Coquelicot Cans

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Abstract

For our final project we decided to focus on creating a solution for litter. At first we did not have a set region that we would focus on, but later we narrowed it down to commercial and educational environments such as malls and schools. Our team, Coquelicot Cans, decided to take an innovative approach to this problem through clever use of robotics. We designed and built a trash can that can autonomously move through a set path at specific times that would be customizable by the owner. By following a set path that any student, citizen, or shopper can easily locate, litter should become drastically easier to deal with.

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Element A:
Identification and Justification of a Problem

Executive Summary (Needs Checking)

Litter in commercial and educational environments is a problem that affects everyone, with those in industrialized countries and lower class areas being affected to an even greater extent. This litter contributes to the growing amount of pollution that can disrupt jobs, learning, and people's futures.

We, Coquelicot Cans, will dedicate ourselves, throughout this year, to trying to provide a rein for this problem. While there already exists many possible solutions for litter, we will strive to create something that is unique, and stands out from the rest. We will create a solution that can make going to school and out to shop even a bit more enjoyable and visibly pleasing.

The Industry (Needs checking)

As a whole, the waste management industry in the U.S.A was valued at $143 billion in 2023. The value and need for this industry has only grown since then, as it is expected to grow by at least %5.2 percent in the next 6 years. As the industry grows, so does litter, and a need for new solutions. Regulations and desirables for this industry have also gotten stricter as people desire better, more environmentally friendly solutions faster.

The waste management industry is broad. The industry can cover anything from air to sea pollutant management. However, focusing in our home state of California the largest focus of waste management industries is commercial making up for about 75% of the focus. Additionally, educational areas are required by law to have some form of waste management which this also contributes significantly to a large portion of the state focus.

Market Analysis (Needs checking)

The general need for this product is for issues with litter in large companies. As stated before, the California industry focuses over 75% of its waste management efforts in commercial and educational areas. By having a demand for our product we could allow a reduction in this focus to spread the efforts elsewhere while still providing a long-term solution to litter in commercial and educational environments.

The target consumers for our product are business and school owners. This is because the product will be too expensive to be a normal household item, but the perfect price to be a cheap solution to a problem which plagues businesses and schools everywhere. If a solution such as ours gains popularity we could help reduce spending on waste management in schools and businesses to allow for more money to be allocated to expenses that could help improve the quality of life in such environments.

Competitive Analysis

There will naturally be a wide range of competitors for our product due to the longevity and size of the waste management industry. Our team, Coquelicot Cans, had to be aware of three main competitors to our project: the normal trash can, alternative solutions that utilize advanced technology, and janitors/janitorial equipment (vacuums and mops). These three items make up a large portion of the industry and seem to be the main focus of development for future solutions to our problem.

We were hoping to make a product that could utilize some form of advanced technology within an environment such as a mall or school. This is because most solutions that use advanced technology are mainly used as solutions or air or water pollution and have no presence in a more crowded environment. *(An analysis of solutions that utilized advanced technology is provided below in table 2)*

Additionally, unlike a normal trash can we wanted our product to have a presence throughout a set area instead of being stationary. This would allow for easier location of an outlet to throw trash away and can hopefully prevent litter from emerging in hard to reach areas such as bushes, flowerbeds, and behind any piece of construction or furniture.

Finally, we wanted to make our product allow for a decrease in janitorial staff and in turn the equipment that they use, without completely ridding businesses and schools of them. This would allow businesses and to save money for other expenses or pay the remaining janitorial staff higher wages which could translate into long term employment. The companies could spend less on equipment repair, maintenance, and replacement which would help to aid the aforementioned points.

Table 1: Analysis of Competitor Types

Competitor	Pros	Cons
Basic Trash Can	Cheap and easy to use. Can typically hold up to 20-30 gallons of trash	Can be hard to find in a crowded or large area Stationary
High Tech Innovations	Able to last for long periods of time Efficient.	Expensive Only used commonly for the water or air
Janitorial Staff	Can move around and collect litter Can work well in tangent to a basic trash can	Work ethic may vary among staff Low pay ($16/hr) can translate to low motivation Requires constant payment

Management Plan

Table 2: Team Roles

Name	**Position**	**Main Job**	**Subsidiary**
Matthew Castello	Chief Program Officer	Programming our project	Documentation
Cameron Jennings	Chief Documentation Officer	Documenting the processes and organizing information	Material overview
Luis Robles-Huerta	Chief Logistics Officer	Overseeing our materials and double checking our processes	Assembly
Logan Wulf	Chief Assembly Officer	Assembling all aspects of our project	Material overview

Element B:
Document Analysis of Prior Solutions

Competitors

Figure 1: Janitors

Figure 2: Trash Can

Figure 3: Backpack Vacuum

Objective Benchmarking Data

Objective Benchmarking Data is a way to show every piece of data that can be reasonably applied to a product or group of products. The data is typically quantitative and based off of data that can be easily measured as “good” or “bad” or “small” or “large” based off of numerical values.

Table 3: Objective Data of Competitors

Competitor	Cost/Gross Monthly	Size	Lifespan/ Longevity	Review Scores (Average Across 5 Websites or Businesses)
Janitor	$2400-$2700	N/A (Too much variation)	15 years	4.58/5
Trash Can	$100-$200	4 cubic feet	3-5 years	4.34/5
Backpack Vacuum	$600-$900	0.6 cubic feet	5-10 years	4.56/5

62,780 lbs per office building
100,436 lbs per school/ university
(This data is the yearly trash pick up. This may not be needed)

Table 4: Objective Data Comparison

Competitor	Cost/ Gross Monthly	Size	Lifespan/ Longevity	Review Scores
Janitor	3	3	5	4
Trash Can	2	5	1	4
Backpack Vacuum	4	5	3	4

Rated from 1-5 (1: worst, 5: best)

Subjective Benchmarking Data

Table 5: Janitor Benchmarking Data

	Worth for Cost	Complexity	Efficiency	User-Satisfaction
Janitor	5	3	3	5
Comments	A decent business/worker will do a good job for the correct amount of pay.	There are many levels of service if you order from a business and work ethic would vary too much depending on the payed amount	Too much variation between business and individuals hurts overall efficiency. One worker may do a good job, but another may just do the bare minimum.	Rating scores are relatively high on average and reviews are positive. Overall a decent business or worker that could be easily found seems to be satisfactory.

