Junk Jenius: Final Report

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Executive Summary

Our capstone project, the Plastic Bottle Recycling Machine, is an innovative solution designed to simplify and encourage recycling on campuses and other high-traffic public spaces. The machine cuts, drains, and crushes plastic bottles in one streamlined process, addressing common barriers to recycling such as leftover liquids and the effort required to manually prepare bottles for recycling. The machine utilizes a linear actuator connected to two blades, which ensures efficiency and precision.

The machine's design allows users to insert plastic bottles into a chute made of PVC pipe. The bottles then drop into another pipe where, upon pressing a switch, the linear actuator activates the blades to simultaneously cut and crush the bottles. The crushed bottles and drained liquid fall into a bin with a filter, allowing the liquid to flow out while retaining the crushed bottles. A slanted pipe ensures effective drainage, making the process hygienic and efficient. Its one-button operation makes it accessible to users of all ages, while the compact and robust design allows for easy installation in various locations. Additionally, the machine is constructed using sustainable materials wherever possible and is designed for minimal energy consumption.

Unlike existing solutions that require users to manually empty and prepare bottles, our machine automates these steps, making recycling quicker and hassle-free. Competing machines often focus solely on crushing, whereas our multi-functionality reduces waste volume and optimizes recyclability in a single device. By focusing on essential features and leveraging standard components like linear actuators, our design is both affordable to produce and maintain. Studies show that convenience significantly impacts recycling rates, and by removing common barriers, this machine encourages users to recycle more frequently.

Our primary target market includes college campuses, where students are often deterred from recycling due to inconvenience. High foot traffic in these areas ensures consistent utilization. Public trash areas such as parks, malls, and stadiums also benefit from reduced waste volume and cleaner recycling streams. Corporate offices looking to enhance their sustainability initiatives can use this machine as a visible commitment to environmental responsibility. Government and municipal recycling programs can promote cleaner recycling streams and reduce transportation costs by compacting waste.

The design choices reflect careful consideration of practicality and efficiency. The linear actuator and blade mechanism provide precision and durability for cutting and crushing processes while

ensuring minimal maintenance and long service life. The PVC chute guides bottles efficiently into the mechanism, and the slanted ramp ensures all liquid drains effectively, preventing mess and improving hygiene. By addressing the primary reason people avoid recycling—inconvenience—the machine creates a user-friendly experience that incentivizes recycling behavior. Additionally, by selecting off-the-shelf components, manufacturing costs are minimized, making the machine accessible to a broader audience.

The Plastic Bottle Recycling Machine serves a clear need by eliminating barriers to recycling and enhancing waste management efficiency. Its innovative design, combined with a strong value proposition, positions it as a game-changing product in the recycling and sustainability sector. We are confident that this machine will significantly impact recycling rates in its target markets and contribute to global environmental goals.

User Scenario

Emily is a busy college student juggling classes, extracurricular activities, and a part-time job. Like many of her friends, she cares deeply about the environment but finds recycling inconvenient. Her campus is dotted with traditional recycling bins, but the process of preparing bottles—unscrewing the cap, emptying leftover liquids, and crushing them—feels like an added hassle in her already busy day. When she finds the bins overflowing with bulky plastic bottles, she is that much less inclined to add to the pile.

One afternoon, Emily notices the Plastic Bottle Recycling Machine installed at her campus food hall. Curious, she approaches the sleek, compact device with her half-full water bottle. The machine features a chute clearly labeled "Insert Bottle Here" and a simple one-button operation. She drops her bottle into the PVC chute and presses the button. Within moments, she hears a satisfying crunch and sees the crushed bottle fall into the bin below, with the liquid neatly drained into a separate container.

The experience is quick, hygienic, and effortless. Emily feels a sense of accomplishment knowing she contributed to reducing waste without extra effort. Over time, she begins to actively seek out the machines around campus, sharing the convenience with her friends. For Emily and many others, the Plastic Bottle Recycling Machine transforms recycling from a chore into a fun and straightforward activity.

This small change has a ripple effect: recycling rates on campus surge, and Emily becomes more conscious of her waste habits overall. The machine not only simplifies recycling but also fosters a culture of environmental responsibility, proving its value as a practical and impactful solution for modern sustainability challenges.

Design Solutions

The Plastic Bottle Recycling Machine is a compact, user-friendly device designed to fit seamlessly into public spaces such as campuses, parks, and office buildings. Junk Jenius underwent many design iterations to ensure our final prototype fulfilled the intended specifications.

