ENGS 21 Fall 2024
Final Report

"RECYCLEASY"

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I. Background & Problem Statement

At Dartmouth College, dining patrons often fail to properly dispose of plastic bottles, leaving leftover liquids that can contaminate other recyclables. This places the burden of sorting and cleaning on recycling facilities as the college follows a Zero-Sort™ method for waste collection.

Dartmouth College is focused on sustainability, but leftover liquids in plastic bottles create a big problem for recycling facilities. When bottles are thrown into recycling bins without being emptied, they contaminate other recyclables, and the entire batch can become unsuitable for recycling. The Environmental Protection Agency (EPA) reports that millions of tons of recyclable waste end up in landfills each year because of contamination which undoes our recycling efforts (Environmental Protection Agency, 2023).


News

‘A tough nut to crack:’ Dartmouth faces ongoing recycling challenges

The College has decreased its proportion of waste sent to recycling programs in recent years due to strict regulations on contamination in recyclable materials, according to staff and students familiar with the issue.

Figure 1.1 “The Dartmouth Faces Ongoing Recycling Challenges.” The Dartmouth

Mixing recyclables with liquids often means the whole batch cannot be processed, leading to more waste and higher costs. For example, handling contaminated recycling in cities like New York can cost up to $766 per ton, compared to $126 per ton for regular waste. Nationwide, contamination adds up to $300 million each year in extra labor, equipment damage, and safety risks (Berkeley Center, 2023).

Dartmouth follows a Waste Centralization Program which uses central collection locations and a Zero-Sort™ method whereby all recyclables—paper, cardboard, glass, cans, and plastics—are collected in one area and sorted at a facility in Rutland, VT. This system does not address the issue of bottles with leftover liquids, shifting the burden of sorting and cleaning to recycling facilities. If the materials are not properly prepared (i.e., emptying liquids from bottles), the entire system becomes less effective, which then contributes to increased costs and decreased recycling efficiency. Our project aims to create a system which ensures bottles are emptied before recycling, reducing contamination and making Dartmouth’s recycling more effective.

II. Users & Purchasers

To understand our users, we had a meeting with Susan Weider, who is in charge of campus services at Dartmouth. She confirmed that our project is indeed addressing a very serious recycling challenge: **contamination**. She also informed us that we needed to consider three things. One is having a convenient waste collection method for the custodial team. Second, it would be better if the trash can would be able to run by itself without requiring too much power. And lastly, we should also think about the user's convenience when using it.

For our users, we narrowed it down to the dining patrons of Dartmouth College, specifically that of Novack Cafe. The purchasers will be the Dartmouth College Custodial Services and Facilities, who will ultimately be handling the maintenance of the recycling bins.

III. Qualitative Summary of Specifications

For our specifications, we considered the strengths and weaknesses of existing designs in addition to our personal thoughts about where the crux of the problem lies in order to provide alternatives. Keeping in mind our problem statement and users, we came up with 11 specifications, assigned a 1-3 weight to signify relative importance, and gave tentative quantifications to each specification. We did not weigh legality & ethicality as it is a simple Yes/No question and is required for any potential solution to be considered. The most important specs are **safety, ease of use, capacity,** and **effectiveness**. Moderately important specs are **cost, size,** and **durability**. Finally, the least important are **toughness** and **aesthetics**.

IV. State of the Art

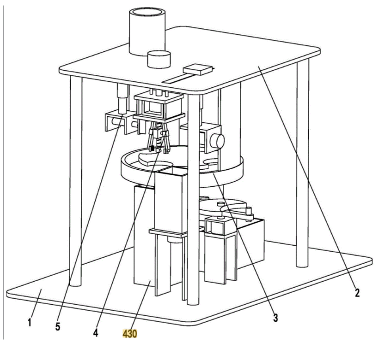


Figure 4.1 Patent # CN108724527B
Cap and label separating machine

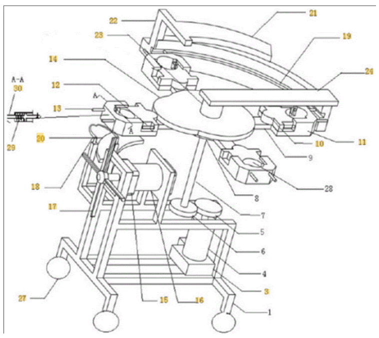


Figure 4.2 Patent # CN108162242B
Automatic recycler

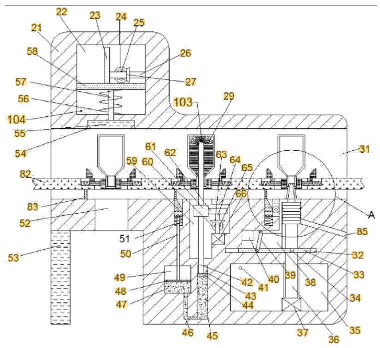


Figure 4.3 Patent # US20200094299A1
Conveyor system for recycling environments

Patent 1: Cap and Label separating machine

The invention provides an automated system for separating polyethylene (PE) plastic bottle labels and caps from the bottle body, featuring a conveying device, a bottle cap removing device, and a label removing device. This system addresses issues of high labor costs, low efficiency, and safety hazards in the manual recycling process, enabling efficient and automated separation of plastic components.

