

# The Development of a Smart Mobile Waste Bin with Lifting Mechanism for Enhanced Urban Waste Management in Abia State, Nigeria

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## ABSTRACT

Moving around Abia State, the capital city included, I see a lot of littered environment, and I imagined that things could have been done differently. I see so many public plastic waste bins filled to the brim and many to overflow smearing the environment with stink, bad odours, and flies which ultimately can lead to a break out of an epidemic if care is not taken. I also saw such in different school environments including universities in the State. This paper presents the development and use of smart dustbins to digitalize waste disposal in Abia State. This smart waste bins operate with a software/app that can alert the waste collectors and operators when any waste bin is filled and also the location of the waste bin. This in turn will enhance the cleanliness of the environment and save a lot of lives from sicknesses as well as untimely death, save fuel and reduces labor cost. Equipped with IoT sensors, mobility through tyres, and an automated lifting mechanism to improve the efficiency, hygiene, and safety of waste collection. The system incorporates real-time waste level monitoring, GPS-based location tracking, and automatic lifting capabilities to facilitate easier waste transfer and reduce manual labor. bring significant improvement in waste collection time, reduced human exposure to hazardous waste, and increased responsiveness of waste collection services.

## I. INTRODUCTION

The challenge of effective solid waste management remains a major concern for urban centers in Nigeria, particularly Abia State—the most

populous and economic hub of the South East. Traditional waste bins are often manually operated, immobile, and prone to overflows, posing risks to health and the environment.

Technological interventions such as Smart Waste Bins offer an innovative solution by incorporating Internet of Things (IoT) technologies, automated lifters, and mobile platforms (tyres) to facilitate more efficient, hygienic, and responsive waste management systems. This paper presents a conceptual framework for design and deployment of a smart, mobile waste bin with an integrated lifting system tailored to the urban realities of Abia State

## II. STATEMENT OF THE PROBLEM

Current waste collection practices in Abia are hindered by:

- 1) Manual lifting of heavy bins by sanitation workers,
- 2) Overflowing bins due to lack of monitoring,
- 3) Immobility of public bins, restricting ease of access,
- 4) Delays in pickup due to lack of real-time waste data

To address these issues, there is a need for a smart, mobile, and semi-automated waste collection unit capable of enhancing urban cleanliness while promoting safety and efficiency.

The use of smart waste bins will not only alleviate sickness but will make environments clean, neat and sweet. The environment will also be attractive and healthy, be it schools, industry areas and market places

### III. OBJECTIVES

The main objectives of the study are:

To design a smart waste bin system incorporating IoT for real-time monitoring.

To add mobility to the bin using wheels/tyres for easy relocation and deployment.

To integrate an automated lifter to aid waste evacuation and minimize human labor.

### IV. LITERATURE REVIEW

Oluwadare,(2022) examines handling disposal and management of electronic waste in Nigerian environment and speaks about the dumping of these wastes, in Nigeria as a result of poverty.

Nnorom,(2020). He said that Nigeria lacks the necessary recycling infrastructure to management of E-waste, consequently relying on informed sectors that use crude recycling techniques.

Nnorom and Olusegun,(2019) said Nigeria is a dumping place for used electrical and electronic equipment from other developed countries and because of the enormity of those wastes, environmental contamination and human exposure to dangers and harmful chemicals is what attends the Nigerian environment and said that importation of electronic products should be banned while he decries the lack of proper E-waste management practice in Nigeria.

Bongr,Roman,and Recker Volume 40 issue 6) focused on firms digitalization intentions largely neglecting the level of actual adoption of digital technologies and do not differentiate the level of digitalization alongside different steps of the waste management value chain.

According to Czekala, (2023.) Thanks to digitalization we have the possibility to automate processes, using software including waste.

Jan. (2023), The review, presents a compendium of various sources of E-waste, environmental hazards, its composition and characterization.