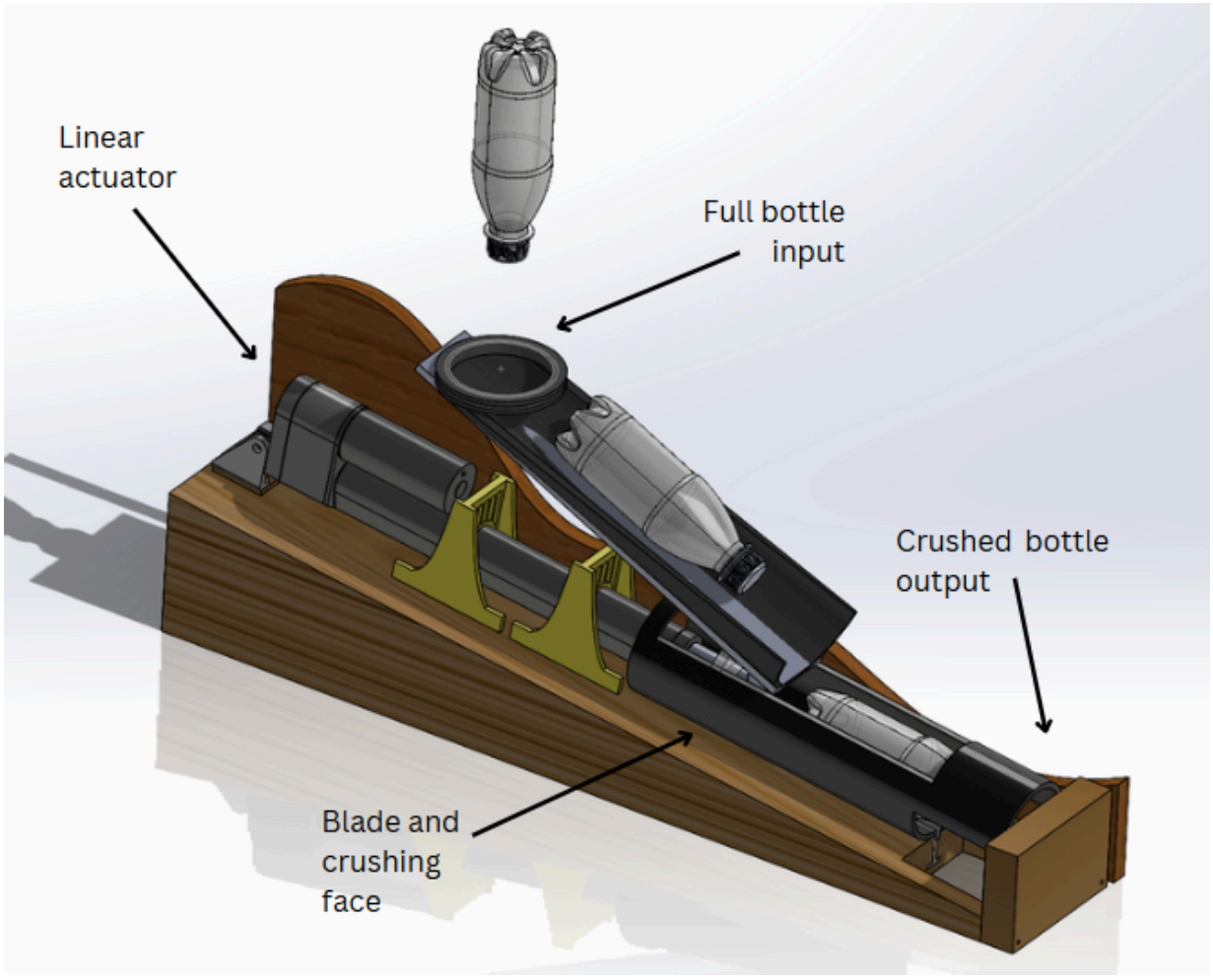
First Iteration: Linear actuator and a pipe

Second Iteration: Added sample blades and custom pipe

Third Iteration: Blades, frames, and ramp addition

Its primary features include a PVC chute for bottle insertion, a slanted ramp to facilitate liquid drainage, and a heavy-duty linear actuator with blades for cutting and crushing. Once a user places a bottle into the PVC chute, gravity guides it into the cutting and crushing chamber. By pressing a single switch, the linear actuator engages, slicing through the bottle while simultaneously compressing it. The crushed plastic and drained liquid are then directed into a bin equipped with a filter, which separates the liquid from the solid waste.

