VIRIDIS TERRA

AUTO-SORTING RECYCLING SYSTEM

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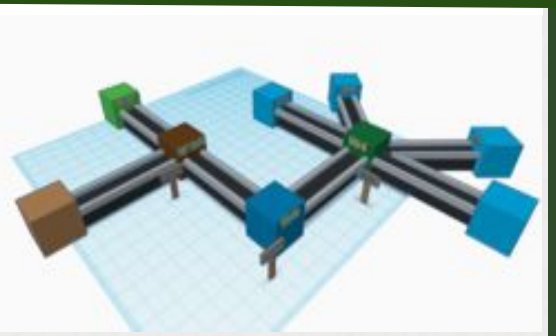

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Problem

The problems we're trying to solve include:

- ***High contamination rates of recycle bins*** - Dry waste can no longer be recycled if it comes into contact with wet waste (food waste). Recycle bins typically have contamination rates from 13% - 40%. This suggests that this much amount of trash put into recycle bins is useless. Moreover, high contamination rates cost countries and recycling agencies millions of dollars every year.
- ***Lack of awareness*** - This issue is something not a lot of people are aware of. Most people are unaware of the right methods of recycling and the kind of trash that can be recycle. Furthermore, there is a lack of knowledge on the difference between dry waste and wet waste, and how each kind should be treated.

Background

We did research into the issue of 'recycling contamination rates' in various parts of the world. Below is a summary of our findings:

UK:

In recent research, Biffa, a waste management company revealed that nearly one-fifth of (17%) of England and Wales' waste (from both businesses and households) cannot be recycled due to contamination. Biffa's analysis found that, in 2016, the average contamination rate of recycling waste was 13.4%. This rose to over 17% in four years, by the end of 2020.

Singapore:

In Singapore, 40% of the items in recycling bins cannot be recycled due to contamination, causing people's efforts to go in vain. Furthermore, Ms. Pek Hai Lin, the manager of the non-governmental organisation Zero Waste SG believes that contamination "seems to still be a huge problem", preventing items from being recycled in Singapore. Moreover, Singaporeans are recycling incorrectly, throwing items that are not recyclable into the recycle bins, which decreases the efficiency of the waste management process. This provides testimony to the lack of awareness of recycling.

US:

"Consumer confusion" is one of the five main reasons why America's recycling system is flawed. People often throw non-recyclable items into recycling bins, contaminating items that could have been recycled and reused. According to the Environmental Protection Agency (EPA), around 25% of all recycling is contaminated and can thus no longer be recycled. Furthermore, in the US, for many, learning that their recycling is contaminated and will not be recycled can be frustrating. This creates friction between customers and recycling companies and thereby decreases their recycling involvement. In America, the average municipality sees a recycling contamination rate of at least 19 – 40% generally. Moreover, the EPA's research has revealed that 1 in every 4 recycling items collected are usually contaminated.

Other countries:

Canada: Cities in Canada have varying contamination rates, some up to 26%. This is costing recycling programs millions of dollars a year.

South Africa: Forty-three percent of recyclable plastic waste in South Africa during 2020 was lost, owing to its being contaminated before reaching the dump site where waste is recovered. Moreover, only 10% of all waste is actually recycled in South Africa.

Our Secondary background research highlighted that the problem of 'high contamination rates in recycling' is a global issue affecting several countries. Moreover, it's exacerbated by the lack of awareness amongst the general population about proper waste management. These issues hinder the propagation of Green Communities and cost countries a lot of money.

Our research led us to brainstorming and thus the idea of *a bin system that separates wet and dry waste before they come in contact, plus further separates the dry waste into plastic, paper, cans/metals, and glass. And, it could also separate wet waste into compostable and non compostable waste.* This could be extremely helpful in school settings, as students are often careless in recycling. Furthermore, adding posters, information leaflets, infographics, etc along with this bin in schools can help raise awareness amongst students of the importance of recycling.

We did secondary research into current bin systems and came across **Bin-E**. Bin-E has a machine that uses AI ML to separate any kind of dry waste thrown into plastic, cans, glass, and paper. Separating wet and dry waste is still being researched, and no proper bin system exists for this. However, several studies conducted and some research have revealed that **AI ML** could also be used in the separation of dry and wet waste. Furthermore, using **dampness sensors and ultrasound sensors** can further increase the efficiency rate of such a bin system.

Hypothesis

“Will the implementation of auto-sorting recycle bins reduce contamination rates of recycling bins and waste and increase awareness of the correct way to recycle amongst students in schools (and people in general)?”

Methods + Results

Journey Mapping - flowchart

After deciding on our idea, we created **simple journey mapping flowchart** to highlight the flow of trash from the start to the end of the machine / bin system. This helped us Identify which technologies we need to further research into, and the general flow of the system

Rapid Prototyping - CAD

We created a basic CAD model which helped us identify how our idea would look like in reality. Creating this CAD also helped us identify some flaws within the idea which we have addressed.

