Waste Separation Smart Dustbin

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***Abstract*— This research proposes the use of technology to tackle the issues being faced in terms of waste management. Nowadays poor waste management has caused an increase in landfilling and dumping sites that instigated pollution and a waste of recyclable materials that can be used for recycling or remanufacturing. The method approached to solve this issue was to construct a waste separation smart dustbin by integrating proximity sensors and a moisture sensor into a microcontroller to detect metal, moist and recyclable waste while using a conveyor belt to segregate it. The constructed prototype provided sufficient results to justify the method attempted. With this research attempted, waste management system is taking its first steps into a successful system to achieve a sustainable environment for the present and the years to come.**

***Keywords*— waste; management; sensors; separate; sustainable; smart; dustbin; recyclable; metal; moist**

I. INTRODUCTION

In today's current general environment around urban households there has been many situational problems of residential sanitization condition. This unethical problem is concerned from the general waste management. This problem does not only unfold under the urban residential surroundings, but globally in all environments. From residue food to redundant materials and recyclable objects going uncultivated. Waste management in general has not been a full focus in today's trend and it has now been a main problem due to its causing of natural diseases, pollution and other problems that should be solved. Usually this management process goes from a manual process where humans need to separate the waste to different categories, based upon [1], there are seven categories of waste. Waste categorizing goes through different researches and generalizing based from country to country. The general decomposition of waste goes about five categories. They are: Liquid Waste, Solid waste, Organic waste, Recyclable, Hazardous. Table 1. [1] shows how the researchers completed a survey about waste decomposition and how every category of waste is generalized. According to the research study of Waste management in Malaysia by Sin et al. (2014), it is deemed to be that the increase number on municipal solid waste has become a large-scale environmental problem, and now with the increase in population as well, the number of excessive waste increases. The study is generated from households, industrial and commercial. The main purpose of this researchis the awareness of a simple, low cost and user-friendly separation system for industries, commercial centers or urban households to simplify the waste management process. A smart dustbin which is cheap, easy to use solution for a separation and alert system at centers, so that it can be sent directly for processing. The idea is simple and is focused by the fact that dustbins require constant cleaning, which is not always possible. This leads to unhealthy environment and unwanted diseases. However, behind every idea is a problem that erases and covers the idea completely. Similarly, behind the Waste management system is challenges that hinder the ideal implementation of the system to effective use of the sustainability of the waste management system.

TABLE I. TWASTE DECOMPOSITION FROM A FINNISH SURVEY [1]

Fractions	
Bio-waste	*Plastic*
1. Wasted Food	16. Plastic packaging
1.1 Edible food parts	16.1 Plastic film packaging
1.1.1 Unpackaged food	16.2 Dense plastic packaging 16.3 PVC
1.1.2 Packaged food	plastic packaging 17. Other plastic
1.2 Inedible food parts	17.1 Other plastic film
2. Garden waste	17.2 Other dense plastic 17.3 Other
2.1 Plant fragments	PVC plastic
2.2 Soil	*Glass*
2.3 Other garden waste 3. Other bio-waste	18. Glass packaging
Paper	18.1 Colored glass packaging 18.2 Clear
4. Recyclable paper	glass packaging 19. Other glass
4.1 Newspapers, flyers, posters	19.1 Other colored glass 19.2 Other clear
4.2 Books	glass
4.3 Drawing and printing paper	*Metal*
5. Tissue (toilet paper, paper towels,	20. Metal packaging
napkins)	20.1 Aluminum packaging
6. Paper packaging	20.2 Other metal packaging 21. Other
7. Other paper	metal
	Other fractions
	22. Textiles
	22.1 Shoes and clothes 22.1.1 Shoes
Paperboard and cardboard	22.1.2 Clothes
8. Paperboard wrapping	22.2 Other textiles
8.1 Paperboard liquid wrapping 8.2	23. WEEE
Aluminum-layered paperboard	23.1 Fluorescent tubes, low energy light
wrapping	bulbs
8.3 Types of paperboard packaging	23.2 Other WEEE
9. Cardboard packaging	24. Hazardous waste
10. Types of paperboard	24.1 Batteries and accumulators 24.1.1
11. Other cardboard	Small batteries
Wood	24.1.2 Automotive accumulators 24.2
12. Recyclable wood	Hazardous chemicals
13. Treated wood	24.3 Medicines
14. Wood packaging	24.4 Other hazardous waste
15. Sticks and branches	25. Tires