Patent 2: Automatic recycler

The invention provides green recycling equipment for plastic containers, integrating both manual feeding and mechanical automatic processing. It automates positioning, clamping, cutting, and separating bottle caps and labels, making it suitable for high-density areas like markets and schools, where bottles are processed without the need for specialized personnel.

Patent 3: Conveyor system for recycling environments

The invention discloses a device for cleaning, recycling, and compressing plastic beverage bottles, featuring a conveyor belt and a fixing device that holds the bottles for cleaning. This system automates the preliminary treatment of plastic bottles, saving manpower and resources, while ensuring cleanliness for safer subsequent processing.

However, these solutions do not address the main issue of individuals finding it inconvenient to drain their plastic bottles; they primarily focus on separating caps from the plastic bottles in an industrial setting. **As such, our prototype focuses on separating the water from the plastic bottles.**

V. Benchmark Testing

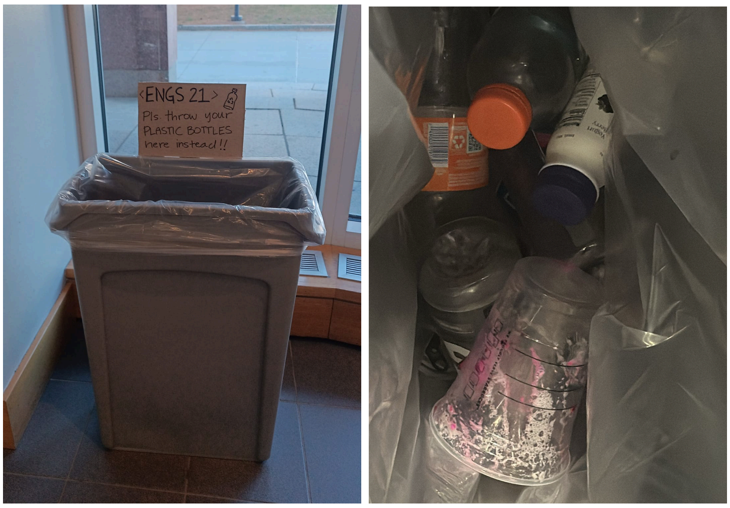


Figure 5.1 Benchmark tests at Novack Cafe (Oct. 18-22)

To have an understanding of the recycling process in the daily setting, we conducted benchmark testing at Novack Cafe with a regular recycling bin of a similar size (0.5 x 0.5 x 1.0 m). The testing involved a regular trash can with a sign requesting people to throw away their plastic bottles being placed in Novack Cafe between October 18th and 22nd. The main purpose of the test was to determine the average amount of liquid waste per bottle in a typical recycling bin in a relatively busy area.

The results were **10 plastic bottles** and five instances of unrelated trash (aluminum cans, paper plates, etc). The liquid remnants from the 10 bottles totaled to 290 mL, equaling to **29 mL/bottle**. Additional constraints imposed by the added cost to produce the machine led us to aim for our machine to only leave **< 10mL/bottle.**

Furthermore, demonstrations were conducted to determine the capacity of the trash can, which we found to be approximately **40 bottles**, and the ease-of-use factor of throwing a bottle in a hole, which turned out to be **1 second** at maximum. With these in mind, we aimed for a design that has a capacity of **32 bottles** and takes around **3 seconds** to use.