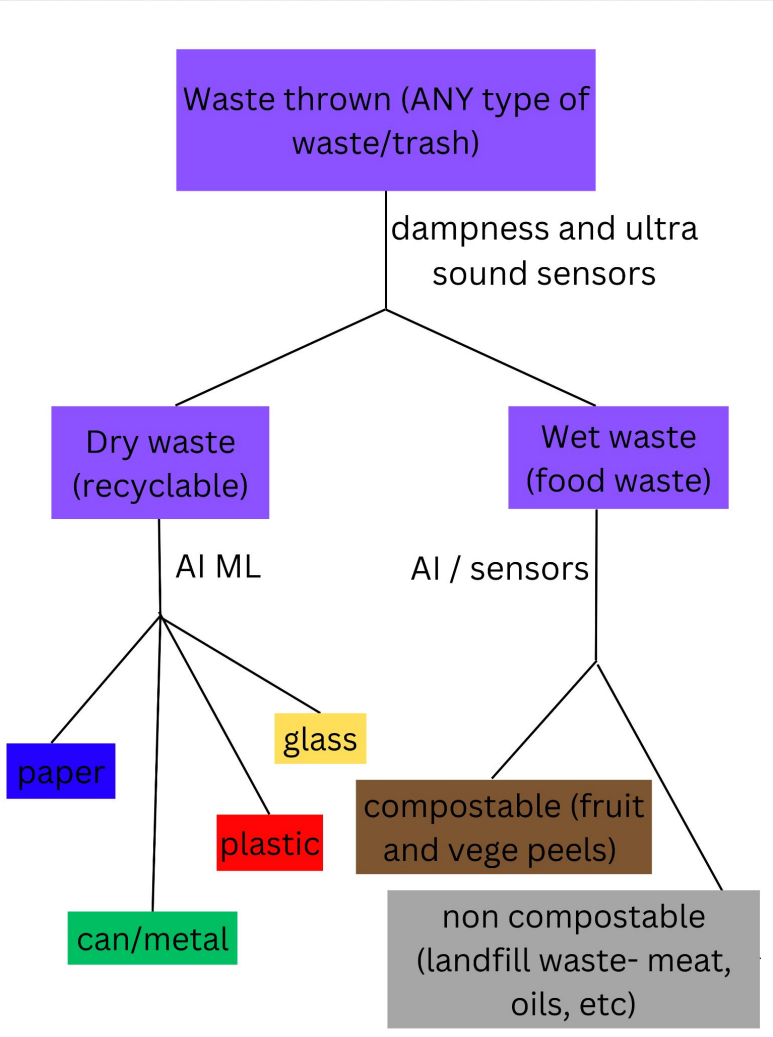
Primary research - Online survey + contacting experts

Our survey had 2 parts. 1 for “problem identification” and 1 for “user testing”. The 1st part helped us identify how widespread the problem we identified is, and it backed our background research. The 2nd part did the user testing of our idea and gave us invaluable feedback for improvement, which we have incorporated in the solution. We also contacted a STEM expert for feedback on our idea.

Method 1- Simple Journey Mapping Flowchart

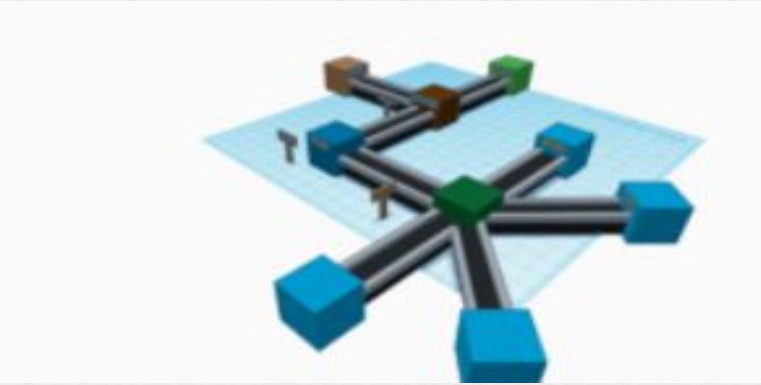
Results 1: This method helped us highlight the flow of trash in the system, and the various segregation points of the trash. It also gave us a clearer idea of how our waste segregation system would work and enabled us to create the CAD design. It also helped us categorize information into the following:

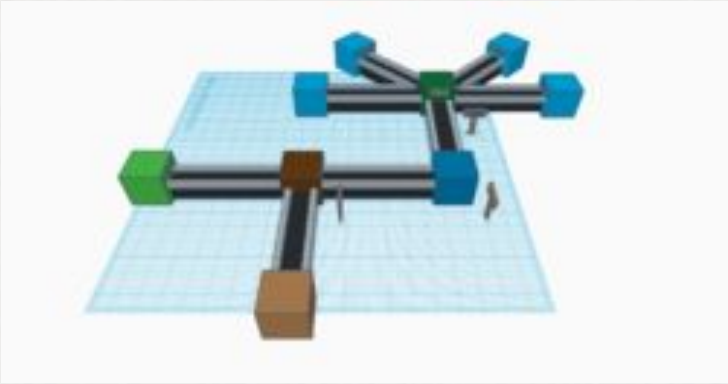
a) **Segregation Station 1 (main)**- Separation of dry waste (recyclable) and wet waste (food or medicinal waste).
b) **Segregation Station 2** - separation of dry recyclable waste into plastic, cans, paper, glass.
c) **Segregation Station 3** - separation of wet food waste into compostable waste (fruit and vegetable peels, or other biodegradable waste) or landfill waste (non compostable- other food waste, medicinal waste, etc).

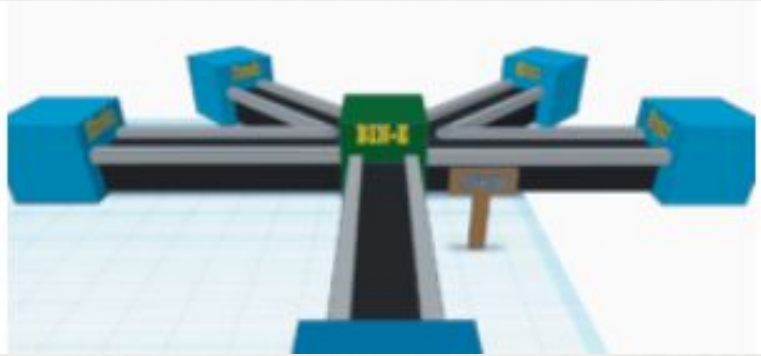


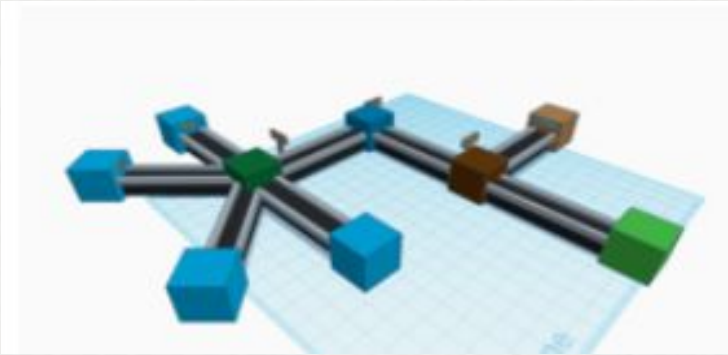
Method 2- Rapid Prototyping –> CAD

Top Views

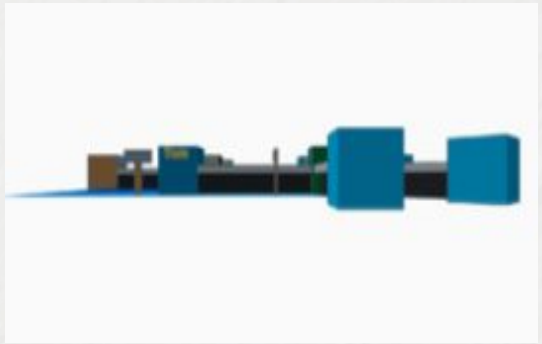


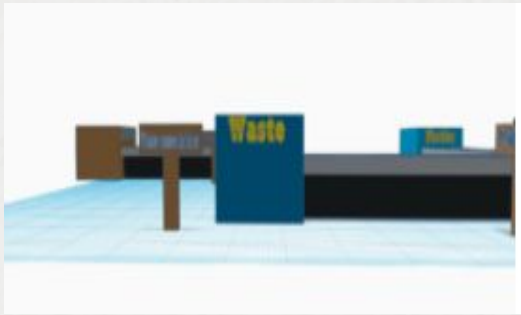


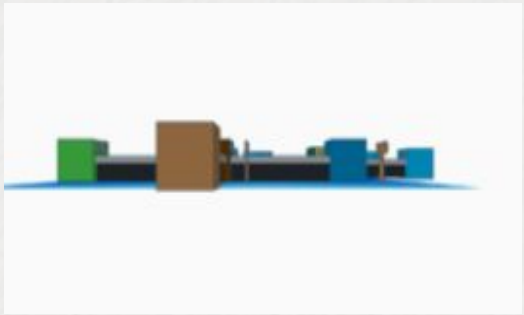




Side Views







Explanation of CAD:

The dark blue block represents segregation station 1- trash thrown to dry waste or wet waste. Then, dry waste moves via the conveyor belt to the dark green block, which is segregation station 2- dry waste to plastic or cans or paper or glass. Meanwhile, wet waste moves to the dark brown block (segregation station 3) and then into either compostable waste or non compostable/ landfill waste.