The system architecture proposed by [2] consists of an auto feeder, object sensor, robotic arm, conveyor belt and a PLC system. The auto feeder brings in the waste onto the conveyor belt while the object sensor detects whether there is a waste on the belt, if the sensor detects something it will then sends a signal to the PLC system to set on the conveyor belt. The metal objects are being detected using an inductive sensor, the reason why an inductive sensor is used because of its high detection rate, accuracy and its ability to work in dense and rough conditions. The robotic arm uses its attached electromagnet to pick up the metal scraps from the conveyor belt. The arm has a base rotation.

[3] proposed a Smart Garbage bin when a bin is full, it sends and SMS to the municipality office. The approach for this solution is by using ultrasonic sensors and load cells to detect the amount of waste in a bin. When the sensors detect the bin is full, the GPS sensors provides the location of the bin

while the GSM module sends the SMS. Segregation for the waste management is done by using the NIR. The proposed research tends to separate plastic for biogas plant. Plastic separation is first done using the NIR spectroscopy or using manual sorting. The limitations deducted is that this system does not work on black colored plastic or bottles with plastic around or sealed caps. [4] Waste managing has caused many problems, unsegregated waste is just dumped into dump yards increasing garbage to limits of which it will be difficult to monitor and manage. The proposed system is designed to have IR sensors to detect the level of waste collected, a gas sensor that detects any harmful gas inside the bin, a load cell the measure the weight of the bin and to act as notifications, LEDs and an LCD is used. The sensors and actuators are interfaced to microcontroller which collects the data and sends it to a LoRa transceiver module. The Device layer is built around five different colored waste bins, each bin collects different types of waste. Every bin consists of all the sensors and actuators of the system architecture with the inclusion of a temperature and humidity sensor.. If a non-authorized user access or an interference occurs when the system runs, an alert is sent to the main server. [5] created a new concept of waste management disposal, this is done with the help of engineering tools, an ultrasonic sensor. This provides data based on real-time information about a dustbin being full or not. The system architect is based on a web application, GSM module, Node MCU controller and an ultrasonic sensor. The methodology for this system is based on when the garbage bins are almost full (80-90 percent) the bins transmit a signal to the network connection that the bins need to be emptied, the network is a web-based software application. Once a signal has been received, an authorized person goes an collect the bins which have sent a signal and the bins will once again notify once the bins have been emptied.

[6] proposed a solution to the established problem by automated waste segregation for the scrap industry. The use of electronic sensors such as IR sensor to detect the waste entering the bin. The waste is categorized into three sections, metal, glass and plastic. An inductive sensor is used to detect the waste to be either metal and if not, the conveyor belt moves the waste to the capacitive detection to see whether the waste is glass or plastic. [7] proposed on the topic of waste management based on the current problems being caused from it. This was caused to irresponsible waste managing and was thus stated that it effects negatively by time. Waste managing is proposed for not only the common solution which is a sanitary environment but also other benefits, economically, socially, environmentally and inter-generation. The research was anticipated due to their country's situation of which it is requested to segregate waste from wet or dry, however lack of time causes waste to be segregate generally without much of thought, nevertheless a projected solution is to create automated waste segregation using a moisture sensor. The sensor detects if the waste is wet or not and segregates it. Furthermore, the use of ultrasonic sensors detects the bins of the wet and dry waste detecting whether the bins are full or not, if full the bins. [8] conducted among 144 houses in India to gather data on household waste quantity and quality. The researchers conducted this test based on a 10kg capacity waste bag with in a 24-hour period. Main wastes found were biodegradable then plastic waste. The research concluded that HW generation showed direct relation between wastes and family size and that it can be a potential resource for energy production if proper waste separation system is designed for the area.

[9] proposed a method for waste management to improve the efficiency and increase the its benefits, cost and sanitation wise. The solid waste is first collected from different collection points then transfers to recycle and disposal plants. Segregation of waste differentiates from one study to study. This paper characterizes waste on daily consumption, the type of solid waste composition is found and its density. This is then listed to in a format of which the most common or found solid type tops the list. A simulation model is designed based on the collection equipment and points, the model includes calculation of the pickup time, average speed and fuel consumptions.