VI. Initial Individual Drawings & Prototypes

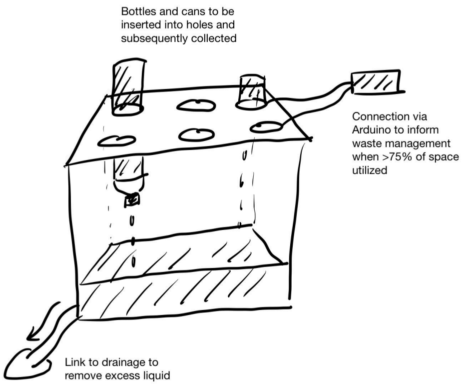


Figure 6.1 The Bottle Drainer

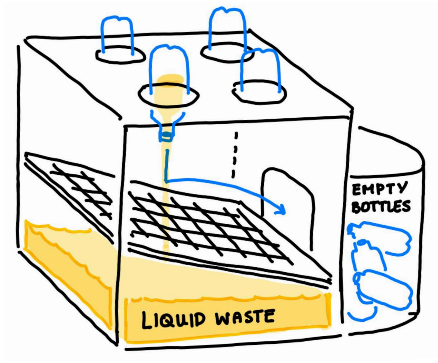


Figure 6.2 The Bottle Mesh

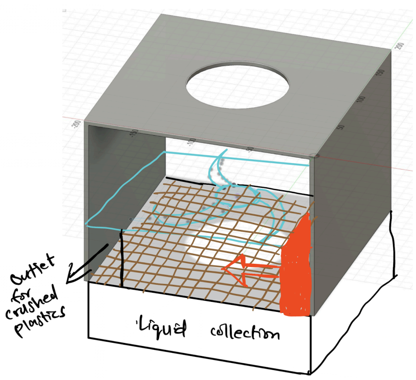


Figure 6.3 The Bottle Crusher

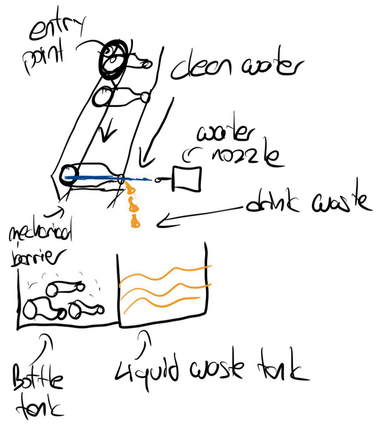
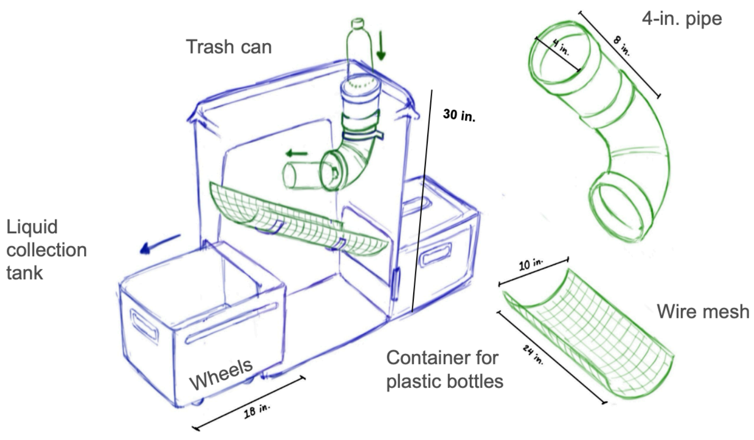


Figure 6.4 The Bottle Cleaner

We took elements from the individual drawings, such as separate compartments of waste and bottles and a water sensor mechanism to manage capacity, to create our initial and final prototypes.



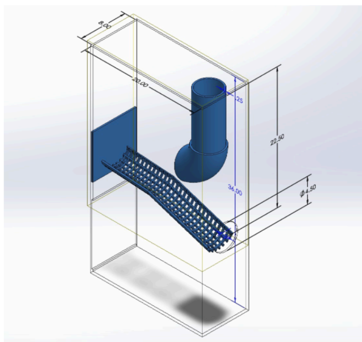


Figure 6.5 Combined initial prototype **Figure 6.6** SolidWorks Prototype

VII. Initial & Final Prototypes

With all of our initial drawings and individual prototypes, we move on to the actual building process. We originally considered creating the plastic frame/container ourselves, but we decided to simply modify a pre-existing trash can, as depicted in Figure 6.5. Below, Figure 7.1 shows the initial prototype (RECYCLEASY 1.0), and Figures 7.2-3 show the final prototype (RECYCLEASY 2.0). The initial prototype only featured the PVC pipe which 'flips' the bottle and the angled mesh.

Figure 7.1
Initial Prototype

Figure 7.2
Final Prototype

Figure 7.3
Final Prototype, other angle

We had two main points which we accounted for with our design choices, those being the drainage process and the liquid waste collection. For the bottle-draining, we had to ensure that our machine gave the bottle enough time to drain as it traveled on top of the mesh. Initially, we used more passive solutions: changing the steepness of the mesh, higher friction surfaces laid atop the mesh (V-belt rubber, several different kinds of tape, etc.), and obstructions with memory attached on the mesh (pipe cleaners).

Figure 7.4 Example of higher friction surface on mesh

After extensive testing, we determined that none of our passive solutions consistently gave the bottles enough time to drain. Thus, we pivoted to a more active solution: a sensor-operated door using Arduino.

