroller boards in terms of specifications as well the related studies.

No.	Technical advantage	ATmega328P (Arduino Uno)	ESP32	STM32	References
1	Architectural type	8-bit RISC	32-bit X tensa LX6 dual-core	32-bit ARM Cortex-M	Tsebesebe et al., (2025)
2	Basic speed	16 MHz	MHz to 240	MHz from 32 to 480 depending on the model	Kaffale, and Liu (2025)
3	Wireless connection support	No	Wi-Fi Bluetooth	Model dependent	Tsebesebe et al., (2025)
4	Energy consumption	Low,	Medium to High	Low to Medium	Bhushan et al., (2025)
5	Number of I/O pins	~20	Over 30	Over 40	ATmega328P - Microchip Technology, ESP32 Pinout Guide, STM32 Pin Configuration
6	Ease of learning and programming	High	Medium	Medium	Kaffale, and Liu (2025)

Ultrasonic Sensor

Smart systems that monitor the levels of waste inside tanks employ the ultrasonic sensor. It is located in front side of the bin to measure the distance from it to waste surface continuously (STMicroelectronics, 2022: Kavitha and Rajesh, 2019) Periodic measurement is made (small time intervals). The sensor module has four pins: Vcc, Trig, Echo, and GND. It comes into operation by sending a high frequency sound wave from the transmitter unit, reflected after striking an object in container (Patil and Solanke, 2020 Sinha and Shukla. 2021). The receiver unit receives the sound signal and converts it into digital data that can be processed by a microcontroller. The body of the sensor is made up of two lens-like modules (eyes). This technology is popular in non-contact detection applications due to its precision and easy porting into embedded systems. 2. (Espressif Systems, 2022: Kavitha and Rajesh, 2019).

Main Waste Types

- Bio-waste: Deriving from food remnants and organic characteristics.
- Plastic waste: All products made of plastic, of any kind.
- Paper and cardboard rubbish: Generated by office and commercial use.
- Metal: Cans, Aluminum iron etc.
- E-Waste: Old phones, computers, batteries make this refuse.
- Medical waste: Produced at hospitals and clinics, it is one of the most dangerous types.

Parts of Waste Separation Machine

- Material sensors: Scan the material by weight, density, color or electrical conductivity to determine it.
- Mechanical and pneumatic arms separating different parts according to the sensor results.

- Camera and image analysis systems: These are used to recognize waste with the help of AI algorithms.
- Intelligent control room: For steady system work according to the fixed program software.
- Communication & IoT: The ability to send data in real time to control centers or mobile devices.
- Database and statistical analysis: To provide measures on system effectiveness.

Advantages of Electronic Sorting Device

The electric sorting system is one of the commonly seen modern technologies in waste management, which significantly contributes to improving the working efficiency, saving wastes, and reaching environmental harmony (Shichao et al., 2019; Amaral et al., 2020). Such systems use artificial intelligence and sophisticated sensing techniques, which have a better classification rate and faster processing speed when compared to the conventional way of pH measurement (Zhu et al., 2022; Aniza et al., 2023; Ghanbari). Reducing dependance on manual labour helps to prevent human errors and increases workers' occupational health and safety by minimizing contact with hazardous waste (Chiem et al., 2023). Incorporation of these technologies can also enhance the quality of recyclable materials, higher recycling rates, create secondary markets for recycled materials within circular economy (Wang et al., 2022; Kumari et al., 2023). Moreover, by tracking waste origin to final disposal site (for example, via a "finger printing" system), more transparency can be achieved and regulatory compliance improved such that regulatory authorities may better assess performance under existing systems or make more informed decisions with respect to waste management (Chew et al., 2023).

Smart Sorting Systems Implemented Worldwide

- Germany: Has implemented a national level system with residents accessing underground compartments via smart cards, with a recycling rate of over 65%. (Fraunhofer, "ILT Laser technology and AI push the circular economy" (Mar 2024)). RECYCLING magazine, Recycle Robotics The “AI” of waste sorting, Recycle Robotics “AI-powered waste sorting” (May 2022), European Environment Agency (2022).
- Japan: Employs robots powered by artificial intelligence to separate industrial and household rubbish. (Fang, et al., 2023). arXiv Archive Robotic Waste Sorter with Agile Manipulation and rapidly trainable detector (April 2021: Cheng, et al., 2024)
- Sweden: Linking its system for collecting waste with smart sensor networks has already eliminated 40% of truck trips. We now summarize these results for three countries on use of AI in waste management.