II. PROPOSED SYSTEM METHODOLOGY

The overall block diagram shows the schematic diagram of how the entire project is developed. Figure 1. shows that when the waste is placed, the ultrasonic sensor detects the waste and sends a signal to the conveyor belt to rotate the belt. When the waste's reaches the first sensor which is the Eddy current proximity sensor, if the waste is metallic, the sensor sends signal response to the Arduino microcontroller to justify the waste state, if the sensors responses as HIGH, the conveyor belt stops moving, and the metal bin compartment rotates forward so the conveyor belt can drop the waste in. If the senor response as LOW, then the waste goes to the next sensor, the capacitive proximity sensor. If the capacitive proximity sensor detects the waste as a capacitive holding material or recyclable waste, then it transmits as signal to the Arduino and if the response is HIGH, the belt stops to move and the bin rotates to the recyclable bin compartment to allow the belt to drop the waste. If the response is LOW, the belt moves the waste to the moisture sensor. When the waste contacts the sensor's probes, the sensor transmits the signal to the Arduino to read the resistance value of the waste, based on the resistance value, the waste state is considered. If its moist, the moist bin compartment rotates forward and the wastes drops in, if not then the first bin compartment which is the scrap bin takes the wastes that none of the sensors are able to detect. Figure 1. shows the overall block diagram of the system.

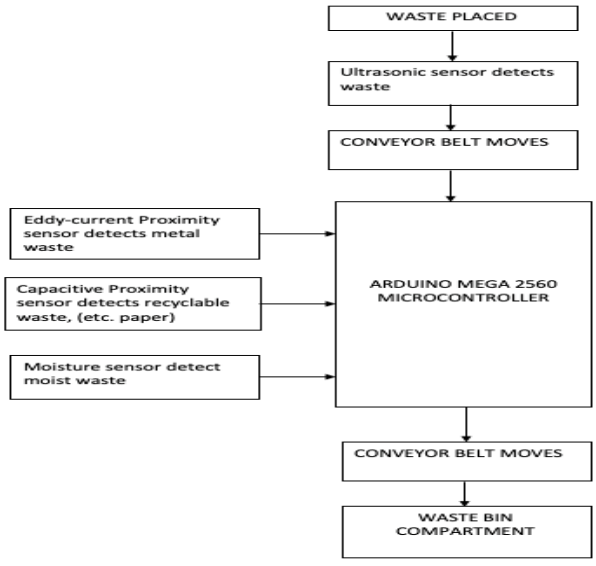

Fig. 1. Overall Block Diagram

The waste separation smart dustbin has been planned to be constructed through three different phases. Phase 1 is the sensor connection and detection testing, phase 2 is the bin motor angle control and phase 3 is the conveyor motor speed control and the final phase is the ultrasonic sensor detection and GSM module signal connection. To commence, all parts for the conveyor belt Additionally, the phase 3 is conveyor belt construction and motor speed control. This phase is done at the end as the sensor parts were laid out on the ground to visualize the design of the system.

Firstly, 4 50cm Aluminum 2020 extrusion frames were set in a rectangular design with 4 30cm aluminum extrusion frames were set at each joint. 90-degree T-Slots were used to connect the 30cm frame against the 50cm frame and tighten with M5 screws. The width of the belt was set at 20cm so after a 30cm frame was purchased, it was cut down by 10cm and the edges were filed for a smoother end. The frame ends were connected also using 90-degree t-slots and M5 screws. After building the conveyor frame, 6 M5 nuts were slid inside each top frame to connect 6 ball bearings on each side. The ball bearings were tighten also using M5 screws. After connecting the ball bearings, 3 8mm liner shafts were connected, at the front, center and back, one for each pair of bearings. Two M4 nuts were placed below the top frame and connected to the stepper motor bracket with M4 screws. After placing the motor to its bracket, one GT2 5mm pulley was connected to the motor and a Gt2 8mm pulley was connected to the first shaft. The pulleys were linked using a GT2 timing belt and with this, the stepper motor can rotate the shaft allowing the belt to move. First the frame of the conveyor belt is built by using Aluminum 2020 extrusions for durability, sustainability and easy assembly.

