FLORIDA INTERNATIONAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EEL 4920 – SENIOR DESIGN I

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Waste Recognition System

Team 3

Alejandro Aloma

Dillon Archer

Sergio Lasprilla

SENIOR DESIGN 1: FINAL PROPOSAL

Submitted to: Dr. Wilmer Arellano

Senior Design I Instructor: Dr. Wilmer Arellano

Mentor: Dr. Wilmer Arellano

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ABSTRACT

The Waste Recognition System is a research project developed by Florida International University (FIU) students as part of the Senior Design I class for the Spring of 2023. Recycling bins throughout the country provide a way for waste to be pre-sorted by the end users. However, these bins failed to reliably fulfill their purpose as the end users frequently could not sort waste into recyclable and nonrecyclables due to a lack of education on what could or could not be recycled or a lack of interest in recycling altogether, which creates a strain on our recycling infrastructure. Our Waste Recognition System separates from other waste products using image verification techniques and removes the need for user sorting as the system sorts the waste automatically. This system allows for reliable and consistent sorting standards that can be replicated en masse, which would vastly improve the recycling rate if adopted. Our preliminary design reliably detected an object placed within the testing chamber while correctly identifying a bottle approximately 86% of the time. The Waste Management System's overall aim is to create a much cleaner and greener world, and it does exactly that.

Table of Contents

I. EXECUTIVE SUMMARY

Waste Recognition System	
Team Number: 3	Team Leader: Sergio Lasprilla
Mentor: Dr. Wilmer Arellano	Team Member: Alejandro Aloma
Professor: Dr. Wilmer Arellano	Team Member: Dillon Archer

A. ***Summarized Problem Statement***

Getting rid of waste is an essential component of our day-to-day lives. We are constantly doing waste removal to ensure a clean and safe environment for humans and animals. Making sure that we are removing as much waste and keeping the world cleaner is essential for our livelihoods, but what if we can take it further? The product our team proposes is a waste recognition device that can identify, sort, and separate bottles from waste. Once our product identifies an object, it will sort and separate it automatically into the proper trash/recycling bin. On top of correctly identifying, sorting, and separating, the waste recognition device will also be able to monitor autonomously how full each container is getting.

B. ***Objectives and Constraints***

1) Project Objectives

1. Safety
2. Accuracy
3. User-friendly
4. Marketability

2) Project Constraints

1. The waste recognition device should be as low cost as possible.
2. The waste recognition device should be as accurate and precise as possible.
3. The waste recognition device should be as compact as possible.

C. ***Project Description***

Recycling is one of the best ways to keep our planet, ecosystems, animals, and ourselves safe and clean. Recycling is the action or process of converting waste into reusable materials. Recycling has many environmental benefits: conserving energy, reducing air pollution, reducing water pollution, reducing greenhouse gas emissions, and conserving natural resources.

The Waste Recognition System is a device that can recycle objects automatically. The process begins with placing a waste object into the opening of our machine. The microcontroller and camera can scan and recognize the waste and quickly identify whether it is a recyclable object or waste. Then, the microcontroller will control a motor that is connected to a holding platform and tilt itself properly to send the identified object to its desired location. The team also plans to add depth and sensors to detect how full a bin is.

D. ***Sections***

- Executive Summary
- Problem Statement
- Needs Feasibility Analysis
- Risk Analysis
- Operating Environment
- Intended Use(s) and Intended User(s)
- Background
- Intellectual Property
- Globalization
- Standard Consideration
- Health and Safety Considerations
- Environmental Considerations
- Sustainability Considerations
- Manufacturability Considerations
- Ethical Considerations and Social Impact
- Concept Development
- End Product Description and Other Deliverables
- Plan of Action
- Multidisciplinary Aspects
- Personnel
- Budget
- Results Evaluation
- Life-Long Learning
- Conclusion
- References
- Appendices

E. ***Conclusion***

II. PROBLEM STATEMENT

Getting rid of waste is an essential component of our day-to-day lives. Waste removal is something that as humans we are constantly doing. The purpose that we take part in the removal of waste is to make sure that we maintain a clean and safe environment for both humans and animals alike. Making sure that we are removing as much waste and keeping the world

cleaner is essential for our livelihoods, but what if we can take it a step further?

Recycling is one of the best ways to keep our planet, ecosystems, animals, and ourselves safe and clean. Recycling is known as the action or process of converting waste into reusable materials. Recycling has many environmental benefits: conserving energy, reducing air pollution, reducing water pollution, reducing greenhouse gas emissions, and conserving natural resources. The more we recycle a society has the better positive impact it has on our planet. This leads us into making sure we recycle as much as possible. Recycling in today's world has never been easier, but what if we can make it even better?

The product our team proposes is a waste recognition device, which can identify, sort, and separate diverse types of waste. Our product will be able to identify a certain object, sort and separate it automatically into the proper trash/recycling bin. On top of being able to correctly identify, sort, and separate, the waste recognition device will also be able to monitor autonomously how full each bin is getting. The waste system should be safe as safety is the most important objective, secondly it should be accurate in its precision, thirdly, it should be user-friendly, and lastly, it should be marketable in that specific order.

A. ***Objectives***

1. Safety
    1.1. The waste recognition device should be safe and reliable.
    1.2. The waste recognition device should adhere to fire safety regulations.
    1.3. The waste recognition device should have the proper electronic components.
2. Accuracy
    2.1. The waste recognition device should accurately identify waste objects.
    2.2. The waste recognition device should sort and separate the identified objects.
    2.3. The waste recognition device should properly measure the level of waste in each bin.
    2.4. The waste recognition device should be able to detect rotten waste.
3. User-friendly
    3.1. The waste recognition device should be autonomous and easy to use.
    3.2. The waste recognition device should be easy to maintain.
4. Marketability

4.1. The waste recognition device should be convenient to access.
4.3. The waste recognition device should be able to be expanded upon.

B. ***Constraints***

1. The waste recognition device should be as low cost as possible.
2. The waste recognition device should be as accurate and precise as possible.
3. The waste recognition device should be as compact as possible.

III. ASSUMPTIONS AND LIMITATIONS

The following section will consist of the assumptions and limitations made by our team during our project's brainstorming phase. It is important to produce a set of clear assumptions and limitations to have a clear idea of the

restrictions that the team will be faced with. After doing some preliminary research was done, lists of both assumptions and limitations were created.

Assumptions are a form of restrictions used to narrow down a project's scope. Assumptions normally take place during the initial research phase and brainstorming of a project idea. Assumptions allow the team to keep specific goals in mind during the implementation stage when limitations arise. Assumptions may consist of incorrect pricing of the project, incorrect materials, and so on.

Similarly, limitations are a set of restrictions but are more defined because they pertain to physical restrictions or restrictions set upon request(s) from a client. Limitations refer to aspects of the project that may give the team a certain technical error or fault. Limitations may consist of incorrect physical dimensions once the project has begun, electronic errors, ease of use issues for the consumer and so on.

To recap, assumptions are like an educated guess of restrictions that the team may run into, and limitations are a type of restriction that is more set-in stone than that the team as faced. Now that we have specifically defined the difference between assumptions and limitations, it is time to define them for our team's waste recognition system.

A. ***Assumptions***

- The Raspberry Pi camera will be able to correctly identify waste objects.
- The trash bin volume sensor will correctly detect a full trash bin accurately.
- The separation mechanism is accurate in assigning which bin to drop the waste object in.
- The gas sensor will correctly detect any rotten waste within the bins.

B. ***Limitations***

- The location of where the waste recognition system can be located due to power source.
- The capabilities of the Raspberry Pi camera.
- The budget to build the system must be less than $400.
- The accuracy of the trash bin volume sensor and its capabilities.
- The reach of the Bluetooth and Wi-Fi antennas.
- The accuracy of the gas sensor and its capabilities.

IV. NEEDS FEASIBILITY ANALYSIS

An important part of the implementation process of any project is doing a needs feasibility analysis. Normally, the beginning stages of any team

project are vague and consist of restrictions and specifications not set in stone. Conducting a needs feasibility analysis allows for an engineering team to follow a specific process in narrowing down their scope of work and gain an insight on specific specifications of their project idea. A needs feasibility analysis consists of speaking with clients, conducting surveys, and having several meetings with your team to clearly identify what the result of the project will be like. The needs feasibility analysis can be broken down into two main sections: a needs analysis and a feasibility analysis.

*A. **Needs Analysis***

In the needs analysis section, the information, which was gathered during speaking with clients, conducting survey interviews, and speaking with the team are presented. The goal of conducting a needs analysis is to narrow down desired specification to give the team a specific goal to satisfy its future users. This section of our proposal allows shows and demonstrates all information gathered from clients, surveys, and from the team.

1) Client Interview

The team believes it is important to have a good understanding of what our future customers would want from our product. Therefore, we interviewed our client, who in this case happens to be our mentor. This client interview was important for our team to help identify specifications, constraints, and certain requirements that the everyday user may want. Once our team interviewed out client, we were able to produce a list of attributes which are shown in TABLE I:

Table I. CLIENT INTERVIEW

Source	Attribute
Client	The waste recognition system should cost around $200.
Client	The waste recognition system should use a depth detector.
Client	The waste recognition system should be able to communicate through an application via Bluetooth or Wi-Fi.
Client	The waste recognition system should use bins larger than 8 gallons.
Client	The waste recognition system should have a long-life span.
Client	The waste recognition system should be easy to empty and replace trash bins.
Client	The waste recognition system has a gas sensor to determine if something is rotten.

2) User Survey

After assessing the client's needs, the next step is to conduct surveys to assess the needs of users. This allows us to get an even better idea of what

our users would want to see in our product and allows them to have some input. The team put together a survey and listed below are some of the most common attributes that users would like to see in our system. TABLE II:

Table II. USER SURVEY

Source	Attribute
Survey	The waste recognition system should be low cost.
Survey	The waste recognition system should be easy to maintain.
Survey	The waste recognition system should be safe to use.
Survey	The waste recognition system should be able to be monitored.
Survey	The waste recognition system should detect rotten foods.

3) Team Discussions

After assessing the client's and user's needs, the next step discusses as a team what some of the attributes we would like to implement. It is important to meet as a team and discuss this topic because ultimately, we are the ones creating this project, so we should have a large input on our project. TABLE III.

Table III. TEAM DISCUSSIONS

Source	Attribute
Team	The waste recognition system should be a standalone system.
Team	The waste recognition system should be able to monitor the battery of the system.
Team	The waste recognition system should be less than $200.
Team	The waste recognition system should send notifications once the bins either contain rotten food or are full and ready to be replaced.

4) Combined

After assessing the client's, user's, and team's needs, the next step is to create a combined list of all the attributes that were acquired. In the table below any repeated attributed were removed for simplicity. Also, an extra column was added to further describe the type of attribute in question. TABLE IV:

Table IV. COMBINED

Source	Attribute	Type

Client	The waste recognition system should use a depth detector.	Marketability
Client	The waste recognition system should be able to communicate through an application via Bluetooth or Wi-Fi.	User-friendly
Client	The waste recognition system should use bins larger than 8 gallons.	Marketability
Client	The waste recognition system should have a long-life span.	Marketability
Client	The waste recognition system should be easy to empty and replace trash bins.	User-friendly
Client	The waste recognition system has a gas sensor to determine if something is rotten.	Marketability
Survey	The waste recognition system should be low cost.	Marketability
Survey	The waste recognition system should be safe to use.	Safety
Survey	The waste recognition system should be able to be monitored.	User-friendly
Team	The waste recognition system should be a standalone system and be DC powered.	Safety
Team	The waste recognition system should be able to monitor the battery of the system.	User-friendly
Team	The waste recognition system should be less than $200.	Marketability
Team	The waste recognition system should send notifications once the bins either contain rotten food or are full and ready to be replaced.	User-friendly

After completing all the assessments with our client, potential future users, and internal team members, TABLE IV was able to be put together. This combined table gives our team a clear picture of the attributes that our waste recognition system should contain. Also, the completion of TABLE IV allowed the team to separate the different types of attributes into specific categories giving a more specified goal for the team. With the need analysis completed, the team can now narrow its scope of work and refine our initial problem statement.

5) Problem Statement

The product that our team is proposing is a waste recognition device, which has the capability to identify, sort, and separate different types of waste. Our product will be able to identify a certain object, sort and separate it automatically into the proper trash/recycling bin. On top of being able to correctly identify, sort, and separate, the waste recognition device will also be able to monitor autonomously how full each bin is getting and recognize any

rotten waste within each bin. The waste system should be safe as safety is the most important objective, secondly it should be accurate in its precision, thirdly, it should be user-friendly, and lastly, it should be marketable in that specific order.

6) Objectives

1. Safety
    1.1. The waste recognition device should be safe and reliable.
    1.2. The waste recognition device should adhere to fire safety regulations.
    1.3. The waste recognition device should have the proper electronic components.
2. Accuracy
    2.1. The waste recognition device should accurately identify waste objects.
    2.2. The waste recognition device should sort and separate the identified objects.
    2.3. The waste recognition device should properly measure the level of waste in each bin.
    2.4. The waste recognition device should be able to detect rotten waste.
3. User-friendly
    3.1. The waste recognition device should be autonomous and easy to use.
    3.2. The waste recognition device should be easy to maintain.
4. Marketability
    4.1. The waste recognition device should be convenient to access.
    4.3. The waste recognition device should be able to be expanded upon.

7) Constraints

1. The waste recognition device should be as low cost as possible.
2. The waste recognition device should be as accurate and precise as possible.
3. The waste recognition device should be as compact as possible.

To conclude, the need analysis is an essential part of any engineering project, especially during the early stages. The needs analysis allowed our team to take open-ended loose ideas of what our potential clients and users would like to see in our product and solidify them. The need analysis was completed by conducting interviews with our client and surveying potential users on what attributes they would like to see in the waste Recognition system. These interviews allowed our team to gain a clear indication of what our end system should be like. Once interviews were conducted and reviewed, then the team had an internal discussion to further narrow down their problem

statement and end goal for the waste Recognition system. The needs analysis is an essential part of an engineering project.

*B. **Need Specification***

On the completion of our needs analysis, our team now has the needed objectives and attributes given from client, potential user surveys, and team discussions. Now that the team fully understands what the consumer needs are, it is time to provide technical specifications to make sure that our waste Recognition system is plausible. This process of identifying certain technological specifications occurs during the need specification section of the need feasibility analysis. The need specification is important because it assigns limits to the attributes and objectives that were collected and analyzed in the need analysis. TABLE V will show all the team's objectives that require further specification.

Table V. NEED SPECIFICATIONS

Objectives	Specification	Justification
2.1	A Raspberry Pi camera should have capabilities to detect both photos and videos. The photo max capabilities are: 3280 x 2464 pixels and the video max capabilities are 1080p @ 30 frames per second.	The Raspberry Pi camera will be able to hold items which are inserted into the lid of waste recognition system. This will allow for the identification of waste objects for the sorting process.
2.3	An ultrasonic sensor should be used for volume detection of waste bins.	The ultrasonic sensor will be able to detect when the waste bins are reaching 100% capacity and relay this information back to the user.
2.4	A gas sensor will be used to determine biogenic amines (BA), which are released when food is rotting.	A gas sensor will allow the user to know when a certain trash item is rotten and notify the user to replace the bin.

To conclude this section, the specifications needed to accomplish our waste Recognition system were highlighted and expanded upon. It was important that the team take qualitative data that was gathered during the need analysis and turn into qualitative data for certain attributes. This process of need specifications was achieved by taking the open-ended request from our client and potential further users and researching the possible devices which would help the team build the waste Recognition system. The need specification analysis is an essential part in the brainstorming and research phase of our project because it will allow for more implementation down the road. This analysis also will allow the team to reference its intended devices to help formulate the system.

*C. **Feasibility Analysis***

The feasibility analysis is an important part of the implementation process to help determine if a project idea is possible. The feasibility analysis is used to evaluate possible issues that may occur during the project's development and how the team should tackle them. The method being used to measure the feasibility of a certain attribute is a scoring system of 1 to 5. Once each attribute is given a score for a section, then the average is entered into the weighted scale.

The feasibility analysis is divided into seven sections: technical, resource, economic, scheduling, cultural, legal, and marketing. Each of the sections mentioned are divided, briefly explained, attributes listed, a score assigned to each attribute, and then averaged out for a given section. The purpose of scoring each attribute is to give each factor a level of importance. Once all the scores are average, then a final score will be reached about the overall feasibility of the project.

1) Technical Feasibility

The technical feasibility section will help the team assess if the technology that is necessary to design and build our waste Recognition system is available currently. The technical feasibility analysis will focus on the technical aspects of the project. This section allows the team to determine if the technology needed to develop the system is available or not. The average score obtained from this section is 4.5, seen in TABLE VI.

Table VI. TECHNICAL FEASIBILITY

Attributes	Score	Why?	Solution
Does the technology already exist?	5	All necessary technology exists currently.	No solution needed.
Can it be obtained?	5	All technology can be obtained locally or online.	Purchasing from the most affordable parts.
Are fundamentally new inventions required?	4	No new inventions are required.	No solution needed.
How much risk is involved?	4	No risk of implementation of each technological device.	Understating each technological part.
Total	18		
Average	4.5		

2) Resource Feasibility

The resource feasibility section will help in the team’s assessment of the required skills, equipment, and ability to create the system. All three

resources mentioned are vital to the development of the project. The team currently has the ability, equipment, and skills to complete the project. The only resource that may be an issue is the team's skill with the technology in use. The average score obtained from this section is 4.6, seen in TABLE VII.

Table VII. RESOURCE FEASIBILITY

Attributes	Score	Why?	Solution
Do we have sufficient skills?	4	Inexperience may add to our lack of skill needed to complete the project.	Understand and practice the necessary skills that are giving us trouble.
Do we have sufficient equipment?	5	All equipment needed for the project will be purchased or refurbished.	No solution needed.
Do we have enough members?	5	The team has 3 members.	No solution needed.
Total	14		
Average	4.6		

3) Economic Feasibility

The economic feasibility section will help in the team's assessment of whether the project can be sustainable from an economic standpoint. The economic feasibility section will also determine if the project will run into any financial burdens. The team can re-use technological equipment that was originally costly but now has no cost, keeping our expenses low. The average score obtained from this section is 4.0, seen in TABLE VIII.

Table VIII. ECONOMIC FEASIBILITY

Attributes	Score	Why?	Solution

Is the project given budget constraints?	4	Key components have already been purchased from previous uses, leaving only minor costs.	No solution needed.
How much economic risk is there?	4	Minor risk of components being damaged.	Fully understand hardware components and connections made to avoid any damage.
Total	8		
Average	4.0		

4) Schedule Feasibility

The schedule feasibility section will help in the team's assessment of whether the project will meet certain milestones. It is important as a team to have proper scheduling for the development of the project and its milestones. If there are setbacks in the project, the team must all be on the same page and tackle them together. Lastly, it is important to have weekly evaluations to make sure progress is kept at the correct pace. The average score obtained from this section is 4.6, seen in TABLE IX.

Table IX. SCHEDULE FEASIBILITY

Attributes	Score	Why?	Solution
What are the chances of meeting intermediate milestones?	5	The team has the organizational skills required to meet all milestones set.	Creating a schedule to meet deadlines appropriately.
Can the team meet preliminary design review?	5	It is necessary to be organized with scheduling to finish preliminary goals.	Constantly communicate as a team and tackle issues together.
Can the team meet critical design review?	4	Time constraints and not being in the same location may affect scheduling.	Schedule with ample time, communicate well, and minimize risks of being late to milestones.
Total	14		
Average	4.6		

5) Cultural Feasibility

The cultural feasibility section will help in the team's assessment of whether the project will provide a positive social impact. Without the project not having a positive impact on society, the product can then fail its indented users. Since the team conducted a market study and surveys, it shows that our project should have a positive impact. This is mainly because our project idea is extremely environmentally beneficial. The average score obtained from this section is 4.5, seen in TABLE X.

Table X. CULTURAL FEASIBILITY

Attributes	Score	Why?	Solution
Will there be a positive impact on the local culture?	5	The market studies show that the project is widely accepted and is beneficial to society.	Good marketing will show that the project has a positive impact on local culture.
Will there be a positive impact on global culture?	4	Although most countries do recycle, a product like ours is not a necessity for countries who cannot afford it.	Good marketing will show that the project has a positive impact on global culture.
Total	9		
Average	4.5		

6) Legal Feasibility

The legal feasibility section will help in the team's assessment of whether the project will run into any issues with laws or regulations that can prevent the project from being adopted or approved by any organization. It is also important for the team to know if any patents or regulation will prevent the project from being successful due to its design or use(s). The team researched similar projects and patents that may be faced. The average score obtained from this section is 5.0, seen in TABLE XI.

Table XI. LEGAL FEASIBILITY

Attributes	Score	Why?	Solution
Laws or regulations impeding the project?	5	There are no laws or regulations impeding the limits of the project.	No solution needed.
Will there be any organizational or policy conflicts?	5	The project has no organizational or policy conflicts.	No solution needed.
How much legal risk is there?	5	Low legal risk for our specific project idea.	No solution needed.
Total	15		
Average	5.0		

7) Marketing Feasibility

The marketing feasibility section will help in the team's assessment of whether the project will be accepted by the public. If the product is not accepted by the public, a lot of money and time that was spent developing the product was then ineffective. Through the team's market studies and surveys, it is believed that there is a need for a product like this one. If the product is developed properly and marketed correctly then it will be successful. The average score obtained from this section is 4.0, seen in TABLE XII.

Table XII. MARKETING FEASIBILITY

Attributes	Score	Why?	Solution
Will the public accept the project?	4	If the public does not accept the project, no units will be sold.	Market studies and surveys will help what the public needs are.
Will the intended user of the product accept the product?	4	If the intended user does not accept the product, they will have to be refunded.	Market studies and surveys will help what our intended user needs are.
Total	8		
Average	4.0		

TABLE XIII is a combined representation of the values the team provided for each of the different feasibility assessments. Also, the table will display the calculated geometric mean and the weight for each assessment. The total weight for all the assessments must equal 1. The diagonal 1's shown in the table represent assessments which are related to themselves. This exercise is an important part of the feasibility assessment because it allows the team to analyze which assessments are more important than another. The scale used to complete TABLE XIII: is:

- 1 = Equal Importance
- 3 = Moderately Important
- 5 = Strongly Important
- 7 = Very Important
- 9 = Extremely Important

The formula used to calculate the geometric mean in TABLE XIII is:

$$\text{G.Mean - (A1 x A2 x A1.... x An)}^{I/N}$$

The formula for geometric mean is used by having the *A* value equal the importance value given to an assessment and the *N* value is the number of assessments.