Figure 7.5
Infrared Reflective (IR) Sensor attached to pipe entrance

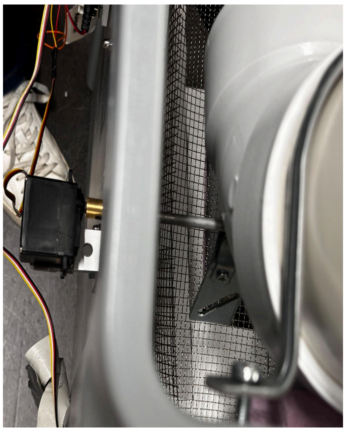


Figure 7.6
Servo motor which controls door

Figure 7.7
Door which stops bottles from falling through

We attached an IR Sensor to the entrance of the pipe, which detects any bottle that passes through. Once a bottle has been detected, the sensor communicates to the Arduino board through our custom program (written using the Arduino Programming Language) which then communicates for the servo motor to rotate. This closes the door and prevents the bottle from falling through while still allowing it to drain. After an allotted time frame, the door opens and allows the now-drained plastic bottle to exit the machine and fall into a separate container for emptied bottles.

Additionally, we had to design a system which notified the custodial team when the maximum capacity of the liquid waste tank had been reached. We initially considered float and liquid level sensors before settling on a Govee WiFi Water Sensor. This sensor would be attached inside the liquid waste collection tank (as shown in Figure 7.8) and would detect if the liquid waste has reached a certain level, after which it would send a phone notification to the custodial team informing them that the prototype is ready for liquid collection.

Figure 7.8
Govee WiFi Water Sensor

Figure 7.9
Water sensor attached to the tank

We also had to design for the two main safety risks which we identified: the wire mesh and the electrical components.

Figure 7.10
Lid covering the prototype

Figure 7.11
Cover for electronics

For the wire mesh, we put a cover on top of the entrance of the trash can. This prevents the users or custodians from accidentally or purposefully inserting their hand inside the machine, which could cause injuries or possibly break the prototype. For the electrical components, because our machine deals with liquid waste, it was imperative to cover the Arduino board, motor, and wires to prevent these components from being in contact with the liquids.

Demonstration & User Journey

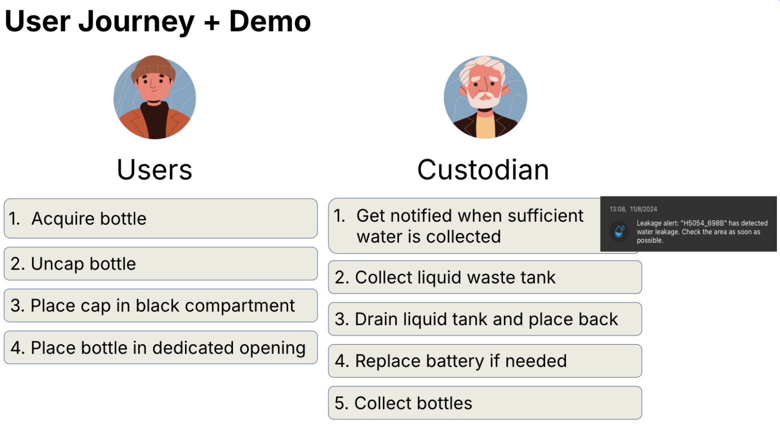


Figure 7.12 User Journey Diagram

For users, the process begins with acquiring a bottle. Once the bottle is obtained, the user uncaps it and places the cap into a designated black compartment. After this, the bottle is inserted into the dedicated opening provided for it.

For the custodian, the process starts with receiving a notification when sufficient water has been collected. The custodian then collects the liquid waste tank, drains it, and places it back in its position. If necessary, they replace the battery before proceeding to collect the bottles. An additional notification system alerts custodians in case of issues like water leakage, ensuring timely resolution of problems. A demonstration on our website: https://sites.google.com/dartmouth.edu/recycleasy.

VIII. Testing & Feedback

Water Drainage Tests

One of the central goals of RECYCLEASY is to drain liquids effectively from discarded bottles to reduce contamination of recyclable materials. To evaluate this, the team conducted rigorous water drainage tests. Bottles of various volumes—ranging from 50 mL to 300 mL—were filled with water and placed in the prototype. The remaining liquid in each bottle was measured and averaged over three trials for accuracy.

Bottle Type	Volume Tested (mL / bottle)	Results (mL / bottle)	Remaining Liquid (%)
Gatorade	50	40	80
	100	82	82
	150	124	83
	200	170	85
	250	217.3	87
	300	266.67	89
Pure Leaf	50	40.5	81
	100	83	83
	150	126	84
	200	168	84
	250	212.3	85
	300	256.7	86
			Avg: 84%

Figure 8.1
Results of RECYCLEASY 1.0

Bottle Type	Volume Tested (mL / bottle)	Results (mL / bottle)	Remaining Liquid (%)
Gatorade	50	20	40
	100	20	20
	150	23.3	15.6
	200	28.3	14.2
	250	33.3	13.3
	300	43.3	14.4
Pure Leaf	50	2	4.0
	100	2.3	2.3
	150	2.3	1.5
	200	2.4	1.2
	250	2.3	0.92
	300	2.5	0.77
			Avg: 10.6%