Rated from 1-5 (1: worst, 5: best)

Table 6: Trash Can Benchmarking Data

	Worth for Cost	Complexity	Efficiency	User-Satisfaction
Trash Can	3	5	3	5
Comments	Easy to use, but larger trash cans seen in commercial and educational environments are far too expensive.	There is little to no confusion on how this product should be used.	The product is stationary which leads to it only being efficient if it is easily located.	On average the scores and reviews are positive. It seems the simplicity makes it a decent product.

Rated from 1-5 (1: worst, 5: best)

Table 7: Vacuum Benchmarking Data

	Worth for Cost	**Complexity**	**Efficiency**	**User-Satisfaction**
Backpack Vacuum	3	4	3	5
Comments	The product has a decent holding capacity and ease of use, but their price is far to expensive.	There is little confusion when using the product, but not every model is the same so small variation may lead to less ease of use when switching between models.	The product is great at gathering dust and smaller pieces of trash, but the product struggles when trying to clean larger pieces of trash.	Overall on average the reviews and scores are high. It seems the portability and simplicity make the product decent for use.

Rated from 1-5 (1: worst, 5: best)

Similar Solutions Matrix

Table 8: Solutions Matrix

Competitor	Cost/ Gross Monthly	Size	Lifespan/ Longevity	Review Scores	Worth for Cost	Complexity	Efficiency	User-Satisfaction	Total (Out of 40)
Janitors	3	3	5	4	5	3	3	5	31
Trash Cans	2	5	1	4	3	5	3	5	28
Backpack Vacuums	4	5	3	4	3	4	3	5	31

Scaled 1-5: 1 is the worst, 5 is the best (except for total values)

Summary of Results

- Cost
  - Objectively, we should have our product be no more than $900
  - Subjectively, we can make it fairly expensive because are targets are businesses and schools
- Size
  - Objectively, the size should be no more that 4 to 5 cubic feet.
  - Subjectively, the size needs to be around that of a typical trash can, but big enough to be noticeable at a glance.
- Lifespan
  - Objectively, our product should last 4-8 years.
  - Subjectively, the product needs to long lived enough to not be a financial liability with constant replacements.
- Worth
  - Objectively, our product needs to be able to make full use of everything it provides.
  - Subjectively, Our product needs to do better than its competitors and not be seen as “worthless” or “not useful.”
- Complexity
  - Objectively, our product should be simple and easy to get start working.
  - Subjectively, our product should should allow for owners and users to easily understand how the product works and put it into action.

- Efficiency
    - Objectively, our product should allow for businesses to collect litter and trash easier
    - Subjectively, our product should allow for a reduce of spending on alternative solutions.
- Satisfaction
    - Objectively, our product should be seen as decent among users.
    - Subjectively, our product should have a great image and ratings so that people return to buy the product.

Patent Research

For our patent research we, Coquelicot Cans, looked towards what high tech solutions were made or are being made.

Ecobot III

The Ecobot III is an ambitious idea to solve for litter in water and air. The Ecobot recycles the pollutants it gathers from the air or bodies of water where it can operate (typically shallow waters) and uses those pollutants to power itself while it cleans its surroundings.

The Great Bubble Barrier

The Great Bubble Barrier utilizes pressurized air to create a wall that prevents trash from flowing down a river into the ocean while making it easier to clean up. As stated previously this device will only operate in the mouth of a river in order to prevent trash and litter from entering the ocean

Mr. Trash Wheel

Mr. Trash Wheel is similar to the Great Bubble Barrier. Both operate near the mouths of river, but it very different ways. Mr. Trash Wheel uses a net and conveyor belt system to wheel trash into its mouth and into a collection site.

Table 9: Analysis of Patents

Patent name, number, and publication date.	**Advantages**	**Disadvantages**
Ecobot III GB2012050537 August 24, 2010	This bot can get rid of waste, and use said waste to sustain itself for elongated periods of time via artificial metabolic reactions	This idea is still largely in development, and it requires a lot to make one. Additionally, it wouldn't be something for use in public areas.
The Great Bubble Barrier WO2021075962A1 April 22, 2021	Good at stopping trash from entering the ocean and directing it to a collection site. Covers the entire depth of a river	Requires a constant stream of pressurized air, and if it is turned off it is useless.
Mr. Trash Wheel US2007015825 February 3, 2009	This device is strong in collecting and containing the trash that comes into its system	This can only be used in limited space or smaller bodies of waters such as rivers.

Opportunities For Competitive Advantage

The biggest opportunity for gaining a competitive advantage is having a high tech solution for on land that can operate in more crowded environments. Besides the previously researched competitors in our Objective Benchmarking Data not many solutions for commercial or educational environments utilize the same level of technology we do. This will provide a great advantage when a buyer is looking into our product because we will stand out. Additionally if our product works as intended then the idea of a convenient money saving solution will populate among potential buyers which will provide another advantage.

Element C:
Presentation and Justification of Solution Requirements

Form

Our product has a very simply form as it is shaped like a smaller rectangular trash can. It will also appear to be slightly elevated off the ground because of the drivebase that the trash can component sits on. The form is not erratic or abnormal in any section as to not cause problems when driving or hurt anyone.

Function

Our product has a very simplistic function that it has to follow accurately. Our product will move based on code that pre-programmed into the electronic system. It will turn and move forward as well as stop when the ultrasonic sensor attached to it senses any type of obstacle.