Table 2. Summary results of three countries about AI use in waste management.

No.	Country	Smart Tech	Main Scientifically Supported Result
1	Germany	LIBS, AI for metal separation; AI robot lifter, sensors; computer vision	robotic pickers: Improved metal and plastic recycling, increased purity and efficiency
2	Japan	AI robots with deep learning sorting systems; Convo Waste devices	GSM sensors: Accuracy up to ~98% in sorting industrial and household waste
3	Sweden	Sweden Smart Sensor Networks (Filling, Gas, Sound), Improvement in Schedules	optimization: Reduced rounds by 30–50%; data support suggests a logical 40% reduction

Theory of Sustainable Waste Management

Low impact of waste system follows the concept of reduce, reuse and recycle under this system it focuses on use technologies of waste that have minor impact on environment (Chertow et al., 2024; Ruparel et al., 2024; Cheng et al., 2024). Electronic waste sorting systems are an important step towards this direction, since they improve the recycling of materials and decrease the amount of discarded items ending in landfills (Pučnik et al., 2024; Abderrahim, 2025).

3. Research Methodology

In this article, we utilize a descriptive-analytical applied engineering research method, suitable to examine the up-to-date phenomena associated with electronic waste sorting system and waste management. The methodology aims to:

- Literature review on waste separation systems with particular focus on e-waste Perform a literature search of scientific papers and previous studies conducted in the field.
- Apply intelligence and smart technologies (sensors, artificial vision) for improving sorting at source.
- Evaluate the efficiency of the proposed system against conventional waste handling processes.

Several sources from both theoretical and applied viewpoints were selected in order to obtain a comprehensive grasp of the problem. This strategy is consistent with planned efforts to integrate artificial intelligence into the provision of trash services in the future, such as in emerging nations, as seen in **Figure 1**.

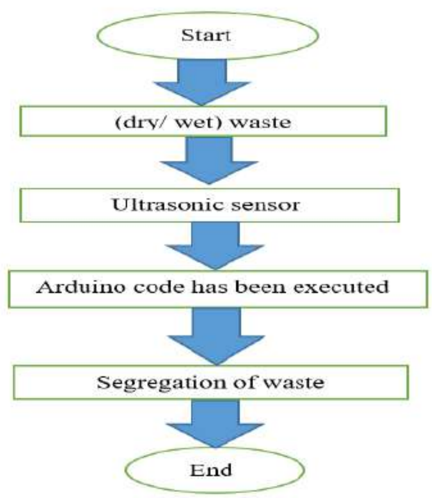

Figure 1. Provides a flowchart of the waste separation process used in this work.

System Engineering Design

The circuit connections of the system are shown in **Figure 2**. The system was modeled in Proteus software to guarantee perfect harmony between all the modules.

- Main Controller: Arduino UNO R3 board.
- Electronic Components:
  1. Soil Moisture Sensor (to pin 7): To detect moisture level of organic waste.
  2. Ultrasonic Sensor (Trigger: pin 6, Echo: pin 5)–to detect plastic waste through distance calculator
  3. Inductive Proximity Sensor: Detects metal and scrap.
  4. Servo Motor (pin 8): Moves the valid waste to a respective category.
  5. LCD Screen with I2C Module (A4, A5 pins) : It shows the type of waste that detected.

6. Buzzer (pin 3): Used to notify a user when a metal is detected.

The system-level design makes individual sensor, actuator and the central processor co-work with each other, so that in real-time garbage is detected at one step and sorted at another.

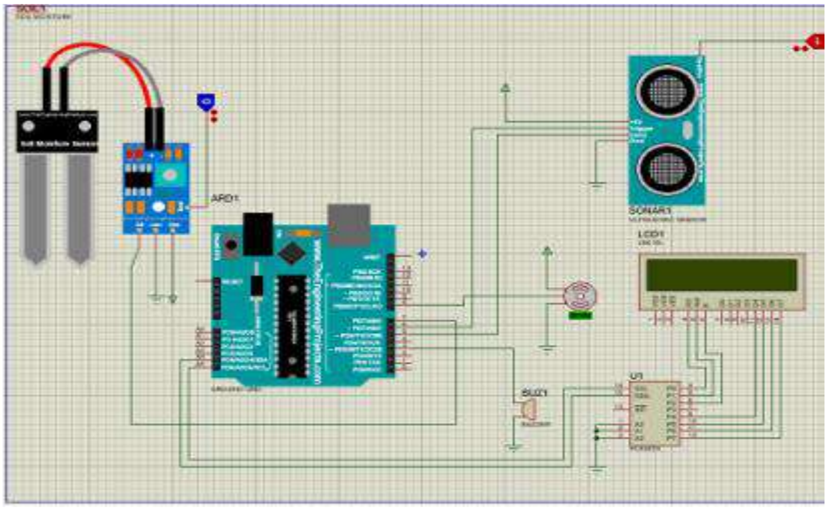

Figure 2. Circuit connection of system.