Figure 8.2
Results of RECYCLEASY 2.0

The results from the initial design, RECYCLEASY 1.0, revealed significant limitations. On average, approximately 84% of the liquid remained in the bottles after the drainage process. This was due to inadequate mesh angles and suboptimal pipe placement, which hindered liquid flow. Recognizing these shortcomings, our team made adjustments to the mesh angle and the orientation of the pipes to improve drainage efficiency. Moreover, the introduction of a sensor and motor system automated bottle handling, ensuring a controlled and thorough drainage process. **This also aligned with our benchmark testing criterion, which aims for an average of < 10mL/bottle of liquid waste remaining.**

In subsequent tests with RECYCLEASY 2.0, the results were markedly improved. The updated prototype left an average of only 10.6% of liquid in the bottles – that is, our prototype drained 89.4% of the liquids.

User Surveys

Understanding user experience was essential to ensure the prototype was practical and convenient for its primary audience: Dartmouth students and staff. Surveys were conducted to gauge the usability, aesthetics, and overall satisfaction with RECYCLEASY. Users were asked to rate their experience on a 10-point scale, and the prototype achieved a median score of 7.0 on ease of use and aesthetics.

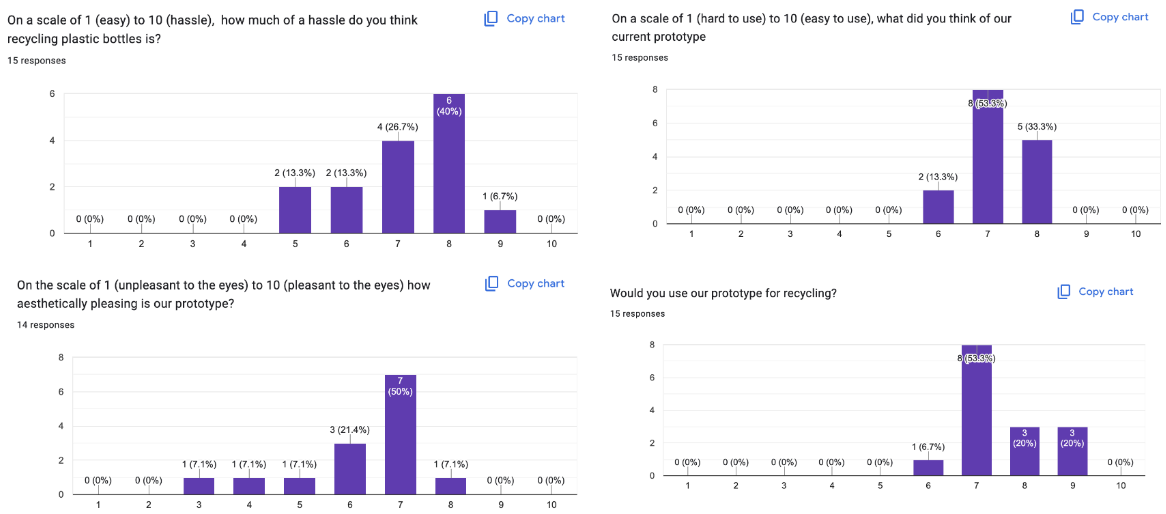


Figure 8.3. Survey Results

While the feedback was largely positive, it also revealed areas for further improvement. Some users found the sensors insufficiently sensitive, which occasionally affected the automation. Durability was another concern, with suggestions to reinforce the prototype to withstand heavy usage. Additionally, feedback on aesthetics indicated that while the design was functional, it could be more visually appealing to fit seamlessly into public spaces. These insights guided future iterations, ensuring the prototype evolved to effectively meet user needs.

Custodian Feedback

The custodial staff, as the primary maintainers of the system, provided valuable insights into the prototype's operational practicality. During the testing phase, custodians highlighted two key concerns: the capacity of the system and the placement of LED indicators. Initially, the prototype's capacity was limited to 24 bottles, which necessitated frequent emptying. The LED indicators, positioned next to the motor, were less visible to users than anticipated, leading to occasional confusion.

In response, the team explored solutions to increase the system's capacity and reposition the LEDs to improve visibility. This feedback also emphasized the need for further testing under real-world conditions to refine the system's maintenance requirements and overall usability.

Recommendations for Future Testing

While the testing process yielded significant improvements, further evaluations are recommended to optimize the prototype further:

- Deploy RECYCLEASY in various campus locations, such as dining halls and common areas, to understand user behavior across different settings.
- Measure the frequency with which the liquid waste and bottles need to be collected. This data could inform adjustments to container size and storage capacity.
- Extend testing to include cans, ensuring the prototype's versatility in handling a broader range of recyclable materials.