Materials

Our product that we have currently built is made up of PVC, a wooden base, a metal drivebase with mecanum wheels, an arduino, two motor controllers, four motors, and one ultrasonic sensor. We used these materials because they were cheap yet durable enough to allow us to build a decent product that we could test. If this product were to be fully realized and made market ready the materials wouldn’t change much. Ideally, to be ready for commercial use the product would still use a plastic trash can and a metal drivebase. Overall, we bought our materials with durability and cost in mind so that we could make a product that would accurately represent its possible commercial version.

Aesthetics

Our product was designed with the coquelicot theme in mind - a reddish color similar to what would appear on the poppy flower. Aesthetics aren't as important as other subjects, because no one really expects much design-wise from a trash can. It will look like a trash can on a drivable base, which is exactly what it is supposed to be. However, it does primarily use the red color previously mentioned to fit with the brand standards.

Ergonomics

Our product is fairly ergonomic. There is little difficulty in its use, both for the owner and those throwing trash in it. It serves as a trash can, so it has a large opening and there is no real challenge to using its trash can capabilities. It runs autonomously, so the owner doesn’t have to put in effort to move or even drive the robot. Additionally, anyone that has to conduct repairs or replacement of parts should have little trouble because the trash can and the drivebase would easily separate.

Safety and Legal Issues

Our product drives on its own, and as such must ensure it doesn’t hit anything or anyone. It has ultrasonic sensors to detect whether or not something is around it, which means it should be able to avoid bumping into anything. Additionally, it is set to run at a low speed so that if it were to make contact the resulting damage would be negligible. Outside of operation the plethora of wiring on the prototype may suggest additional safety and legal issues, but when scaled up to a final draft that is market-ready, the wiring should pose no issues for a professional and be covered properly to not be a safety issue for the average person.

Cost

It must be relatively cheap as it only serves as a trash can, but can have some cost as it allows for cheaper labor costs. The main cost of putting together the trash can is the electronics, in particular the motors. Overall, the target price is below $700 but above $250. This is because $700 would ensure that we could gather highest quality parts that would make any other issue negligible, but the high price may result in the parts being a waste of money and an unnecessary expense. However, a pricing at $250 should only occur if we can gather no budget and need to save money. Ideally, the pricing will remain between these two prices as stated before.

Customer Needs

The customer needs a working product that isn't a potential liability. The product must be able to perform its job of collecting and holding trash without spilling. It needs to drive around, as that is what makes it stand out from other products and is what would likely make customers buy the products. The product must also not hit any obstacles/people in order to prevent potential damages.

Summary of Product and Design Specifications

1. Function
    a. Function is the most important part of our product because without function there is no appeal and no originality.
2. Customer Needs
    a. Costumer needs is important because we are trying to make a product that is a better solution to a common problem. This means that if we cannot meet and exceed customer needs we have no market value.
3. Ergonomics
    a. Ergonomics are important because we are trying to make a customer and consumer friendly product that will replace other products that already excel in ergonomics.
4. Cost

    Cost is not as important as the previous specifications because our product is not innately expensive and it will be easy to market it at a reasonable price as long as it has good function.
5. Materials
    a. The materials we use have to be durable and rival that of other trash cans and solutions so overall as long as these two conditions are fulfilled the importance of what or how we use them does not matter..

6. Safety and Legal Issues
    a. Due to how simplistic our function will be we do not have to worry about safety and legal issues.
7. Aesthetics
    a. Aesthetics is one of the least important specifications because we are making a product around functionality so as long as it does not look sinister or unfriendly our product can be as simplistic and as plain as need be.
8. Form
    a. Form is the least important specification because there is not anything to worry about with it. There are no complex parts protruding from our product and the form is inherently simple and not open to change.

Element D:
Design Concepts Generation, Analysis, and Selection

Concept Development (Done)

Concept #1

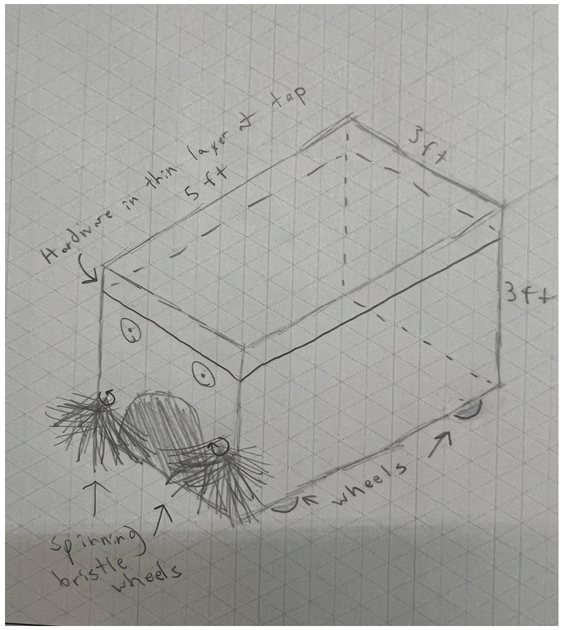


Figure 4: Concept #1

Table 10: Concept #1 Summary

Description of concept:	Cleaning apparatus with intake on bottom to eat trash.
Additional research:	Needs to have a gyroscope and other positioning sensors. Having an intake that uses wheels (bristles) or a vacuum will require less accuracy than using an arm with a claw. Needs a sturdy intake that can deal with sharp metals or glass. Likely needs a camera in order to avoid running into things.
Functionality and operation:	It will drive around and take in litter off the ground. It will have some sort of wheeled or vacuum intake at ground level in order to pick up trash.
Justification:	People feel more inclined to litter in areas in which there already is litter. As such, cleaning up areas with litter will help prevent more litter from accumulating.
(For physical products) Preliminary ideas about size, shape, materials, and other product features	It will need wheels and motors to power them. It will need a gyroscope and camera, and likely encoders on the wheels. It will be about 5 feet long, 3 feet wide, and 3 feet tall. It will be shaped like a rectangular prism with an opening with an intake in the front.