The formula used to calculate the weight of an assessment in TABLE XIII is:

$$Weight = \frac{G.Mean}{Total}$$

Table XIII. G.MEAN & WEIGHTS

	Technical	Resource	Economic	Schedule	Cultural	Legal	Marketing	G. Mean	Weight
Technical	1.00	1.00	5.00	1.00	5.00	7.00	7.00	2.76	0.27
Resource	1.00	1.00	5.00	1.00	5.00	7.00	5.00	2.63	0.26
Economic	0.20	0.20	1.00	0.14	3.00	5.00	3.00	0.82	0.08
Schedule	1.00	1.00	7.00	1.00	5.00	7.00	5.00	2.76	0.27
Cultural	0.20	0.20	0.33	0.14	1.00	1.00	3.00	0.48	0.05
Legal	0.14	0.14	0.20	0.14	1.00	1.00	1.00	0.34	0.03
Marketing	0.14	0.20	0.33	0.20	0.33	1.00	1.00	0.35	0.03
Total								10.14	

TABLE XIV shows the weighted score that can be derived from the team's feasibility analysis and TABLE XIII. Two metrics will be shown in TABLE XIV: the first being, weight score which is average score of an assessment multiplied by weight of an assessment. Then the weighted average will be shown which is the average of the weighted score divided by the average of weight.

The formula used to calculate Weighted Score in TABLE XIV is:

$$Weighted\ Score = Weight \cdot Score$$

The formula used to calculate Weighted Average in TABLE XIV is:

$$Weighted\ Average = \frac{\Sigma Weighted\ Score}{\Sigma Weight}$$

Table XIV. WEIGHTED SCALE

	Weight	Score	Weighted Score
Technical	0.27	4.5	1.21
Resource	0.26	4.6	1.19
Economic	0.08	4.0	0.32
Schedule	0.27	4.6	1.24
Cultural	0.05	4.5	0.22
Legal	0.03	5.0	0.15
Marketing	0.03	4.0	0.12
Total	1.00	31.2	4.45
Weighted Average			4.45

To conclude the feasibility analysis, the team conducted seven separate assessments. The seven assessments completed: technical, resource, economic, schedule, cultural, legal, and marketing assessments. Once the assessments were completed, further analysis was conducted in the form of G.Mean and weighing of the different assessments. Lastly, the weighted averages of all the data were done. For the project to be feasible, the project would need to have a weighted average of 3.0 and our project has a weighted average of 4.45. This means that our project idea is extremely feasible. This left the team with a good idea of how feasible our project truly is.

D. ***Marketability***

Marketability is a key aspect that must be kept in mind when designing any product. Marketability is defined as "a measure of whether a product will be appealing to buyers and sell at competitive price range to generate profit." [1] The team's waste recognition system will be marketable to both individual customers and large corporations. Our waste recognition system is a product that will make recycling easy, painless, and accurate. This product is something individual users would like in their homes along with large companies having them in their businesses. To make sure that our product is going to be successful and marketable, the team must first do some preliminary research on other similar products within the waste and recycle realm. This research will allow the team to gain an insight into the field that

they are entering. The team will be using Kickstarter to do its research, analysis, and comparisons on two similar products within the waste and recycling worlds. The team will first give a brief description of the selected company, a project summary of the product, the company's fundraising strategies, a technological overview of the product, and a system description. Hopefully once this task is completed, the team will be able to see and understand similar campaigns to their own.

1) Bruno

a) Project Summary

Bruno, also known as "The World's First Smartcan," is a product which is both a trash can and a vacuum. Bruno is a product created by a company called Poubelle. Poubelle is a small company created by serial inventors, Jim Howard and Lori Montag in Tulsa, Oklahoma. In 2015, Bruno was created to replace the traditional dustpan and make sweeping dirty floors more efficient. This was accomplished by combining a vacuum to the bottom of a trash bin and having the waste from the vacuum directly empty into the trash bag within the bin combining the two.

b) Fundraising Strategy

Before launching any product into fruition, it is important to not only figure out all technical aspects of the product, but also make sure a proper marketing and fundraising strategy are in place. Luckily Poubelle had a very good and successful fundraising strategy. The company set a $50,000 goal and surpassed it immensely gathering $117,240 in pledged funds. The company did this through a series of rewards. Below in TABLE XV, are the details of each reward category per pledge.

Table XV. BRUNO REWARDS

Pledge	Reward

$5 or more	Name of backer will be scribed on Bruno wall of fame.
$20 or more	Name scribed on wall of fame + an official Bruno T-shirt.
$149 or more	Would receive 1 of the first 300 Bruno's made + 3 month's supply of Bruno Bags.
$159 or more	Would receive a Bruno + 3 months' supply of Bruno Bags.
$169 or more	Would receive a Bruno + 3 months' supply of Bruno Bags.
$179 or more	Would receive a Bruno + 3 months' supply of Bruno Bags.
$189 or more	Would receive a Bruno + 5-year supply of Bruno Bags.
$229 or more	Would receive a stainless-steel Bruno + 3 months' supply of Bruno Bags.
$349 or more	Would receive 2 Bruno's + 3 months' supply of Bruno Bags.
$849 or more	Would receive 5 Bruno's + 3 months' supply of Bruno Bags.
$1650 or more	Would receive 10 Bruno's + 3 months' supply of Bruno Bags.

c) Technology Overview

Bruno combines two everyday household appliances together using technology. It is important to quickly go over the components to understand how Bruno is made. Below is TABLE XVI, the components along with the technology used and their functions that make up Bruno.

Table XVI. BRUNO SPECIFICATIONS

Components	Technology Used	Function

Vacuum	Integrated Vacuum and Filtration System.	The purpose of the vacuum component is to be able to suck in any dust and small waste to then get filtered into the built in trash bag.
Motion Sensor	Motion Sensing Lid	The purpose of the motion sensor is to be able to open the lid of the Bruno via a hand swipe above the lid.
Ultrasonic Sensor	Trash Bag Volume Detection	The purpose of the ultrasonic sensor is to determine how full the trash bag is and relay that information to the user.
Software Application	Low Bag Notifications	The purpose of the software application is to be able to relay information taken from the ultrasonic sensor about how full the trash bag is back to the user via a nice interface.
Power Supply	18 Volt Battery Supply	The purpose of the 18V power supply is to power the Bruno for up to 30 days on a single charge.

d) System Description

Bruno is the world's first smart trash can. The capability of the Bruno consists of being your normal trash can with a high-powered vacuum built into the bottom. The Bruno is a product that reinvented the traditional dustpan by making sweeping the floor a much easier process. The user will no longer need to bend down or use a separate dustpan to make sure their floors are clean. This is accomplished a powerful vortex vacuum which is connected to the same trash bag within the Bruno. It does not stop there, Bruno also functions as a normal trash bin, therefore combing the too. It also has nice features such as: motion sensing door lid functionality, application linked to an ultrasonic sensor to inform the user if the Bruno Bag within the Bruno is full, and a long lasting 18V battery.

Fig.1. BRUNO [2]

In Fig. 2, the block diagram of Bruno is shown. The Bruno diagram can be explained as follows: a vacuum, motion sensor, and ultrasonic sensor are built into the trash bin. The trash bin is then connected to a microcontroller which then enables the software application to be controlled.

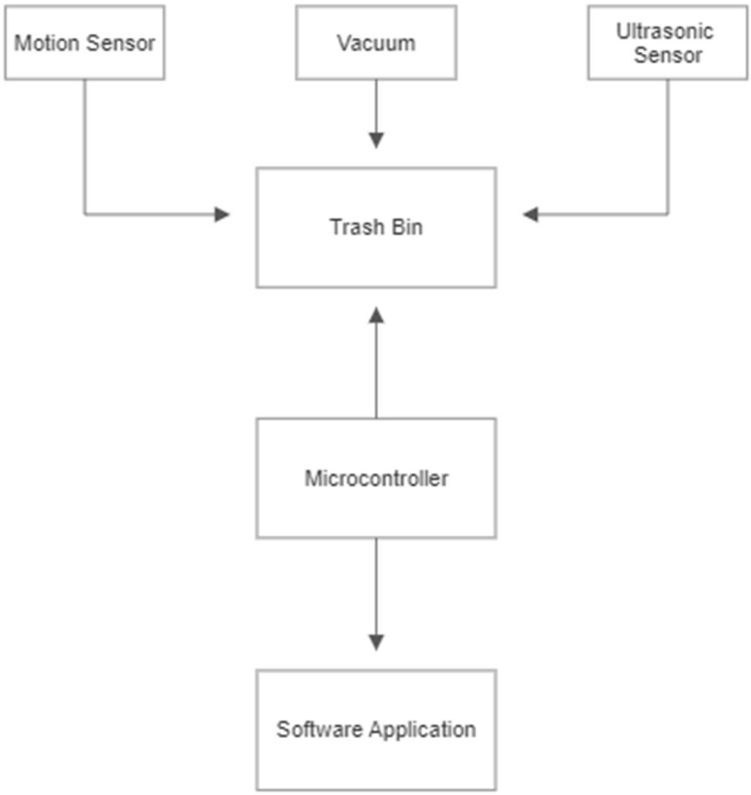

Fig.2. BRUNO BLOCK DIAGRAM

2) QUBE

a) Project Summary

QUBE also known as "The World's First Smart Recycling Trash Can," is a product that is connected to the individual by allowing the user to manage their waste while helping the environment. QUBE is a product which was created in Madrid, Spain. Their main mission as a company was to develop a product which is 100% committed to protecting the planet.

b) Fundraising Strategy

Before launching any product into fruition, it is important to not only figure out all technical aspects of the product, but also make sure a proper marketing and fundraising strategy are in place. QUBE seemed to have a good plan for fundraising in place but felt short in their fundraising campaign. The company set a $254,167 goal for fundraising, but their fundraising was deemed unsuccessful as of December 22, 2016. The company did this through an ample number of rewards. Below in TABLE XVII, are the details of each reward category per pledge.

Table XVII. BRUNO REWARDS

Pledge	Reward
€5 or more	Donation, user will be kept up to date with QUBE updates.
€15 or more	Gifted a reusable shopping bag.
€279 or more	Super Early Bird/Receive a dual compartment QUBE.
€299 or more	Super Early Bird/Receive a triple compartment QUBE.
€299 or more	Early Adopter/ Receive a dual compartment QUBE.
€314 or more	Early Adopter/ Receive a dual compartment QUBE + 1-year of Cleanbins.
€319 or more	Early Adopter/ Receive a triple compartment QUBE.
€329 or more	Early Adopter/ Receive a dual compartment QUBE + 1-year of fit bags.
€334 or more	Early Adopter/ Receive a triple compartment QUBE + 1-year of Cleanbins.
€334 or more	Early Adopter/ Receive a dual compartment QUBE + 1 extra battery.
€340 or more	FULL QUBE PACK/ Receive a dual compartment QUBE.
€349 or more	Early Adopter/ Receive a triple compartment QUBE + 1-year of fit bags.
€354 or more	Early Adopter/ Receive a triple compartment QUBE + 1 extra battery.
€360 or more	FULL QUBE PACK/ Receive a triple compartment QUBE.
€837 or more	Corporate Pack/ Receive 3 dual compartment QUBE's.
€897 or more	Corporate Pack/ Receive 3 triple compartment QUBE's.

c) Technology Overview

QUBE combines combined recycling and technology in efforts to better help the environment. It is important to quickly go over the components to understand how the QUBE is made. Below is TABLE XVIII, the components along with the technology used and their functions that make up QUBE.

Table XVIII. QUBE SPECIFICATIONS

Components	Technology Used	Function
Sensors	The System uses: weight sensors, T sensors, humidity sensors, presence sensors, and photo reflector sensors.	Each individual sensor has a specific role in the overall functionality of the QUBE, also making it highly effective for its' software application.
Screen Display	5 Inch LCD Display	The purpose of the screen display is to help display information to the user of QUBE.
Software Application	IOS and Android Phone Applications	The purpose of the IOS and Android application is to assist with the ease of use of the QUBE, allowing for adding on to the user interface.
Wi-Fi	802.11AC	The purpose of Wi-Fi is to connect the phone application to the QUBE.
Power Supply	Rechargeable Lithium Battery or Optional Charger Cord.	The purpose of the power supply is to properly supply power to the entire device.

d) System Description

QUBE is the world's first smart recycling trash can. It is a product which allows the user to control and manage their household waste while helping protect the environment [3]. QUBE is a product that will let the user be informed on the real impact they are causing on the environment giving the user real time data to their waste via their QUBE application. The QUBE containing several types of sensors will allow the user to know the state of their waste, when their trash was last emptied, how many bin liners are left, and how well the CleanBin freshener is working [3]. Also, the QUBE tracks a lot of different data points such as: weight of waste, waste generated, the amount of CO2 saved by the user's recycling, and even has a leaderboard between all QUBE users. This not only helped attract the product but really helps to see how much of the planet is benefiting from a product like the QUBE. The QUBE from an aesthetic perspective is very compact, clean in design, and durable. The QUBE comes in 8 assorted color options: metal, black, white, cream, red, green, blur, and yellow. The QUBE is really a product that will not only revolutionize the way we recycle but the way the planet is saved.

Fig.3. QUBE [3]

In Fig. 4, the block diagram of QUBE is shown. The QUBE diagram can be explained as follows: a standard trash bin with either dual or triple compartments built in. The sensors that are built in are: weight sensors, T sensors, humidity sensors, presence sensors, photo reflector sensors, controlled. These sensors relay information back to the microcontroller which also controls the software application for the QUBE.

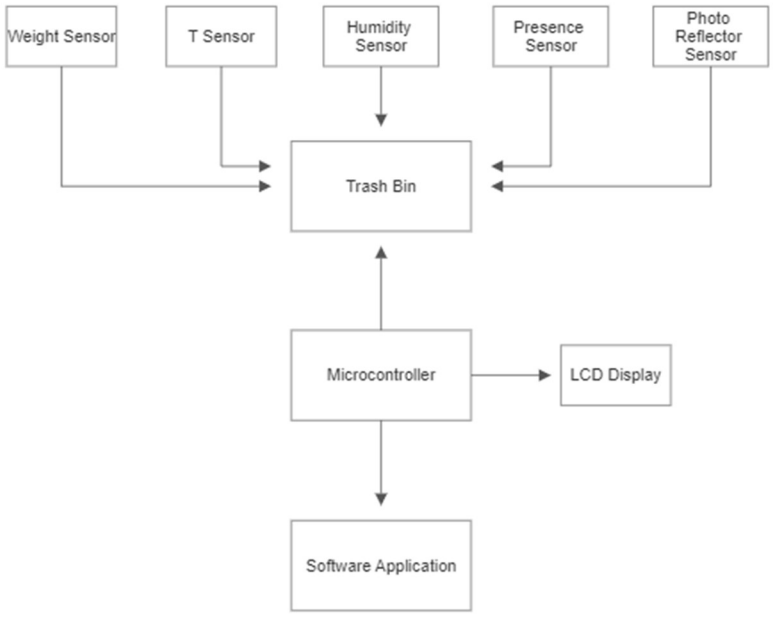

Fig.4. QUBE BLOCK DIAGRAM

Looking at both projects has given our team an insight into what a marketing and fundraising campaign of a similar idea to ours is like. It has allowed us to have further discussions on what our own Kickstarter campaign for fundraising would be like. It has allowed us to see what does and does not work in a campaign for raising funds. If our team were to create a Kickstarter

campaign, we would focus on 4 main categories: defining our goal, creating a good reward system, creating marketing advertisements such as videos and images, and inspiring future customers to donate to our idea. The next paragraph will go into detail on the four categories chosen.

First, defining our goal would consist of finding how much it would take to fund our project financially. This first step is important because the following steps heavily rely on making sure our team has the proper funding to fully make our product a reality. Second, we would produce a good reward system via Kickstarter for our early backers. Thankfully, due to our previous research, the team knows that a simple reward system is the way to go. Our reward system would consist of five tiers. Tier 1: $5 or more, a thank you email to the backer. Tier 2: $15 or more, thank you email and t-shirt. Tier 3: $50 or more, previous tiers + 30% discount at official product launch. Tier 4: $150 or more, one waste Recognition system. Tier 5: $250, two waste Recognition systems. Having a simple, yet good reward system in place for potential backers is pinnacle part to a successful fundraising campaign. Third, creating a marketing video along with several images that can be sent via email and our Kickstarter page. Lastly, inspiring people to donate will allow our dream to become a reality. This will be done using the third step in our plan and a persistent effort by the team to reach as many potential backers as possible.

In conclusion, it is important to research similar products to the one you are trying to create and get a good idea of what does work and what does not. Then a plan can be formulated to conduct your financial funding goals. The last step in the process is conducting the plan.

V. RISK ANALYSIS

Conducting a risk analysis is an important part of any research project. A risk analysis allows the team to measure the different potential risks and consequences to those risks that can arise due to the creation of the project. The risk analysis is essential to properly understand all the risks and benefits of the project idea because then it will allow the team to minimize any risks and maximize any benefits.

During the risk analysis, risks will be classified into seven different categories. These categories include technical, resources, economic, schedule, legal, marketing, and cultural risks. Each of the different categories will contain a specific area of risk that may arise in the project's development. In the list below, the seven different risks categories are listed in order of greatest risks to lowest risks. This is done to highlight the more challenging aspects the team may face during the project.

The following list includes all the of potential risks organized neatly within their desired categories:

1) *Technical*
   - T.1. Programming Raspberry Pi Micro-Computer.
   - T.2. Wiring sensors properly with the Raspberry Pi.
2) *Resources*
   - R.1. Acquire correct equipment needed for the project.
   - R.2. Acquire electronic and electrical skills.
3) *Economic*
   - E.1. Not exceeding the budget set.
   - E.2. Financial burdens due to destruction of equipment.
4) *Schedule*
   - S.1. Time to learn technical skills.
   - S.2. Improper use of time and not meeting deadlines.
5) *Legal*
   - L.1. Very low chance of infringement.
   - L.2. Chance of imposing on current waste company contracts with potential clients.
6) *Marketing*
   - M.1. Marketing product to appeal to target market.
   - M.2. Marketing product so that it is affordable for every user.
7) *Cultural*
   - C.1. Very low social acceptance.

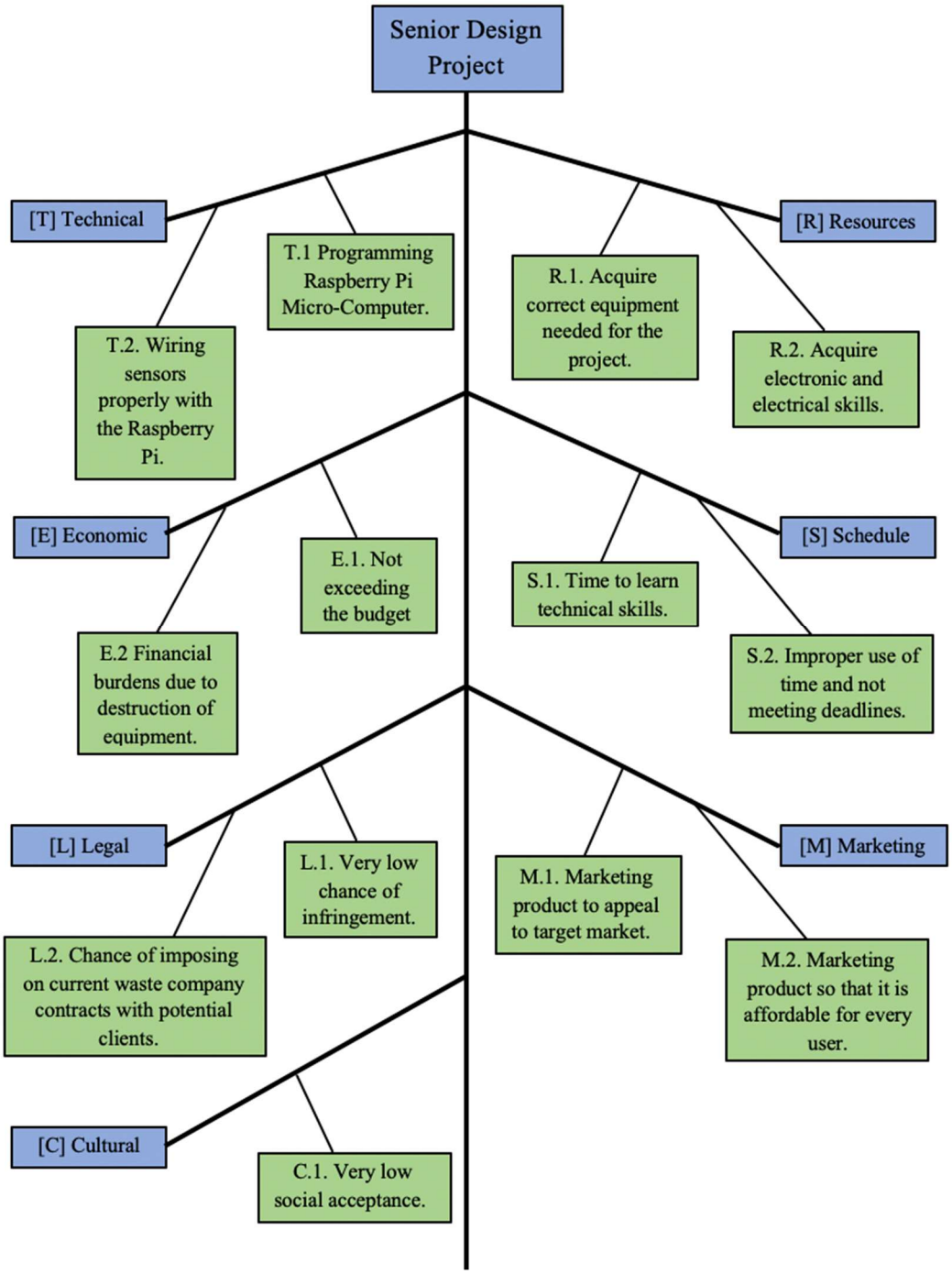

Fig 5. Fault Tree Analysis

Figure 5 demonstrates our team's fault tree analysis for our project idea. The way the fault tree analysis is set up is the seven different risk categories are set up as a branch from the central theme. The seven categories are shown in a blue box. Then, the leaves are added to their corresponding categories. The leaves are shown in a green box. The fault tree is set up so that the greater risks are at the top and the lesser risks are at the bottom. The fault tree clearly highlights all the possible risks categories and their specific concerns vividly. This allows for further analysis.

Once the fault tree analysis was completed and the risks were known and categorized, the team was able to conduct a risk exposure matrix. The risk exposure matrix allows for further separation and identification of the risks involved with the project. The risk exposure details the likelihood of exposure of a certain risk. The matrix allows for a cross examination of a certain risk that comes from the fault tree analysis. The risk exposure matrix has two main sections: how likely a risk is set to occur and the level of importance of a risk, where a *Class I* risk requires little to no attention and a *Class IV* requires immediate attention.