After constructing the conveyor belt, the sensors are mounted using plastic sensor holders placed in between the ball bearings and just above the belt at height. Since the moisture sensor requires contact when detecting, it is connected to a servo motor and placed in the middle of the belt so it can properly detect the waste, after that the motor rotates it on line of the frame. The waste bin is done by using a normal waste bin and have cardboard placed inside the bin to separate the waste into different categories. The ultrasonic sensors are attached at the side end of each waste bin sector. The entire circuit connection is linked to one microcontroller, Arduino Mega 2560. The power supply is provided from a power bank to the microcontroller and the stepper motors and proximity sensors are supplied power from a 12v battery. The schematic diagram in Figure 2. provides a visual representation of how the sensors, motors, GSM module drivers, and LEDs are connected the microcontroller.

The working process of the entire project is segregated into two different categories. The detection process, waste separation process and the notification process. The detection process provides a detailed explanation regarding how the waste is detected and being differentiated with other wastes. The waste separation process provides a detail explanation of how the mechanical design separates the waste and why the prototype was designed in such a way. Finally, the notification process shows how the sensor detects the waste and transmits the signal from the module to the receiver. Figure 3. Shows the flowchart of the working principle for the entire system.

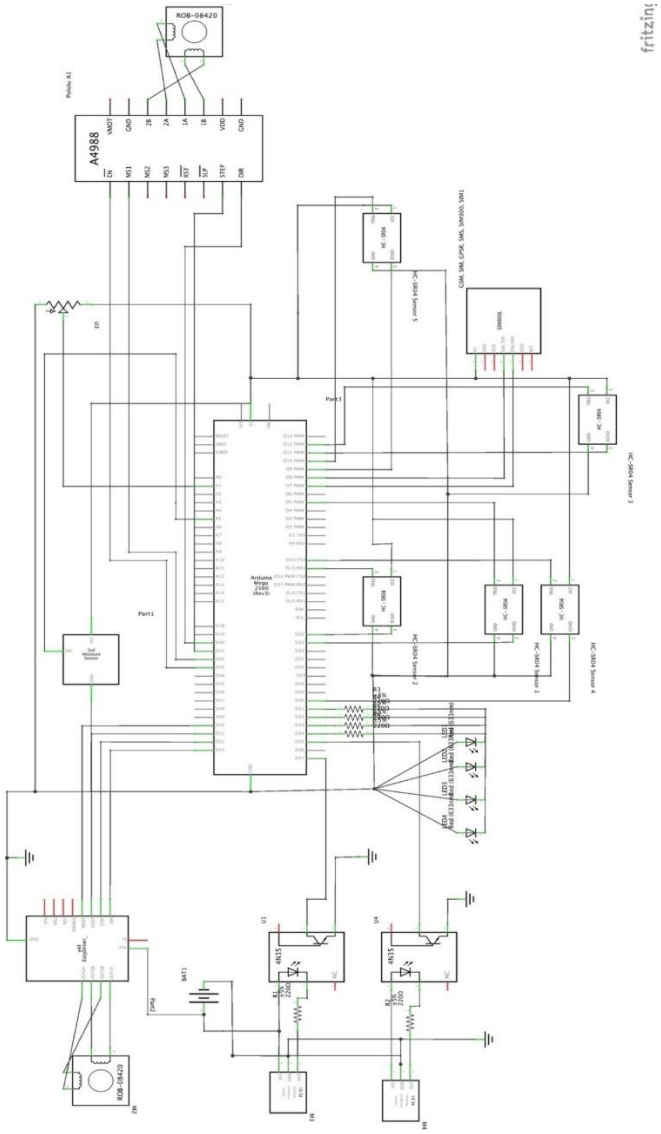

Fig. 2. Circuit schematic diagram

The prototype was designed using a conveyor belt with the sensors placed on the top frame of the belt to detect the waste and determine its sort. The first sensor placed was the eddy current proximity sensor or in other terms, the inductive sensor. The eddy current proximity sensor detects objects that are conductive within its sensing the range. Previous researchers such as [4] and [6], have attempted to detect metal by using an inductive proximity sensor. Both sensors are capable of detecting metal as their working process is based on when the metal target enters the sensing zone as that metal being a conductive material induces electrical current within it by a magnetic field and this action lead to the discovery of Faradays law of where in a closed circuit, the induced electrical current is equal to the change rate of the magnetic flux negatively. This occurrence is the principle leading to the role of proximity sensors however the difference between inductive proximity and eddy current proximity sensors is that eddy current has a faster response time due to the help of the air-core coil instead of the ferromagnetic core which is in the inductive proximity sensor. Figure 4. Shows waste separation smart dustbin prototype