Concept #2

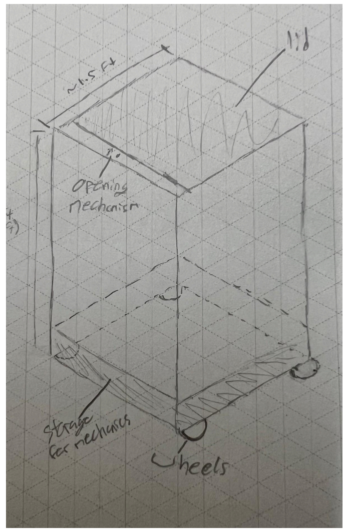


Figure 5: Concept #2

Table 11: Concept #2 Summary

Description of concept:	Motorized wheels on the bottom with a trash can on the top.
Additional research:	It can have sensors, or follow a set pattern as it roams (spiral, columns, rows, etc). Would have to have a stronger frame and motor in order to hold a 10-20lb trash can that can get as heavy as 80lb when it is full.
Functionality and operation:	It would move around like a roomba with ai mapping and motorized wheels.
Justification:	This could be a strong solution because its movement would allow it to reach parts of a store/operating environment that doesn't have trash cans.
Preliminary ideas about size, shape, materials, and other product features	Should be no taller than 4ft (even that may be too tall). Would be a vertical rectangular prism in shape. Light metals and plastic would primarily be used. Would need some form of a motor.

Concept #3

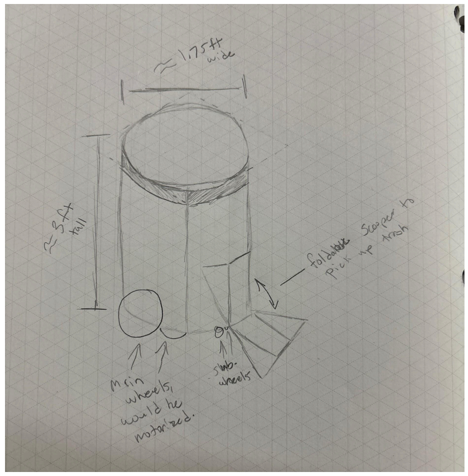


Figure 6: Concept #3

Table 12: Concept #3 Summary

Description of concept:	Movable trash can that can detect and pick up trash.
Additional research:	Would have to have a separate compartment so the regular trash does not fall out when scooping up trash. Needs to have some sort of vision or sensors and the ability to recognize trash. Needs a sturdy frame so it lasts and does not just break down. Similar to the “Sociable Trash Box” in Japan.
Functionality and operation:	The product would be able to move freely to go to trash that it detects. It would have a scooping mechanism that will fold up and down depending on whether it is in use.
Justification:	The product’s ability to detect trash will help to eliminate the litter that comes from people throwing trash on the ground.
Preliminary ideas about size, shape, materials, and other product features	Would be similar to a standard trash can in size, but would likely need to be more rectangular. Would likely be made out of a sturdy plastic for the base and then light metals for the mechanical components. Would need wheels that could go on all terrain. The scooper would need to have a softened edge so as to not scrape the sidewalk or ground when the trash can picks up trash.

Concept #4

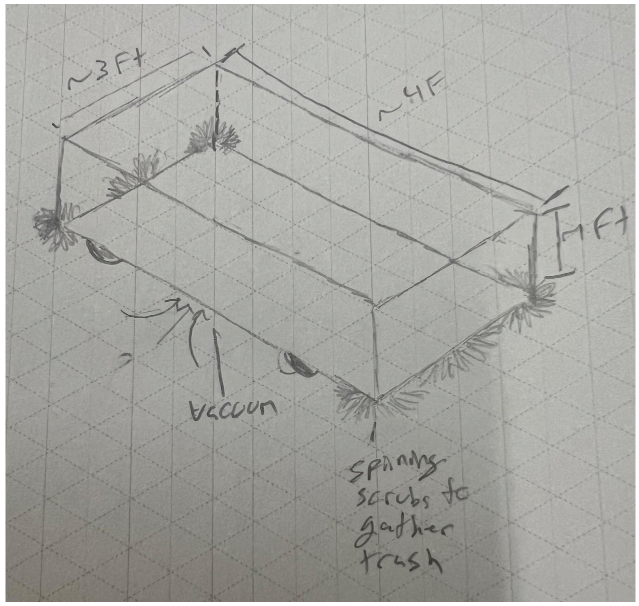


Figure 7: Concept #4

Table 13: Concept #4 Summary

Description of concept:	Small moving rectangular prism with spinning bristol brushes on a bottom (like street cleaners) that also uses a vacuum on the bottom to collect trash.
Additional research:	Bristols would have to be able to grab onto trash and not spread it out. Vacuum has to be small and strong, but quiet enough to not disturb people Needs compartment to store trash
Functionality and operation:	The product will move in a designated pattern set by the owners. The trash collecting part of the design would be much like a roomba's.
Justification:	This product will be an out of the way solution to litter in malls because it is small, but also customizable enough to be out of the way of customers.
Preliminary ideas about size, shape, materials, and other product features	Would be, overall, about half to three-fourths the size of a normal household trash can and roughly twice that of a typical roomba. Would use metal and plastic for the frame and typical wheels. It doesn't have to accommodate for most terrains because it is designed for malls.

