**ECO VENDING MACHINE – SENSOR DETAILS**

**Overview**

A cost-effective smart waste sorting system that leverages multiple sensors to accurately detect and classify different types of waste. By combining sensor data, the system improves recycling efficiency and accuracy. Below is a breakdown of the key components, their budget-friendly options, and their roles in the system.

**Key Components and Their Functions**

**1. Weight Detection**

* **Sensor**: **Load Cell (Weight Sensor)**
  + **How It Works**: A load cell measures the weight of an item by detecting the strain on a material when a load is applied. This strain is converted into an electrical signal that can be read by the system.
  + **Function**: Differentiates between light and heavy items, providing a preliminary classification based on weight.
  + **Cost**: ₹415 - ₹1,660.
  + **Pros**: Inexpensive, widely available, and easy to integrate.
  + **Cons**: Measures only weight; should be used in combination with other sensors for better accuracy.

**2. Volume Detection**

* **Sensors**:
  + **Ultrasonic Sensor**:
    - **How It Works**: Uses sound waves to determine the distance to an object. The time it takes for the sound to bounce back to the sensor is measured, indicating the size or volume of the item.
    - **Function**: Helps estimate the volume of the waste item by detecting its distance from the sensor.
    - **Cost**: ₹250 - ₹830.
    - **Pros**: Affordable and simple to implement.
    - **Cons**: May be less accurate for irregularly shaped items.
  + **Infrared (IR) Sensor**:
    - **How It Works**: Uses infrared light to detect the presence and proximity of an object. The IR light reflects back to the sensor when it hits the surface of an item.
    - **Function**: Measures the item's dimensions, assisting in volume estimation.
    - **Cost**: ₹415 - ₹1,245.
    - **Pros**: Inexpensive and easy to use.
    - **Cons**: Less accurate for items with irregular shapes or surfaces.

**3. Material Type Detection**

* **Sensors**:
  + **Camera-Based Image Recognition (Computer Vision)**:
    - **How It Works**: A camera captures images of the waste item, which are then processed by machine learning models to identify the type of material based on visual features.
    - **Function**: Classifies materials (plastic, metal, glass, etc.) based on visual analysis.
    - **Cost**: ₹1,245 - ₹2,490.
    - **Pros**: Versatile and capable of recognizing a wide variety of materials.
    - **Cons**: Requires training a model and higher processing power.
  + **Near-Infrared (NIR) Sensor**:
    - **How It Works**: Uses infrared light to analyze the spectral properties of the material. Different materials absorb and reflect NIR light uniquely, aiding in identification.
    - **Function**: Detects specific types of materials, especially plastics, glass, and some metals, based on their light absorption characteristics.
    - **Cost**: ₹4,150 - ₹8,300.
    - **Pros**: Effective for distinguishing between similar materials.
    - **Cons**: More expensive and complex.

**4. Metal Detection**

* **Sensors**:
  + **Inductive Sensor**:
    - **How It Works**: Generates an electromagnetic field and detects changes when a metal object comes close. The change in the electromagnetic field indicates the presence of metal.
    - **Function**: Identifies metal objects, particularly non-ferrous metals like aluminum.
    - **Cost**: ₹415 - ₹1,660.
    - **Pros**: Cost-effective for metal detection.
    - **Cons**: Limited to metallic items.
  + **Capacitive Sensor**:
    - **How It Works**: Detects changes in capacitance when an object is nearby. Different materials cause different changes in capacitance, allowing the sensor to identify them.
    - **Function**: Senses non-metallic objects like plastic, paper, and glass.
    - **Cost**: ₹830 - ₹2,490.
    - **Pros**: Effective for detecting non-metallic materials.
    - **Cons**: Needs calibration for different materials.
  + **Magnetic Sensor**:
    - **How It Works**: Detects the presence of ferrous metals (iron-containing materials) by sensing changes in a magnetic field.
    - **Function**: Distinguishes between ferrous (magnetic) and non-ferrous (non-magnetic) metals.
    - **Cost**: ₹415 - ₹1,245.
    - **Pros**: Inexpensive and effective for metal sorting.
    - **Cons**: Cannot detect non-metallic items.

**Multisensor Fusion for Improved Accuracy**

Combining different sensors enhances the overall accuracy and reliability of the system:

1. **Weight Detection**: Measures the item’s weight using a Load Cell.
2. **Volume Detection**: Uses Ultrasonic/IR Sensors to estimate the item's size.
3. **Material Detection**: Camera-based vision or NIR sensors confirm the type of material.
4. **Metal Detection**: Inductive, Capacitive, and Magnetic sensors differentiate metal from non-metal items.
5. **Confirmation**: Acoustic or Vibration sensors identify non-recyclable items like rocks.

**Pros: Increases accuracy and reliability in material classification.**

**Cons: Requires integration of multiple sensors, increasing system complexity.**

**Processing Hardware (Budget-Friendly Options)**

* **Arduino (₹1,660)**: Suitable for basic sensor tasks and integration.
* **Raspberry Pi (₹2,905 - ₹4,980)**: Capable of handling more complex tasks like image processing.
* **NVIDIA Jetson Nano (₹8,235)**: Ideal for advanced AI processing, such as machine learning models for material detection.

**Pros: Affordable options for processing tasks.**

**Cons: More advanced tasks require higher processing power.**

**Budget Estimate (Basic Setup)**

| **Component** | **Cost (INR)** |
| --- | --- |
| Weight Sensor (Load Cell + HX711) | ₹1,245 |
| Ultrasonic Sensor (HC-SR04) | ₹415 |
| Camera (Raspberry Pi Camera) | ₹2,075 |
| Inductive Proximity Sensor | ₹830 |
| Acoustic Sensor (Microphone) | ₹830 |
| Microcontroller (Raspberry Pi) | ₹3,320 |
| **Total Estimated Cost** | **₹8,715** |

**Setup Benefits: Cost-effective setup covering weight, volume, and material detection with high accuracy within a reasonable budget.**

**Conclusion**

The proposed smart waste sorting system utilizes a combination of inexpensive sensors and microcontrollers to effectively sort and classify waste. This scalable system is designed to improve recycling processes, reduce contamination, and provide accurate sorting within a limited budget.