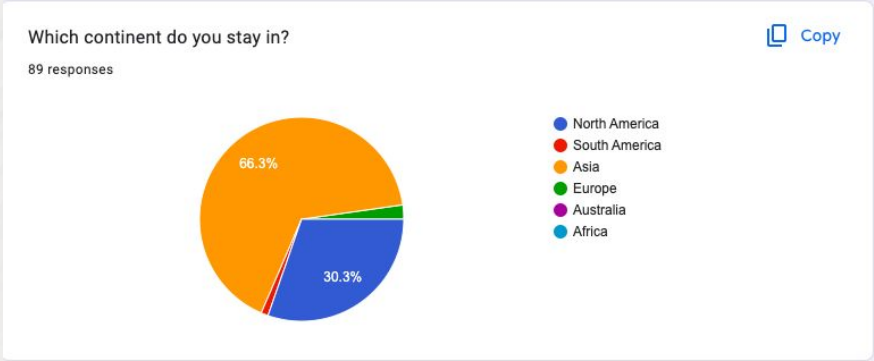
Conclusion:

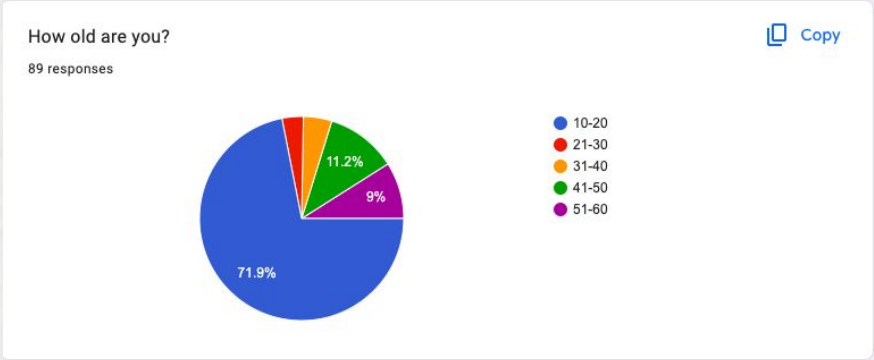
Our CAD helped us realise that the design could be **a bit more compact** to increase efficiency, and could be positioned better, ie **rearranged to reduce errors** while functioning.

Method 3- Primary research online survey + contacting experts

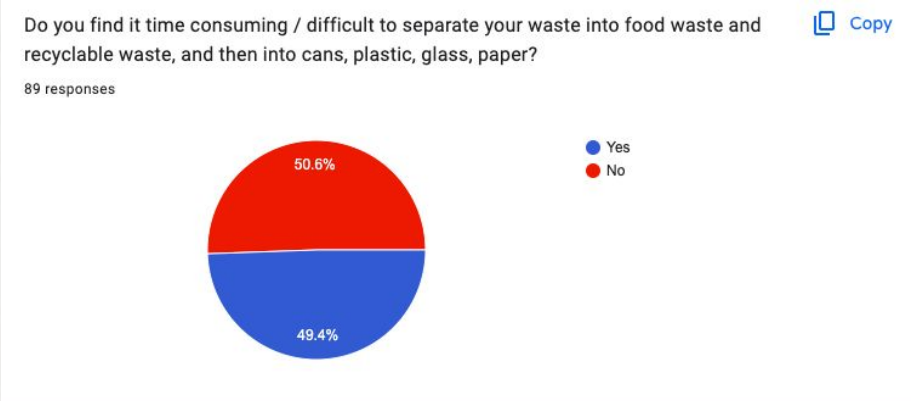
Our survey had **2 parts**. Part 1 was for **"problem identification"** and helped us identify how widespread the problem of 'lack of awareness' and 'high contamination rates' is from our users (the public). Part 2 was for "**user testing"** and tested our idea. The second part covered helped us gain feedback on our prototype and idea. We have used our results and the suggestions we received to improve our idea and CAD for the final solution. **On the next few slides are the collated results from the survey and their analysis.**

We received feedback from **a diverse range of people**, from all around the world, and from a number of different age groups. This increases the **credibility** of our feedback as **a number of market segments and socioeconomic groups** responded to our survey. Moreover, we did not know the people filling out the survey as we used online platforms such as Launchpad to spread the survey- this **reduces the element of bias** in our response.