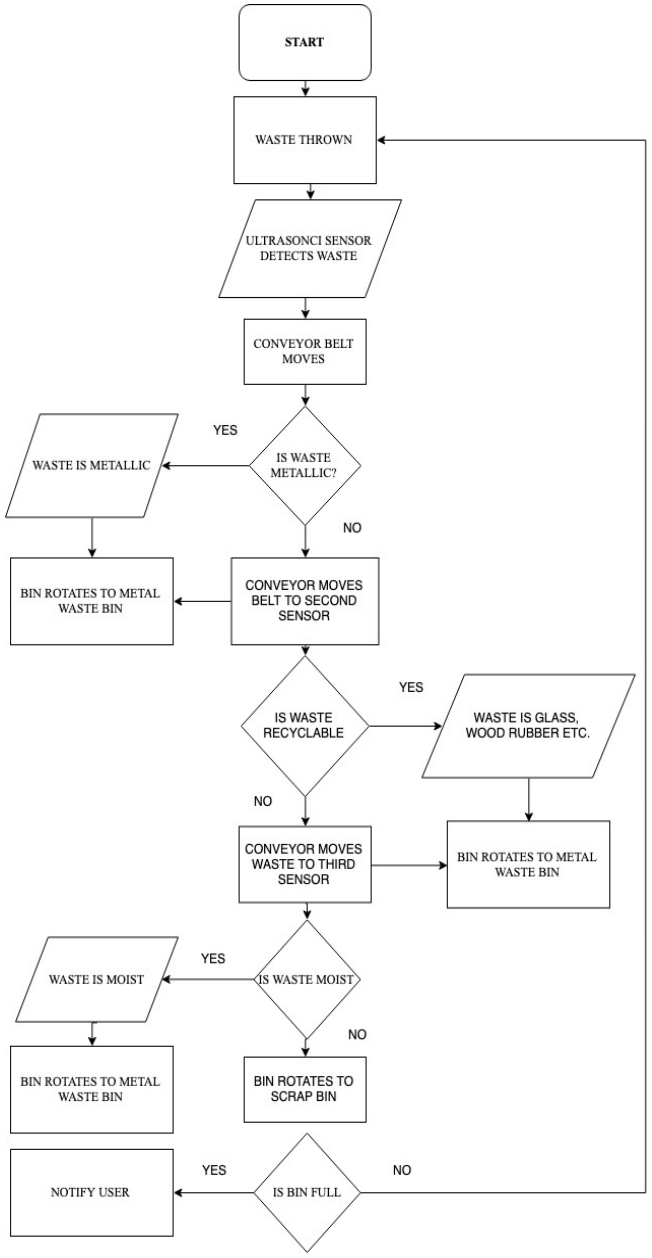

Fig. 3. Overall project flowchart

Fig. 4. Waste separation smart dustbin prototype

III. TESTING AND FINDINGS

A. *Capacitive proximity sensor detection test*

This test is conducted to determine what the sensor detects, how far the waste from the sensor can it detect and how accurate is the sensors detection. In terms of waste segregation by detecting the waste and analyzing if the system detects the waste as a recyclable waste and casting it to the recyclable bin. The setup of the system was to run the system with the capacitive proximity sensor placed on top of the belt 2cm away from the belts center. Five different types of waste are set for testing and each waste was tested in different positions. The first position is tested when the waste has slight contact of the sensor and the second is where the waste is 8mm away from the sensor. Below, provides the list of waste used to test the sensor: Empty plastic water bottle (600ml), 10% filled plastic water bottle (600ml), Empty glass perfume bottle (250ml), Single crumbled A4 paper, 100pg notebook. These listed wastes are set for testing by placing them one by one through the sensor. Each waste is tested three times each to provide accurate results. The detection accuracy provides the final result for the sensor detection from three tests. The analysis shown of the capacitive proximity sensor detection test proves that the proximity sensor is not suitable for detection without contact. Considering the data sheet of the sensor states that the sensor has a proximity detection range of 8mm, it can be concluded that the sensor can detect only dense objects. The first testing shows that the empty