This design offers unintentional benefits, including reducing the frequency of waste collection by compacting bottles, which decreases transportation costs and lowers carbon emissions. The process also raises awareness about recycling by providing an interactive and convenient solution. By addressing user needs, the Plastic Bottle Recycling Machine promotes sustainability and encourages more responsible waste management practices.



Future Iteration: Third Iteration + Bridges

The future iteration aims to further encourage plastic bottle recycling by incorporating an interactive and visually appealing design, featuring Pittsburgh bridge-inspired brackets and a rod holder styled as a red bus.

Market Analysis

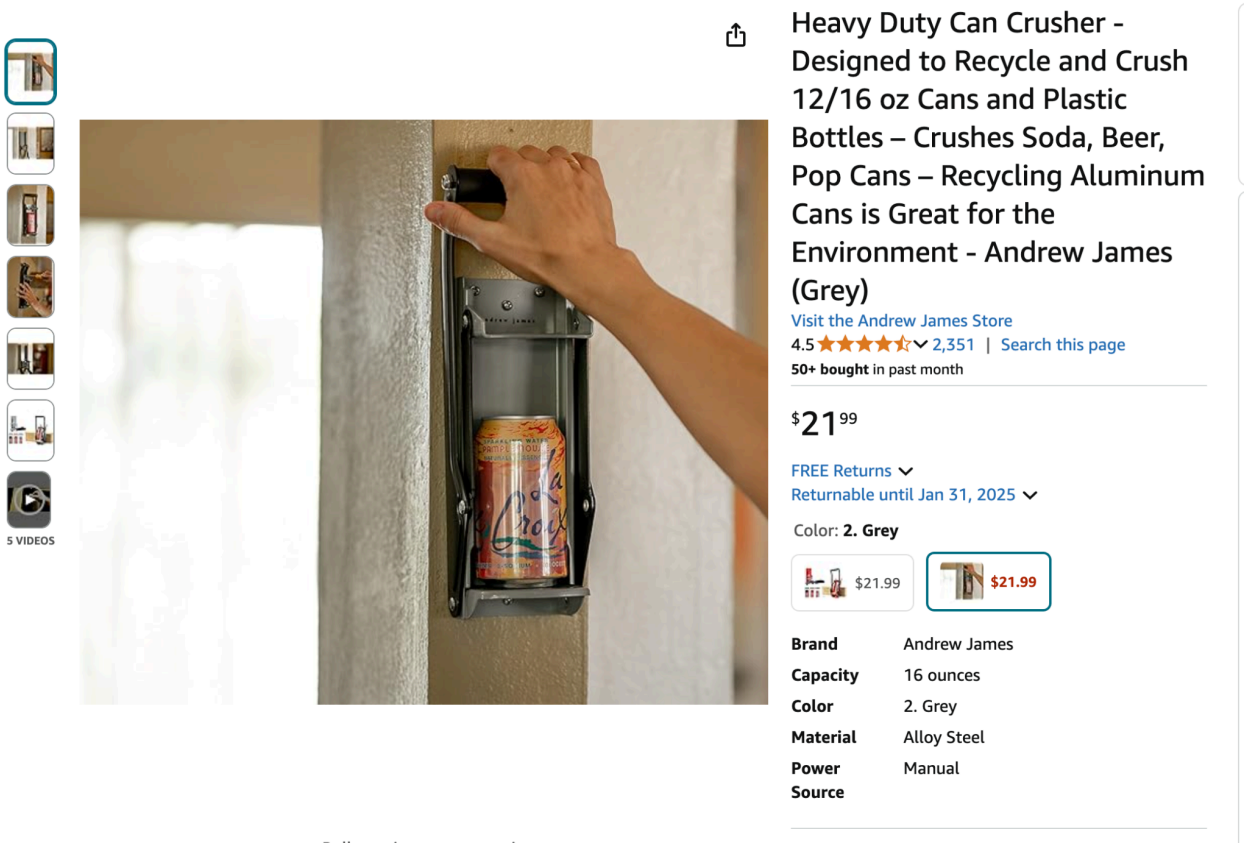
Why We Need a Recycling Machine: Recycling plastic bottles is essential for reducing environmental pollution and minimizing the carbon footprint associated with plastic production and waste management. Despite the availability of recycling bins in public areas, many individuals don't recycle due to the inconvenience of draining liquids or cleaning bottles. Studies show that the majority of plastic waste ends up in landfills or the environment, contributing to pollution and public health risks.