The system classifies waste into three categories as show in **Table 3**.

Table 3. Classifies waste into three categories.

No.	category	Category Detector	Classification
1	Plastic waste	Ultrasonic sensor	Direct waste to designated container
2	Metal waste	Inductive proximity sensor	Direct metal waste to appropriate container
3	Wet waste	Moisture sensor	Rotate platform toward wet waste container

Prototype Development and Operation

The waste type and corresponding bin are indicated by for the LCD screen,. A fill level gauge with volume and weight measuring system has also be implemented to further increase work productivity by being able to determine container capacity before it is 100%full.

Figure 3 presents the designed prototype which consists of an Arduino UNO R3 board to attach sensors and motors and three containers placed on a circular platform. The system is designed to:

- Accurately recognize waste characteristics.
- Automatic revolutions of the platform depending on determined waste product kind.
- Give the user real time feedback on the LCD screen.
- Set up smart trash disposal by sorting trash to the right compartment.

A flow diagram is shown which depicts the separation and successive stages through which waste process, be classified and sorted.

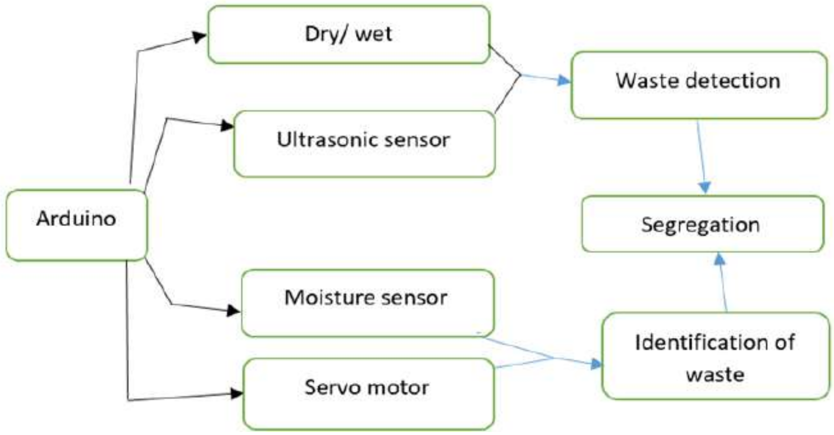

Figure 3. Illustrates the process of the separation of waste and the phases of this process.

The main goal of this research is to classify the waste as correct, which can help the decision making process by waste management and municipal service companies. This strategy leads to an enhanced efficiency of disposal, enables the effective implementation of smart technology and offers potential for scaling up such system in developing countries.

Figure 4. Classifies the waste as "metal waste" and locates the appropriate metal waste bin.

Chemical Composition and Its Effect on Waste Classification And Prototype Operation

Figure 4 shows the procedure of characterization of waste into three main categories that are organic materials, plastic wastes and metal wastes. The presence of waste is detected as soon as it is dumped into the processing module and, upon imputing pre-established parameters, its nature can be accurately and swiftly identified.

- Organic waste: If there is certain type of material with a certain level of moisture detected, then the system marked it as wet waste and directed servo motor to rotate towards the relevant designated bin for all organic waste.
- Plastic waste: If there is object which the ultrasonic sensor identified that it may be in a range, then the system set "plastic waste" and change the rotation of platform.
- Metal waste: The inductive proximity sensor identifies a metallic particle as „metal waste" and places the conveying platform according to metal bin.

A Liquid crystal display (LCD) screen prompts the user with step-by-step instruction and information for the detected waste category and recommended disposal receptacle. In order to even further improve precision of operation, the system also comprises a volume measuring sensor for sensing fill level in each bin, and a weight measuring system for said metal bin.