plastic water bottle can be detected once out of three tries with contact of the sensor but is not detected at a 8mm rage, however when the bottle is filled with 10% water, the bottle was detected three out of three times at contact and twice out of three without contact. Another test has been done but with an empty glass perfume bottle, the bottle was detected at contact and was detected once without contact.

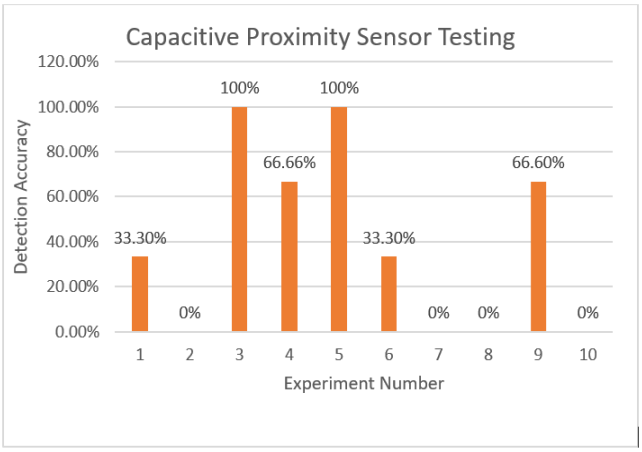

Fig. 5. Analysis chart for capacitive proximity sensor testing

B. *Eddy Current Proximity sensor detection testing*

This test is conducted with a similar setup of the capacitive proximity sensor testing. This test helps to determine the detection of different types of metal from different positions. The results then provide a decent evaluation of the sensor detection abilities of different types of metal. The eddy current proximity sensor is placed on top of the frame 2cm away from the belt's center. The waste required for this test is done by testing the five different metal waste at two different positions, at 0mm which means with contact of the sensor and at 4mm. The five different waste that are used to conduct this test are:

20cm Aluminum 2020 extrusion frame, Empty Tin can, 10mm Screw, Metal Keychain, Crumbled 100cm2 Aluminum foil. Similarly, to the capacitive proximity sensor test, each waste is tested three time to provide accurate results where the detection accuracy provides the final outcome of the three tests. The eddy current proximity sensor graph analysis shows that the detection test is highly accurate with contact and when the metal wastes are going past the sensors proximity range of 4mm, the sensor is able to detect it.