Table XIX. RISK EXPOSURE MATRIX

Likelihood of Occurrence				
	Very Likely	**Possible**	**Unlikely**	**Legend**
Class IV		[L.2]		**Catastrophic**
Class III		[L.1] [T.2]	[S.1]	**Severe**
Class II	[E.2]	[T.1] [S.2] [M.1]	[C1]	**Moderate**
Class I		[E.1]	[R.1] [R.2] [M2]	**Low**

As shown in TABLE XIX, most of the risks that come with our project can either be avoided or managed easily, however there is one catastrophic risk and that interfering with any business who have current waste contracts with companies we wish to work with. This risk is possible to occur and will definitely make our dream a non-reality.

Table XX. ACTIONS TO MINIMIZE RISKS

Actions	
E.1	Our budget is relatively small due to a lot of key components already purchased.
C.1	Understand who how target market is and aim our product for those cultures.
[R.1] [R.2]	Take time to learn and understand components needed, along with learning how to use them via online tutorials and classes.
[M.2]	Understand who how target market is and how much they are willing to spend on our already inexpensive product.
[S.1] [S.2]	Take time to plan out a schedule and timeline for project and include in that schedule time to learn technical skills.
[M.1]	Take time to research and fully understand our target market.
[T.1]	Take time to learn all of the technical skills needed to program and use the Raspberry Pi.
[L.1]	Research and write down a list of any possible infringements that the project may be affected by.
[T.2]	Take time to learn all of the wiring and components needed to use the Raspberry Pi Micro Computer.
[E.2]	To avoid any financial burdens due to improper use of equipment, make sure a good foundation for components is in place before building starts.
[L.2]	Understand business contracts and meet with business to set up contracts if needed.

TABLE XX shows all the potential risks that were sorted using the risk exposure matrix and how the team should take actions to minimize those said risks. Making sure the team pays extra attention to L.2, E.2, T.2, L.1, is essential for the execution of our product. These risks can mainly be minimized by conducting extensive research and making sure everyone in the team understands all the risks thoroughly.

In conclusion, risk analysis is an essential part of the team's project, and it is done to present and understand all possible risks pertaining to a project. The risk analysis began by separating all possible risks into seven subcategories. These subcategories were then used to build a fault tree analysis. The fault tree analysis gives the reader and team a visual of the level of importance of each individual risk. Then using the fault tree analysis, the risk exposure matrix was created which categorizes the level of importance of each risk and the likelihood of a risk occurring. Finally, actions to minimize risks were listed to clearly state how the team would prevent and tackle any risks that would arise.

VI. Operating Environment

For our project, it is essential to consider the expected operating environment for which it must be used. When considering the waste recognition system, it is crucial to consider the objectives it needs to meet to work in most environments. The project's design must take deliberate measures to ensure it works in most environments and be intuitive and resource-efficient to do its tasks in its environment. The ideal operating environment would be where average trash cans are in indoor public areas with an opportunity to throw away something conveniently. For example, next to or near a vending machine where they serve beverages in plastic bottles is an optimal area to use the waste recognition system for the convenience of easy disposal of waste. The conditions needed to be considered for the operating environment mentioned make sure the waste recognition system does not take too much space in comparison to an average trash can and that it would share the same electrical outlet as the vending machine to continue operating in vast amounts of time like the vending machine. Since the waste recognition system can only function with an electrical outlet, the preferred area and operating environment where our product should be placed are nearby indoor and outdoor electrical outlets. Furthermore, the waste recognition system will have front doors that will be needed to have enough space to open so that the required replacement of the bags inside is easy for those responsible.

The waste recognition system must also incorporate and accommodate its operating environment to ensure the product lasts as long as a regular trash bin. To ensure the waste recognition system operates without any uncontrollable circumstances hindering the product, it must be durable and resistant to most environmental outcomes. One of the ways to make sure it becomes durable is to make sure all the necessary electronics inside are encased in a heavy-duty material and make sure it is water resistant in case of water spillage. Another requirement that the waste recognition system will have been to implement outside surfaces that are easy to clean since there is the potential to get cluttered in a mess from product overuse. For the use of an outdoor environment when able to be plugged in an outdoor outlet there must be considered the profound changes of outside weather that can happen. In outdoor rain, the waste recognition system will have all its outer encasement with water-resistant material to ensure no drops enter the electronics inside. Also, drastic temperature changes should not affect the waste recognition system's functions in any way.

Critically, the waste recognition system has some care requirements to ensure that it continues working its intended function. The waste recognition system, when plugged in, should not be carried, or dropped by anyone as it could destroy any vital parts inside the product. Additionally, the waste recognition system should not be placed on any surface that is on a tilt; the product only works if it is on a flat surface. Places with the potential to be near any body of water should also not be near it, as the waste recognition

system being submerged in water would make it out of commission and be dangerous to anyone inside that body of water. Other drastic environments such as heavy snow, insect-infested, or hurricane-level winds should be avoided to place the waste recognition system there and instead be carried to the ideal indoor environment. Based on the operating environment in question, the product must first overcome its challenges to determine if it can be handled to be used in more environments.

VII. INTENDED USER(S) AND INTENDED USE(S)

It is essential to point out the intended user(s) and intended use(s) for our project in terms of its design and motives of use. To ensure that our product is created to meet the demands of its purpose, it is important to remember what type of intended user(s) and intended use(s) are considered when designing the product. Our intended user(s) and intended use(s) were decided through insightful consideration of what we had in mind for the product, its intended purposes, and visualizing how it would be utilized in a real-world scenario.

A. ***Intended user(s)***

What we had in mind for our intended user(s) regarding the waste recognition system is that it would be used by everyday people for throwing away unnecessary trash. Considering that it would replace standard average trash cans and promote the support of recycling, educational environments like schools, colleges, public libraries, and other widespread public educational facilities would be a high priority as one of our intended users. Similarly, areas such as outdoor parks with recreational buildings for the need of an electrical source would be beneficial for the waste recognition system as large amounts of people throw away trash there daily.

Other potential intended user(s) are places that commonly trash away trash daily and that have a high number of plastics needed to be thrown away and would utilize the need for the waste recognition system. Places like food courts and extensive eating facilities like cafeterias would take advantage of the waste recognition system for separating uneaten food with plastic bottles and utensils. To an extent, busy public areas with vending machines that dispense plastic bottles synergize well with the waste recognition system as it automatically sorts the plastic bottle in the recycling bin after the intended user finishes their drink.

B. ***Intended use(s)***

From designing the waste recognition system, the most vital requirement needed to be understood is the acknowledgment of its intended use(s). Essentially, the intended use of the waste recognition system is to detect plastics, so it automatically sorts them into a recyclable bin for the ease of the user to not need to decide when throwing away items. If the user does not throw away anything plastic-related, it will use the same sorting system to throw away regular trash separate from the recyclable bin.

Additionally, the waste recognition system will have other functions, such as detecting and alerting when trash bags are full for the need to change bags. Other additional functions are informing the product's status, ensuring it runs smoothly, and troubleshooting when needed. Outside of its specifications and mechanisms, the waste recognition system was designed as an intended use to promote recycling and make sure that people are motivated to recycle with the help of automation so that they would recycle more often and naturally within their daily life. As emphasized, the waste recognition system is primarily intended for recycling more often than usual.

VIII. BACKGROUND

Understanding the background of a project is essential to know for its supply of previous knowledge in terms of creating a design and comparing previous works with what a team plans to do for a project. Regarding using earlier projects as a background for our project, the expectation we wanted is to inform others of the potential of contributing previous works with ours and researching for improving our project with other previous examples. From researching similar topics and fields from our project, we highlighted and selected three projects that share similarities or features with our project. We can examine these three projects to serve as a guide for designing our waste recognition systems and provide a background for our project. The three projects all contribute unique features, architectures, and systems that share similarities with what we hope to do for the waste recognition systems. Features like object detection, automatic sorting, full bin alerting, and more will be informed from the three projects mentioned further. They will function as a guideline for adding features to the waste recognition system. The three projects are the YOLO-based object detection for separate collection of recyclables and capacity monitoring of trash bins, the automatic trash bin system with mobile wireless technology, and the IoT-project smart trash can with blynk platform integration.

*A. **YOLO-Based Object Detection for Separate Collection of Recyclables and Capacity Monitoring of Trash Bins***

1) Project Summary

This object detection project was developed by Aria Bisma Wahyutama and Mintae Hwang. The development was for creating a smart trash bin that separates and collects recyclables using object-detecting software called You Only Look Once (YOLO). It works by using a webcam and connecting it to a Raspberry Pi. It runs the YOLO software located in the Raspberry Pi and detects the object opening the respective bin according to the detected object classification. The separated bins open up to the respective classification of the detected object by rotating a lid that has an opening and will rotate as soon as the opening is located above the separate individual bin. Throughout its testing, the model that implements the YOLO software is measured to have an accuracy of 91% under the given optimal computing environment. When tested on the Raspberry Pi, it has an accuracy of 75%. Other features related to the Internet of Things hardware were added, including an ultrasonic sensor for measuring the trash bin capacity and a GPS for locating the trash bin's coordinates and location. All these features were added and uploaded to a Firebase Database via an ESP8266 Wi-Fi module so that it can monitor through a developed mobile application.

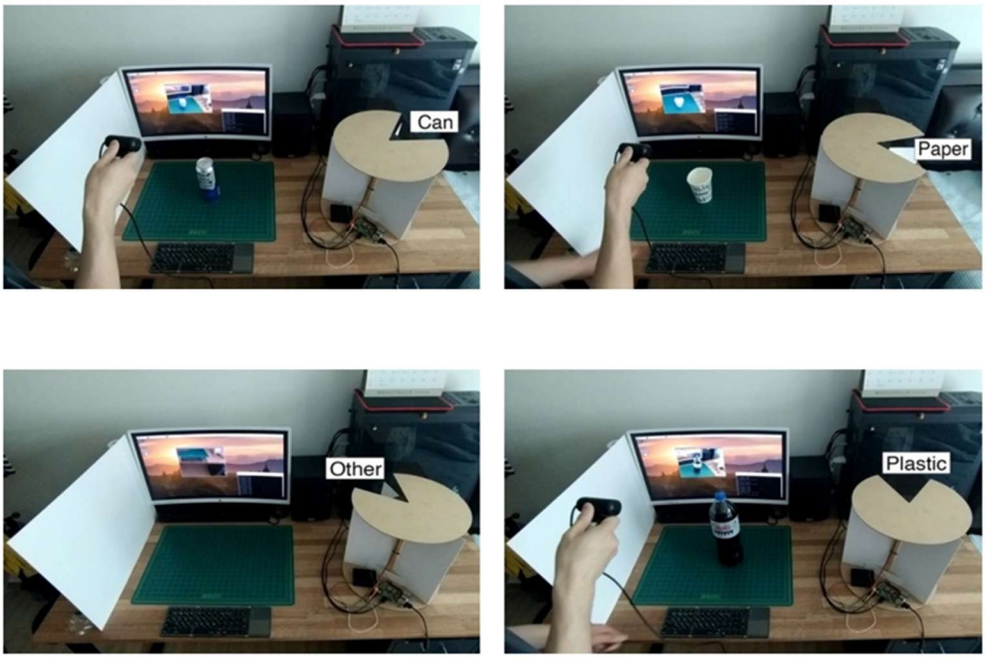

Fig. 6. Demonstration of Object Detection Testing with Can, Paper, Other, & Plastic

2) Technology Overview

The project's trash can, and separator lid hardware layout uses a relatively small cylindrical structure to divide each recycling bin into pieces of the round lid. The project used two Arduino Unos, one for controlling the servo motor and another for controlling the GPS, ultrasonic, and ESP8266 Wi-Fi module. The project also uses the ESP8266 Wi-Fi module to upload the gathered data to the Firebase Database to monitor via mobile smartphone. The GPS (NEO-6M) is to locate the trash bin coordinate information for locating, and the Ultrasonic (HC-R04) measures the distance from the lid to the recyclable trash to inform when the container is full. The Raspberry Pi is for running the YOLO software object detection, which is vital for the trash bin. The servo motor rotates the trash bin lid to reveal the respective container regarding the object detected. The USB camera captures the trash video image for the YOLO software to detect the object.

Table XXI. Trash Bin Lid Separator Hardware Specifications

Hardware	Specification
Controllers	Two Arduino Uno
Wi-Fi Microcontroller	ESP8266 Wi-Fi Module
Data Collection	GPS (NEO-6M)
Data Collection	Ultrasonic (HC-R04)
Computer	Raspberry Pi 4B+
Motor	Servo Motor (MG946R)
Camera	USB Camera (WNA-PC200)

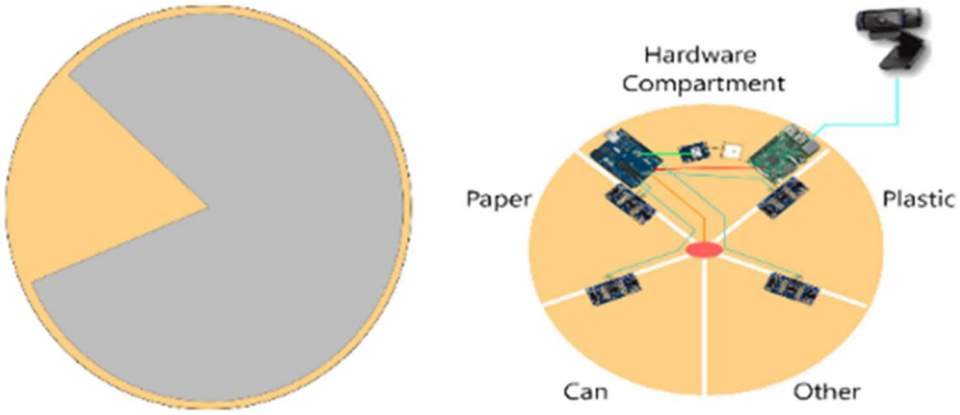

Fig. 7. Hardware Design of Trash Bin Lid Separator

3) System Description

The system for the project starts with first the camera detecting input from an object which sends that object input to the Raspberry Pi, where the YOLO object detection software is running. The classification gathered from the YOLO object detection software sends to the Arduino Uno, which depending on what the classification is, will control the servo motor to rotate a specific amount according to the object being detected. From the Arduino Uno, it is connected to the ultrasonic to measure the distance of the bin to check if it is full, as well as the GPS for gathering the coordinate information. The Arduino Uno is additionally connected to the ESP8266 Wi-Fi module, where all the data collected from the ultrasonic and GPS is uploaded to Firebase Database, where a mobile application shows the uploaded data.

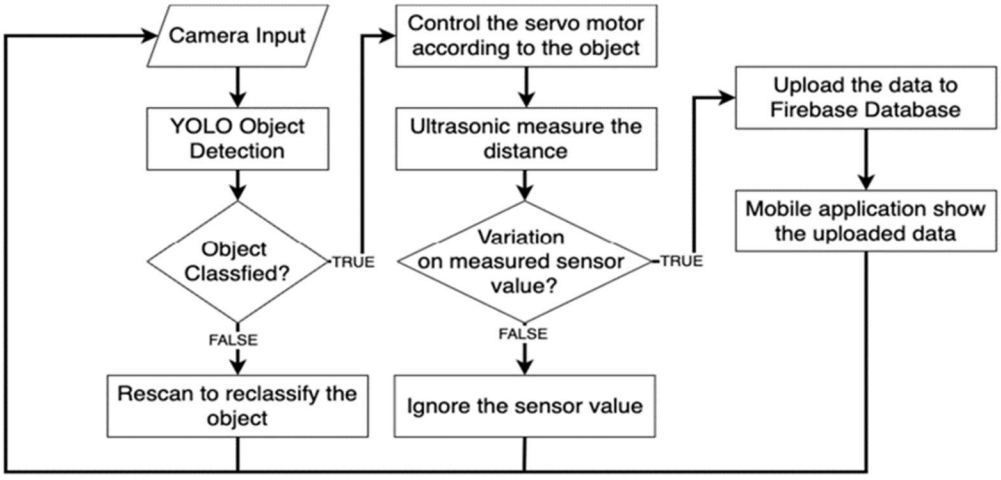

Fig. 8. YOLO Operated Separator System Block Diagram

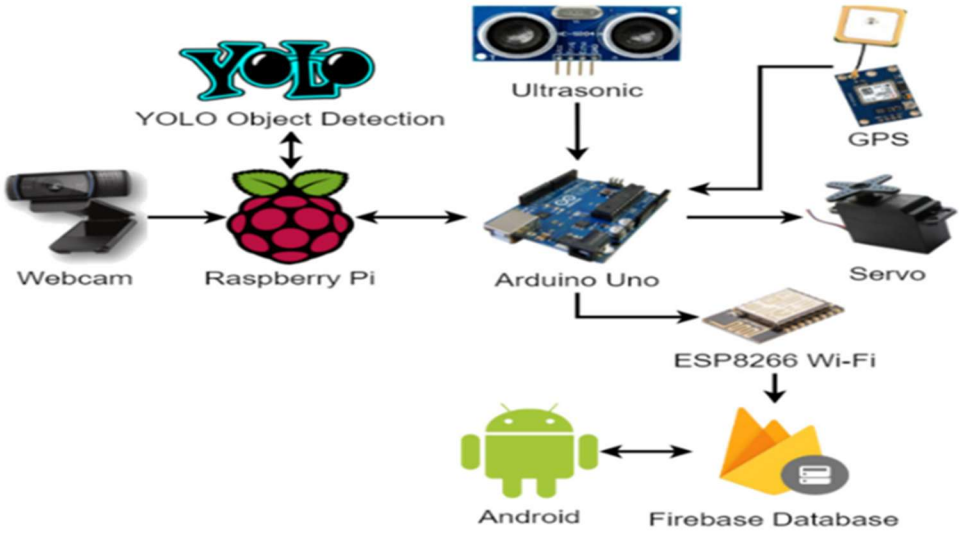

Fig. 9. Visual Software & Hardware System Architecture

*B. **Automatic Trash Bin System with Mobile Wireless Technology***

1) Project Summary

The simulation and construction of the automatic trash bin system with mobile wireless technology were located in Keffi, Nigeria, worked on by Samson D Yusuf1, Kabiru M Osu, Abdulmumini Z Loko, and Ibrahim Umar, stemming from the issues of solid waste Recognition that are happening. This project aimed to create an effective device that is a simple alternative for checking the trash levels of a bin and will use mobile wireless technology to send an SMS to the users when the waste level reaches a specific threshold value informing the user to tell when the bin was full. The goal was to use this effective device in homes or public commercial areas to monitor container waste levels to handle proper waste Recognition more effectively and create a cleaner environment. What makes this project unique is the number of materials needed to create this automatic trash bin system, as it only requires four crucial components to assemble.

Fig. 10. Top & Side View of Automatic Trash Bin

2) Technology Overview

What was used for the casing and bin was measured in total with a length of 45 cm, a width of 40 cm, and a height of 63 cm. Its casing has a compartment for the open bin to throw away the trash, and the rest of the casing holds the hardware constructed to gather data for when the trash levels reach a certain threshold to alert the user on their phone. The hardware used was an AT89S51 microcontroller for low-power and high performance to have it programmed to receive input and send signals to other components in the device to control it. The component that implements mobile wireless technology is the SIM800L GSM modem which is used for sending or receiving messages and can be connected to a cellular network to send messages to a mobile phone. The HC SR04 ultrasonic sensor is the component used for ranging the distance of the trash levels to a specific capacity, and if it meets that threshold, it will alert the microcontroller. The 5V/500Am step-down transformer works as a power supply for the whole device to run continuously at an appropriate AC voltage level from a DC voltage source, as a simple small device such as this project needs to have the required correct voltage. All the components are assembled on a Vero board as it will hold everything in place and will be required for placing inside the casing for the automatic trash bin system.

Table XXII. Automatic Trash Bin Hardware Specifications

Hardware	Specifications
Controller	Atmel AT89S51 microcontroller
Communication	SIM800L GSM modem
Data Collection	HC SR04 ultrasonic sensor
Voltage Transformer	5V/500Am step-down transformer

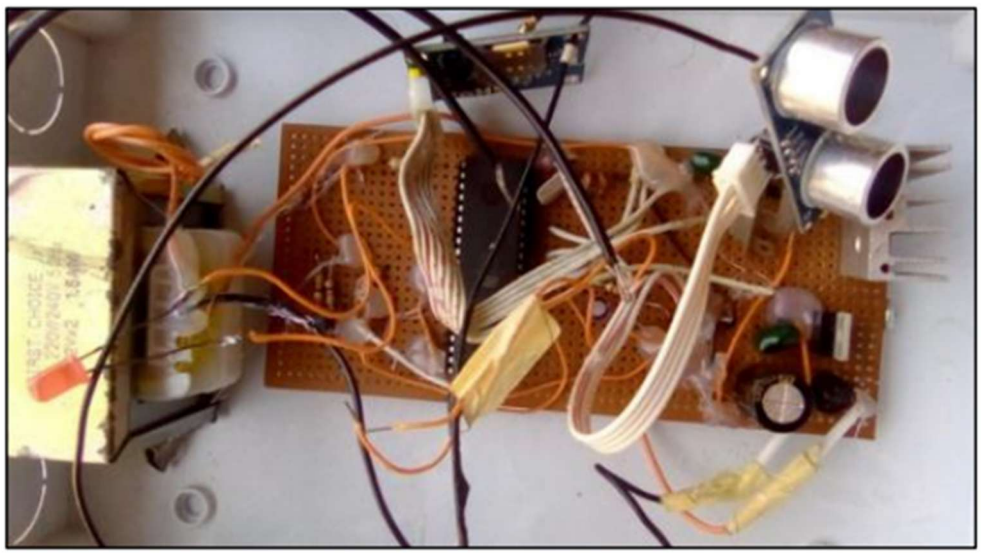

Fig. 11. Top View of Constructed Device on Vero Board

3) System Description

The automatic trash bin system first receives power from the power supply that powers the microcontroller. As the microcontroller receives input from the ultrasonic sensors, it gathers that data and sends it to the GSM module to alert the user with a mobile message when the trash can reach a certain threshold for the need to empty the bin. The flowchart informs the algorithm that takes place in the device, as mentioned below.