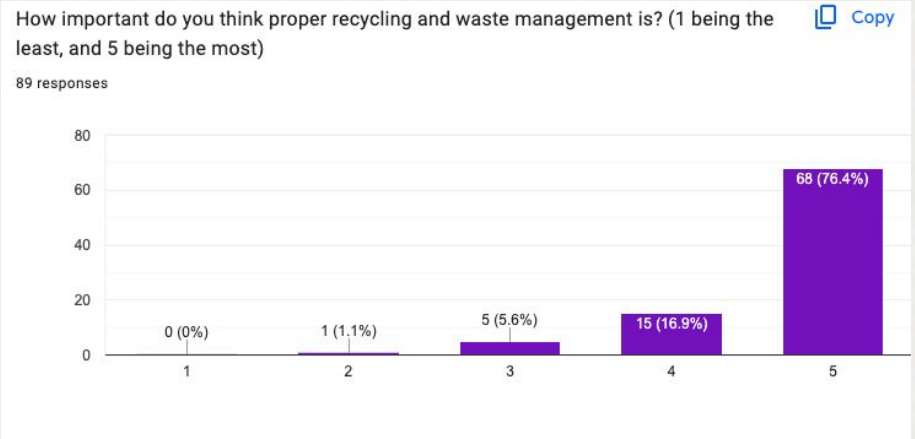




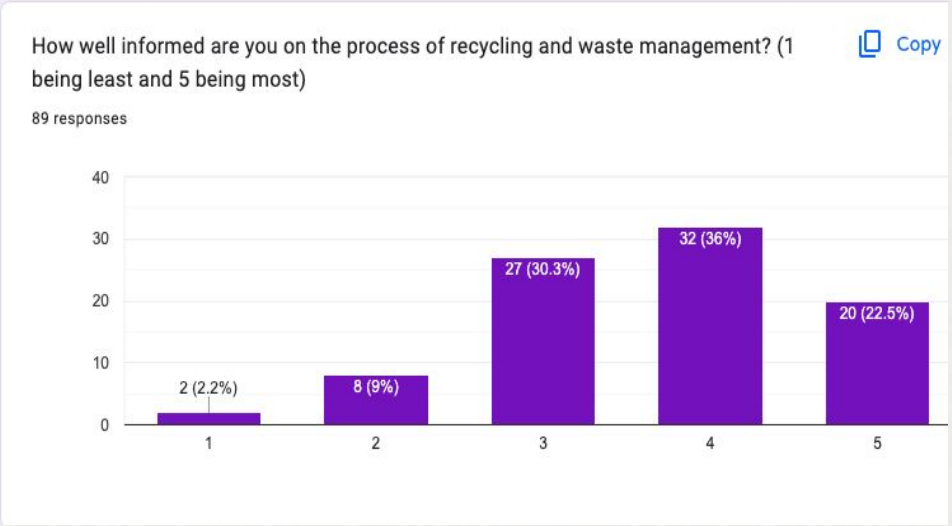
Collated Results from Part 1- “problem identification”



1. 50% of people said that they find it difficult and time consuming to segregate their waste. This suggests that **the problem we identified is relevant** and has a demand/ need to be filled.

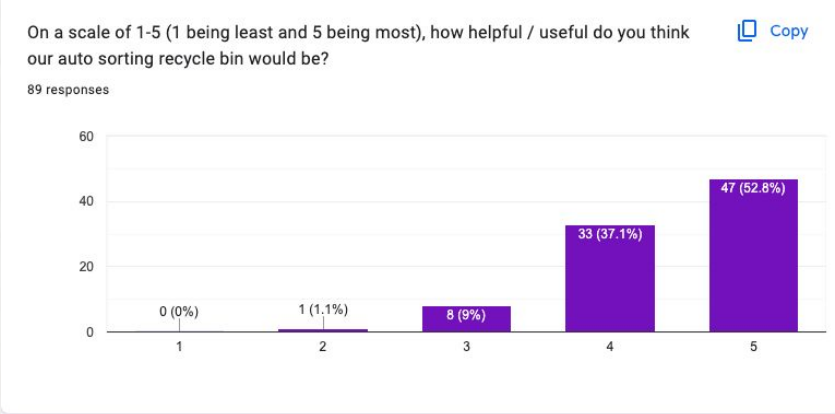


2. 76% of people said that waste management and recycling is ‘very important’ which suggests that the public has the same view on this agenda as us suggesting that we have **identified our target problem and user correctly.**