A working prototype of the garbage segregation system was constructed and tested on an Arduino UNO R3 controller. The sensor and inhibitor prototype consists of a moisture sensor, ultrasonic sensor, inductive proximity sensor, servo motor, LCD display and three custom-made bins mounted on the rotating platform. Two sensors were located at appropriate point on the feed belt, which collect waste parameters and servo motor change the position of platform according to category. Feedback from the LCD screen is intuitive and it assists in waste disposal management (refer to **Figure 5** of the Proposed Model).

Figure 5. final system of waste separation

The main goal of this study is a reliable identification of different waste fractions, which deliver input data for optimizing the decision making process for waste management and public-service companies by enabling efficient disposal. Ultrasonic sensor identified the general waste, moisture sensors detect wet and metallic substances. When the type of waste is identified, it can be dropped into a receptacle and system automatically sort it depending on the category. It has two compartments to hold different types of waste, while a motor rotates the platform to divide wastes it contains for secondary processing.

Waste was separated into three types, such as organic, plastic and metal in order to achieve ease of operation and system complication. However, additional categories such as paper glass and wood can be added to the system by adding more sensors so that the sorting precision is improved and the equipment can also work for a wider range of applications.

4. Results and Discussion

Waste sorting is essential to facilitate the later reuse, recycling, and recovery of materials involved in recycling activities. And they're not just convenient; smart waste sorting systems keeps humans out of harm's way, shortening exposure to dangerous substances and minimizing the consequences of the careless dumping of unwieldy objects on our planet. They facilitate the proper disposal and conservation of resources for future generations.

Applying them in field and smart city trials has shown notable increases in sorting accuracy, efficiency of collection, and recycling rates. They accomplish this through in-bin sensors, optimized routing, and automated sorting. For example, Dileep et al. (2021) note that in current urban waste management, the problem of a constant physical presence can be mitigated at least to some extent through sensor-based automated setups.

The novelty of the proposed system is that it is composed by several sensors, which operate in cooperation:

- Moisture/Humidity sensor: It senses if object is wet or dry, and it let the system know for categorization.
- Ultrasonic sensor: To measure the distance between the surface of the bin and waste, in order to estimate the fill level of the bin.
- Servo motor: Controla los residuos hacia su contenedor gracias a sensores.

If a bin is full, it sends a signal to an Arduino Uno, which signals the control system that the bin needs to be emptied. This feature allows the reservoir to function as intended, will not overflow and prevent system from functioning properly.

Waste is commonly defined in two basic ways:

- Solid waste: Refers to inorganic dry waste such as plastic, paper, metal and glass.
- Wet/Mineral waste: Comprising biodegradable wastes like food scraps, vegetable peels and garden waste.

Its capability to separate wet waste was demonstrated using different types of waste, such as vegetable peelings or wet wipes. The waste is dropped on to the upper container and in seconds of about 3, it gets automatically transferred or shifted to the specific sub-container for wet waste. This feature ensures the precise separation and minimizes users' intervention, time & energy.

By controlling the system bin by bin according to the size, an Arduino Uno based method is used for efficient pick up of unsorted garbage. Liquids from solids can alternatively be split using mechanical techniques if desired. The combined implementation of sensors and automatic sorting helps communities better dispose waste, eliminating unnecessary public resources and helping them develop more sustainably while protecting the environment.

In general, this intelligent waste separation system provides a low-cost and scalable way for municipal solid waste management in urban area and is an effective approach to improve recycling efficiency, reduce landfill dependence, and create a feasible means of the developed countries which suffering rapidly growing amount of generated wastes from increasement of urbanization.

Performance of Electronic-Waste (E-Waste) Handling and Disposal Systems

However, according to recent researches and international practices the collection systems with electronic separation proves effective in waste management since it appears that sorting precision is greatly increased. The use of AI and sophisticated material recognition technology in warm mix asphalt systems achieve some accuracy rates beyond 90% (Dada et al, 2024). These systems also improve the quality of recycled materials by preventing cross-contamination between waste streams, so they can be reused in industry more easily than manually sorted materials (Bhuvaneswari et al., 2025).

Furthermore, electronic sorting replaces some materials from the waste stream to backfilling and by doing that increases the recovery rates which decongests landfills and puts less pressure on sanitary landfill sites (Quinto et al., 2025).

Ecological Effect of Electronic Sorting System Application

A literature review with case studies in Germany, Sweden, South Korea and Japan reveals some of the environmental benefits:

- Greenhouse gas emission savings: By reducing the need for incineration and landfilling while optimizing recycling.
- Soil and groundwater protection: When toxic and hazardous substances no longer leak out of the unsorted waste, there is less risk to the environment.
- Improvement of sustainability metrics: Especially for cities with e-sorting systems that are connected to environmental reporting and monitoring.