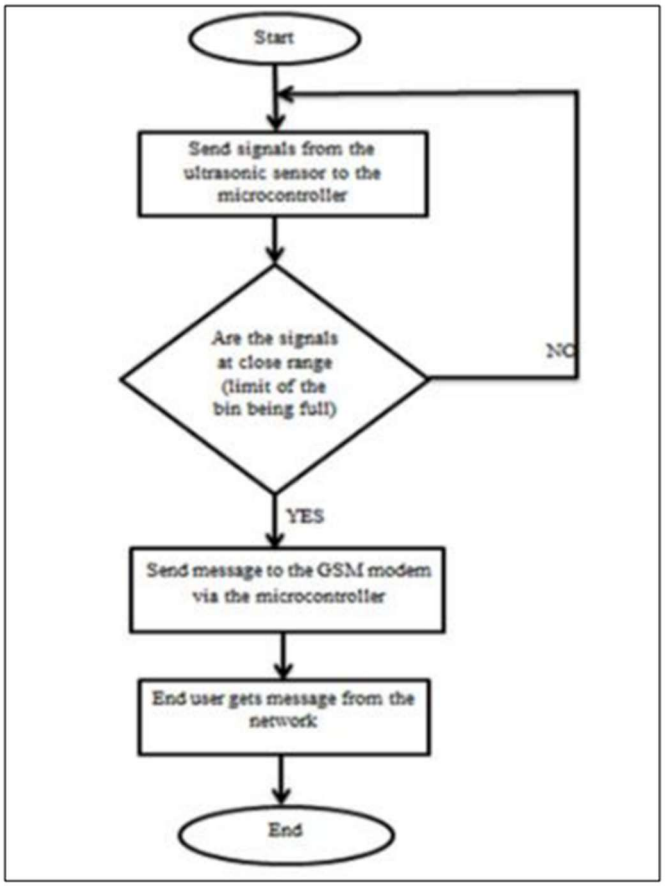

Fig. 12. Automatic Trash Bin System Block Diagram Flowchart

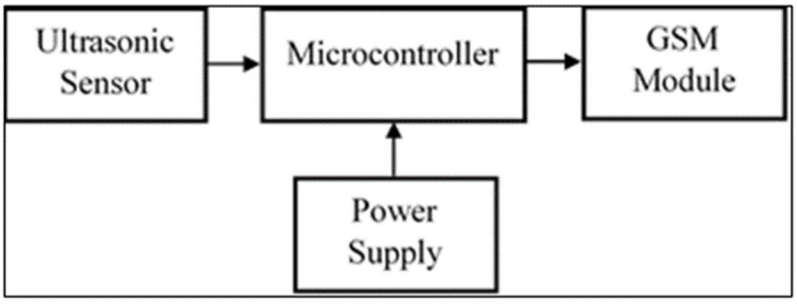

Fig. 13. Hardware Components System Block Diagram

C. ***IoT-Project Smart Trash Can with Blynk Platform Integration***

1) Project Summary

In 2020, a team of four at Bina Nusantara University in Jakarta, Indonesia researched the implementation of the Internet of Things (IoT) into smart trash cans to aid the issue of the current Covid-19 pandemic happening in Indonesia during that time by reducing the need to touch the lid of a trash lid. The IoT-project smart trash is used to measure the distance between the person disposing of waste and the trash can to open the cover automatically so that it removes any requirement of touching. The IoT smart trash can also has a sensor for detecting when the trash can is full so that it can send an alert audio sound from the trash can and send the user a mobile message to alert to replace the bin. The IoT smart trash can uses the Blynk application to connect the device to the internet and smartphones to monitor and send alerts to the user when the bin is full.

Fig. 14. IoT Smart Trash Can Prototype

2) Technology Overview

The IoT smart trash can uses a miniature trash bin with a height of 17 cm. The hardware used starts with a NodeMCU ESP8266 microcontroller, which not only acts as a controller for the device but also includes Wi-Fi,

making it easier to connect to the internet for sending data to the Blynk application. The device uses two sensors: the PIR infrared obstacle sensor and the HC-SR04 ultrasonic sensor. The PIR infrared obstacle sensor is used for detecting the human hand with signals measuring from 5cm in from of the sensor. The HC-SR04 ultrasonic sensor is used for measuring the distance of the trash inside the bin using signals also. A passive buzzer is connected to the device to alert the user when the trash is full using an audio queue. The TowerPro Motor Servo MG90 is used for raising and lowering the cover of the smart trash can whether a hand is nearby the trash can or not.

Table XXIII. IoT Smart Trash Can Hardware Specifications

Hardware	Specifications
Controller	NodeMCU ESP8266 Microcontroller
Data Collection	PIR infrared obstacle sensor
Data Collection	HC-SR04 ultrasonic sensor
Audio Alert	Passive buzzer
Motor	TowerPro Motor Servo MG90

3) System Description

The IoT smart trash can is set up by a power supply connected to the device's controller with around 5V-12V to power the whole device. The NodeMCU ESP8266 microcontroller is the center of the entire device. It receives input data from the PIR infrared sensor and ultrasonic sensor, and with that, input is given out output data for the motor servo and the passive buzzer. Also, with the implemented Wi-Fi module on the controller, it can connect to the internet and send output messages to smartphones and the Blynk server. The system workflow diagram represents the order of receiving inputs and outputs correctly in a unison way so that the device can effectively do the task needed most efficiently.

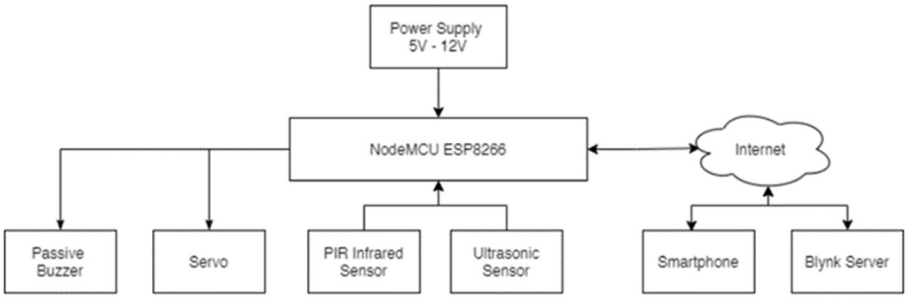

Fig. 15. IoT Smart Trash Can System Architecture

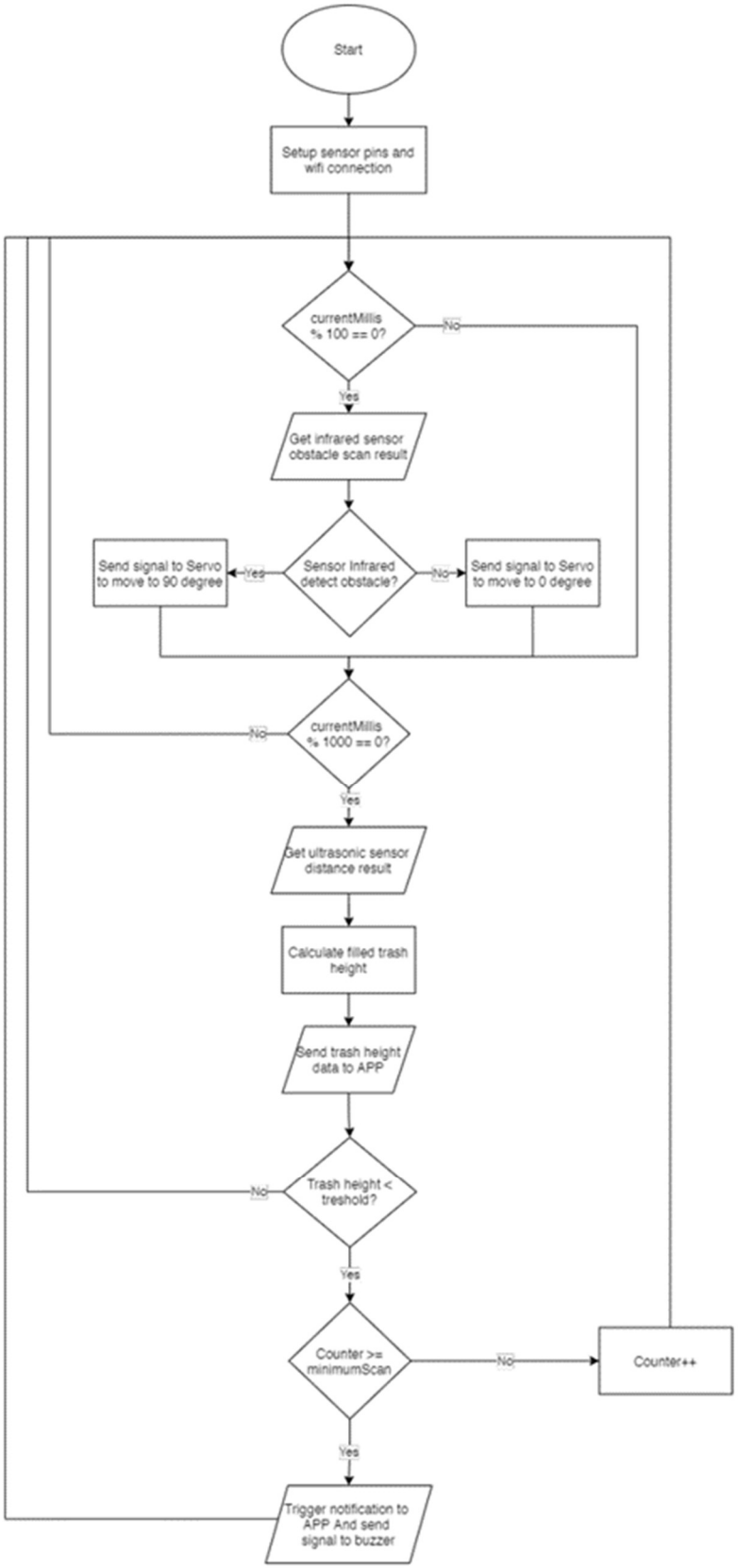

Fig. 16. IoT Smart Trash Can System Block Diagram Workflow

From the three gathered projects that share similarities or potential extra features for the waste recognition system, our team concluded that these projects serve as a baseline for our project and can open more ideas and implementations for the waste recognition system. All these projects introduced new features and practical designs that can inspire our project to improve and build onto. Remarkably, each of these projects established many utilizations of hardware components that can be applicable to our project. Additionally, the various amounts of potential systems from the three projects can be advantageous to learn when designing our waste recognition system. These three projects served us well as a background for our project to develop a good design for our waste recognition system confidently.

IX. INTELLECTUAL PROPERTY

Intellectual property is anything that can be considered a creation of the mind, whether that may be books, movies, symbols, or logos. For something to be protected under the law that is within the category of intellectual property, no additional actions need to be taken. When creating anything, at least within the United States of America, one's creation is automatically protected. This serves to protect the creative works of people who may either not be aware of the laws or may otherwise lack the financial ability to protect their property. This, in turn, helps to protect and encourage creativity within the country. Before an inventor designs or creates an invention, great care must be taken to ensure that the inventor does not infringe upon the intellectual property of others. To this end, thorough research must be done to ensure one's another cannot claim intellectual creation.

In this section, our team will explore and analyze three different patents that are related to our project. The patents we will be looking at are *Image Recognition Verification*, *Item Put and Take Detection using Image Recognition*, and *Retrieving Contact Information based on Image Recognition Searches.* Since we would be filing in the US patent office, we used Google's patent search engine and narrowed our search down to the US patent office. The goal of this search is to find projects that utilize image recognition.

A. ***Image Recognition Verification***

The inventors of this patent are Mustafa Jaber, Bing Song, and Jeremi Sudol and their patent was granted on May 12, 2020. Their patent number is **US 10,650,041 B2** [4]**.** A summary of the patent and its purpose will be given below:

1) Summary

This patent utilizes image recognition to determine which candidate images retrieved from a database best matches a query image. An image recognition process is performed on the query image. The verification engine could determine the best image recognition process to apply to the set of candidate images. From there, it would classify the images within the candidate set and re-rank or reorder them so that the best match is confirmed as a proper match to the query image.

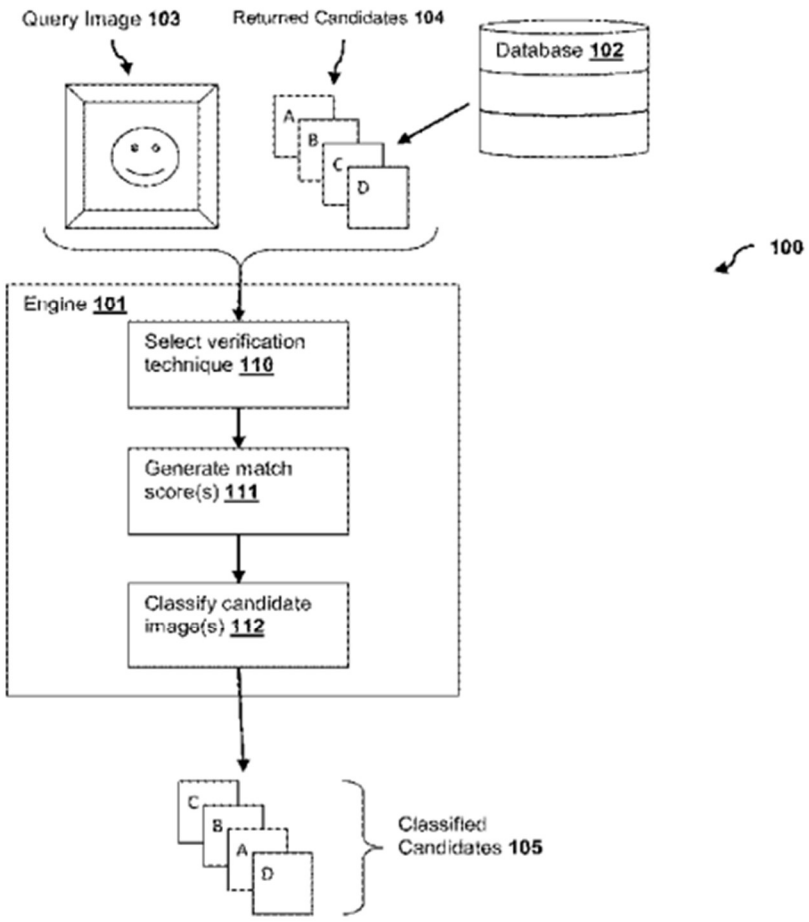

Fig. 17. Simplified Diagram depicting the logical flow of the verification engine.

In figure 17, a query image is inserted into the engine alongside a set of candidate images for comparison and processing. The verification engine goes through a process of selecting the best verification technique to use on the candidate images. After the images are processed, the verification engine assigns match scores to each of the classified candidates in which the images are then reorganized so that the one with the highest match score is identified as the correct match.

2) Claims Summary

This patent has a total of twenty-one claims, but the claims that are related to our project are:

- A computer-implemented method of image recognition
- Image recognition processes for determining candidate image match scores.

3) Non-Infringement

The patent uses images uploaded to an image recognition which is then processed and compared to several candidate images stored in a database. It then generates match scores and the reorders the images with the best match being the proper match. Our system is different and does not risk infringement in that it just needs to confirm if the garbage falls within a category of trash such as a glass or plastic bottle. The images received by the camera simply need to be processed to determine if it falls into the category of glass or plastic bottle.

B. ***Item Put and Take Detection using Image Recognition***

The inventors of this patent are Jordan E. Fisher, Daniel L. Fischetti, Brandon L. Ogle, John F. Novak, Kyle E. Dorman, Kenneth S. Kihara, and Juan C. Lasheras. Their patent number is **US 10,133,933 B1** and was granted on November 20th, 2018 [5]. A summary of the patent and its purpose will be given below:

1) Summary

This patent utilizes image recognition to track objects that are removed or added to inventory by subjects in an area of real space. It uses cameras with multiple overlapping fields of view to produce images with varying fields of view. These images are then processed within an image processing system which is tied to the system. The system then classifies the identified subjects and uses them to determine if items are placed or removed from the shelves to keep track of the amount of every item in the system's inventory.

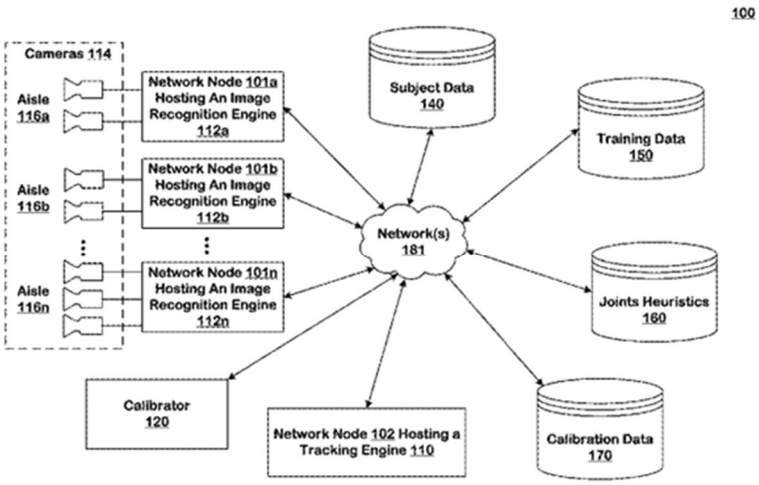

Fig. 18. Shows a simplified model of the relation and interconnectivity of the various systems within the network(s).

In figure 18, the network or networks (181) would host various data to properly calibrate and train the image recognition engine. It includes calibration data (**170),** Joint Heuristics data **(160)**, Training data **(150)**, and Subject Data **(140)** which are then sent and received across the network(s) to be used in improving the accuracy of the image recognition engine within each of the network nodes **(101x)**. These network nodes are then connected to a series of cameras which then retrieve the images used in the image recognition process.

2) Claims Summary

The patent has a total of 27 claims, but the claims that are related to our project are:

- Computer system for tracking puts and takes from an inventory system by subjects in real time.
- Image recognition process for analyzing several images captured by several cameras in an area.
- Process for recording and analyzing a series of images from various angles to classify objects in the images.

3) Non-Infringement

This patent uses a variety of cameras to capture an area from various angles. It then processes these images using an image recognition software which is hosted in a network node. Our project will be different from this patent as the implementation of an image recognition system in our project will be vastly different to its implementation of this patent. Our objective is to create an image recognition system that utilizes a camera and will be fully contained within a garbage disposal unit.

*C. **Retrieving Contact Information based on Image Recognition Searches***

The inventors of this patent are Christopher Richard Wren and Nadav Aharony. Their patent number is **US 10,142,351 B1** and was granted on November 27th, 2018 [6]. A summary of the patent and its purpose will be given below:

1) Summary

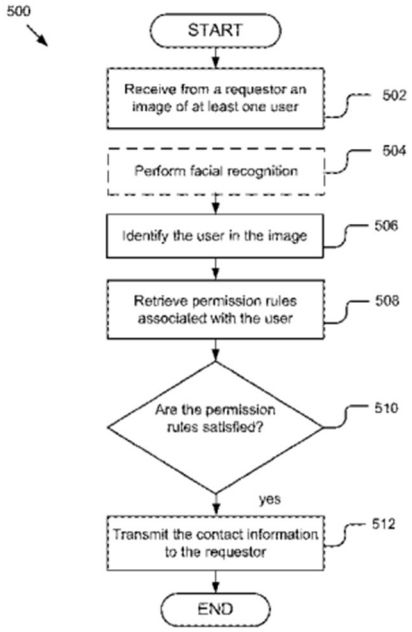

Fig. 19. The logic flow of the image recognition module

This patent uses image recognition software to determine if someone can view the contact information of another individual. The requestor would take a picture or upload an image of their target to the image recognition module. From there, the module will process the image to identify the requestor's target to determine if the requestor has sufficient permissions to view the contact information of their target using predetermined permission rules. Once these rules have been satisfied, the module releases the information to the requestor.

2) Claims Summary

This patent has a total of twenty-one claims, but the claims relating to our project are:

- A computer program and processing system to engage in facial recognition of the targeted individual.

3) Non-Infringement

This patent uses facial recognition software to process a requestor's uploaded image to find a user who matches the uploaded image. Our project is fundamentally different to this in that this project is using image recognition software to identify people whereas ours will be used to identify and separate plastic and glass bottles from regular trash.

X. GLOBALIZATION

Globalization is an essential part when developing a new product idea, the team has to take into consideration this concept for the success of the project. The idea of globalization will allow the team to show its awareness of global issues and markets. This is important because the team plans on not only selling the product nationally, but also internationally. For the team to make this possible, the Waste Recognition System must be able to meet standards and guidelines effectively. The team is aware that the product will most likely be able to sell in many global markets, therefore the project is globalized. The Waste Recognition System is beneficial to all, making recycling easier than ever before. Due to this, the team believes the Waste Recognition System can sell around the globe.

The more the world moves towards a technological and greener society, the more need there is for systems to be autonomous and easy to use. A product tends to come into fruition in its most natural form by tending to a local need. The way successful products being global fixtures is by tending to that local need and then scaling outwards towards the whole entire world. It is important for a product to not only appeal to local markets but to global ones as well. The team's Waste Recognition System plans to do just that. The product is so environmentally friendly and easy to use, that it will make cleaning up waste easier and more effective.

Before the team can get ahead of themselves, it is important to be globally aware of their current situation. The team must have a good understanding of the view that people will have of their product around the world. This includes many cultures and many world views that they must recognize. To achieve their long-term goal of globalization, the product must be able to sell across the world. The purpose of the Waste Recognition System is making recycling autonomous. This is accomplished by placing a waste object into the opening of the system, the system automatically identifies the waste object as recyclable or not, and then automatically recycles the object correctly. Due to this being beneficial to the entire world the team must start somewhere. It plans to start its launch locally and if the response is good, then there will be a global launch set into motion. The Waste Recognition System is a product that will be used around the world, due to everyone having to get rid of waste objects and some of those objects being recyclable. The Waste Recognition System is a cost-effective way to recycle objects in almost any setting. The team wants to create a product that will change the way the world recycles.

The team not only wants to sell the Waste Recognition System nationally but globally. For this to be achieved the global perspective must be at forefront during product development. Cultural and international issues could potentially affect the Waste Recognition System in some serious ways. This is because different communities and cultures tend to react differently to a product. Even though our product is beneficial for the environment, diverse cultures get rid of waste differently and our team cannot ruin those cultures.

To sell the product globally, the team must meet specific requirements and standards. These guidelines and standards are set by the World Trade Organization (WTO). The World Trade Organization (WTO) regulates trade for the entire world. The Waste Recognition System must meet these requirements to be sold around the world.

A. ***World Trade Organization (WTO)***

The World Trade Organization (WTO) is an international organization that handles trade between different countries and nations. The purpose of the WTO is checking products that are going across international borders and to make sure they are meeting the right standards and guidelines. The WTO is like a safety check for the consumer, when one of the main goals of the organizations is to provide consumers with assurance and safety when buying products internationally. The World Trade Organization (WTO) creates a trade flow that is smooth, predictable, and as freely as possible helping the world economy. This World Trade Organization (WTO) does this by implementing rules and guidelines, having open forums for trade disputes, regularly updating trade guidelines, settling any trade disputes, and working closely with other global organizations.

The World Trade Organization (WTO) is composed of 164 members (countries) that represent over 97% of global trade. Any decision the World Trade Organization (WTO) implements must follow these four key rules. The first rule being the most valuable nations must give the same treatment to every other nation. This rule states that everyone is on the same playing field and that everyone abides by the same rules. The second rule indicated that both local and foreign entities are subjected to the same rules and regulations. This ruling adds to rule number one and strengthens the credibility of the WTO and its members. The third rule of the WTO is that participating parties may not change any contents of a trade agreement in a way that it will destabilize the markets. The fourth and last rule through negotiations, tariffs and import bands that are in place, will reduce through time. These are just some of the major rules that members (nations) of the World Trade Organization (WTO) must abide by.