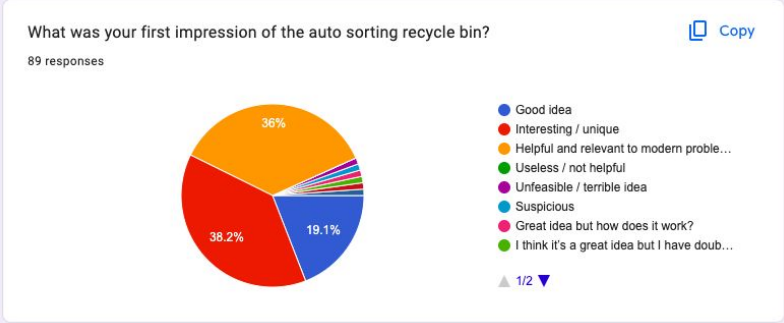


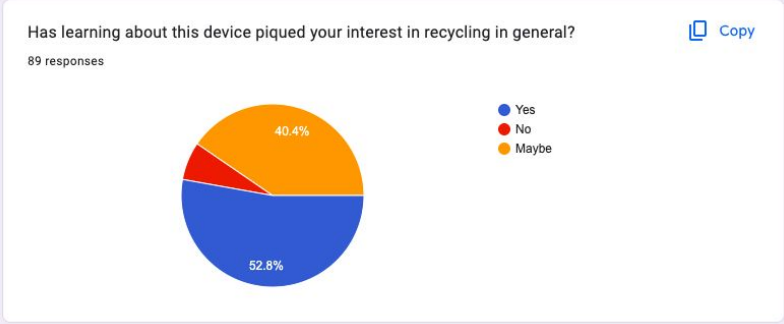
3. When asked about how aware you are of recycling methods, around 60% answered between 3-4 with 10% at 1-2 suggesting that there is **still an issue of lack of awareness on recycling and waste management. Even though many people claim they are well informed on the process of recycling and waste management, they do not actually implement this.** Secondary research has shown that the reason we have such high contamination rates is because people don't follow recycle norms either because they don't know how to, or because they know, but find it time consuming or irritating. Our idea proposition involves tackling this issue as well.

Collated Results from Part 2- “user testing”

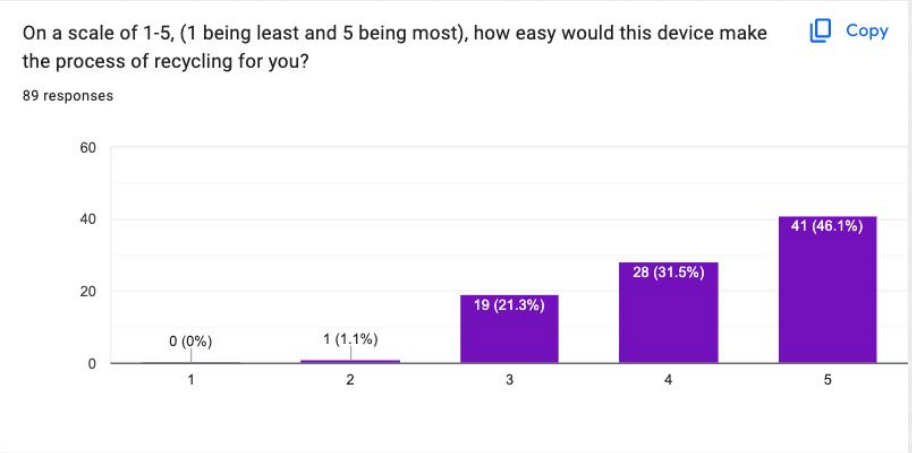


4. Moving on to **user testing**, we asked a couple of questions on our product. After giving a project description, we asked how useful or helpful our project is. Around 90% answered between 4-5 suggesting that **the public deems this invention as something relevant and worthwhile.**





5. We received **a variety of first impressions, majority positive**. They are summarized in the pie chart below. Also, 50% + people said that **learning about this device piqued their interest in recycling**, which affirms our hypothesis of whether this device would raise awareness on recycling and waste management.



6. Next, we asked how easy this device would make recycling for the public. This question focussed on gaining user testing data. 46% said 5 and 30% said 4, which suggests a **positive response on user testing, thus strongly supporting our initial hypothesis.**

7. We added a final question that allowed people to **suggest ideas/ give feedback.** Listed below are some responses we have received:

a. **Feasibility?**
b. **Portability and convenience?**
c. **Where will it be placed? If at a home, how will you manage size and energy costs? If in a public area, location and maintenance costs?**
d. **It would be useful in commercial establishments rather than individual homes.**
e. **It's a great idea to implement in developed countries.**

Collated results from contacting experts

Name: **Rajiv Santhanam**
Background: **Mechanical Engineer with 20 years of experience**

1. How viable do you think this solution is to the problem we stated?

Answer: **It depend on how automated the sorting is**

2. How feasible or realistic is our idea?

Answer: **Depends on the separation procedure/principle**

3. Is there any other technology / process / method that could be used to sort out the trash?

Answer: **There is a manual method to do initial sorting of metal, plastics and glass.**

4. Do you think this idea has a potential for being implemented on a larger scale in the future? Maybe at waste / recycle plants or inside garbage trucks?