Limited research exists on plastic bottle compactors, which resulted in the identification of the trash can market since the device would be an add-on to a trash can.

Market Size for Trash Cans (Including Smart Trash Cans)

- Trash Can Market Size: The global waste container market is valued at over $2.5 billion annually, with consistent growth driven by urbanization and waste management efforts.
- Smart Trash Can Market Size: The smart trash can segment is relatively small but growing. Market projections indicate an estimated CAGR of 12.4% between 2023 and 2030. The rising adoption of smart home devices is pushing this growth, though most of the demand is still in commercial spaces like hospitals, airports, and urban public areas.

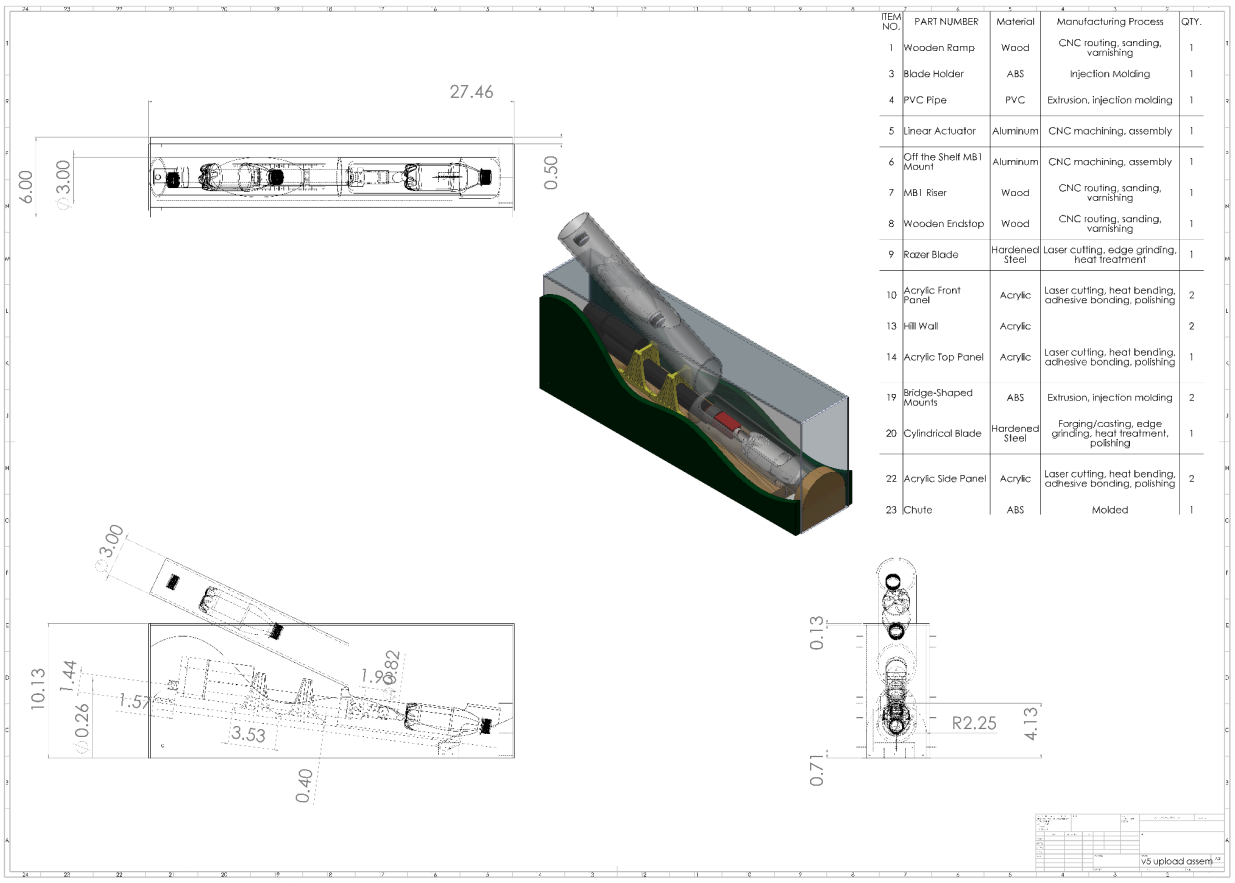
The target market for the Plastic Bottle Recycling Machine includes college campuses, public spaces such as parks and malls, corporate offices, and municipal recycling programs. These locations experience high volumes of plastic waste and have an inherent need for efficient waste management solutions.