Concept #5

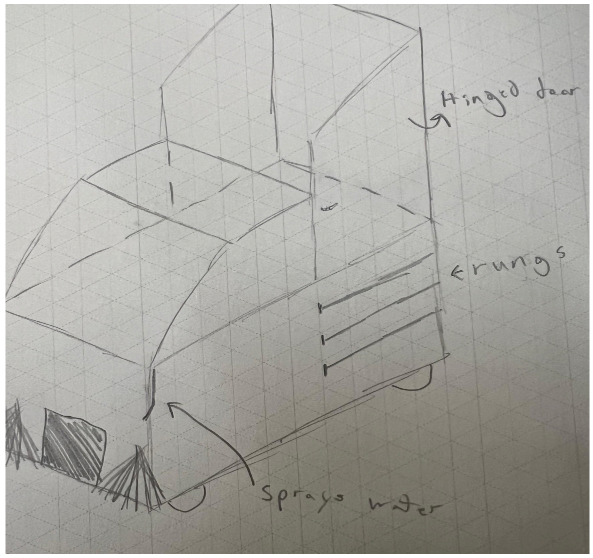


Figure 8: Concept #5

Table 14: Concept #5 Summary

Description of concept:	Small street cleaner
Additional research:	Street cleaner but for sidewalk
Functionality and operation:	It would intake trash with a vacuum. Trash would be funneled to the vacuum using large bristle brushes. It would also spray water (if enabled) to help clean the ground.
Justification:	It would operate similar to a street cleaner (brushes and water spraying) but would be small enough to drive down a sidewalk or more residential areas.
Preliminary ideas about size, shape, materials, and other product features	Box shape. Size of small rideable lawn-mower. Metal interior. Internal rack/layer for containing electronics. Bristle brushes. Canisters for storing water. Large interior section for holding trash.

Concept #6

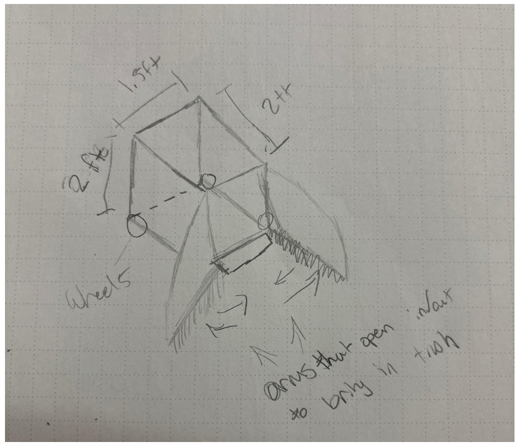


Figure 9: Concept #6

Table 15: Concept #6 Summary

Description of concept:	A small box that moves around to bring trash into its system using arms that open in and out.
Additional research:	Would need to have a way to not trip people to ensure it is safe. Would need to recognize people so it does not hit them when trying to pick up trash. Would likely need to have bristles on the arms to ensure that it actually picks up the trash.
Functionality and operation:	Would have arms that would open then close around trash and bring it into its tray. Would have a box to store the trash. Would need wheels and vision to move around.
Justification:	It would be able to pick up the trash that often gets left behind on the sidewalks or concrete. Should work well for the main places we hope to target with this product.
Preliminary ideas about size, shape, materials, and other product features	Would be a smaller box, probably around 2x2x1.5 feet. Would need sturdy arms/arm plates to ensure it can push the trash. Would need to have motors to move the arms and wheels.There should be bristles on the bottom of the arms to better grab trash.

Decision Matrix

This matrix rates the three best concepts from the previous six in order to give our team an idea for what we will make our final product like.

Table 16: Decision Matrix

	Desirability	Functionality	Constructability	Cost	Does it fix the problem?	Complexity	Originality	Total
Collector Can *Concept #3*	4	3	2	3	5	1	5	22
Traveling Trash *Concept #2*	2	4	5	3	5	5	3	27
Floor Flosser *Concept #5*	4	3	4	4	5	4	1	25

Scale: 1-5; 1=lowest 5=highest

Final Product Description and Justification

The final design for our product will take inspiration from concept #2 with some refinement in order to make a better overall product. The final product will be a full sized (or close to full sized) trash can that is carried on a drivebase that will move automatically utilizing an arduino, motor controllers, and ultrasonic sensors. We decided to go this route because it was simplistic, reasonable for us to be able to build, and not a clear copy of an existing product such as the roomba.

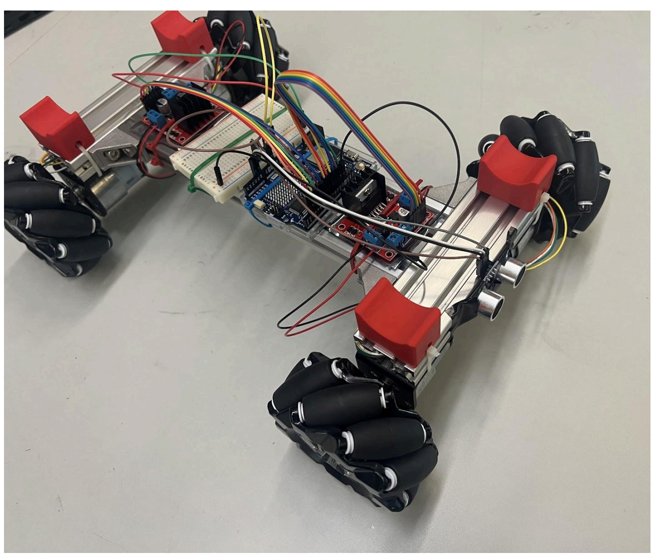


Figure 10: Drivebase

Figure 11: Trash Can Frame

Figure 12: Final Product

Element E:
Application of STEM Principles and Practices

STEM Principle #1: Mechanical Engineering

The product requires mechanical engineering skills. It uses motors to have the capability to move in all directions, and must be able to smoothly operate while carrying lots of additional weight or none at all. It must also maintain its structure and not tip, fall over, or release its contents when moving.

STEM Principle #2: Electrical Engineering

The robot has many electrical components. It has motors, which are wired to a breadboard and then to an arduino. It also has ultrasonics sensors. All of these must receive proper power and controls. The wiring must ensure the connections never become loose or faulty, and can’t snag or get caught.

STEM Principle #3: Software Engineering

The robot relies on software to operate. It must run autonomously, meaning it must be capable of using sensors to process the outside world (ultrasonic sensors), then react based on that information. The software will have the robot drive while not hitting obstacles or people.