A literature study on electronic waste management in Indonesia,(2023) provides a more systematic analysis of electronic waste management, government regulation number 27 of 2020, and hence studies to understand the regulation, policies and practice in addressing the electronic waste of developing countries.

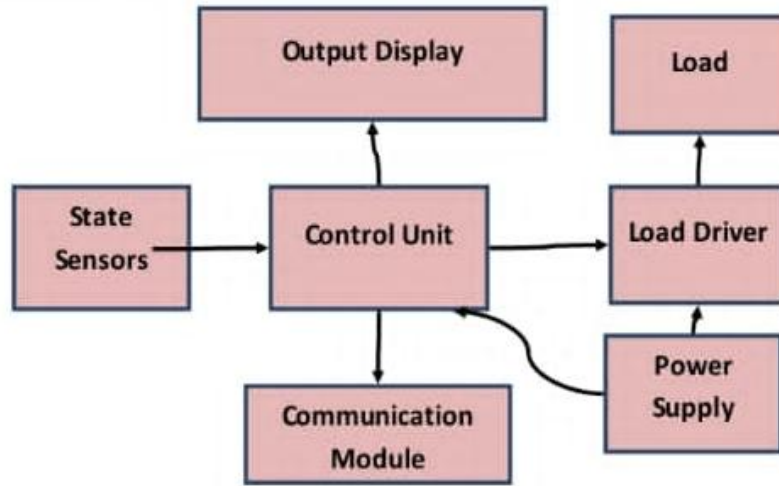
Idehio,(2012) recommends that Nigeria should develop an effective policy framework which encourages the development and manufacture of national I.T. knowledge and appliances.

Alibi,(2021) Federal University of Technology Akure explains that exposure of humans to electronic waste in Nigeria is on the increase because of the indiscriminate disposal of and crude informal recycling methods in the country. This he opined has damaged the health and welfare of individuals exposed to these hazardous constituents. According to him electronic waste in Nigeria sheds light on the ongoing problems of environmental recession. It is evident that e-waste has had a devastating effect on both environmental and human health and continued that what is even more evident is that disposal of e-waste by

### V. METHODOLOGY

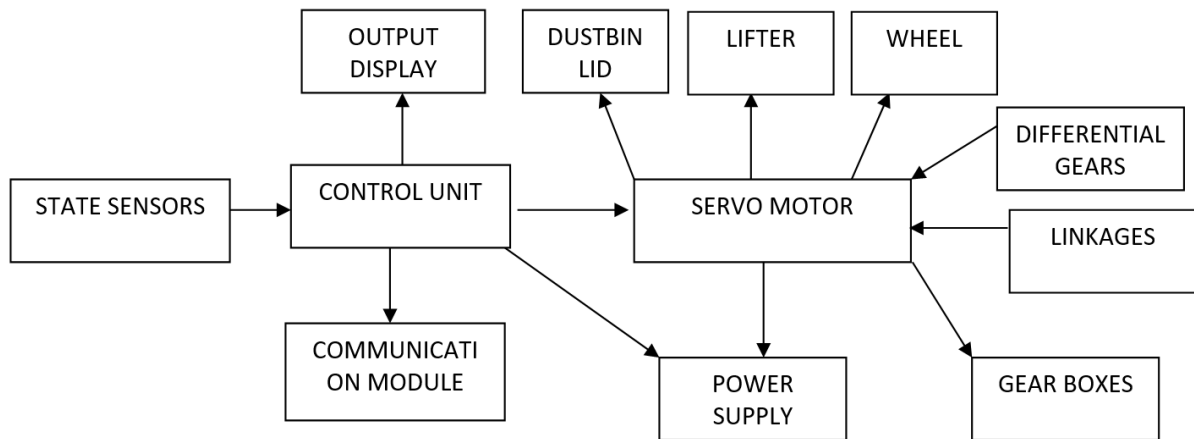
The development of a Smart Waste Bin with lifters and wheels involves an interdisciplinary approach combining mechanical design, electronics, embedded systems, and software integration. Which outlines the systematic steps that will be taken from conceptualization to implementation and testing of the prototype.