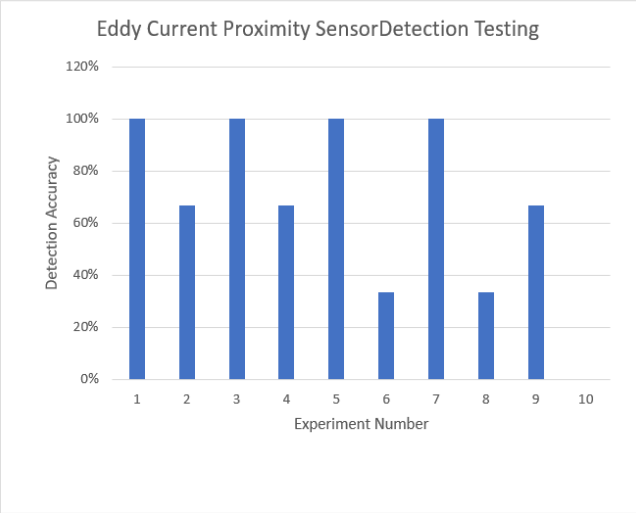

Fig. 6. Analysis chart for eddy current proximity sensor detection test

C. *Moisture Sensor Detection Test*

This test is conducted to determine the moisture sensor probe's sensitivity to wet waste. The context wet can differ based on the available water content of the waste, so to determine the proper state of wet waste, this test is concluded to evaluate what type of waste can be considered as wet and what is dry. The setup for this test is done by first testing the sensor average sensitivity value that is displayed on the serial monitor of the Arduino, the moisture sensor is connected to the analogue pin of the Arduino and is first left without any waste contact to analyze the threshold of the resistance value to differ between wet and dry. This test provides adequate information to analyze and evaluate the wet waste threshold by examining different situations of waste types and logically, to what waste can be considered as wet waste. This system considers wet waste as waste that have water content which are in this case, biodegradable or food substances. Below, provides the list of waste used to test the sensor: Half eaten apple, Full Apple, Banana peel, Spoon of cooked rice, Wet tissues, Uncut carrot, Soaked cardboard roll, Soaked paper, Orange peel and Tomato slice.

As see on the moisture sensor probe sensitivity test graphical analysis, the lower the resistance value a waste has, the moisture content it carries, and if the waste's resistance has a higher resistance value than the detection threshold of being wet, then the sensor detects that the waste 0% moisture content. The testing's done on the sample wastes have provided logical results which justifies the values taken for setting up the moisture content threshold, however when a waste test for the half eaten was done, the moisture sensor detected the waste as wet but only when the sensor had contact with the eaten side of the apple, around that the sensor considers it as a dry waste.

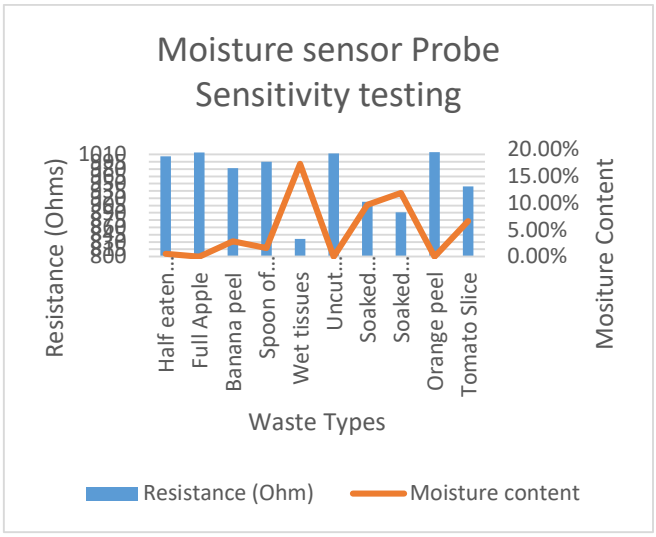

Fig. 7. Analysis chart for moisture sensor probe sensitivity test

D. *Conveyor belt stepper motor speed test*

This test is conducted to examine the conveyor belt motor speed and time taken for waste of different weights to be dropped from the point of its original position. The speed test helps to analyze and limit the weight of the waste placed to avoid a slow waste separation process. The speed motor test is conducted by examining ten different weight class waste on the same motor speed and determine the time taken for the waste to be dropped on a 50cm conveyor belt. The weight class of the waste are taken by using cups filled with rice at ten different weights ranging from 100grams to 550 grams. The objective of the test is to analyze and calculate the time taken for the 10 different weighted waste to be placed and dropped. Based on the analysis chart of the conveyor belt speed control, time increase when more weight is applied. From the information taken, speed is calculated in meter/seconds and then the speed in rpm is found using the formula below

$$Speed(ms^{-1}) = rpm \times 2 \times \pi \times R \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where R is the radius of the shaft rotating the belt. The data collected for the motor's speed is deemed to be slow in average however this speed is the best speed for accurate waste detection results. Faster the belt, drop in accuracy for waste detection.