Answer: **Yes,in waste recycle plants specifically**

5. Do you have any suggestions / feedback for us on how this project can be improved?

Answer: **Steps and procedures have been structured and clarified at each level.It could possibly have a more detailed explanation.**

Conclusion: Mr. Santhanam believes that we could explain our **idea in more detail,** and implement it inside recycling plants. His advice pushed us to do further research into technical components and the AI we would use, as well as where all our bin system could be used. This is discussed in “solution”.

Solution:

Our final solution is an **auto sorting recycling system** that sorts any type of general waste into:

a. Dry waste
   i) Plastic
   ii) Metal/ Can
   iii) Glass
   iv) Paper
b. Wet waste
   i) Compostable waste (fruit and vegetable peels / leftovers - biodegradable waste)
   ii) Non compostable / landfill waste (other food waste, medicinal waste - non biodegradable waste)

After building a CAD model, we realised that such a complex technology and flow of trash will not fit into a bin. Thus we decided to create a **system that could be installed in recycle plants (and even garbage trucks once it's more compact).** We received feedback from our survey to place such a system in commercial establishments rather than homes or in public parks. Furthermore, the expert we interviewed also suggested recycling establishments. **To tackle this issue of maintenance costs, we plan to implement such a system on a large scale in recycle plants instead of in local communities. This would allow large scale sorting of trash.**

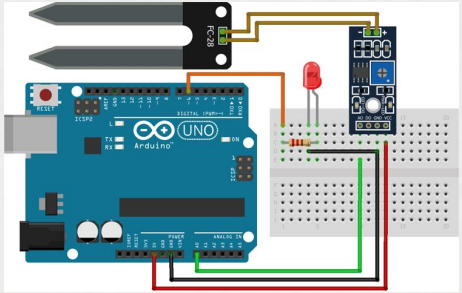
Next, we did detailed research into the technical components, sensors and technology that could be used at each segregation station (after advice from the expert and survey results)

Technology used + Technical components:

a) ***Segregation Station 1 (main)***- *Separation of dry waste (recyclable) and wet waste (food waste):*

For this we would be using a couple of dampness sensors and ultrasound sensors. We will use a number of these to increase the overall efficiency rate and accuracy of the device. These sensors include:

1. AHT10 High Precision Digital Temperature And Humidity Measurement Module - to identify wet waste which is rich in moisture.
2. AHT25 Integrated temperature and humidity sensor -40℃ —> +80 ℃ - another sensor to identify wet waste which is rich in moisture. 2 types of sensors are used to improve overall accuracy.



(Basic layout of moisture sensors)

3. Ultrasonic Distance Sensor Module - HC-SR04 - to measure the distance to a wide range of incoming objects regardless of shape, color or surface texture.

*b) **Segregation Station 2** - separation of dry recyclable waste into plastic, cans, paper, glass:*

For this we will use AI Ml and image processing, similar to the technology used by Bin-e in their machine (https://bine.world/functions). A few potential technical components are listed below:

1. Smart Vision Cameras - Seeedstudio Grove Vision AI Module with Himax HX6537-A processor, thumb-size AI-powered OV2640 camera sensor, support Yolo V5 and Edge Impulse
2. Baumer industrial cameras for image processing
3. Vision sensors

*c) **Segregation Station 3** - separation of wet food waste into compostable waste or landfill waste (non compostable):*

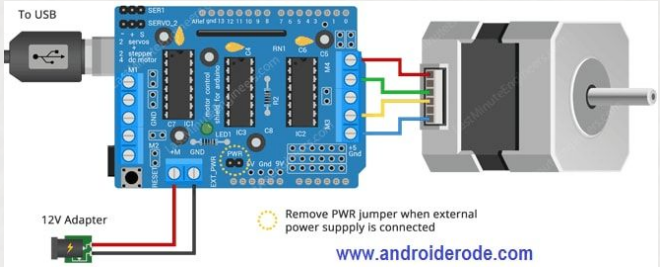
For this we will again use AI Ml and image processing. A few potential technical components are listed below:

1. Smart Vision Cameras - Seeedstudio Grove Vision AI Module with Himax HX6537-A processor, thumb-size AI-powered OV2640 camera sensor, support Yolo V5 and Edge Impulse
2. Baumer industrial cameras for image processing
3. Vision sensors

d) Powering the 3 Segregation Stations + conveyor belt:

We will use motors such as the ones listed below. These will help run our machines at each segregation point, and these will help in operating the conveyor belt that carries trash around the machine:

1. The Tower pro MG90S Micro Digital Servo is 360 rotation servos.
2. Servo Motor Mg995- 360 Degree
3. Kinmore 37b385 12 Volt 4 Kg 150 Rpm Gear DC Motor for Robot
4. RPGS Single Phase Universal Motor, Power: <10 KW, 220-440 V