**EXISTING MODEL OF SMART WASTEBIN FIG 1**



**THE PROPOSED MODEL OF SMART WASTE BIN**

Block diagram of the proposed smart waste bin fig.



**Block Diagram of the Proposed Model fig 2**

**ENHANCED POWER SUPPLY**

Enhanced Power Supply Design for Smart Waste Bin (with Mobility & Lifters)

Main Power Source: Battery Pack

Recommended:

Lithium Iron Phosphate (LiFePO<sub>4</sub>) battery pack

Voltage: 24V (commonly used for small electric mobility systems)

Capacity: 20Ah–40Ah depending on runtime requirements

**Advantages:** Safe, long life, high current output, better thermal stability

**Features:**

BMS (Battery Management System) included for:

Over-voltage/under-voltage protection

Overcurrent protection

Short circuit and temperature protection

Cell balancing

**Power Distribution Unit (PDU)**

Distributes the main battery power to all subsystems

Includes:

DC-DC converters for voltage regulation to subsystems:

24V → 12V (for motors or sensors)

24V → 5V (for microcontrollers, logic)

24V → 3.3V (for low-voltage sensors or BLE modules)

Fused outputs to protect each branch

Power switches or relays for controllable power to different modules

### Voltage Regulation Modules

- a. Motor Drivers (Wheels & Lifters):  
 Use high-efficiency DC motor drivers with wide input range (e.g., 12V–30V)  
 Must support the stall current of motors (usually 2–5x rated current)  
 Add a large capacitor (electrolytic + ceramic) near drivers for spike protection
- b. DC-DC Buck Converters:  
 High-efficiency (90%+) converters for sensitive electronics:  
 24V → 5V (Raspberry Pi, microcontroller)  
 24V → 3.3V (sensors, communication modules)

### Charging System

External charger with matching voltage and current specs:  
 For 24V LiFePO<sub>4</sub>: Use a 24V, 5A–10A smart charger  
 Include:  
 Charging port with anti-spark protection  
 LED indicators for charge level and status

### Optional: Solar Charging Module

Adds energy autonomy and sustainability  
 Flexible solar panels (e.g., 50–100W) on bin surface  
 Paired with:  
 Solar charge controller (MPPT preferred) compatible with LiFePO<sub>4</sub>  
 Useful for:  
 Prolonging operation in outdoor/static deployments  
 Trickle charging when idle

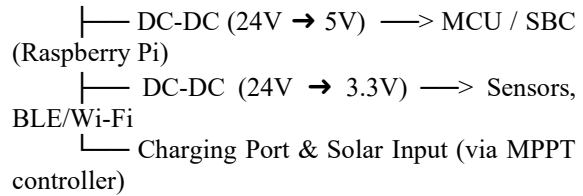
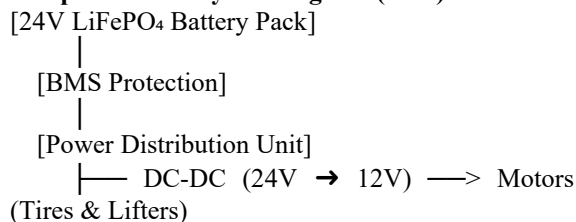
### Power Monitoring and Diagnostics

Integrate sensors or smart chips to monitor:  
 Battery voltage and current  
 Power consumption per subsystem  
 Temperature  
 Interface via I<sup>2</sup>C/SPI to MCU or Pi for live reporting

### Physical and Electrical Protection

Fuses or resettable PTCs on every power line  
 TVS diodes for surge protection  
 EMI filtering capacitors  
 Waterproof enclosure (IP65 or higher) for outdoor use