IX. Quantitative Analysis of Specifications

After having completed the prototype and testing, a conclusive summary regarding the outcome of the specifications can be made.

1. High-Importance Specifications

a. **Safety** — For the purposes of this project, it consists of safety regarding electrical hazards and injuries related to the steel mesh. To solve the safety issue, a custom lid was crafted to fit the prototype and extensive care has been taken to cover all the electronics of the prototype. While more testing is needed to conclusively determine the safety of the design, no accident occurred in the two weeks and about 500 bottles of testing. Thus, the safety spec is considered a success.

b. **Ease of Use** — This criterion comes directly from the formulation of our problem statement and constitutes the heart of the issue we are challenging. Most people do not recycle because it is inconvenient and time-consuming to do so. An easy-to-use solution, which involves little extra input like draining and rinsing the bottles, would incentivize people to recycle more as it costs them little to no time. In the final design, the whole process, including uncapping the bottle, takes about **3 seconds** on average, which while long compared to the benchmark of a regular trash can, is significantly shorter than manual draining. Our survey results confirmed this expectation, with people ranking the ease-of-use of the design a **7.2/10**, which is a clear improvement on 7/10, which was our initial goal.

c. **Capacity —** Another integral design consideration is the capacity of the product. A low-capacity product would both be detrimental to the recycling service workers and prone to more errors due to machine clogging. To align with our problem statement, the project must meet the capacity requirements to successfully replace regular recycling bins. Our aim for our product was to have **80%** of the bottle capacity of a regular bin of its size. In the end, we only achieved 24 bottles of storage, which is **60%** of the benchmark. Considering, also, the semi-frequent issues with machine jamming due to limited size, we can conclude that this spec still needs to be improved.

d. **Effectiveness (Dryness) —** The main issue with recycling is that the PET bottles need to be in a very specific state to be reprocessed: dry, clean, labelless, and capless. We encountered multiple patents offering solutions to the other issues and decided to focus on the dryness of the bottles. As such, effectiveness will be a measure of how well the machine drains the bottles. The aim was to reduce the liquid waste to less than **10mL/bottle**, with current benchmarks placing the problem at about 29mL/bottle. In the end, the design performed very differently with the two different types of bottles tested. In one, we managed to reduce the waste to about **2.5mL/bottle**, while the other saw a lacking effectiveness of **20mL.bottle**. Thus, the outcome of this spec is unclear and in need of further examination.

2. Medium Importance Specifications

a. **Cost** — As with any project, cost is a major aspect of its engineering, though perhaps not as mandatory for this one as it is not a product to be owned by individual customers. Still, a low cost is desired to allow for large-scale production and distribution of the product; having this product in just a few places around campus will not meaningfully improve recycling as people will find it hard to reach said locations. An initial budget of **$100** was set before starting the project. Looking back, the total material cost of the second and final prototype is **$95**, with significant reductions foreseen as scale of production grows. As such, the goal has clearly been surpassed.

b. **Size** — Similarly to cost, an appropriate size is important for a more dense distribution of the product in a particular environment; a lot of smaller bins is better than a few very large ones. We have decided that a good metric would be to base our quantification off of trash cans already present on campus, and thought that **0.5x0.5x1m** would be a reasonable goal. The final prototype approached, but did not meet, this criterion due to the necessity of an additional bottle storage system outside the main trash can, ending up becoming **0.74m** in one dimension.

c. **Durability —** Durability is included in the specifications for its indirect effect on many other specs, namely cost and efficiency. A highly durable device will operate for much longer without needing extensive maintenance, therefore reducing costs. Initially, we hoped to have a lifespan of at least 30000 thousand bottles, or about **a year** of moderate use. Unfortunately, the longevity of the current design is far from meeting those goals, with daily machine jamming and weekly battery replacement problems hindering its performance.

3. Low Importance Specifications

a. **Toughness —** A similar, albeit less important, specification is the toughness of the device, which we define to be the ability of the product to resist outside effects and improper use. Currently, the design handles the inclusion of different types of materials like cans and cups relatively well, but faces significant jamming problems when a larger-than-anticipated object is thrown. Thus, the current design falls short of being adequately tough, but promises a ubiquitous solution to recycling once the jamming problem is addressed.

b. **Aesthetics —** Lastly, an aspect to consider is the aesthetics of the design, as this machine will stand in communal spaces. However, this has less to do with the interior engineering and more with the exterior design. In the end, the design doesn't look dissimilar to a trash can, with several people commenting on how the added machinery made it look better. The general survey results rate our prototype at **6.2/10,** which is decidedly higher than the setpoint of **6/10**, signifying success.