B. ***Trading Barriers***

In today’s world barriers are a major inhibitor of the team's progress towards globalization. Trading barriers are what prevent the spread of a product throughout the world. Some examples of trading barriers are tariffs and quotas that restrict quantity of items during trade. One of the best ways to promote globalization is to remove these trading barriers. The best way to do so is through standards. One of the most important things a member (nation) can do when dealing with the World Trade Organization (WTO) is to comply with various standards that act as trade barriers. These standards or regulations specify the characteristics a product must meet to comply with the WTO.

Some examples of these regulations are size, shape, design, functionality, and packaging of a given product. A product must meet all the guidelines set forth by each country to enter.

Since the team plans to design our product so it has as big of an impact as possible, it is important to keep in mind trade barriers. The team has researched several international bodies that maintain standards on a global scale. These organizations include the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) just to name a few. These organizations oversee products that adhere to common standards for a company to sell internationally without a problem. It is important for the team to keep common standards pertaining to our product's area to ensure it is not breaking any guidelines. The team is confident that they will adhere to the guidelines properly during design.

C. ***Collaboration Tools***

Collaboration and communication are an essential part of a successful team. Throughout brainstorming, design, and building, the team made communication a key aspect of their collaboration process. In today's world that are multiple tools that aid in this process. To begin, the team set up their first line of communication using WhatsApp, a messaging application that allows for easy dialogue between members. Next the team created a Microsoft Teams Page where multiple folders were set up, and many files were added to document and created the project. Microsoft Teams acted to upload and share documents and to work together in real time. Next, the team set up a meeting via the Zoom application to discuss and brainstorm ideas; also, Zoom was a great way for them to conduct meetings and surveys. The Waste Recognition System team used these three tools in conjunction to put forth their best effort and successfully deliver a project.

D. ***International Success***

The Waste Recognition System team needed to know how their product would hold up in the global markets. Now the team got an estimate by connecting with two foreign contacts and getting their thoughts on our project. Now the following statements are not an official survey and do not consist of quantitative data but are a good opinion and insight on how our product will hold up in different countries and should be taken at face value. The team interviewed two different students from two different countries and the contacts were asked what their opinions on the Waste Recognition System were and how it would be accepted in their culture(s).

The first contact is Daniel Vasquez, a 26-year-old mechanical engineer from Columbia. After presenting to Daniel all aspects of our project. We asked him what his thoughts were on the Waste Recognition System. Being an engineer, he thought the idea of our project would provide a lot of benefit to the world. Not only is it a technological advancement in the world of waste reduction

but a product that can be placed anywhere and everywhere. Daniel stated that a product like the Waste Recognition System can make recycling back in Columbia a lot better. A product like this will not only reduce waste objects from the streets but also make sure everyone recycles. He thinks a product like our Waste Recognition System would be extremely helpful for his country.

The second contact is Jose Martinez, a 24-year-old engineer from Spain. After presenting Jose all the aspects of our product. We asked him what his thoughts were on the Waste Recognition System. He stated that this will not only be a massive success in his country but is a necessity around the world. This will allow trash bins back in his home country to be sorted automatically and make recycling autonomous. He said the Waste Recognition System is an important product idea.

To conclude, Globalization is a pivotal concept for the success of our team. Designing our product and keeping these concepts in mind is very important to be able to launch the Waste Recognition System. It is also important for the team to continue to be up to date on any changes to guidelines and new standards that may potentially affect our project. In the Globalization section, the team did its due diligence and research on any impending guidelines to help us better understand how our product needs to be designed and will hold up in global markets. The Globalization section was a key part of our research and development processes.

XI. STANDARD CONSIDERATIONS

Any project that is in development must follow standards because it provides a clear and consistent set of guidelines for designing, implementing, and testing a project. Standards are used for understanding acceptable processes that are used when considering the methods that can be implemented in a project. With means, it can provide a framework for ensuring that a project meets the necessary quality requirements depending on an aspect of the project. Standards as well can be specific to different countries, which is important to consider when developing a project for a wide range of users. Therefore, for a project to be accepted globally or in different respective countries, the project must uphold a substantial number of international standards as it could be approved. To have these standards, many organizations and corporations have developed multiple standards over many years to help add more guidelines on how projects should consider development for improvement and ensure that a project is delivered with the required objectives completed.

There are several organizations and corporations whose purpose is to establish different sets of standards for products and projects to cover all processes and requirements for ensuring that a product is safe and effective for its usage. Examples of these organizations that establish standards are the American National Standards Institute (ANSI), the International Telecommunication Union (ITU), the National Institute of Standards and Technology (NIST), the International Organization for Standardization (ISO), the Electrotechnical Commission (IEC), and the Institute of Electrical and Electronics Engineers (IEEE). Specifically, IEEE is a global organization of professionals who work with the goal of emerging and implementing as well as upholding technology-centered products as well as services. The standards that IEEE establish are used frequently by most projects as they have been continually developing various projects and upholding nearly 1,300 standards in their active portfolio. IEEE, as a leading industry standards developer, plays a crucial role in a wide range of technologies that enhance the functionality, capabilities, and interoperability of products, leading to significant transformation in the way people live, work, and communicate when applied to those developing products.

For our project, we analyzed various existing standards from IEEE as their organization had the most compatibility with the types of guidelines, we want to succeed in the development of our waste recognition system. From IEEE there have been in total three selected for our project as the three selected will provide the necessary guidelines needed to follow. The standards selected for our project were based on specific relevancies that were for specific aspects of our design. Additionally, these selected standards were approved as internationally accepted, as our project considers it essential to make sure it was used globally all over many possible locations. Each standard mentioned there will contain a detailed explanation and description

of what the standard establishes as well as its relation to the waste recognition system.

A. ***IEEE 802.15.7-2018***

The standard that will be implemented for our project mentioned now is the IEEE standard for local and metropolitan area network's part 15.7: short-range optical wireless communications [7]. Is a widely used standard that has recently been revised from a previous version in 2011 that has been updated to a recent redline version in 2018. What this standard dwell into is that a specification has been established for short-range optical wireless communications (OWC) in optically transparent media, utilizing light wavelengths ranging from 10,000 nm to 190 nm. This standard includes a physical layer (PHY) and medium access control (MAC) sublayer, designed to support multimedia services such as audio and video, while also taking into consideration factors such as mobility of the optical link, compatibility with various light infrastructures, and impairments due to noise and interference from sources like ambient light. Additionally, the MAC sublayer is tailored to the unique requirements of visible links, as well as other targeted light wavelengths. The specification also encompasses optical communications for cameras, where transmitting devices include light-emitting sources and receivers are digital cameras equipped with a lens and image sensor. Moreover, the standard adheres to applicable eye safety regulations that are involved in previous scenarios.

The standard specifies a physical layer (PHY) and medium access control (MAC) sublayer for short-range optical wireless communications (OWC) in optically transparent media, utilizing light wavelengths ranging from 10,000 nm to 190 nm. It can deliver data rates sufficient to support audio and video multimedia services, while also considering factors such as mobility of the optical link, compatibility with various light infrastructures, impairments due to noise and interference from sources like ambient light, and a MAC sublayer designed to meet the unique needs of visible links as well as other targeted light wavelengths. The standard also provides for optical communications for cameras, with transmitting devices incorporating light-emitting sources and receivers being digital cameras equipped with a lens and image sensor.

A worldwide standard for short-range OWC is established by this specification, which includes access to several hundred terahertz of unlicensed spectrum. The standard is designed to be immune to electromagnetic interference and not to interfere with radio frequency systems. In addition, visible light systems offer an additional level of security as the user can see the communication channel. The standard is also intended to enhance and supplement existing services, such as illumination, display, indication, and decoration.

Specifically, further in the standard it elaborates on multiple channel information [8] that could be helpful to consider for our project. It explains that in the event that the coordinator does not possess sufficient time slot

resources to allocate to a new user, the coordinator should expand its resources by utilizing multiple bands. In Figure 20, an example provided by the standard is used to demonstrate multiple band usage.

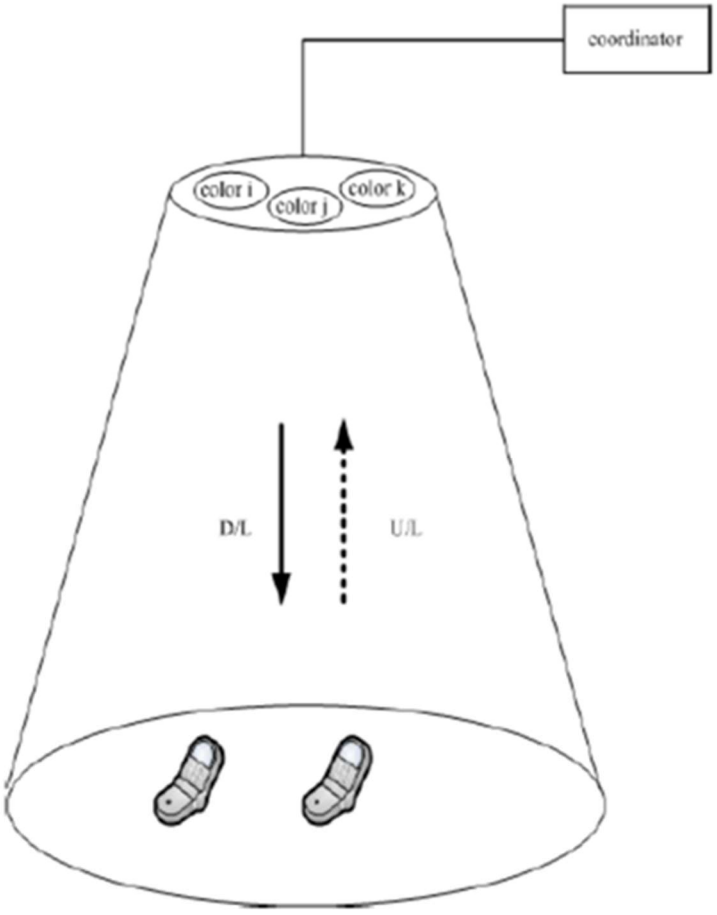

Fig. 20. Example of multiple channel usage.

From the standard, our group will implement the guidelines of the standard within our waste recognition system. Using these criteria, we can improve upon our project by adding these requirements for adding better performance and quality improvements.

B. ***IEEE 386-2016***

This standard that will be considered for our project is the IEEE standard for separable insulated connector systems for power distribution systems rated 2.5 kV through 35 kV. This standard was originally created in 1995 but had revisions in 2006 and furthermore had its most recent revision in 2016. The specifications that are provided in this standard are that it defines load break and dead break separable insulated connector systems, including their service conditions, ratings, interchangeable construction features, and

tests. These systems are intended for use on power distribution systems rated from 2.5 kV to 35 kV and with a current rating of 900 A or less. Features for systems are mostly considered when plugging in a plug into an outlet that receives power.

For shielded power distribution systems rated 2.5 kV through 35 kV, this standard defines load break and dead break separable insulated connector systems rated for 900 A or less. The standard covers the service conditions, ratings, interchangeable construction features, and tests for these connector systems. Considering that most appliances and products require power by means of electrical current this standard intends to have the needed power distribution a system needs to create the conditions needed for a user to use it.

Additionally, the construction and identification of manufactured components for power distribution are effectively needed for awareness of information and labeling. A noticeable example of this is color-coding for the voltage class that a product or cable receives. In TABLE XXIV, it indicated the required color-coding depending on the voltage class for a load break connector color code.

Table XXIV. 200-A LOAD BREAK CONNECTOR COLOR CODE.

Voltage class	Reference figure	Color
15 kV	Figure 5	Red
25 kV	Figure 6	Blue
28 kV	Figure 6	Blue
35 kV 1-PH	Figure 9	Off white
35 kV 1-PH	Figure 8	Tan
35 kV	Figure 9	Gold
35 kV	Figure 7	Purple

Gathering from the standard, our project will involve a Raspberry Pi and other functions that will need an outlet to power the project. Using this standard will be a guideline for understanding power distribution and the needed steps to have a correct protocol when releasing a product that involves an outlet.

C. ***ISO/IEC/IEEE 24748-3-2020***

The standard that is mentioned is exceptional for our project as it is an international standard comprised of three organizations that are ISO, IEC, and IEEE. This international standard is for systems and software engineering as it is for life cycle Recognition. Furthermore, the standard is guidelines for the application of software life cycle processes. The international standard was established originally in 2012 but most recently had a revision in 2020 that covered more modern advances in technology that can affect the software life cycle process.

What this international standard specifically establishes is a guideline that outlines how to apply the software life cycle processes. The guideline establishes a common framework for software life cycle processes and provides well-defined terminology that can be used by the software industry. It provides guidance on how to define, control, and improve software life cycle processes within an organization or project, and recommends suitable methods and approaches for various life cycle models. The guideline emphasizes the importance of establishing a strategy, planning, and stakeholder involvement to achieve customer satisfaction. Its purpose is to ensure consistency in the system and life cycle concepts, models, stages, processes, process application, key points of view, adaptation, and use in different domains. This standard focuses on specific guidance for technical processes and how they can be effectively utilized during the software life cycle, including the use of agile methods.

Furthermore, from the standard, its guideline establishes a standardized framework for software life cycle processes, complete with clear terminology that can be utilized by the software industry. It offers guidance on how to define, control, and enhance software life cycle processes within an organization or project, and recommends methods and approaches suitable for various life cycle models. The guideline stresses the significance of setting a strategy, planning, and involving stakeholders to achieve customer satisfaction as the ultimate goal.

Since our project involves software to function and is supposed to be used universally for as long-lasting as possible this standard would serve vitally to maintaining its software in a longer life cycle needed. The waste recognition system's goal is to have the needed life cycle for it to be used for various amounts of time and the software implemented in the project must have the required maintenance to make sure it keeps up with the life cycle of the waste recognition system.

To conclude, we have gone over three important standards that we will need to follow and consider when in the development of the waste recognition system. All these standards establish technical specifications and procedures designed to maximize the reliability of the materials, products, methods, and

services people use every day. For the waste recognition system, the following standards will be considered:

- IEEE 802.15.7-2018
- IEEE 386-2016
- SO/IEC/IEEE 24748-3-2020

XII. Health and Safety Considerations

Health and Safety are important aspects to keep in mind during any design process. The purpose of this section of our project proposal is to take an in-depth look at how keeping health and safety in mind plays a role in the creation of a project idea. Keeping these two concepts in mind is important because if a product idea poses a threat to the health and safety of the creators or potential users then that is considered a serious issue. Health not only refers to being free of illness and disease, but also being in a state of physical and mental well-being. Safety refers to "a state in which hazards and conditions leading to physical, psychological, or material harm are controlled to preserve the health and well-being of individuals and the community. It is an essential resource for everyday life, needed by individuals and communities to realize their aspirations" [9]. If a product puts someone at risk, the designers of the product are liable and responsible to resolve the issue immediately because it should not be putting a potential user in a situation with risks. Potential users should have confidence when using the product and that their lives are safe. This can be achieved through following several guidelines to ensure a well-made and safe product.

A. ***Health and Safety***

The Waste Recognition System team takes the health and safety of its members and potential users very seriously. Risks start to arise in the first stages of building a product, and this must be kept in mind the team. The engineers on the team must follow the Code of Ethics during design, development, and building of the Waste Recognition System. The reason this is kept in mind is because it is the engineer's responsibility to deliver a safe product. The team has kept this in mind especially when regarding the different components which will be used in the Waste Recognition System. The team has done inspections of the raspberry microcontroller, cameras, and connections to make sure everything is intact and not broken in any way that can lead to a potential safety and health hazard.

The Waste Recognition System is a product that should not require too much physical contact from a user. It is meant to be placed in public places such as universities, malls, and office spaces where the user(s) only have to worry about placing their objects through the opening. The Waste Recognition System does require a small amount of maintenance where the trash bins would need to be emptied. In this case, their specific guidelines should be in place for the potential user(s) to ensure their own health and safety.

B. ***Liabilities***

Liability refers to the state of being responsible for something, to be specific, being responsible for something by the law. The Waste Recognition System team is liable for any consequences that may arise due to a fault or error that may occur. Ideally, for the safest outcome, the system should be

kept in a covered and dry environment, preferably indoors. The team recommends the user(s) to follow the proper protocols which are listed in the instruction manual. Following proper procedures will reduce any chances of fault or errors that may occur to potential user(s).

XIII. ENVIROMENTAL CONSIDERATIONS

IN PROGRESS

XIV. Sustainability Considerations

It is important to design a device that is sustainable so that it does not overly and unnecessarily drain natural resources or produce an excessive amount of waste. When creating our product, we must take into consideration the life cycle of our product and any potential sustainability concerns it may create. We must investigate the any potential effects our product will have on their environment at the beginning and end of its life cycle as a result of its manufacturing resource requirements and the resultant non-recyclable waste produced.

A. ***Hardware***

In our modern world, designing a sustainable device that limits its impact on the environment has become increasingly important. Therefore, we approached the design of our project with sustainability in mind. There were two primary concerns regarding the sustainability of our project. Firstly, we want to minimize the total moving parts required by our project. By doing this, we will extend the lifecycle of our product by reducing the possibility of component breakdown. During the concept design phase of our project, this was one of the considerations made when choosing between one or two platforms controlled by a motor. Even though our product would have improved performance using two rotating platforms, this performance increase did not merit the rise in our project's costs and environmental impact. It also increases the risk of a breakdown.

The second concern was the amount of electrical waste produced when our product eventually reached the end of its life cycle. Debris from electrical components usually contains toxic chemicals and is non-biodegradable. For this issue, our main concern revolved around the power source for our project. We had three choices. These were a replaceable battery, a power supply, and a solar panel. The issue with the battery is that it would drastically increase excess and unnecessary waste produced by the Waste Recognition System. The team ruled out the battery from the start as it provided little benefit over the other two power sources and would increase the amount of toxic waste generated. The next was the utilization of a solar panel to power the components. This component would drastically increase the cost of our Waste Recognition System and its maintenance, as the solar panel would be at risk of being easily damaged and would need to be periodically fixed or changed. It would also limit the usage of the device as it would always need to be placed outside. It would decrease the life of our product due to its vulnerability and be more challenging to replace, which would lower the likelihood of a customer fixing it instead of returning the entire product. After this analysis, we decided to use a power supply as our device's power source as it has a happy medium of limiting waste, increasing longevity, and lowering costs.

Overall, we have made design considerations that make our project's hardware sustainable by reducing its environmental impact and increasing its longevity. The team has considered various aspects of our project that would increase waste by minimizing the maintenance needed and lowering the cost of the overall product and its components.

B. ***Software***

Although a product's software is immaterial, its impact on our environment is not. To limit this, we must make sustainable software. To do this, the software for our product must be easily adjustable, bug-free, and should complete its tasks efficiently to minimize its hardware demands. If we do not do this, our product will be prone to bugs, difficult to fix, and draw more energy than needed to complete its tasks. These flaws would have cascading effects on the hardware components, and they may increase component wear through inefficient code or bugs in the program.

For this reason, our code must be bug-free so that the end user encounters no problems using the product. The code should also be easy to modify. If other programmers or we are changing or upgrading our code, the software should have proper documentation and be written clearly and concisely to make it easy to understand.

Our team has examined the software and hardware in relation to the Waste Recognition System's design and production to ensure that it is sustainable. While developing this product, we have considered the requirements of applying our product and its components. We have taken steps to limit the maintenance of our product and will need to make it as sustainable as possible.

XV. MANUFACTURABILITY CONSIDERATIONS

Whenever a team creates and designs a product, it is of the utmost importance to Design for Manufacturing (DFM). Design for Manufacturing is an emphasis on making a product that utilizes components that are low cost and easy to manufacture or replace in the event of a breakdown. Using the DFM process, the team can create an affordable, sustainable, and accessible product that maximizes the availability of easily accessible components and minimizes the difficulty of assembling and maintaining our Waste Recognition System. A product can only meet these standards if it is simple and inexpensive to build. This can happen by designing components that are difficult to produce, hard to obtain in the event of a component breakdown or take too long to create. To this end, we must design a product that is easy for the manufacturers to assemble by utilizing standardized components to simplify the manufacturing process and focus on a more streamlined and straightforward design. We will explain how our team worked to meet the principles laid out by DFM.

A. ***Design***

The design stage of a product is highly crucial to its success. If the design of a product is too complicated, this can lead to the death of a project. Even if, in theory, the Waste Recognition System would be profitable, a poor or overly complicated design can increase time-to-market, drain resources, or increase the cost of assembly by utilizing extremely complex components or processes. Our team will make the design of our project as straightforward as possible by using the least number of components necessary to accomplish our task, making our project as symmetrical as possible, and clearly labeling all parts. This will make it easier for the manufacturer to understand our project's design, leading to a shorter build time and simpler manufacturing processes, reducing production errors and easier maintenance.

B. ***Build***

The assembly of any product is a crucial stage in its production. This is where a product design is made a reality. The assembly stage is the phase where all of the planning from the design phase is put into action. In addition to simplifying our design and using standard and widely available components, our team will utilize pins and various other connectors instead of soldering the components together. Doing this will reduce the time needed during the build phase as our team can easily and quickly replace and reconnect components while we assemble the project. Using standard components will shorten the project’s build time by decreasing the time it takes to receive and install parts, and replacements can easily be found.

Our team has made several considerations regarding our project’s manufacturability. We created a streamlined design process to reduce the

number of problems that may arise during manufacturing. We will utilize standardized components to improve the ease of maintenance of our product should the end user require it. With our team following the outlined above and the DFM principles, we will create a low-cost product with a quick assembly process.

XVI. Ethical Considerations and Social Impact

Since the beginning of humanity, our technological advancements have directly impacted our advancements as a species. Our quality of life, understanding of our environment, and ability to control and affect the world around us are linked to our technological achievements. As engineers, we know that many devices or products can be used or exploited in ways that go beyond their initial implementation or desired function. Any product that we design should undergo an ethical analysis that serves to deduce the kind of social or environmental impact our product may inadvertently have. Any product that we design should be for the betterment of society and builds off the foundation of what came before us; therefore, we should do our utmost to preserve the moral integrity of the inventions of our predecessors. We should ensure that our designs adhere to a proper moral code of ethics to prevent any perversion of our products either by a third party or any unforeseen interactions of our product with its environment. In this section, we will investigate the ethical viability of our product.