Compared to competitors, such as heavy-duty can crushers, our product stands out for its automation, user-friendly design, and integrated functionality. While some competing machines provide crushing capabilities, they often lack a liquid drainage system, making the recycling process messier and less appealing. Additionally, many competitors rely on manual force, requiring users to pull a handle down to crush bottles as shown above. In contrast, our product integrates a linear actuator, eliminating the need for user exertion and providing a more convenient solution.

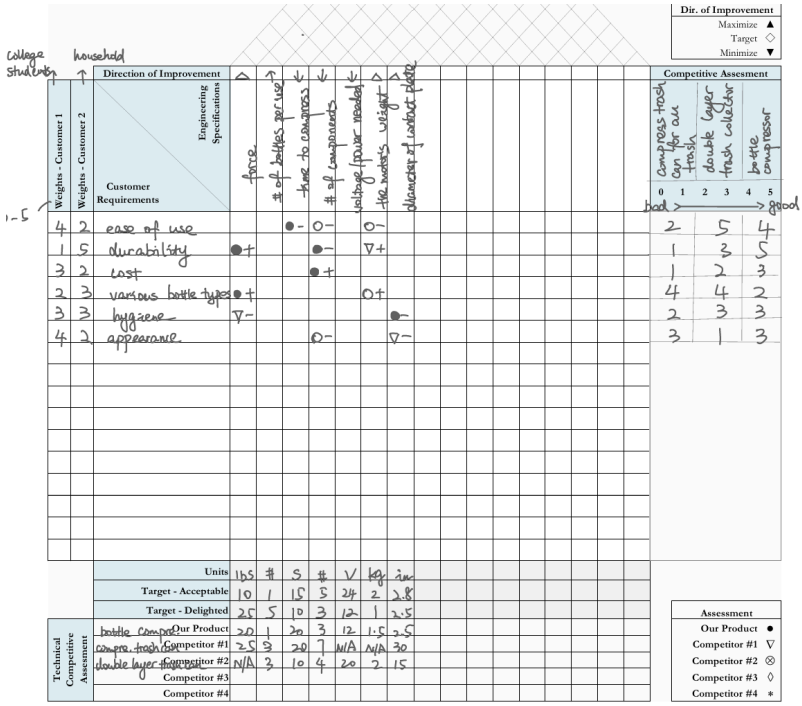
The 180$ estimated cost after mass production is strategically set to balance affordability and profitability. Even though this price is significantly higher than our competitor product shown, ours is fully automated with no manual force required. Outsourcing linear actuators, a key component, can be done cost-effectively, with prices at around $50 per unit. The rest of the price to the manufacturer covers machined parts and manual labor, which results in a profit margin of around 15 percent.

Design Documentation



ITEM NO.	PART NUMBER	Material	Manufacturing Process	QTY.
1	Wooden Ramp	Wood	CNC routing, sanding, varnishing	1
3	Blade Holder	ABS	Injection Molding	1
4	PVC Pipe	PVC	Extrusion, injection molding	1
5	Linear Actuator	Aluminum	CNC machining, assembly	1
6	Off the Shelf MB1 Mount	Aluminum	CNC machining, assembly	1
7	MB1 Riser	Wood	CNC routing, sanding, varnishing	1
8	Wooden Endstop	Wood	CNC routing, sanding, varnishing	1
9	Razer Blade	Hardened Steel	Laser cutting, edge grinding, heat treatment	1
10	Acrylic Front Panel	Acrylic	Laser cutting, heat bending, adhesive bonding, polishing	2
13	Hill Wall	Acrylic		2
14	Acrylic Top Panel	Acrylic	Laser cutting, heat bending, adhesive bonding, polishing	1
19	Bridge-Shaped Mounts	ABS	Extrusion, injection molding	2
20	Cylindrical Blade	Hardened Steel	Forging/casting, edge grinding, heat treatment, polishing	1
22	Acrylic Side Panel	Acrylic	Laser cutting, heat bending, adhesive bonding, polishing	2
23	Chute	ABS	Molded	1

House of Quality



The competitive analysis highlights a mix of strengths and areas for improvement for the product under development. One of the key strengths lies in bottle compatibility, where the product outperforms most competitors by accommodating a variety of bottle types, making it versatile and attractive to a wide range of customers. However, the analysis reveals significant gaps, particularly in durability, where Competitor #4 sets the benchmark with superior materials or construction that allow it to handle wear and tear better. Similarly, cost-effectiveness is another area where the product lags, as Competitor #2 offers a more affordable solution that appeals to budget-conscious consumers. While the product maintains a competitive edge in ease of use and appearance, there are notable opportunities for improvement in minimizing failure points and reducing overall weight to meet or exceed customer expectations and target thresholds. These gaps present clear action areas to enhance the product's marketability.