Specification	Justification	Quantification	Final Results
Legality and Ethics	All projects need to be legal and ethical	Yes/No	
Cost	The project must cost appropriately to allow for large scale implementation around the campus	< $100	$25 (Arduino) + $40 (Trashcan) + $15 (Sensor) + $15 (Misc. Parts) = $95
Safety	The liquid tank must be properly isolated and kept away from the circuitry to not cause electrical accidents	< 1 accident per 1000 bottles	A lid covers the inner workings of the machine and all of the liquid containers are properly sealed to eliminate leakage
Size	The size should be comparable to a typical recycling bin to properly replace traditional bins	< 50cm x 50cm x 100cm	The extra trash can used for bottle collection makes the design larger in width than was desired.
Ease of use	Given that the project seeks to make recycling easier, the product should be easy to use	≥ 7 on 1-10 survey results	7.2/10 Mean 7/10 Median

Specification	Justification	Quantification	Final Results
Durability	The machinery should work faultlessly for months with minimal maintenance	Life expectancy > 30000 bottles	There remains a significant possibility of bottles jamming the machine
Toughness	The design must resist improper usage (e.g. putting the bottles in with too much force)	Testing	For the most part, but still prone to misuse if people put too many bottles at once
Capacity	The design should have sufficient bottle and liquid storing space relative to its size	> 80% of the size is used for storage	The current capacity is 24 bottles, or 60% of maximum capacity
Effectiveness	Is the effectiveness of draining worth the extra costs of installing and maintaining the mechanism	Drains ~90% of the liquid, or reduced the liquid waste per bottle to less than 10mL.	The prototype provides results above the specs in one type of bottle and below the specs in another.
Aesthetics	Given that this will be a trash can for public spaces, it needs to fit in with the environment aesthetically	≥ 6 on 1-10 survey results	6.2/10 Mean 7/10 Median

Figure 9.1

List of specifications, justifications, quantifications,and final results from testing

X. Ethics & Sustainability

Ethical Considerations

From an ethical standpoint, the project was designed to ensure safety and accessibility for all users. A key challenge was addressing potential risks associated with handling liquids and operating mechanical components. To mitigate these risks, the team implemented several safety measures:

- The wire mesh, essential for drainage, was initially exposed and posed a potential safety hazard. This was addressed by enclosing the mesh, preventing accidental contact while maintaining its functionality.
- Given the presence of liquids, the team took precautions to shield all electrical wiring and components, significantly reducing the risk of accidents.

The ethical implications of unintended use were also considered. The design acknowledged the possibility of misuse, such as users disposing of non-plastic items or failing to remove caps from bottles. To address this, the team included clear signage and simple instructions to guide proper use.

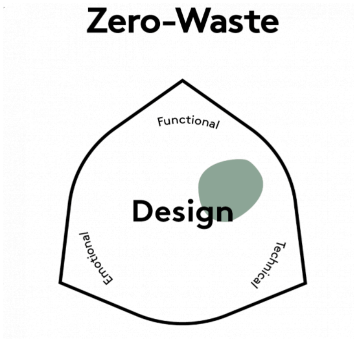


Figure 9.1. Zero Waste Icon, https://sustainabledesigncards.dk/zero-waste/

Sustainability Considerations

Sustainability was at the heart of RECYCLEASY's design ethos and purpose, as the prototype sought to enhance recycling efficiency while minimizing its environmental footprint. The team prioritized waste reduction and resource efficiency in several ways:

By effectively draining liquids from bottles, RECYCLEASY reduced contamination in recyclable materials, enabling sorting facilities to process plastics more efficiently. The prototype was largely passive in operation, relying on minimal energy for its automated features. This low-energy approach ensured that the system's environmental impact remained minimal during usage.

While the prototype incorporated durable materials such as PVC pipes to ensure functionality and longevity, the team recognized the environmental drawbacks of PVC due to its high Okala impact score. **As such, to improve the sustainability of our product, we seek to explore eco-friendly alternatives such as cast iron or biodegradable materials in future iterations.**