The IEEE (Institute of Electrical and Electronics Engineers) organization has created a code of ethics that every engineer should uphold. By recognizing the importance that our technologies have in our society and on our environment, we, as engineers, must uphold these ideals as we design our project. Some of the IEEE cannons which apply to our project are to hold paramount the safety, health, and welfare of the public, to avoid unlawful conduct and reject bribery in all its forms, and to seek and accept honest criticism of technical work by acknowledging and correcting errors [10]. Although the usage of image recognition software for the purposes of our project is not controversial, the technology that our project is based upon is and the ethical ramifications of such a project will be addressed in this section.

Our team will work to ensure that our project adheres to the code of ethics listed by the IEEE, particularly those of great significance to our project. It is important for any commercially viable and marketable product to follow a code of ethics to prevent rampant tampering and abuse of the technology. It is especially important in the case of image recognition technology as, if reprogrammed to do so, it can recognize and track people without their knowledge and their consent. This technology can lead to an invasion of the privacy of the user where a user would not be aware that their movements are being tracked and recorded by third parties. It may even be used to record sensitive information present on files or documents visible by the camera and, if equipped with a microphone, enables to construction and deployment of discreet listening devices that can record speech and recognize who is speaking. Such technology has already been used in espionage and this ethical issue is ever-present when dealing with the implementation of image recognition software.

*A. **Ethical Considerations***

The Institute of Electrical and Electronics Engineers has outlined a code of ethics for all engineers to follow. The Ethical Theory Model is based upon the IEEE's code of ethics and is what our team will be using to determine the necessary ethical considerations for our project. The Ethical Theory Model follows concepts such as utilitarianism, ethical egoism, Kantian ethics, and rights ethics [11]. With utilitarianism, the focus is creating a system that offers the most benefit or least amount of harm to the highest. In ethical egoism, the option that best safeguards our organization's interest is chosen. With Kantian ethics, we select the option that allows a rule or policy to be made in order to apply it to future scenarios. Finally, with rights ethics, we consider options that best respect the rights of individuals in society [11]. These are the foundations upon which our team will develop solutions to various ethical dilemmas surrounding our project.

When it comes to image recognition, great care must be taken. The premise of our project deals with the utilization of image recognition software to identify and sort waste into separate bins. Using image recognition software in any project comes at a risk of breaching the privacy of the users. An example of this would be the facial recognition and logging of each user who uses our product. Since our product would store the necessary analysis technology with a camera to identify trash, it would also potentially have the capability of doing the same with facial features of individuals who stand in front of it. This would create a situation where a third party may be able to compromise the integrity of our product by installing software or manipulating the software present within our device to capture the faces of users. This creates a huge breach of privacy for our users. To produce an effective solution, we shall use the Ethical Theory Model to weigh the feasibility of these solutions with one another.

Once our team identified this ethical issue that is inherent in any kind of image recognition technology, we determined that the risk posed must only be physical as our product would lack any sort of wireless capability. For it to be compromised, a third party must physically access the device while the consumer is not present. Depending on perspective, one can claim that the consumer may be responsible for allowing the device to be tampered with in the first place or it may be the fault of the team for not designing a product that cannot be physically tampered with.

In this section, we will discuss the ethical dilemma and develop some solutions to counteract it. The ethical dilemma being discussed is a breach in device security through a physical, on-site intrusion as our device lacks any wireless capability.

The table below offers potential solutions to the ethical dilemma by our team. We shall follow the guidelines set by the Ethical Theory Model to find the best solution.

Table XXV. SOLUTIONS FOR ETHICAL DILEMMAS

Option 1	Description
1	Deny the device can be tampered with
2	Blame the user for allowing the device to be tampered with
3	Design a failsafe that permanently shuts off the device if unauthorized tampering is detected. Offer customer a full refund
4	Warn users that the device can be tampered if a third party has sufficient access to it
5	Offer a refund to every user

Table XXVI. WEIGHT POTENTIAL SOLUTIONS

Option	Utilitarianism	Egoism	Kantian Ethics	Rights	Score
1	0.00	0.50	0.00	0.00	0.50
2	0.25	1.00	0.00	0.00	1.25
3	0.75	0.50	1.00	0.75	3.00
4	0.25	0.50	0.25	0.75	1.75
5	0.25	0.25	1.00	1.00	2.50

TABLE XXVI shows a number of potential solutions to the ethical dilemma pertaining to our project. It weighs each solution to the four ethical foundations laid out by the Ethical Model Theory [11]. This numerical analysis shows that the best option would be option three. We would develop a failsafe within our product that immediately shuts down the device once tampering is detected. When this occurs, customers are offered a full refund or a replacement model with proof of tampering. Future models could even improve upon the original design to make it even harder for intruders to bypass. The first two options are not feasible simply because their scores are not suitable enough. The fourth option, while higher than options one and two, still possess scores that are two low. The last option has a higher score than option four and competes for first place with option three, but ultimately has no effect to rectify the problem.

B. ***Social Impact***

It is important for us to analyze ethical dilemmas during the creation process of any project. A society and its technology shape each other. The needs of people prompt the development of technology to meet those needs which in turn changes the status quo of the society in question which leads to new problems and therefore new technological solutions. Technology such as image recognition have a plethora of uses and if used incorrectly, can lead to situations where everyday people are tracked, and their activity logged. This

can make it easier for people who may want to steal their identity or personal information to do so.

When one develops innovative technology or implements a new process, they must consider the possible ramifications these new developments can have on society. Technology like this, ideally, would be used to improve the life of the daily consumer. In our case, it makes recycling much easier and much more accessible to everyday people by removing the need for the user to sort the trash. By eliminating this need to sort, we effectively removed any bias a user might have who would prefer to throw away trash without having to figure out what bin to put it in. In this way, we encourage users to recycle.

Following this logic, we arrive at the concept of the Good Life. The Good life is a concept that is based upon determining what aspects of a particular project, product, or concept can make the human experience easier. Something as simple as designing a walkway through a grassy area where people tend to walk is an embodiment of the Good Life. In this way, when designing a product, a designer should put himself in the shoes of the user to figure out what the average user may expect and the difficulties they may encounter when using the product to produce a design that is as close to an ideal as it can be.

Image recognition can be used for more than just waste Recognition. It can be used to unlock someone's door without a key to prevent unauthorized access into a secure location. At Florida International University, this can be used to allow residents who live in any of the resident hall's access to their rooms without having to worry about losing access from losing their FIU One Card or having it stolen.

Our waste Recognition system is a product meant to encourage recycling by lowering the bar to entry. It effectively removes any need for the user to determine which category their trash falls under by doing it for them. In this way, its entire design embodies the principles of the Good Life and the ethical considerations and solutions made help to counteract any exploitation of our product by intrusive third parties.

XVII. CONCEPT DEVELOPMENT

The concept development process for any project is a crucial one as it allows a team to determine the best combination of components for implementing the various functionalities of a project. This process is necessary to prevent our team from selecting the first combination of choices. It allows us to properly analyze our options to select the best choice. In our concept development section, we will examine three combinations and determine which one best suit our choices after analyzing their strengths and weaknesses.

In this section, we will discuss how the waste recognition system will be powered, how the user will know when the waste recognition system is full, and how the waste recognition system will sort trash, and how the waste recognition system will tell the user that the trash contains gases from rotting waste. Three options being considered for powering the system are a power supply, power supply and battery, or a solar powered system. Two options are being considered for the trash sorting functionality which are a motor which rotates the platform the trash is on so that it enters the right bin or a piston-supported structure that performs the same functionality as the motor. Two options are being considered for both notifying the user of the fullness of the trashcan and notifying the user of rotting waste in the bins, with one of these options being used for both purposes.

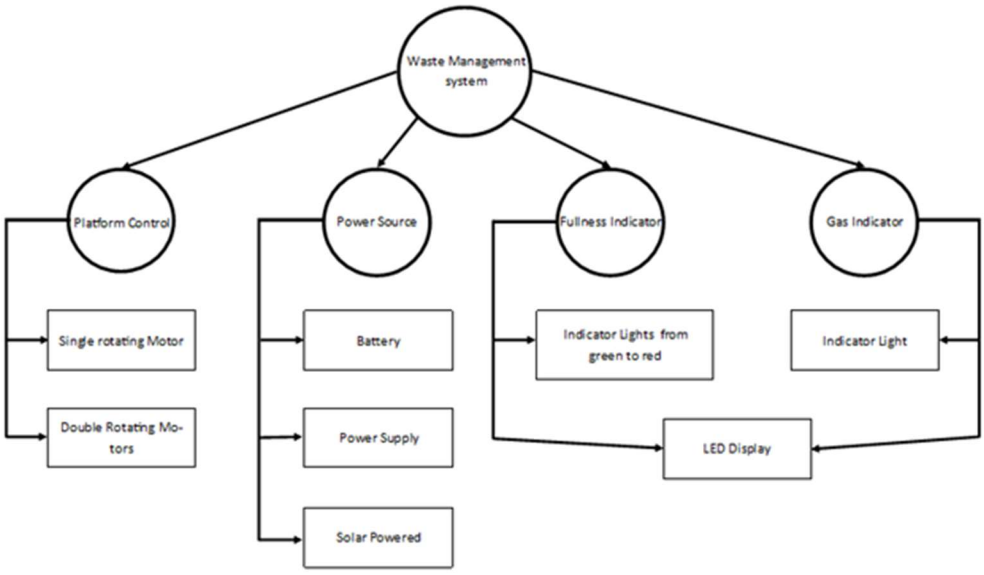

Fig. 21. Demonstrates the Teams Waste Recognition System

*A. **Alternative Options***

Option 1: Single Rotating Motor, Battery, Indicator Lights from green to red, Indicator Light

The first concept design uses a battery supplied system. This would be used in indoor or outdoor locations without any direct access to a wall outlet. A small rotating motor will be used for both the trash and recyclable bin to reduce power draw. For the fullness and gas indicators, small LED indicator lights will be used to limit the amount of power drawn by these systems. The advantages of using this system would be the ability to place the system anywhere the user desires and lower initial cost. The disadvantages would be the need to replace the batteries when the unit runs out of power and the unreliability of only having one rotating platform which may allow trash to enter the wrong compartment.

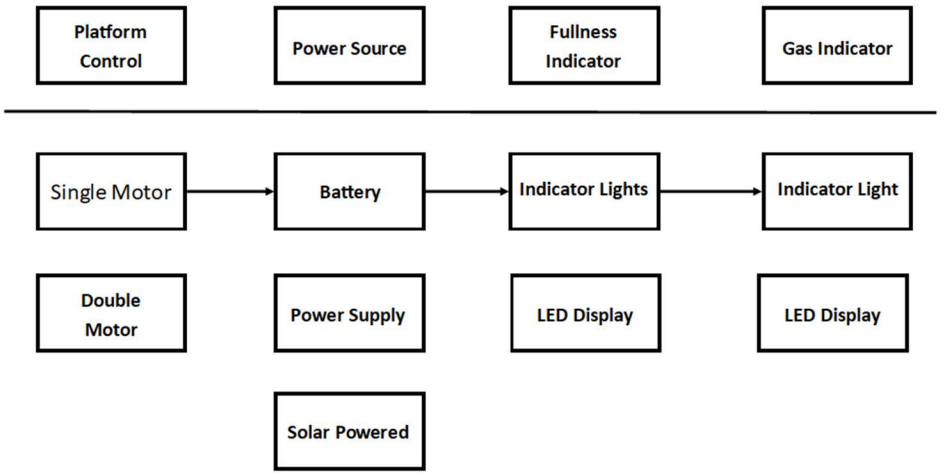

Fig. 22 Option 1 Block Diagram

1. Advantages
   - Portability
   - Inexpensive to make.
   - Low power consumption.

2. Disadvantages
   - Limited Power supply
   - Lower Reliability than the double motor system.
   - Needs to be reset when the battery dies.

Option 2: Single Motor, Power Supply, LED Display, Indicator Light

The second concept uses a power supply to power the system. This design would be used in indoor or outdoor locations with access to a wall outlet. It uses a single motor system like concept one which simplifies it by reducing weight, size, power consumption, component complexity. For the fullness indicator, an LED Display will be utilized to increase visibility to the user by indicating fullness either through graphics or a percentage indicator on the display. For the gas indicator, a single indicator light will be used that will turn on when gases from decomposing organic matter are detected. The advantage of this system is that no recharging or battery replacement would be necessary and that it would make the fullness indicator more user friendly. The disadvantages of this system would be its lower reliability of the double motor system alongside its more limited portability.

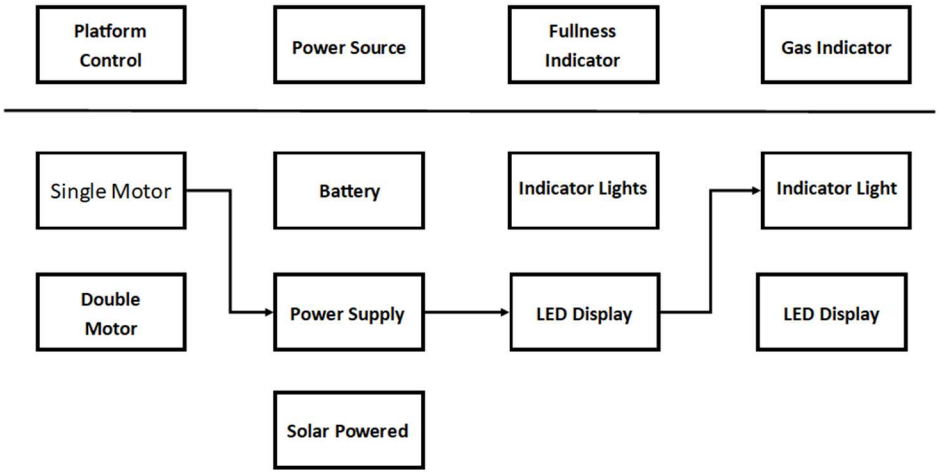

Fig. 23 Option 2 Block Diagram

1. Advantages
   - No recharge required.
   - Increased visibility of fullness indicator.

2. Disadvantages
   - Limited Portability – waste Recognition system must be in range of a wall outlet, or one must be installed for its use.
   - Lower Reliability than the double motor system.

Option 3: Double Rotating Motor, Power Supply, LED Display, LED Display

The third concept uses a power supply to power the system like the second. The main difference with this concept is the use of a double rotating motor system to prevent the possibility of trash entering the wrong compartment by keeping the entrance to both compartments closed unless other indicated by the system. The rotating platforms would be adjacent and tilted towards each other. This would encourage whatever trash is placed on the system's entrance to settle where the two platforms meet. The system would then analyze the trash before determining which platform to rotate. This system would prevent trash from potentially spilling over into the wrong container. The fullness and gas indicators would both go on an LED display to improve user readability over the light indicators.

The advantages of this system would be the increased reliability of the double motor system, improved user readability of the fullness and gas indicators, and that no battery replacement or recharging is necessary. The disadvantages of this system are the expensive price tag and the limited portability of the system.

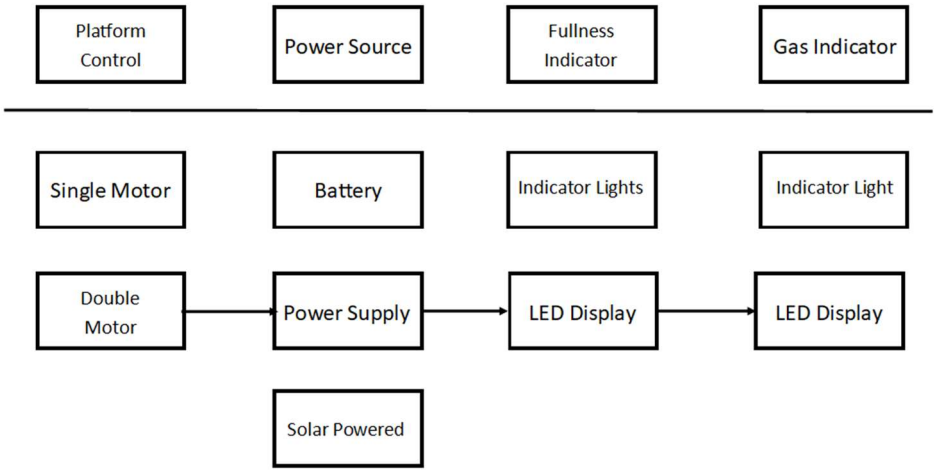

Fig. 24 Option 3 Block Diagram

1. Advantages
   - Increased reliability of the system.
   - Improved user readability.
   - No recharge or battery replacement required.

2. Disadvantages
   - Expensive
   - Limited Portability

The tables below are used to compare the importance of our team's project objectives relative to one another with the numbers being used to indicate this relationship. Number one indicates that both objectives are equally important to one another whereas number 9 indicates that the objective is extremely important. For example, in the table we can see that accuracy is very strongly more important than marketability.

Table XXVII. CONCEPT SELECTION IMPORTANCE SCORE

	Safety	Accuracy	User-Friendly	Marketability
Safety	1	3	5	7
Accuracy	1/3	1	5	7
User-Friendly	1/5	1/5	1	3
Marketability	1/7	1/7	1/3	1

Importance: 1 = equal 3 = moderate 5 = strong 7 = very strong 9 = extreme

Table XXVIII. CONCEPT SELECTION WEIGHT CALCULATION

	Safety	Accuracy	User-Friendly	Marketability	G.Mean	
Safety	1.00	3.00	5.00	7.00	3.201086	0.541021
Accuracy	0.33	1.00	5.00	7.00	1.84351	0.311574
User-Friendly	0.20	0.20	1.00	3.00	0.588566	0.099474
Marketability	0.14	0.14	0.33	1.00	0.283591	0.047930
				Total	5.916753	

Figure 24 outlines our selection process for the three options we considered. While options one and two fulfilled all criteria laid out by our constraints, option three did not meet the requirements and will not be considered. The system would be too expensive to create when compared to the other options so even though it would have a higher accuracy score than option 1 and 2, it is discarded. From the two remaining options, we ranked them from 1 to 5 with our objectives as categories. Using our previous calculations from figure 6, we calculated the weighted average for each option with the highest score belonging to Option 2.

Table XXIX. Concept Selection Total Scores

		Option 1		Option 2	
Constraints					
Accurate and Precise as Possible		Yes		Yes	
Compact as Possible		Yes		Yes	
Low Cost as Possible		Yes		Yes	
Objectives					
Safety	0.54	3	1.62	4	2.16
Accuracy	0.31	4	1.24	4	1.24
User Friendly	0.099	2	0.198	5	0.495
Marketability	0.048	4	0.192	3	0.144
Total Score			3.25		4.039

Our team can determine that option 2 is the best concept design for our waste Recognition system. It implements a power supply and a single motor system to sort trash while using an LED display to show trash fullness levels and a light indicator to show the presence of rotting gases within the trash receptacle. With an overall score of 4.039, we can see that Option 2 is the best option for our waste Recognition system. Our team will be moving forward with this design.

XVIII. End Product Description and Other Deliverables

This particular section will provide the needed information for the product and its associated deliverables. It is essential to know the end product description and other deliverables because it provides the interrelationships of modules and components in a product, the functionality of the product, the required specifications needed for the product, and additional information related to the product. The end product description delivers an explanation of what the product does and how exactly it will do it. For the functions, it will provide further details of the many possibilities of functions that will be further expanded on. The specifications will provide a thorough list of the required components that are used to create the product. As for other deliverables, it will include the additional necessary work that will be provided alongside the development of the product. All these segments involving end product description and other deliverables are to demonstrate how effective and remarkable our project is and to provide insight for the users that want to use our product.

A. End Product Description

The end product description is to demonstrate what the product does and how exactly it will do it. With the end product description, it will provide all the essential details needed to understand what the product is. Most of the end product description is composed of the functionality in relation to the components used for the product in order to demonstrate how the product works. This will help understand users about the intricacies that are involved in the production. For the waste recognition system, the components and functions used inside the product can be broken down into specific diagrams that can explain the functionality of the product with the components that are used for the functions.

The following diagram is a level 0 black box diagram for the waste recognition system and includes the input and output.

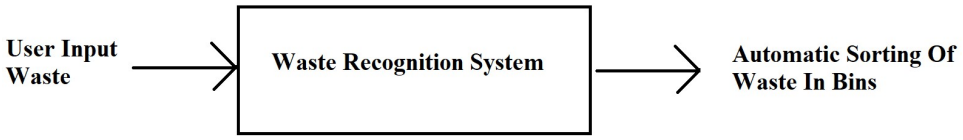

Fig. 25 Level 0 black box diagram of Waste Recognition System

Table XXX shows the description of the input, output, and function based on the previous diagram.

Table XXX. FUNCTIONALITY OF LEVEL 0 OF WASTE RECOGNITION SYSTEM

	Description
Input	Users have disposable waste as they place it on the platform that is within the waste recognition system, acting as the input just as similarly as throwing trash in a regular trash bin.
Output	Inputted waste gets scanned and classified making the decision of sorting, acting as a way to automatically sort waste in its respective bin.
Function	The waste recognition system uses a way to gather data from the user input and with that data, it can transfer the waste to sorting bins.

The following figure demonstrates the Level 1 view of the waste recognition system. Added was the Raspberry Pi 4B which is vital for the system to completely function.

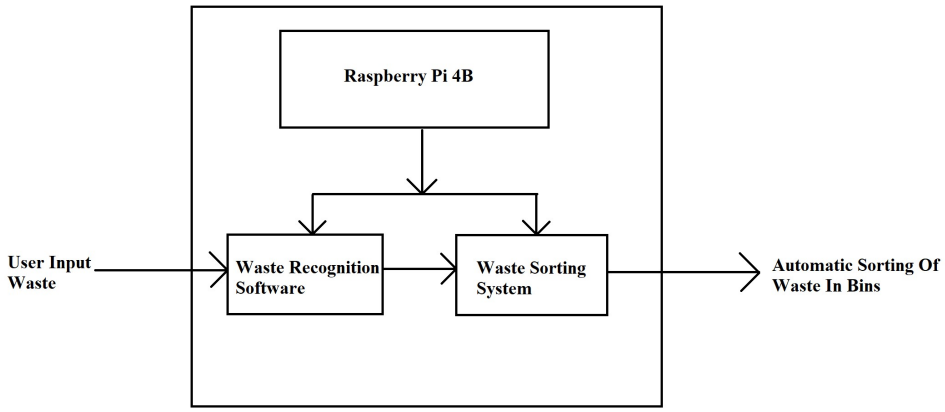

Fig. 26 Level 1 Diagram for The Waste Recognition System

Table XXXI shows the description of the input, output, and function based on the previous diagram.

Table XXXI. FUNCTIONALITY OF LEVEL 1 WASTE RECOGNITION SYSTEM

	Description
Input	The user's input is as simple as it can be as soon as the user places the waste inside the platform then the waste recognition software will gather the data.
Output	With the waste sorting system, the waste that the user places will be sorted using a servo motor that will determine the movement of the waste, making sure that the sorting of waste is automatic for the user.
Function	Using the Raspberry Pi 4B as the computer that runs the waste recognition software and the waste sorting system, the function of having the waste detected and then sorted is all functioned by the Raspberry Pi.