Element G:
Construction of a Testable Prototype

Parts List and Cost

Table 17: Part list

Item Description	Unit Cost	Unit	Quantity	Total Price
1 in pvc pipe	$0.44/ft	10 ft	2	$8.82
arduino uno r4 wifi	$27.99		1	$27.99
ultrasonic sensor 5 pack	$8.99		1	$8.99
duracell-ultra-dura12-8f	$8.48		1	$8.48
L298n motor controller four pack	$9.99		1	$9.99
Mecanum Wheel 4wd Metal Robot Car Chassis	$99.99		1	$99.99
Wires 120 pcs	$6.98		1	$6.98
Red paint	$6.48		2	$12.96
AA Batteries (8 pack)	$8.70		1	$8.70
1-in pvc pipe connecter (4 pack)	$20.24		2	$40.48

Build Procedure

Table 17: Trash Can Frame Build Procedure

Design Part Name	Trash Can
Design Step #1	Cut PVC to Size (Half a block period) - Create/check/measure - Cutting PVC using saw
Design Step #2	Assemble PVC frame (Half a block period) - Gather PVC corner connectors - Assemble, making sure dimensions are right (1.5x1 foot base, 2 foot tall)
Design Step #3	Add plywood walls (Full block period) - Drill holes into the plywood - Zip Tie through holes and over the PVCto hold on.

Table 18: Drivebase Build Procedure

Design Part Name	Mecanum Drivebase
Design Step #1	Check materials and instructions (Half a block period) - Check for wheels and frame - Check for electrical components (if they come with the kit) - Check for fasteners
Design Step #2	Assemble Kit based on given instructions (Half a Block period) - Follow instructions given to our base

Table 19: Electronic Components and Sensors Build Procedure

Design Part Name	Electronic components and Sensors
Design Step #1	Check to make sure we have all components (Half a block period) - Check for arduino - Check for wires - Check for motors - Check for ultrasonic sensors - Ensure compatibility between components
Design Step #2	Create a layout for components (Half a block period) - Look for safe placements for each component - Create a plan for our wire pathing - Mark locations where components will go for future reference - Ensure everything is able to work and is not in danger of breaking due to its location
Design Step #3	Install components at designated location (Full block period) - Recheck all marked locations - Drill holes for zip ties - Zip tie components on
Design Step #4	Wire the components together (Full block period) - Connect all components together through planned path - Ensure that all components are functional

Subsystems and Incremental Testing

Table 20: Subsystems and Incremental Testing

Subsystem Name	Subsystem Description	How can you test each component?	How must the components work to be successful?	What will the test results look like? Pass/fail? Describe.
Drivebase	Subsystem will consist of four mecanum wheels attached to an aluminum drive frame. Each wheel will have its own motor.	We will need to test the wheels to ensure they spin smoothly and that they move in the four directions that they need to properly. We will check if the motors are functioning properly as well. To test the frame we will need to ensure that it can properly hold all that we need it to. Can it drive? Can it drive while full? How much weight can it carry?	The drivebase must be capable of driving, ideally making use of the mecanum wheels to be able to strafe in any direction.	For the wheel's mobility, it will be pass/fail. Either they move properly, (smoothly in all directions) or they don't. For the drive frame, it will be a game of trying to get a numerical value for its weight capacity.

Trash Can	Subsystem will consist of a PVC frame and plywood walls zip tied to each other and the drivebase	We will need to test the volume of the overall trash can to check how much it can hold. The frame and walls must also stay in place while the prototype is moving in all directions. Can it hold items effectively? Can it stay stable while moving?	The trash can must be able to hold any random amount of items while moving as long as the total volume of the items doesn't exceed the trash can's volume. It should also be able to detect when it is full using an ultrasonic sensor.	For the trash can the tests will be considered a pass if it can hold items of varying weight and size properly and not fall of the drivebase while in motion. A failure will most probably result in items spilling and/or the trash can falling off the drivebase
Electronic Components (Ultrasonics, Arduino, Batteries)	Subsystem will consist of ultrasonic sensors connected to an arduino which also controls the wheels. It will be powered by 8 AA batteries	The bot must sense objects close to it and turn to avoid collision. Is the arduino protected? Is the battery safely mounted in a way where batteries can be easily replaced / removed for charging?	The ultrasonic sensors must detect objects and be able to allow the bot to respond to them in real time. The battery must be securely mounted in a way it can provide power while still being easily accessible.	In order to pass testing the electronic components must all function as intended and be securely mounted in a way they won't easily be detached. The ultrasonic sensors must be able to detect the proximity of objects with a maximum tolerance of 3 inches off. The batteries must be easily accessible in order to replace them when necessary.

Element H:
Prototype Testing and Data Collection Plan

Testing Criteria

Table 21: Testing Criteria

Criteria/Benchmark	Description of data needed	Quantitative or qualitative	Degree of accuracy
At what speed is the trash can able to move at while empty?	A general top speed for the trash can while empty.	Quantitative	We will set a distance of 10 feet and record the time it takes to cross that distance. (We will repeat 5 times and take the average speed.)
How much weight can the trash can contain before it is no longer is capable of moving at a working speed?	A measurement of how much weight the trash can can hold before its driving becomes ineffective / too slow.	Quantitative	We will be setting a distance of 10 feet and record the time it takes to span that 10 feet distance. With every pass we will be increasing the weight in order to test at 2 lbs, 5 lbs, 10 lbs, and 20 lbs. We will go until the motors are unable to drive and continue forward. We will have it be a pass if the speed is within 70% and 50% of max (based on the maximum speed test), and fail if it does not.
Will the trash can be able to avoid hitting large obstacles?	Can the ultrasonic sensors detect large objects in front of it, and can the trash can use that information to avoid those objects?	Quantitative	We will begin by placing a large object (wall, chair, person, or cement block) directly in front of the trash can's path. We will have it run and we will see if it runs into the object, or if it stops or avoids the object. This will be repeated with the obstacle straight ahead, off to the left, off to the right, and

			being turned into from each direction. (x5 each). Then the test will be repeated with the next object.
How do varying surfaces affect the trash can's speed / mobility?	How does the trash can function in possibly common terrains? Will the trash can remain functional in rough / unideal terrain?	Quantitative	We will set a distance of 10 feet and record the time it takes to cross that distance. We will run the trash can on varying terrains (sidewalk, smooth, concrete, asphalt, incline, decline) and run the same test, measuring changes in speed.
How do small obstacles affect the trash can's speed / mobility?	Will the trash can get stuck if something is in the way? If it runs something over, could it fall over?	Qualitative	We will put small obstacles (ruler, stick, small rock, cord) in the trash can's way, low enough they are unable to be seen by the sensor. We will test with each object if the trash can can surmount the obstacle. We will test the robots ability to do so at varying weights by increasing the weight held within the trash can based off of the maximum weight tests. We will repeat this test until the weight prevents the trash can is unable to get past the obstacle.