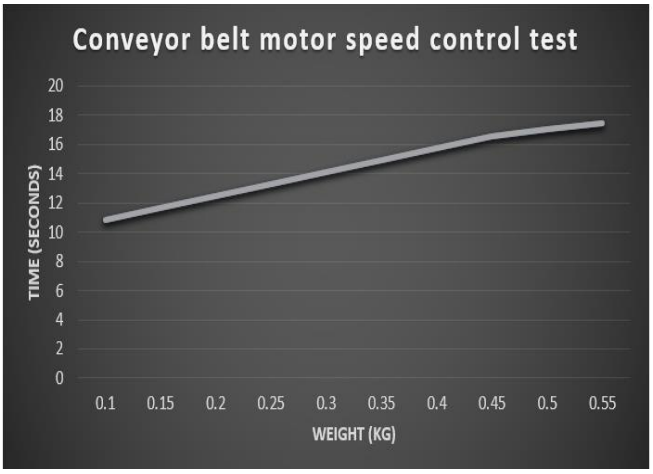

Fig. 8. Analysis chart for conveyor belt motor testing

E. Waste separation accuracy test

This test determines the accuracy and efficiency of the entire system. Different types of wastes are thrown in no order and the objective is to obtain accurate results of segregating waste to its fixed bin compartment when testing the system with different wastes. This testing is conducted after assessing the three sensors and the conveyor belt motor speed to provide enhanced results. This experiment is conducted by setting up all the wastes that were used for the sensor testing is used again for this testing to analyze the performance of the entire system due to the fact that the sensors were tested individually using the same waste and the error of the waste to not be detected should be diminished. The accuracy testing is done by tabulating the data of the waste detection and separation by the amount of correct waste collected by each bin. The waste used for this experiment should be placed in its assigned bin based on the theoretical criteria results with the objective of obtaining an average result of 90% accuracy for each bin. The data analysis of the accuracy test for the waste separation smart dustbin provides the separation results when different wastes are thrown in. The results are based on the bin compartments theoretical estimated waste to collect against the practical waste collected. The Moist bin collected 4 moist wastes out of 5 with an 80% accuracy test proving that the moist detection was successful and the one moist waste which was not detected was the half eaten apple as the eaten side provided a resistance value higher than the moisture limit making the Arduino response for the waste state as dry. The recyclable bin detected 2 out of 5 wastes with a 40% accuracy. This proves that the capacitive sensor does not have the capability of detecting recyclable waste. Not all recyclable waste has high density so the capacitive sensor can detect and accuracy for this result is too low. The metal bin collected 5 out of 5 waste with 100% accuracy proving the eddy current has positive results in segregating metal wastes.

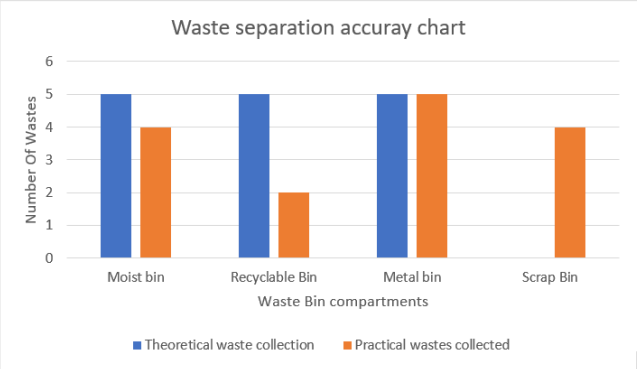

Fig. 9. Analysis chart for waste separation accuracy test

IV. DISCUSSION

The theory behind the project was to improve the efficiency of waste management which though has high critical consequences, was always overlooked due to the lack of awareness about the poor waste management impact on the environment. The concept design was considered based on a thorough literature review of previous journals and researches about the context of waste management, technical and theoretical. This provides enough information to achieve the first objective of the project which is constructing the prototype for waste separation using four sensors to separate three different categories of waste. The design is measured in terms of low-cost sensors and actuators can develop a system that saves much more then invested on. With a procedure which helps the process of recyclable waste separation in which most researches in the literature review faced obstacles to achieve a high success segregation rate of waste. The final results of this research and the previous researchers were concluded based on the final results of the waste segregation between moist, metal and paper. The second objective is to alert the user to notify when the bin is full, which based on the design is achieved using an ultrasonic sensor to detect the waste level and with the GSM module to transmit a message to the user, however this objective has faced a couple of obstacles in terms of signal connection, the objective was still achieved by running the module in outdoor areas. The final objective is the evaluation of the design which is done by a simple calculation to justify the working capability of the system, a thorough testing evaluation was done based on sensor detection, speed and accuracy of the system.

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