*B. **Functions***

In functions, it will cover the waste recognition software functionally as well as the waste sorting system. The functionality of both these systems is vital for the waste recognition system to function. We will go in-depth into each of the systems using diagrams and tables.

1) Waste Recognition Software

The following diagram describes level 0 of the waste recognition software as it first involves the user input waste, then the waste recognition software, giving output for the classification of waste.

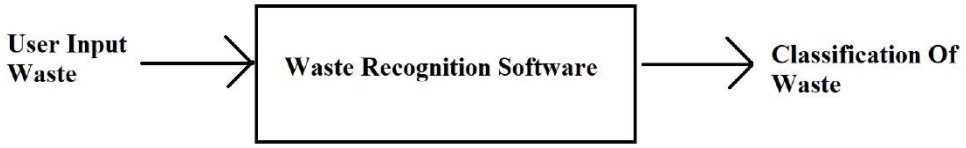

Fig. 27. Level 0 of Waste Recognition Software Diagram.

Table XXXII. FUNCTIONALITY OF LEVEL 0 WASTE RECOGNITION SOFTWARE

	Description
Input	For the user input, it is similar to putting waste in a regular trash bin, as you place your disposable waste onto the platform where the waste recognition software will take place.
Output	After the waste has been through the waste recognition software, the software will determine what classification the waste goes to.
Function	The waste recognition software is able to detect what waste you place on the platform.

The following diagram describes level 1 of the waste recognition software as it first involves the user input waste, then the waste recognition software, giving output for the classification of waste.

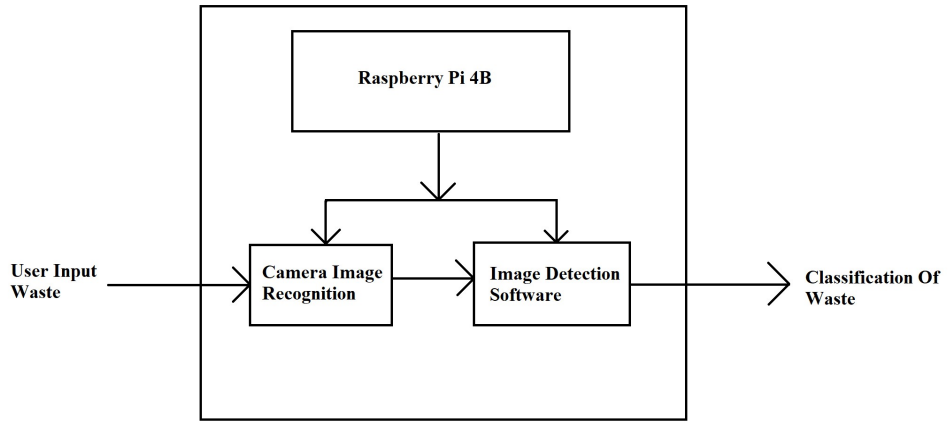

Fig. 28. Level 1 of Waste Recognition Software Diagram

Table XXXIII. FUNCTIONALITY OF LEVEL 1 WASTE RECOGNITION SOFTWARE

	Description
Input	Users will place the waste they want to dispose of on a platform that has the camera image recognition that is able to detect the waste.
Output	After the image detection software takes notice of the waste that was placed, it starts to classify it to a group of common items and starts classifying the current waste.
Function	With the Raspberry Pi being connected to the camera image recognition and also running the image detection software, it starts to process the waste being thrown and starts classifying it.

2) Waste Sorting System

The following diagram describes level 0 of the waste sorting system as it first involves the classification of waste, then the waste sorting system, giving output for automatically sorting the waste in its correct bin.

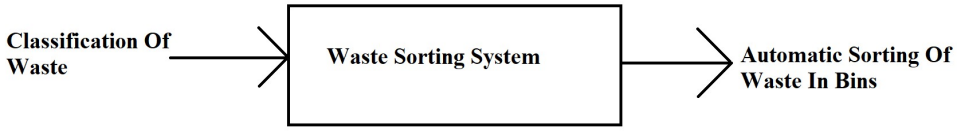

Fig. 29. Level 0 of Waste Sorting System Diagram

Table XXXIV. FUNCTIONALITY OF LEVEL 0 OF WASTE SORTING SYSTEM

	Description
Input	The classification of waste became determined and is being input for the waste sorting system.
Output	After going through the waste sorting system, the waste becomes placed inside the bin that is respective to the classification it belongs to, acting as an automatic way for sorting waste.
Function	The waste sorting system is for a functional way of sorting using movement to place the waste to where it belongs to.

The following diagram describes level 2 of the waste sorting system as it first involves the classification of waste getting received to the Raspberry Pi, then with the Raspberry Pi it will send signals to the servo motor, and depending on the classification of waste it decides if the platform holding the waste will turn to the left going counterclockwise or if it will turn to the right going clockwise. With this process the waste will go toward a left or right bin, making sure the waste is in the bin where it is supposed to go. All of this gives the output as the automatic sorting of waste in its respective bin.

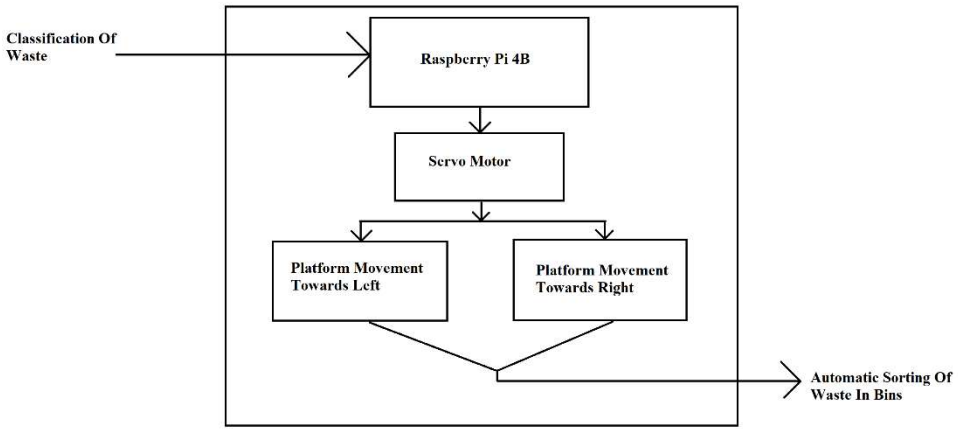

Fig. 30. Level 2 of Waste Sorting System Diagram

Table XXXV. FUNCTIONALITY OF LEVEL 2 OF WASTE SORTING SYSTEM

	Description
Input	The classification of waste is being sent back to the Raspberry Pi where it can lead to the following commands for the result of the output.
Output	After the platform moves to a respective bin, the waste finishes where it should go automatically sorting the waste for the user.
Function	The classification of waste gets received back into the Raspberry Pi where it controls the servo motor that decides if it moves clockwise or counterclockwise to place the waste in the respective bin.

C. ***Specifications***

The waste recognition system involves having many components along with the specifications for each of the components. The following table will have a list of specifications for the waste recognition system as well as the components that correlate to the specific specification that is involved.

Table XXXVI. SPECIFICATIONS

Components	Specification 1	Specification 2	Specification 3
Raspberry Pi 4B	Used as the computer for the whole product	Runs the waste recognition software	Commands the waste sorting system
Logitech Webcam C920S	Used for detecting the waste being thrown	Connected with the waste recognition software being used for detection	Connected also to the Raspberry Pi.
20KG Digital Servo Motor	Can move at a weight of 20KG	Used for moving the platform that the waste is placed on	Can move clockwise and counterclockwise
Programming Languages: Python and C	Programming languages will be used for the waste recognition software	Python for overall classification of waste	C for the commands for the servo motor.
Small Plastic Bins	Dimensions: 2.25" L x 15.91" W x 25.33" H	11 gallons of waste can be stored on each bin	Compact design
Hard Plastic Material Platform & Base	Hard plastic platform for sturdy but lightweight material	Hard Plastic to cover for the base of the waste recognition system	

D. ***Other Deliverables***

Aside from the waste recognition system itself, the team will develop and work on other deliverables as part of the project our team is working on. Although the proposal for the waste recognition system goes in-depth and extensively explains the project, additional resources are useful for giving more opportunities to explain our product and to have interest in other potential users, investors, and larger audiences. Examples of the resources that we want to deliver are an included user manual, video & PowerPoint presentations, and the final report with a finished proposal.

1) User Manual

A user manual will be developed for users of the waste recognition system to further explain the functionality of the product and gives a better idea for users to understand the benefits of the waste recognition system. With the user manual, it will provide images and illustrations explaining the intricacies of the product and gives further instructions on its uses.

2) Video and PowerPoint Presentations

Throughout the development of the waste recognition system, our team worked on a short video and in-depth PowerPoint presentations that highlighted and explained what the waste recognition system is for. Our team

will conduct more PowerPoint presentations and videos to further elaborate our product to multiple viewers that might be interested in our product.

3) Final Report and Proposal

Our team will work on a final report as well as complete the proposal for our waste recognition system. This will serve as the most important document for the product and will have plenty of information describing the product to anyone that fully reads it. With the final report and the proposal, anyone will have extensive and comprehensive information that completely describes the waste recognition system.

All the end product description and other deliverables were fully covered in this section and contains information such as functions, specifications, and other deliverables. In this section, we covered what the product does as well as how exactly it works. We covered the functionality that our waste recognition system can offer and provided the needed specifications to create the product. Furthermore, our product will include other deliverables that relate to the product, such as a Kickstarter page and a user manual. All these types of additional deliverables will be beneficial for our waste recognition system.

XIX. PLAN OF ACTION

To ensure that our project is completed on time, our team must establish a plan of action. A plan of action will allow our team to remain organized and enable us to approach our project with a holistic mindset, enabling us to work on each aspect of our project while keeping in mind our time and the relationship between each of the components of our project. It is paramount for any team to formulate a plan of action so that they can complete their project on time.

A. ***Statement of Work***

A statement of work is used to identify all the necessary work that must be done to complete a project by the deadline. The statement of work is used to identify the scope of the project, the location in which the work that is meant to be done on the project is to be performed, the period in which the work is to be done, and the responsibilities each of the team members will have during the completion of the project.

1) Scope

Our team will design a Waste Recognition System that is capable of sorting recyclables and trash into separate containers within a trash bin. It will make use of a platform upon which items will be placed to be identified by a camera attached to a Raspberry Pi system. Once the item has been identified as either trash or a recyclable, the platform will rotate either left or right to sort the items into their respective bins. The trash container will also make use of an LED display to determine trash fullness levels and an indicator light that will determine the presence of rotting gas. The team will design the trash bin, program the microcontroller, and create a housing unit that will contain the motors and microcontrollers.

2) Location

Most of the work will be done at Florida International University's Engineering Center. The team will independently work on small and easy tasks and use remote tools to review results. The hardware sections will be worked on at Engineering Center whereas the software components will be worked on independently or through remote collaboration.

3) Period

The project's starting period is February 2023 and will be completed by July 2023. Initial designs of the project alongside presentations will be done by April 2023. The team will begin working on the prototype in April 2023. Product testing will begin at the end of June 2023 and will be ready for demonstration by the end of July 2023.

4) Responsibilities

To effectively divide labor, each team member will be given a specific role. Two team members have experience in computer engineering and one team member has experience in electrical engineering. The roles each team member will have been shown below:

- **Sergio Lasprilla:** Team leader – Responsible for scheduling meetings and ensuring all tasks are completed on time. Will work closely with the Hardware and Software Designer to ensure the project is completed on time.
- **Alejandro Aloma:** Hardware Designer – Responsible for designing the trash container, housing for the microprocessor unit, and implementing the LED panel and indicator light. Will work closely with the Software designer to ensure the proper implementation of the components.
- **Dillon Archer:** Software Designer – Responsible for designing the code necessary to implement software functionalities for image recognition, platform control, gas sensor, and LED panel. Will work closely with Hardware Designer to ensure the proper implementation of the components.

B. Work Breakdown Structure

The Work Breakdown structure is meant to provide the team with a guide to managing time efficiently and effectively. The project will be broken up into phases and each phase will be broken up into tasks. Each phase and task will represent a percentage of the total time allocated to the project. The tasks associated with a phase will add up to the total percentage of time to complete each phase. Fig. 31 illustrates the WBS module.

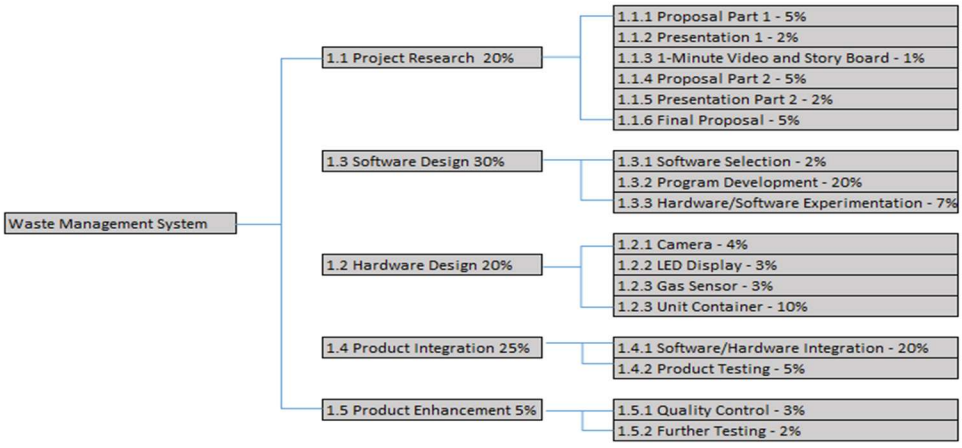

Fig. 31. Work Breakdown Structure (WBS)

1) *Phase 1: Project Research*

- Objective: Review other products similar to ours, examine existing patents, determine the feasibility of the project, and analyze the marketability of the project.
- Approach: Research current products on the market and ensure that the product can be competitive. Research necessary components for the product and determine their usability. Examine related patents so that the project does not infringe on any existing patents.
- Expected Results: Initial designs do not infringe on any existing patents, and they are sufficiently marketable and fit within initial constraints.

2) *Phase 2: Hardware Design*

- Objective: Design several potential hardware systems, select the best one, and implement it in our design.
- Approach. Design and install the camera, Raspberry Pi LED Display and fullness sensor and gas sensor into the Waste Recognition Unit
- Expected Results: The hardware components are fully functional.

3) *Phase 3: Software Design*

- Objective: Research various programming methods and utilize the best one that can perform all of the necessary functions.
- Approach: Perform research into software and coding methods that can perform the necessary functions. Determine and utilize the best method for implementation into our product.
- Expected Result: The Waste Recognition System should be able to identify recyclables reliably and correctly from waste and sort them.

4) *Phase 4: Product Implementation*

- Objective: Fully integrate hardware and software into a complete product.
- Approach: Fully assemble the product and perform final testing. Perform real-world scenarios to find with different people to find hidden bugs.
- Expected Results: The Waste Recognition System should be fully functional. Bugs will be fixed in the Product Enhancement phase.

5) *Phase 5: Product Enhancement*

- Objective: Fix any bugs found in the hardware or software, make quality-of-life improvements, and make the product more aesthetically pleasing for the consumer.
- Approach: Use the results of the Product Implementation phase to fix bugs and design a more aesthetically pleasing container for the product.

- Expected Results: A fully functioning, bug-free product that can be used indoors or within covered areas.

The Work Breakdown Structure allows our team to divide the project into phases and their subsequent tasks. This helps the team with time Recognition and goal setting. With this, we can better understand the purpose and goal of each phase to help us design our product.

C. ***Project Milestones***

Whenever a project is being undertaken, it is important to set a series of deadlines to ensure that goals are completed on time. It will be a testament to the progress made on the project and be an indication of completeness. There are three project milestones:

- Research Phase Milestone – 04/21/2023
- Hardware and Software Design – 07/05/2023
- Prototype – 07/27/2023

In the research phase, the team will perform all necessary research on the project. This phase will take approximately eight weeks to conclude. Once this is done, the hardware and software design of our project will commence. This milestone will be the most difficult to achieve as this is where we will design and implement all of the necessary components to create our Waste Recognition System. Finally, the prototype milestone will show a finished prototype of our project.

Our project must be completed by July 2023. These project milestones will help us keep track of the work done, the work left to be done, and how much time we will have to complete each phase and keep to schedule.

D. ***Gantt Chart***

The Gantt chart for our project is derived from the Work Breakdown Structure created by our team. It shows the phases with their corresponding tasks and allows the team to visualize each task that needs to be done to complete our project. It helps with the team's time Recognition by displaying the estimated amount of time each task and phase should need to be completed. A Gantt Chart can be used by any team to organize and plan for a project. Fig. 32. shows the Gantt chart for our Waste Recognition System that was created on Project Libre.

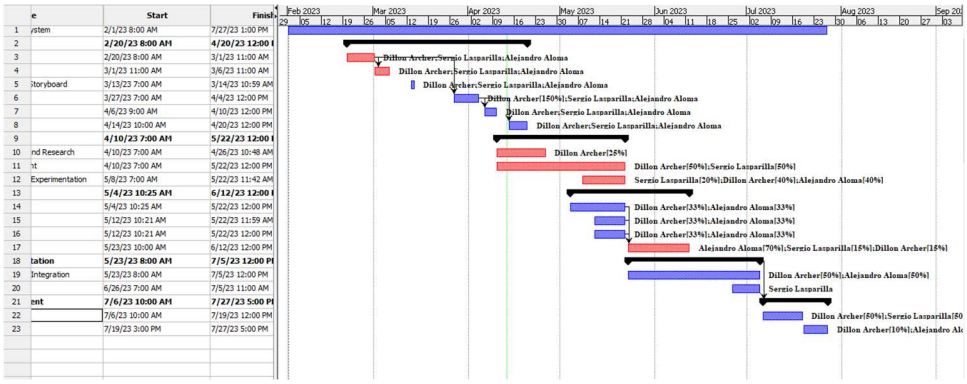

Fig. 32. Gantt Chart

E. ***PERT Chart***

The Program Evaluation Review Technique Chart is used to visualize tasks similar to that of a Gantt chart. The difference is that it allows a team to find the critical path of a project, which is the longest chain of dependent tasks. The critical path represents the shortest estimated time a project will take to be completed. Fig. 33 shows the PERT chart for the Waste Recognition System which was derived from the Gantt Chart.

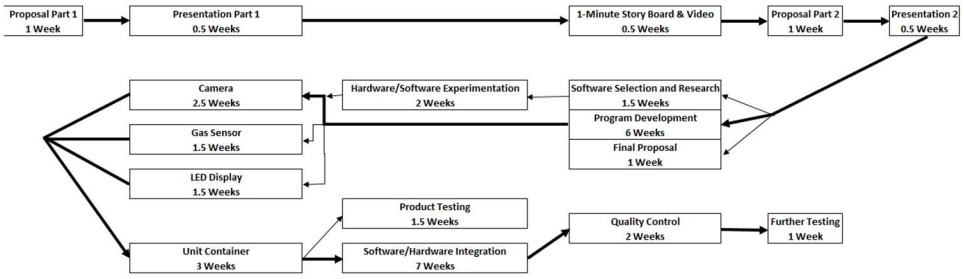

Fig. 33. PERT Chart

A plan of action allows the team to effectively distribute labor and estimate completion times for phases and tasks of a project. We created a Gantt and PERT chart to help in this endeavor. The Gantt chart allows the team to allocate various tasks to each of the group members with estimated completion dates. The PERT chart highlights the deadlines the team must reach to complete the project by the specified deadline. The creation of the plan of action is important for our team so that we can effectively distribute time and resources to deliver a fully functional and bug-free Waste Recognition System.

XX. MULTIDISCIPLINARY ASPECTS

Whenever a project is to be undertaken, the team who is responsible for the completion of the project must be multidisciplinary so that someone covers all relevant technical aspects of the project present on the team. It is also important as having a team with varied backgrounds will provide insights and viewpoints that cannot be found in a team with similar backgrounds. Our team consists of both electrical and computer engineers. This gives us the knowledge of both the programming expertise required to implement the software side of our program and the hardware knowledge to correctly implement the software.

The team consists of two computer engineers and one electrical engineer with diverse backgrounds. This enables us to design a project with members of a team who bring unique insights to the table. The team members and their backgrounds are listed as follows:

A. ***Alejandro Aloma (Electrical Engineer)***

- Experience in designing electrical, data, and fire alarm systems.
- Knowledgeable in C and C++
- Experience in Autodesk AutoCAD and Autodesk Revit
- Fluent in Solid Works

Alejandro is an Electrical Engineering student and the Hardware Engineer of our team. He has experience in designing electrical systems which prove valuable to the development of our project. He also has knowledge of programming languages such as C and C++ which allows him to understand some of the software aspects of our project. His experience with AutoCAD will prove indispensable in the development of the hardware aspects of our project.

B. ***Sergio Lasprilla (Computer Engineer)***

- Knowledgeable in C, C++, and Python
- Experience in team/business Recognition
- Excels in Mathematics

Sergio is a Computer Engineering student and our Team Leader. He has knowledge of Python, C, and C++ and excels in Math which will allow him to assist with the programming aspects of our project. His experience with team Recognition will enable him to effectively lead and manage our team and its resources.

C. ***Dillon Archer (Computer Engineer)***

- Knowledgeable in C, C++, and Java
- Rudimentary knowledge of Python
- Experience with microcontroller implementation

Dillon is a Computer Engineering student and our Software Engineer. He has knowledge of several programming languages such as Python, C, C++, and Java. He also has experience of microcontroller implementation from previous projects which will allow him to focus on the software aspects of our project.

Our team is relatively small compared to previous senior design teams. However, we have given each member has been given a role that capitalizes on their strengths. Alejandro is an electrical engineer and has been designated as our Hardware Engineer as he has the most experience in this area. His knowledge of AutoCAD and prior experience in designing electrical systems affords him the knowledge to design the blueprint for our project. His experience in programming languages also assists him in understanding the software enough to implement it into the hardware. Sergio is a computer engineer who has been designated as our team leader. His experience in business and team Recognition gives him the knowledge to run a cohesive and efficient team. His knowledge of programming languages also allows him to assist the hardware engineer with software implementation and the software engineer in developing the software. Dillon is also a computer engineer who has been designated as our software engineer. His knowledge and experience with microcontrollers and various programming languages make him a good fit for the role. Each team member plays a vital role in the development of our project and is a vital asset.

XXI. PERSONNEL

A team must have members from different engineering backgrounds. This enables the development of a team that can provide different perspectives on an engineering problem. A well-diversified team can produce a variety of engineering solutions that can be compared and integrated with one another to lead to an even more effective solution. Our team possesses a wide range of skills that assist with and improve the development of our project. The resumes of each team member will be listed below.