Testing Procedure

Basic Movement Test

We will program the the robot to move in everyway available to it then test if it can execute those movements efficiently without stopping. Falling over, or being interrupted in any way (outside of ultrasonic detection). This test will either be "pass" or "fail" and will be a simple measurement of the movement capabilities of our project.

Top Speed Test

We will prepare a timer and video then set the bot on a concrete floor. We will then set up a measuring tape at 10ft of the floor and measure how quickly the bot passes the 10ft mark. We will repeat the test five time and take the average.

Maximum Carriable Weight

For this test a failure would be the robots inability to stop or turn without toppling over or spilling its contents. We would also need the bot to reach a viable speed (70% to 50% of max when empty) in order to pass. A pass will be if the bot can properly turn and stop without any problem (falling over, spilling, etc.) and if the bot, as mentioned previously, can reach the desired speed. The measured weights will be at 2lbs, 5lbs, 10lbs, and 20lbs,

Minor Obstacle Test

A small obstacle (ruler, stick, small rock, cord, etc) will be set up in the path of the robot. The robot will be run straight towards the obstacle. If it manages to climb the obstacle the procedure will be considered a success.

Major Obstacle / Ultrasonic Test

We will put the objects of decreasing size in front of the bot after testing the sensors with a wall. After the wall test the objects will begin with the largest item we can find that steadily decreased. We will continue to test until the bot no longer stops in front of the objects.

Different Surfaces Test

We will test the bots ability to turn, stop, move forward, and move backwards while empty on asphalt (or a similarly rough surface), a smooth concrete surface, the sidewalk, and on a large smooth surface. Each test will be recorded for the bot’s speed, and to compare its movement on the control surface from the top speed test.

Element I:
Testing, Data Collection, and Analysis

Testing and Evaluation of Product

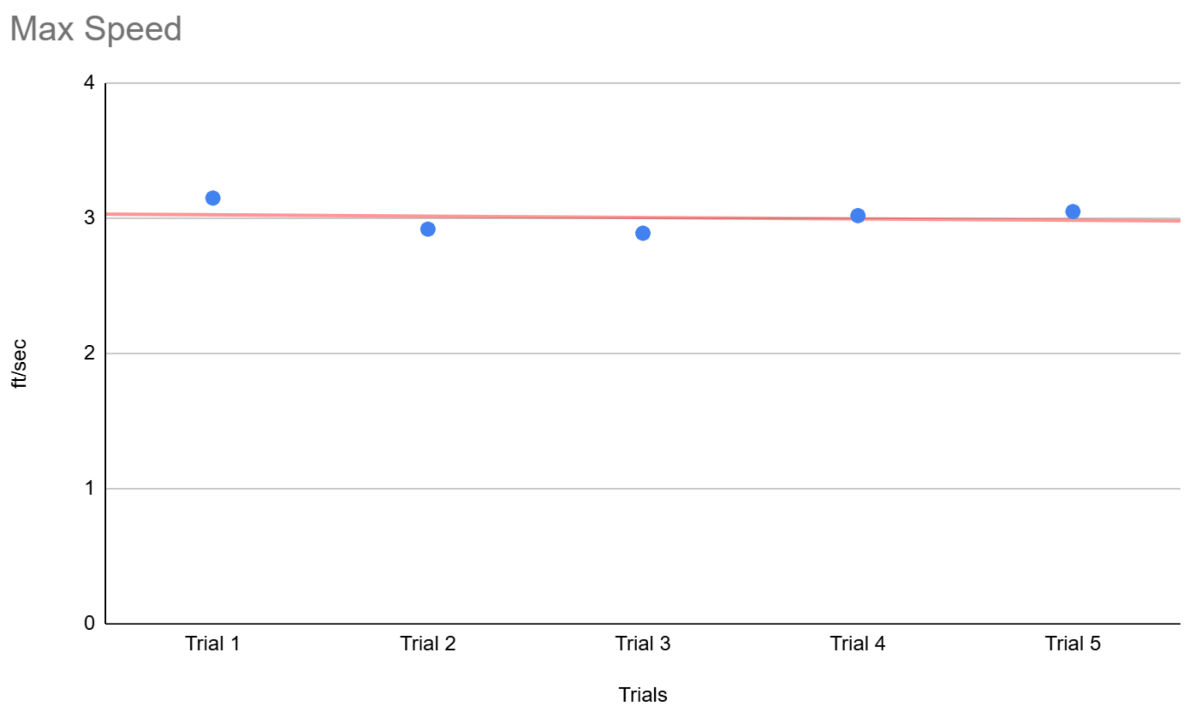
Test #1: Basic Movement Test

Table 22: Basic Movement Test Results

Movement Type	Pass of Fail
Forward	Pass
Backward	Pass
Turn Left	Pass
Turn Right	Pass
Strafe Left	Pass
Strafe Right	Pass