(Basic layout of motor)

e) Other technical components:

1. Electronic Spices PACK OF 5 Yellow On/Off 2 pin Self-Locking Latching Push Button Switch Locking Car
2. Set of 2 - Easy Electronics 12V DC GEAR MOTOR (Geared Motor) - 300 RPM
3. UNIVERSAL SIM900A_GSM_MODEM Sim900A Gsm Modem Module with Sma Antenna
4. ERH INDIA Big Buzzer with Small Enclosed Piezo Electronic Buzzer Alarm 95DB with Wires Pack of 2
5. Raspberry PI 3 Model B+ Motherboard (Raspberry Pi 3 Model B+)
6. Raspberry Pi 3B+ / 3B Plus Motherboard Combo - PiBOX India Variation (PiBOX - Essential Combo Red/White 3215RW) - No with 2.4 Amp Power Adapter
7. Motor Driver Circuit - L293D
8. Liquid Crystal Display (LCDs)
9. Power / Energy Sources

*f) Basic, simple, potential **Code on Arduino** for Segregation Station 1 - dry waste or wet waste:*

This is a super basic code, and is only written to give an idea of how this machine would work; of course the actual code will be more detailed. This code has also not been tested yet.

```
#include <Servo.h>

class Smart_Segregator
/*
  ____________________________________________________________
  |
  | Description
  | -----------
  | - This is a smart segregator which seperates dry and wet
  |   wet waste. (It cannot segregate metal or plastic)
  |
  |.............................................................
  |
  | Attributes
  | ----------
  | pin_1 : int
  |    - Servo Motor pin number.
  |
  | pin_2 : int
  |    - Moisture Sensor pin number.
  |
  | pin_3 : int
  |    - Touch Sensor pin number.
  |
  |.............................................................
  |
  | Methods
  | -------
  | dry_waste()
  |       - Lid of the segregator slides towards right side.
  |
  | wet_waste()
  |       - Lid of the segregator slides towards left side
  |
  | neutral_state()
  |       - In which the lid of segregator is in the middle.
  |
  | execute()
  |       - Smart Segregator starts operating.
  |
  |____________________________________________________________
  */
{
  public:
    int servo_pin;
    int moisture_sensor_pin;
    int touch_sensor_pin;
    int detect_moisture;
    int detect_touch;

    Servo servo;

    Smart_Segregator(int pin_1, int pin_2, int pin_3)
    {
      servo_pin = pin_1;
      moisture_sensor_pin = pin_2;
      touch_sensor_pin = pin_3;

      detect_moisture = 0;
      detect_touch = false;
    }
```

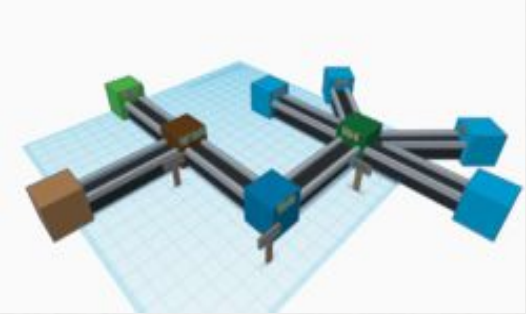
```
    void init()
    {
      Serial.begin(9600);
      servo.attach(servo_pin);
      servo.write(90);

      pinMode(moisture_sensor_pin, INPUT);
      pinMode(touch_sensor_pin, INPUT);

      Serial.println("Your Smart Segregator is ready to Segregate!");
    }

    void dry_waste()
    {
      servo.write(0);
    }

    void wet_waste()
    {
      servo.write(180);
    }

    void neutral_state()
    {
      servo.write(90);
    }

    void execute()
    {
      detect_moisture = analogRead(moisture_sensor_pin);
      detect_touch = digitalRead(touch_sensor_pin);

      if (detect_moisture > 85 && detect_touch == true)
      {
        wet_waste();
      }

      else if (detect_moisture <= 85 && detect_touch == true)
      {
        dry_waste();
      }

      else
      {
        neutral_state();
      }
    }
}

segregator = Smart_Segregator(8,6,2);

void setup()
{
  segregator.init();
}

void loop()
{
 segregator.execute();
}
```

All in all the code is written on the basis of moisture sensing by the motors and the response after by the mechanical parts in the prototype.

We have focused on using **low cost technical components** to keep the manufacturing costs as low as possible since this project is a public endeavor.

From the suggestions we received, we plan to make the design as energy efficient as possible, and as compact as possible.

This is our final cad:



And, to raise awareness on recycling, we plan to send posters, information leaflets, infographics, etc to schools in the local communities near this system. Furthermore, schools can organise field trips to recycling plants in their community to help students learn more about recycling through this system

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