A. ***Alejandro Aloma***

EDUCATION

Florida International University - Miami, FL; Expected Graduation Date: Aug 2023

- Major: Electrical Engineering Current GPA: 3.33

PROFESSIONAL EXPERIENCE

SDM Consulting Engineers – Coral Gables, FL January 2016 –Present

MEP Engineering Intern

- Updating/Organization of MEP drawings/files.
- MEP drafting and plan organization.
- Designing Electrical, Data, and Fire Alarm Systems.
- Revit Drafting and plan organization.
- Load and Voltage Drop Calculations.

Miami Springs Golf Club – Miami Springs, FL January 2017 – December 2022

Golf Cart Attendant/Pro Shop Attendant

- Organize and maintain golf carts.
- Interacting and assisting Customers on their golf outing.
- Managing schedules of other golf cart attendants.
- Managing golf pro shop and customer service.

HONORS AND RECOGNITION

- FIU Dean's List - 2018-2023
- Eta Kappa Nu - 2022
- National Society of Collegiate Scholars - 2021

SKILLS

- Autodesk AutoCAD
- Autodesk Revit
- Knowledgeable in C, and C++
- Quick to learn new concepts.
- Extremely adaptable to a variety of working environments

B. ***Dillon Archer***

EDUCATION

Florida International University - Miami, FL Graduation Date: Aug 2023

- Major: Computer Engineering Current GPA: 3.57

University of the Bahamas – Nassau, The Bahamas Graduated: Aug 2020

- Associates' Degree in Engineering

PROFESSIONAL EXPERIENCE

Student Athlete Academic Center - Miami, FL January 2023 –Present

Student Peer Tutor – Math and Programming

- Assist student athletes in academic achievement by providing hands-on mentorship in selected classes.

Florida International University Housing - Miami, FL January 2022 – December 2022

Resident Assistant

- Provide academic and student support for residents in the community.
- Design, planning, and executing community events for staff and student residents.
- Collaborating with team members to execute community wide and floor events for student residents.
- Engage in crisis intervention by providing counseling and helping skills to residents in need.
- Maintain the safety and security of assigned areas.

Florida International University Housing - Miami, FL October 2021 - December 2021

Desk Assistant

- Operate the front desk.
- Assist residents and visitors.
- Respond to emails, calls, and alerts according to Florida International University's guidelines.

Atlantic Medical – Freeport Grand Bahama June 2019 – July 2019

Office Clerk

- Manage and archive sensitive company documents.
- Jointly collaborating with a team to achieve company goals.
- Assist customers with and provide answers to concerns or queries.

HONORS AND RECOGNITION

- Bahamas Society of Engineers Award - 2020

SKILLS

- IC3-GS4 Certified – Microsoft Office Certification
- Task delegation
- Knowledgeable in Java, C, and C++
- Quick to learn new concepts.
- Extremely adaptable to a variety of working environments

C. ***Sergio Lasprilla***

EDUCATION

Florida International University - Miami, FL Expected Graduation Date: Aug 2023

- Major: Computer Engineering Current GPA: 3.04

Miami Dade College – Miami, FL Graduated: May 2020

- Associate in Arts Degree in Computer Engineering

International Studies Charter High School – Miami, FL Graduated: June 2018

- High School Diploma

PROFESSIONAL EXPERIENCE

Waldans Antiques & Vintage Furniture - Miami, FL January 2016 – Present

Assistant Manager & Salesperson

- Store keep in a small furniture shop business.
- Perform negotiable sales to clients for a variety of antique furniture & items.
- Respond to phone calls for assistance in queries for clients & consigners.
- Assist in managing & negotiating consignment offers.
- Manage and archive consignment contracts & essential documents.
- Collaborate in running accounts on multiple social media platforms.
- Contribute to accounting for sales inside the store.
- Assist in creating and consulting for the decision-making of the business.
- Collaborate in moving and carrying furniture as well as reorganizing the layout of the furniture in the store.

HONORS AND RECOGNITION

- Academic Achievement in Spanish APID 2018

SKILLS

- Experienced in sales and negotiating with others.
- Experienced in the Recognition of a small business.
- Efficient in organizational skills
- Knowledgeable in C, C++, and Python
- Quick to learn new concepts.
- Ability to adapt to new working environments.
- Persistent in accomplishing needed tasks.

XXII. BUDGET

Our team made the budget for the project using phases that will go throughout the development of the waste recognition system. The phases will be the project research, the software design, the hardware design, the product implementation, and the product enhancement. Each phase will have its own budget that will estimate the necessary budget needed, and how we plan to pay off each of these budgets is by having an account where we each pay weekly an amount of $15 or more as we proceed with the phases. Some costs can be varied to change in the near future depending on unforeseen circumstances.

Table XXXVII. BUDGET BY PHASE COST

Phases	Cost
Project Research	$2429.99
Software Design	$1348.50
Hardware Design	$1071.11
Product Implementation	$1185.00
Product Enhancement	$600.00

To start with our first phase, project research will begin with the first budget to consider. What project research entails is the work for the proposals, presentations, and videos that will be created for the first phase of the project. The costs listed are mostly to express the time commitment needed to create these segments of the project research as some need to be more developed than others.

Table XXXVIII. BUDGET PHASE COST BY PROJECT RESEARCH

Project Research	Cost
Proposal Part 1	$675.00
Presentation 1	$270.00
1-Minute Video and Storyboard	$134.99
Proposal Part 2	$630.00
Presentation 2	$270.00
Final Proposal	$450.00
Total	$2429.99

After the project research is complete comes the phase for the software design. In this phase what is focused on is the program development as code for the image recognition and other functions are crucial for the product. Experimentation such as trial and error for coding is also an important part of the software design and will be considered.

Table XXXIX. BUDGET PHASE COST BY SOFTWARE DESIGN

Software Design	Cost
Software Selection and Research	$93.00
Program Development	$930.00
Hardware/Software Experimentation	$325.50
Total	$1348.50

The phase for the hardware design will include all the significant parts needed to construct the waste recognition system. Most of the costs here are for the actual payments of parts and the needed hardware to have the functionality needed for the waste recognition system to work.

Table XL. BUDGET PHASE COST BY HARDWARE DESIGN

Hardware Design	Cost
Camera	$243.31
Gas Sensor	$55.80
LED Display	$135.00
Unit Container	$450.00
Raspberry Pi	$165.00
Servo Motor	$22.00
Total	$1071.11

The next phase is the product implementation which involves adding the software and hardware together to the product and the first phase of testing. The phase will make sure the software and hardware integration will have the necessary budget needed in case something goes wrong and after that is in completion it will move on to the product testing to make sure our product is consistent enough to be functional.

Table XLI. BUDGET PHASE COST BY PRODUCT IMPLEMENTATION

Product Implementation	Cost
Software/Hardware Integration	$960.00
Product Testing	$225.00
Total	$1185.00

To end at the final phase is the phase for the product enhancement, making sure our product reaches the highest quality for consumers and is ready for use. With the quality control, we want our product to reach marketability as well as consumer-friendly, making sure it meets the standards we want the product to have for everyone. To finish, final further testing is needed to make sure that our product meets all the criteria we set for the waste recognition system.

Table XLII. BUDGET PHASE COST BY PRODUCT ENHANCEMENT

Product Enhancement	Cost
Quality Control	$450.00
Further Testing	$150.00
Total	$600.00

XXIII. RESULTS EVALUATION

The results evaluation for the waste recognition system will become essential for this project. What results evaluation will cover are the methods and criteria used to evaluate the various types of results that our team will gather in the next semester when we create the waste recognition system. The purpose of results evaluation is to demonstrate the effectiveness of the proposed project and to determine if the project goals have been achieved. Those project goals that our team will work towards are the objectives for the waste recognition system, the constraints needed to be satisfied, the standards that we will follow, the patents that we will not infringe on, and the specifications for the waste recognition system. All these project goals will be evaluated at the end of the next semester, and the results will be compared to what we mentioned in this list of goals that we strive to achieve.

The waste recognition system will have a multitude of objectives that our team will aim to accomplish by the end of the next semester. Most of these objectives have been developed based on the necessary functions needed for the waste recognition system and the requirements that our project must uphold. For that, our project's objectives are going to focus on the accuracy, stability, ease of use, and functionality of the waste recognition system. All of these categories for our objectives are to provide a list of required objectives our team will pursue and because our goals align with these categories for our objectives. Each one of these categories of objectives will be evaluated individually and rated comparatively to what we initially wanted for the waste recognition system.

The accuracy of the waste recognition system is a crucial objective as it pertains to its success of the waste recognition system. Identifying objects requires needed accuracy; therefore, our objective is for the waste recognition system to correctly identify objects with 85% accuracy. How our team plans to achieve and evaluate this accuracy is successfully implementing YOLOv5 software, which can detect and identify objects with 88.9% accuracy. Furthermore, we will evaluate the results of accuracy by testing the YOLOv5 software extensively. For the stability of our project, the waste recognition systems need to be sturdy and compact enough for the project to have a long-life cycle and not be prone to tear or fall apart. What our team plans to do is to make it out of hard casing and material so that it can endure any unwanted damage that could happen to the waste recognition system. How our team will evaluate the stability of the waste recognition system is testing if the project endure movements, pushing, or any other physical contact on the waste recognition system. The stability of our project should be strong enough to endure, similar to regular trash bins. For ease of use, our team wants to make sure that the waste recognition system can be used seamlessly compared to any ordinary trash bin. The objective for ease of use is to have the user not do any work other than throwing trash in a bin and making sure that the system works automatically without any human input. We want to evaluate the ease-

of-use results by asking others to use our waste recognition system and give us feedback on their experience with it. The final objective that we want to meet is functionality. Our objective with functionality is to make sure all the moving parts of the waste recognition system are successful in doing their task. Tasks such as the sorting system is essential for the project and extensively needs to be reliable for use. The evaluation for the functionality of the waste recognition system is to test it for long periods of time and to check if there are no errors happening during long-time use.

For the waste recognition system, there will be some constraints that will have to limit the uses, development, and various other factors. These constraints are mostly created due to the time given to develop the waste recognition system and the guidelines that our proposal withheld. One constraint that the waste recognition system will have been for the camera not to identify the user throwing the waste in the bin, as that could be a breach of privacy. Therefore, the camera must be hidden internally inside the waste recognition system and can only detect the waste being thrown. Another constraint for the waste recognition system is that the project needs an outlet to function as most of the waste recognition system is powered by the raspberry pi 4 and, therefore, must be plugged in at all times.

The waste recognition system will abide by a set of standards that will be followed and not violated. The standards that our waste recognition system will follow will include those mentioned in our standards consideration standards and many other standards set by the same organizations. Examples of standards that our waste recognition system will follow are the ones set by organizations such as the Institute of Electrical and Electronics Engineers (IEEE), the Electrotechnical Commission (IEC), and the International Organization for Standardization (ISO). With our waste recognition system, is important to consider standards that apply to many different nations that have different values, therefore, is essential to follow sets of standards that apply to various countries. Other standards we will follow will relate to the manufacturing, sustainability, and regulations our waste recognition system must uphold.

The waste recognition system will not impose or infringe on any patents or copyright works that might be related to our project. How our team will uphold not infringing on any patents by analyzing any similar products or patents that might be similar to the waste recognition system and carefully developing our project around those patents. Most of the examples of patents that our team does not want to infringe on are in the intellectual property section, and our design will not violate any of the patented works that are mentioned in that section.

Throughout the proposal, our specifications for the waste recognition system demonstrate the requirements needed for the project to be assembled. In the feasibility section, there it shows the considerations that our

specifications will have on the waste recognition system. Furthermore, this list of specifications is there to make sure it meets the operations of the waste recognition system. Examples of specifications are that it needs to be run by the Raspberry Pi 4. Additionally, other specifications are required, such as the parts needed to be created, the servo motor functionally to the sorting system, and the other various additional tasks that the waste recognition system will do.

In summary, our waste recognition system will ensure that all these aspects of results are evaluated and that the promised objectives, constraints, standards, and specifications are evaluated after the development of the waste recognition system. At the end of the following semester, we will evaluate the results and compare them to the promises we stated above.

XXIV. LIFE-LONG LEARNING

Life-Long Learning is vital for any engineer. We should strive to build upon the knowledge we gain to improve our craft. Whether through job training, work in our professional or personal lives, or continuing formal education, all our members are committed to enhancing knowledge of the skills we have acquired. In this section, our team will discuss how our team will improve our project over time, get it into production, and build upon our skills. We will also discuss any technical societies, magazines, or activities any of our team members participate in, along with any intentions of furthering our formal education.

Regarding our project, our team will need to continue researching ways of improving the Waste Recognition System. We will first focus on improving current systems and hardware to make our product more reliable, dependable, and efficient in its tasks. Afterward, we will focus on enhancing our Waste Recognition System to overcome deficiencies, adding new features, or designing related products that fulfill a need in the market. Doing this will prevent our development from falling behind its competitors.

Our project is still new and requires much more work, time, and resources to get to market and succeed. This is because of our team's inexperience with designing and creating novel products. Since this is the first time any of our members would have formal experience designing and building a product and all related paperwork or patent development that comes with that. As such, we are using this as a learning opportunity to better ourselves and our product. We will make use of various interviews and surveys in targeted communities to get a better idea of our own product's strengths and weaknesses. We will analyze the feedback from the end users and use it as a source to improve the Waste Recognition System.

Our team strives to understand engineering concepts better, improve our knowledge of related fields, and learn new skills to apply in personal and professional projects or research. Our members have engaged in various activities and groups to further this goal. One of our members, Dillon Archer, plans to pursue a Master's degree in Computer Science and acquire an internship before heading into the professional world. Another one of our members, Alejandro Aloma, is currently a part of Eta Kappa Nu, an honor society of the IEEE, National Society of Collegiate Scholars, and is an Intern at SDM Consulting Engineers. He also plans to take the Professional Engineer exam for Electrical Engineering once he graduates. The last member of our team, Sergio Lasprilla, plans to enter the professional world once he graduates to gain hands-on experience in the computer engineering field. In summary, the Waste Recognition System team will continue their pursuit of knowledge and engage in Life-Long Learning.

The team will continue researching to improve the Waste Recognition System. We will enhance our design, add new features, and then assess and correct any hidden flaws or weaknesses to stay competitive. We will conduct interviews and surveys with professionals and our end users. Overall, our team will pursue the ideals of Life-Long Learning to improve our product and ourselves.

XXV. CONCLUSION

To conclude our proposal for the waste recognition system, we wanted to highlight the many aspects that helped in the development of the waste recognition system and go over our input on how we conceived the waste recognition system. Most of what we will cover in the conclusion is our idea of the waste recognition system became in development, the main objectives we started with and evolved during the process, the activities involved in completing the proposal, how our waste recognition system will contribute to society, and the contributions it brought to our lifelong learning.

The idea of the waste recognition system first came from the first proposed idea of an automatic robot that can pick up trash on the floor. It was an idea that resonated with most of the team members as it involved a new challenge that our team members were excited to use our acquired skills to develop a creation involved in robotics. It was not until our mentor guided our team to an idea that was more feasible to create with a team of three that we decided to brainstorm again to think of a better idea that was related to the first idea. One of our team members brought a new idea, such as a mopping robot instead of a robot that picks up trash, as the idea felt simpler to do and had less functionality, such as spraying and mopping water on the floor. The whole team decided not to pursue that idea, but instead, one of the team members decided to take advice from our mentor, and instead of being a robot that picks up trash, it was instead of a smart trash bin that sorts of trash instead. That is how our team decided on the idea of the waste recognition system, as all of our team members decided it would be the best idea for all of the team members to develop and work on, focusing on the trash recognition aspect of the idea.

Most of the activities we did as a team for the development of the waste recognition systems were to do research and create schematics that helped us envision our project. Our team had many discussions about the waste recognition system and decided on the necessary parts and requirements needed to create this project. Most of our team split necessary sections of the proposal to each team member for it to be productive, and so each team member contributed to the proposal. Meetings and continuous updates on each of the team members helped to create the proposal for the waste recognition system.

How the waste recognition system will contribute to society is by furthering the act of recycling to more people. With the waste recognition system, it will automatically do the recycling for people that throw away all their waste in a single bin. It will help the cause of recycling and possibly help do more recycling passively without pushing others to do it themselves.

The waste recognition system has contributed to all of the team members' formation and lifelong learning. This project helped us develop

teamwork skills and gave us experience in the process of developing a project. With the waste recognition system, we started to learn about the organization of work and forming various roles within our team. The lifelong learning of teamwork in engineering projects such as this one will be persistent in our following careers.

XXVI. REFERENCES

[1] C. Contributor, “What is product marketability?” *Small Business - Chron.com*, 13-Nov-2020. [Online]. Available: https://smallbusiness.chron.com/product-marketability-17351.html. [Accessed: 28-Feb-2023].

[2] “Trash can + vacuum = Bruno, the world's first Smartcan.” [Online]. Available: https://www.kickstarter.com/projects/brunosmartcan/trash-can-vacuum-bruno-the-worlds-first-smartcan?sf8935936=1. [Accessed: 01-Mar-2023].

[3] “Qube: The World's first smart trash can,” *KickTraq*. [Online]. Available: https://www.kicktraq.com/projects/1056381504/qube-the-worlds-first-smart-trash-can/. [Accessed: 28-Feb-2023].

[4] M. Jaber, B. Song and J. Sudol, "Image Recognition Verification". United States of America Patent US 10,650,041 B2, 12 May 2020.

[5] J. E. Fisher, D. L. Fischetti, J. F. Nevak, B. L. Ogle, K. E. Dorman, K. S. Kiharu and C. J. Lasheras, "Item Put and Take Detection Using Image Recognition". United States of America Patent US 10,133,933 B1, 20 November 2018.

[6] C. R. Wren and N. Aharony, "Retrieving Contact Information Based on Image Recognition Searches". United States of America Patent US 10,142,351 B1, 27 November 2018.

[7] World Trade Organization, “World Trade Organization - Global trade,” Wto.org, 2022. https://www.wto.org/

[8] IEEE Standard for Local and metropolitan area networks--Part 15.7: Short-Range Optical Wireless Communications - Redline, in IEEE Std 802.15.7-2018 (Revision of IEEE Std 802.15.7-2011) - Redline , vol., no., pp.1-670, 23 April 2019.

[9] “Definition of the concept of safety,” *INSPQ*, 01-Aug-1970. [Online]. Available: https://www.inspq.qc.ca/en/quebec-collaborating-centre-safety-promotion-and-injury-prevention/definition-concept-safety#:~:text=Safety%20is%20a%20state%20in,of%20individuals%20and%20the%20community. [Accessed: 20-Apr-2023].

[10] “IEEE code of Ethics.” [Online] Available: https://www.ieee.org/content/dam/ieeeorg/ieee/web/org/about/corporate/ieee-code-of-ethics.pdf. [Accessed: 01-Mar-2023].

[11] W. Arellano, "Ethics Powerpoint Presentation".

[12] “YOLO-based object detection for separate collection of ... - researchgate.” [Online]. Available: https://www.researchgate.net/publication/360145212_YOLO-Based_Object_Detection_for_Separate_Collection_of_Recyclables_and_Capacity_Monitoring_of_Trash_Bins/fulltext/627e1db4107cae2919a23bff/YOLO-Based-Object-Detection-for-Separate-Collection-of-Recyclables-and-Capacity-Monitoring-of-Trash-Bins.pdf. [Accessed: 01-Mar-2023].

[13] “Simulation and construction of an automatic trash bin system with a ...” [Online]. Available: https://www.researchgate.net/publication/363831313_Simulation_and_construction_of_an_automatic_trash_bin_system_with_a_mobile_wireless_technology. [Accessed: 01-Mar-2023].

[14] “IOT-project smart trash can with Blynk Platform Integration.” [Online]. Available: https://www.researchgate.net/publication/355298524_IoT-Project_Smart_Trash_Can_with_Blynk_Platform_Integration. [Accessed: 01-Mar-2023].

XXVII. APPENDICES

A. ***Team Contract***

As a member of the Waste Recognition Team, I hereby agree to the following conditions:

1. I will actively participate in class discussions, contribute my own thoughts, and engage in open dialogue with my teammates.
2. I consent to abide by the norms and standards that the team has decided upon and set by a "majority of votes" decision.
3. I am fully accountable for any work the team assigns me. I will turn in my assignment on time and in good condition.
4. It is my duty to swiftly inform my team members of any new information in the event of an unplanned absence. We appreciate an anticipated and announced absence.
5. The team routinely evaluates and openly discusses my performance. If I perform poorly (as determined by the majority of votes), I will receive a warning.
6. After the third (3rd) warning, the team has the authority to release me (determined by a majority vote); in this case, I have the right to appeal to the professor of the class and ask for arbitration.
7. The following justifications are possible but not required for issuing a warning:
    a. Failing to turn in a project on schedule.
    b. Apathy on the part of the group.
    c. Indecent and improper behavior.
8. Under no circumstances may I turn my back on my team.

Team Leader Name	Signature	Date
Sergio Lasprilla	Sergio Lasprilla	04/21/2023
Team Member Name	Signature	Date
Alejandro Aloma	Alejandro Aloma	04/21/2023
Dillon Archer	Dillon Archer	04/21/2023

B. ***Intellectual Property Contract***

As a member of the Waste Recognition Team, I hereby agree to the following conditions:

1. The team, consisting of Alejandro Aloma, Dillon Archer, Sergio Lasprilla has approved this contract.
2. The designated spokesperson of the Waste Recognition System Team is Sergio Lasprilla.
3. The inventors will be Alejandro Aloma, Dillon Archer, Sergio Lasprilla.
4. The team mentor is Dr. Wilmer Arellano.
5. In the event of the invention going on the market, the profit will be shared evenly amongst all the team members equally.
6. Any decision regarding the intellectual property of the Waste Recognition System will be determined by a majority vote between team members.

Team Leader Name	Signature	Date
Sergio Lasprilla	Sergio Lasprilla	04/21/2023
Team Member Name	Signature	Date
Alejandro Aloma	Alejandro Aloma	04/21/2023
Dillon Archer	Dillon Archer	04/21/2023

XXVIII. SIGNATURES PAGE

Course Number: EEL 4920 Semester: Spring Year: 2023

Mentor Name: Dr. Wilmer Arellano

Senior I Instructor's Name: Dr. Wilmer Arellano

Name	PID	E-mail Address	Phone Number
Alejandro Aloma	5907823	aalom014@fiu.edu	305-790-8812
Dillon Archer	6224872	darch019@fiu.edu	786-771-1374
Sergio Lasprilla	6108636	slap002@fiu.edu	305-778-6118

	PRINT	SIGNATURE	DATE
Team Leader	Sergio Lasprilla		04/21/2023
Team Member	Alejandro Aloma		04/21/2023
Team Member	Dillon Archer		04/21/2023
Mentor			