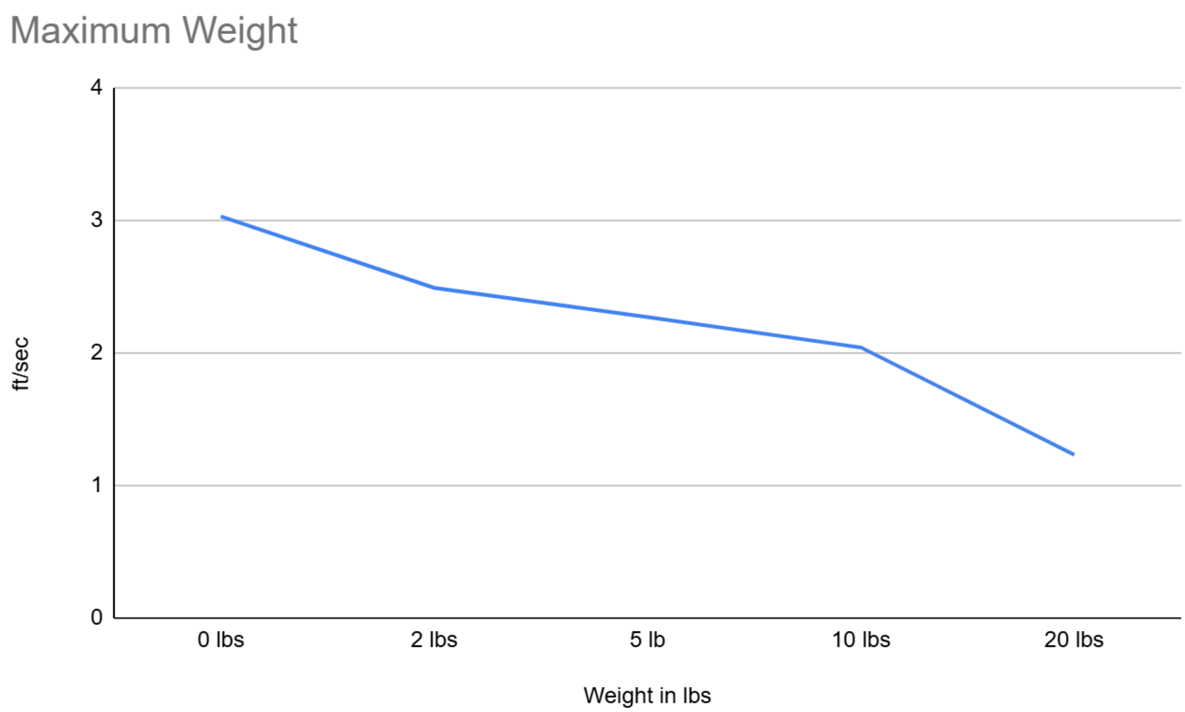
Test #2: Top Speed Test

Chart 1: Maximum Speed Test Results



<u>Test #3: Maximum Carribale Weight Test</u>

Chart 2: Maximum Viable Weight Test Results



Test #4: Minor Obstacle Test

Table 23: Minor Obstacle Test Results

Height (in mm)	Pass or Fail
2	Pass
4	Pass
8	Pass
14	Pass
16	Pass
37 (steep incline)	Pass
37 (normal)	Fail

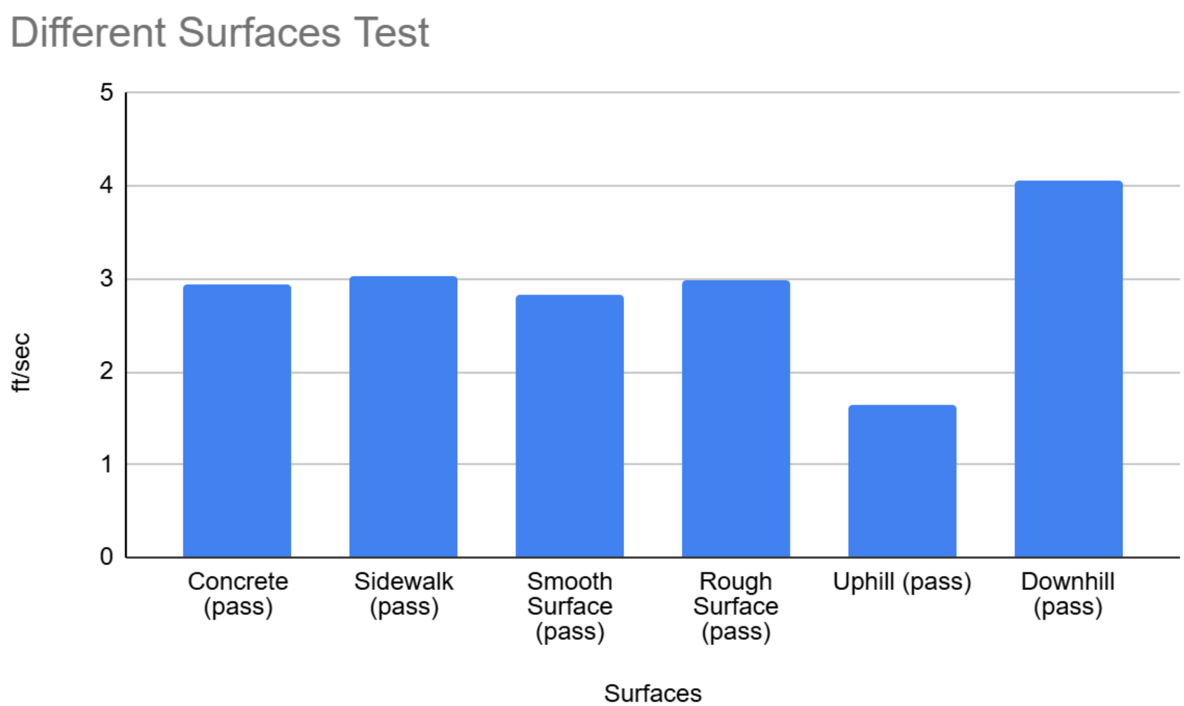
Test #5: Ultrasonic Test

Table 24: Ultrasonic Test Results

Height of Obstacle (in cm)	Pass or Fail
2	Fail
4	Fail
6	Pass
8	Pass
10+	Pass

Test #6: Traversing Different Surfaces Test

Chart 4: Different Surfaces Test Results



Works Cited