### Sample Power Layout Diagram (Text)



### Summary of Components

Component	Specs	Purpose
LiFePO <sub>4</sub> Battery	24V, 20–40Ah	Main energy source
BMS	7S or 8S	Battery safety and balancing
DC-DC Converters	24V → 12V / 5V / 3.3V	Regulated power to subsystems
Motor Drivers	12–24V, 10–30A	Control tires/lifter motors
Smart Charger	24V, LiFePO <sub>4</sub> compatible	Safe recharging
Solar Panel (Optional)	50–100W + MPPT	Renewable power
Power Monitor IC	INA219 or similar	Live power stats

### CODING FOR THE ENHANCED POWER SUPPLY

```

Hardware Assumptions:
Microcontroller: ESP32, Arduino Mega, or similar.
Power sensor: INA219
Power relays: Connected to digital pins.
Battery: 24V LiFePO4
BMS: Handles cell-level protection (not directly coded here).
Libraries Needed (Arduino IDE):
#include <Wire.h>
#include <Adafruit_INA219.h> Arduino Code
Example: Power Management & Monitoring
#include <Wire.h>
#include <Adafruit_INA219.h>
Adafruit_INA219 ina219;
// Relay pins for power control
const int MOTOR_RELAY_PIN = 5;
const int LIFTER_RELAY_PIN = 6;
// Thresholds (set based on your system)
const float MIN_SAFE_VOLTAGE = 22.0; // For 24V LiFePO4, consider 22V low
const float MAX_SAFE_CURRENT = 10.0; // Adjust to your system's max load
void setup() {
  Serial.begin(115200);
  Wire.begin();
  // Initialize INA219
  if (!ina219.begin()) {
    Serial.println("Failed to find INA219 chip");
    while (1) { delay(10); }
  }
}
  
```

```
// Setup relay pins
pinMode(MOTOR_RELAY_PIN, OUTPUT);
pinMode(LIFTER_RELAY_PIN, OUTPUT);
// Initially power everything ON
digitalWrite(MOTOR_RELAY_PIN, HIGH);
digitalWrite(LIFTER_RELAY_PIN, HIGH);
Serial.println("Power management system
started.");
}
void loop() {
float busVoltage = ina219.getBusVoltage_V(); //
Voltage of system
float current_mA = ina219.getCurrent_mA();
// Current draw in mA
float power_mW = ina219.getPower_mW();
// Power in mW

// Print data
Serial.print("Voltage: "); Serial.print(busVoltage);
Serial.println(" V");
Serial.print("Current: "); Serial.print(current_mA /
1000.0); Serial.println(" A");
Serial.print("Power: "); Serial.print(power_mW /
1000.0); Serial.println(" W");
Serial.println("-----");
// Safety checks
if (busVoltage < MIN_SAFE_VOLTAGE) {
Serial.println(" ⚠ Voltage too low! Shutting
down motors/lifters.");
digitalWrite(MOTOR_RELAY_PIN, LOW);
digitalWrite(LIFTER_RELAY_PIN, LOW);
}
if (current_mA / 1000.0 >
MAX_SAFE_CURRENT) {
Serial.println(" ⚠ Overcurrent detected! Shutting
down motors.");
digitalWrite(MOTOR_RELAY_PIN, LOW);
}
delay(2000); // Sample every 2 seconds
}
```

#### What This Code Does:

FunctionPurpose  
 ina219.getBusVoltage\_V() Reads system voltage  
 ina219.getCurrent\_mA() Reads current in milliamps  
 Relays on GPIO Turns subsystems on/off (motors, lifters)  
 Safety logic Shuts down on low voltage or high current

#### Optional Enhancements:

Add temperature sensors for thermal protection.  
 Send data to cloud dashboard (via Wi-Fi/ESP32 or GSM).

Use OLED or LCD to display voltage, current live.  
 Add real-time clock (RTC) to log when power events occur.