XI. Business Plan

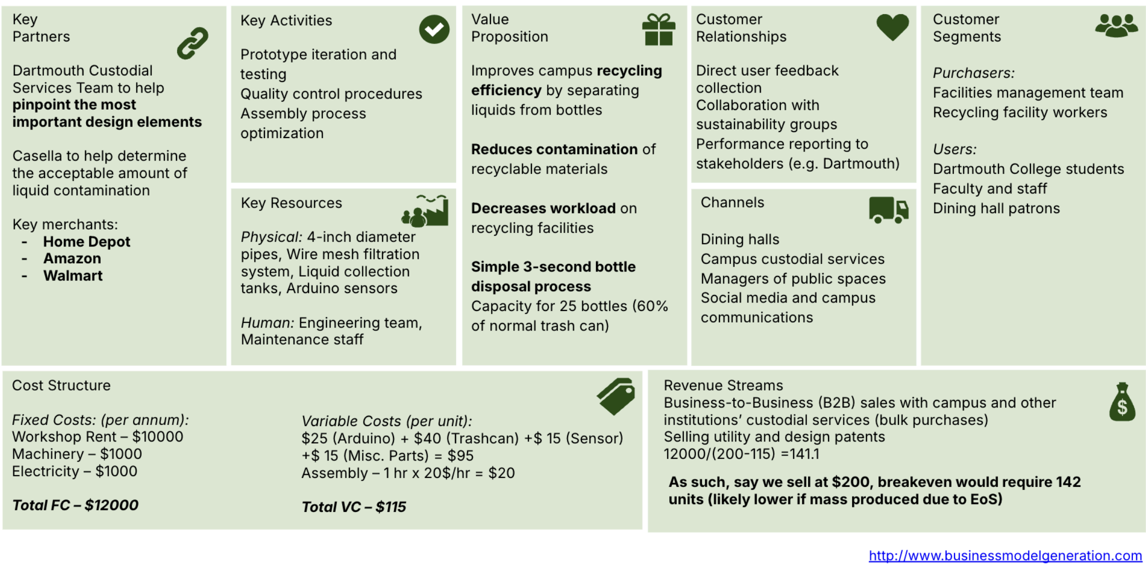


Figure 10.1 Business Plan Canvas

Our key partners involved include Dartmouth Custodial Services, which plays a vital role in refining the design by identifying critical requirements, and Casella, a recycling company providing insights on acceptable levels of liquid contamination. Key merchants such as Home Depot, Amazon, and Walmart are identified as suppliers of necessary materials.

The value proposition focuses on improving campus recycling efficiency by effectively separating liquids from bottles, thereby reducing contamination in recyclable materials. This innovation decreases the workload on recycling facilities and offers users a simple and quick three-second bottle disposal process. The system can hold 25 bottles, approximately 60% of the capacity of a traditional trash can, ensuring practicality without sacrificing efficiency.

Key activities include iterative prototyping, testing, quality control, and assembly process optimization to ensure the product meets performance and usability standards. The physical resources required include 4-inch diameter pipes, a wire mesh filtration system, liquid collection tanks, and Arduino sensors, while human resources are concentrated on the engineering and maintenance teams.

The financial plan includes fixed costs of $12,000 annually for workshop rent, machinery, and electricity. Variable costs per unit are calculated at $115, including materials and assembly. Revenue streams focus on B2B sales to custodial services at campuses and other institutions, with potential revenue from utility and design patents. **At a selling price of $200 per unit, the breakeven point is estimated to be 142 units,** a figure expected to decrease with economies of scale.

XII. Reflections & Next Steps

Looking back, we identified several areas of improvement, namely our **project scope**, **prototype iteration**, **resource allocation**, **testing**, and **feedback.**

Firstly, our project scope could have been wider. Early in the term, we narrowed our scope from aluminum cans and plastic bottles to only the latter. This gave us a more manageable scope, indeed, but we later realized in our testing phase that our prototype could also handle aluminum cans. This is notable given that many beverages on-campus are sold in these containers. Going forward, we will also include aluminum cans in our specifications, benchmark testing, and prototype testing.

Secondly, we could have iterated more on the important design choices (e.g., the mesh angle and container sizes). While we did extensively test throughout the building process, we still realize that more iterations could have better optimized our designs. For example, in the future, we could test a wider range of mesh angles to determine which would work best with our sensor-operated door. Additionally, a larger container would have increased our capacity and decreased the frequency of maintenance.

This leads to another area of improvement: resource allocation. Our team should have adopted a more “make things, break things” approach. We were, at times, hesitant to find more creative solutions as we had unnecessarily limited ourselves to only one prototype (i.e., only one trash can/container).

Thirdly, our testing phase should have answered the question, “How often do the liquid waste and bottles have to be collected?” This is an important point for our purchasers, especially the custodians who are responsible for maintaining the prototype.

Lastly, we should have considered earlier and constant feedback from all stakeholders (students, custodians, Casella, sorting facilities, etc.), which would have led to more informed design choices. We still collected user and purchaser feedback, of course, but much of it was late into our testing phase.

As a team, we feel that this class introduced us to the essence of engineering: make, break, iterate. While we are still inexperienced in much of the prototyping process, we learned a wealth of important skills that helped us improve tremendously. And all told, we will leave ENGS21 with a more creative, confident, and solution-driven outlook on our engineering problems.

Acknowledgements

We would like to thank the following people for helping us throughout our learning journey: Professor Vicki May, Susan Weider, Kevin Baron (our assigned Technical Instructor), the ENGS21 Review Board, Tad Truex, Danny DeNauw, Joe Poissant, Marina Rodriguez (our assigned TA), and the MShop and ENGS21 TAs.

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