Economic and Social Impact

Economic Impact:

- Low operation costs over the long term, in spite of large initial setup costs.
- Supplying recyclable materials to a market for resale or industrial reuse, such as metal and virgin plastic.
- More efficient logistics by connecting smart bins to monitoring systems and using fewer collection trips that are not required.

Social Impact:

- Enhanced awareness of members of the community when they engage with intelligent, source-oriented waste sorting systems.
- Better environment of work for waste management workers due to reduced exposure to mixed/hazardous waste.
- Development of new positions in technician-related technical areas (Introduced for system maintenance, software management and sensor calibration).

Table 4. Shown comparison between electronic and traditional systems

No.	**Traditional system**	**Electronic system**	**Indicator**
1	Low - Medium	High (up to 90%)	Sorting accuracy
2	High	Low	Manual labor requirement
3	High long-term	Low after establishment	Operational costs
4	Mostly negative	Positive	Environmental impact
5	N/A	Available via smart systems	Real-time control and monitoring
6	Limited	High	Scalability

Challenges Facing the Implementation of AI Waste Separation Systems

Although the advantages of e-waste separation systems are evident, their application faces many challenges, especially in poor countries and cities. And which can be classified under the following challenges:

1. Technical Challenges

- Digital infrastructure lagging in many cities as it pertains to integrating with communication and data networks.
- Lack of qualified technical support to manage and service electronic equipment and related software.
- Failures of devices or sensors due to improper use or unfavorable environmental factors, e.g. humidity, heat and dust.

2. Economic Challenges

- The capital costs for installing and operating systems were high.
- Scarce government or city financing, and lack of private sector and donor support.
- Compressed near term financial returns leading to lack of investor interest.

3. Social and Behavioral Challenges

- Limited public awareness in source sorting and the application of intelligent waste containers.
- Workers resistance to change in conventional waste pick up sectors.
- No legislation to bind the use of home or institutional systems for electronic sorting.

5. Recommendations

The following recommendations are made based on the findings and discussion of challenges:

1. Public Policy Level

- Incorporate electronic sorting systems in the national waste management plans.
- Promote the investment of smart waste management technologies by the private sector.
- Pass a law to make large organizations (government departments, factories, hospitals) install smart waste management systems.
- Offer tax breaks to encourage investment in these technologies by the private sector.

2. Institutional and Municipal Level

- Train technicians on use and maintenance of electronic sorters.
- Facilitate public and private partnerships to carry out scalable pilot schemes.
- Execute phased pilot deployment before full roll-out to hedge against risk and measure impact.

3. Community Level

- Organize media, school and community programs to raise awareness leading to source separated waste sorting. 2.
- Motivate civil users by the reward scheme or digital incentives to use electronic sorting machines as they should be used.
- Improve transparency by issuing regular reports on environmental effect and recycling performance.

Summary of Results

This research further concludes that e-waste separation systems have revolutionised solid waste management. The systems demonstrated:

- strong effectiveness in enhancing the accuracy of sorting.
- Reduced reliance on traditional landfills.
- Higher recycling rates and better material reclamation.
- Long-term reductions in operational costs.
- Positive Environmental impacts like reduced emission and conservation of natural resources.

Electronic and traditional sorting systems were compared, proving the prioritization of AI-assisted sorting as competitive in terms of environmental aspects, cost efficiency and technical performance. Yet, an effective operation of these systems, particularly in the context of resource-constrained countries, will depend on orchestrated political actions and societal as well as technical support to address existing challenges and move toward sustainable waste management development.

6. Conclusion

The smart electronic waste segregation system is a highly-intelligent system for smart integration of waste recycling. It exhibits significant superiority compared to the conventional manual devices in sorting precision, operation speed, and safety.

Although challenges are posed in terms of technical, economic and social issues, they can be addressed through holistic and participatory practices. Lessons learned From Successful international experiences provide a useable model that can be adjusted and applied in the Arab countries with respect to Iraq to help promote sustainable urban waste management.

7. Future Research Prospects

This study identifies several directions for future work, such as:

- An exploration of the influence of e-waste segregation systems on household waste sorting behaviour and community participation.
- Create mathematical models to project the biologic and economic benefits of these systems.
- Performance assessment of real-time sorting by applying AI and machine learning.
- Investigating possibility for national electronic sorting systems in prominent Iraqi cities and their role in sustainable waste management.

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