#### HARDWARE COMPONENTS

Mobility System (Tires & Movement)  
 DC motors with encoders or Stepper motors – for controlled movement  
 Motor driver module (e.g., L298N, TB6612FNG)  
 Caster wheels – for balance and direction  
 Battery pack – Li-ion or LiPo battery (12V or appropriate rating)  
 Chassis frame – metal or strong plastic to house components

#### LIFTER MECHANISM

Linear actuators or servo motors – to lift garbage or open lids  
 Limit switches – to detect end positions  
 Gears or rack-and-pinion system – for load transfer (optional)  
 Weight sensor (load cell + HX711 module) – to measure bin load

#### SMART ELECTRONICS/CONTROL

Microcontroller / Processor:  
 Raspberry Pi – for high-level control, image processing, IoT  
 Arduino Uno / Mega – for low-level control (motors, sensors)  
 ESP32 – good for wireless and sensor control (Wi-Fi + Bluetooth)

#### SOFTWARE COMPONENTS

A smart waste bin with tires and lifters is essentially a mobile robotic system with waste management capabilities. Its software components need to support mobility, waste detection, automation, safety, communication, and control. Here's a breakdown of the key software components:

##### Embedded Control System (Firmware)

Runs on a microcontroller or SBC (e.g., Arduino, Raspberry Pi, or STM32).

##### Handles:

Sensor input (weight, proximity, bin fill-level).  
 Motor control (tires, lifters).  
 Basic decision-making logic (e.g., when to lift, when to move).

##### Sensor Integration Software

Interfaces with:  
 Ultrasonic/IR sensors (for obstacle detection and bin fill-level).  
 Weight sensors (for load detection).  
 Cameras/LiDAR (if advanced navigation or object recognition is used).

### Navigation and Path Planning

For autonomous movement:

SLAM (Simultaneous Localization and Mapping) for map-building.

Pathfinding algorithms (A\*, Dijkstra) to navigate efficiently.

Obstacle avoidance logic (e.g., RRT or potential field methods).

4. Actuator Control Module

#### Controls:

Wheel motors (DC/stepper motors with encoders).

Lifter mechanisms (servo or hydraulic controls).

Braking and steering (if applicable).

May include PID or other feedback control systems for precision.

### Connectivity & Communication

Manages:

Wi-Fi / Bluetooth / 4G / LoRa for remote monitoring.

MQTT/HTTP/REST API for sending data to a central server or cloud.

OTA updates for firmware/software upgrades.

### Cloud Backend or Edge Processing (Optional)

For:

Data storage & analytics (e.g., bin usage statistics).

Machine learning (e.g., object classification or predictive maintenance).

Fleet management (if multiple bins are deployed).

Platforms: AWS IoT, Azure IoT, Firebase, or custom servers.

### User Interface Software

Web dashboard or mobile app for:

Monitoring bin status.

Setting operation schedules.

Sending commands (manual movement/lifting).

Viewing alerts (overfilled, malfunction, etc.).

### Safety and Error Handling Module

Software that:

Monitors for unsafe conditions (e.g., overload, tipping).

Stops movement or lifting in emergencies.

Logs faults and notifies users/maintenance.

### AI/Computer Vision (Optional but Powerful)

For: Object recognition (e.g., detecting recyclable items). Route optimization based on visual inputs.

Human detection (to avoid collisions).

### Configuration and Logging System

Stores:

Device settings (movement speed, lift height).

Operational logs (usage, errors, events).

Diagnostics data.

## VI. CONCLUSIONS

This work presented an enhanced solution to the problem of waste disposal especially in Abia State where a lot of wastes are generated. The automation of the opening and closing of the lids, the movement and evacuation of the bin by the help of the wheels and lifter will ensure that very high standards of hygiene is maintained as the operator will not have any contact with the bin. Again, both time and cost is reduced Environmental pollution and littering of the environment is minimized as the lid of the bin will be shut to the users until the disposal truck empties it thus the users will not be allowed to over fill the bin. Timely disposal of the wastes is ensured as the system automatically sends an SMS alert to the disposal truck driver once the bin is full thereby ensuring that the bin is made empty to avoid dumping of refuse on the floor.

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