Standards Review and Evaluation

1. ISO 14001: Environmental Management Systems
    - ➢ Purpose: Provides guidelines for effective environmental management and minimizing environmental impact.
    - ➢ Application: The machine is designed to encourage recycling and reduce plastic waste in landfills, aligning with environmental management goals
    - ➢ Design Features:
        - Use of sustainable and recycled materials where possible.
        - Efficient liquid drainage to prevent contamination.
2. ISO 12100: Safety of Machinery – General Principles for Design
    - ➢ Purpose: Ensures machinery is designed to operate safely, protecting users from potential hazards.
    - ➢ Application: Safety measures are critical to avoid injuries during operation.
    - ➢ Design Features:
        - One-button operation simplifies use and reduces the chance of misuse.
        - Enclosed blade mechanism ensures users do not come into contact with cutting components.
        - Emergency stop ability in case of malfunctions.
3. ISO 602: Plastics – Safety in Processing
    - ➢ Purpose: Provides safety requirements for handling and processing plastics.
    - ➢ Application: Ensures safe handling of plastic waste during the cutting and crushing process.
    - ➢ Design Features:
        - Hygienic liquid drainage prevents bacterial growth or contamination.
        - Slanted pipe design minimizes residue buildup.
4. IEC 60204-1: Safety of Machinery – Electrical Equipment
    - ➢ Purpose: Defines safety requirements for the electrical systems of machinery.
    - ➢ Application: Ensures the electrical components of the machine operate safely.

- ➢ Design Features:
  - Proper insulation of electrical wiring.
  - Safe and intuitive switch design to prevent electrical hazards.
  - Low-power design to minimize electrical consumption.

5. UL 94: Standard for Flammability of Plastic Materials
   - ➢ Purpose: Sets fire safety standards for plastic components.
   - ➢ Application: Ensures that the PVC chute and other plastic parts are fire-resistant.
   - ➢ Design Features:
     - Use of fire-resistant PVC for the chute and housing.
     - Proper ventilation to prevent overheating of components.

Design Analysis

DFMA Analysis:

Findings:

- Simplified design with a limited number of components to streamline manufacturing and assembly processes.
- Use of standardized parts like the linear actuator and PVC piping minimizes complexity and reduces cost.
- Modular construction allows for easy assembly, maintenance, and replacement of components.

Recommendations:

- Use snap-fit connections or standard screws for securing the housing and chute to improve assembly efficiency.
- Optimize the blade and actuator interface for consistent performance and ease of alignment during assembly.
- Minimize the variety of fasteners and materials to reduce inventory and assembly time.

FMEA Analysis

Findings:

- Major Failure Modes Identified:
  - Blade mechanism jamming due to improper bottle insertion.
  - Electrical failure caused by exposure to liquids or wear over time.
  - Actuator misalignment, leading to ineffective cutting or crushing.
- Each failure mode was analyzed for severity, occurrence, and detectability, guiding corrective actions.

Recommendations:

- Incorporate a guiding mechanism to ensure proper bottle alignment before cutting.
- Add a sealed enclosure around electrical components to prevent liquid ingress.
- Implement a regular maintenance protocol and user-friendly diagnostic tools to identify and fix actuator alignment issues.

DFE Analysis

Findings:

- Design Decisions with Environmental Impact:
    - Selection of recyclable and sustainable materials, such as PVC and other eco-friendly components, minimizes environmental impact.
    - Low-power actuator reduces energy consumption, supporting sustainability goals.
    - Efficient liquid drainage system prevents contamination and enables cleaner recycling streams.

Recommendations:

- Explore biodegradable or recycled materials for non-structural components to enhance sustainability further.
- Investigate integrating renewable energy sources, such as solar panels, to power the machine in remote locations.
- Encourage a take-back program for end-of-life machines to ensure proper recycling and disposal.

Mechanical Analysis

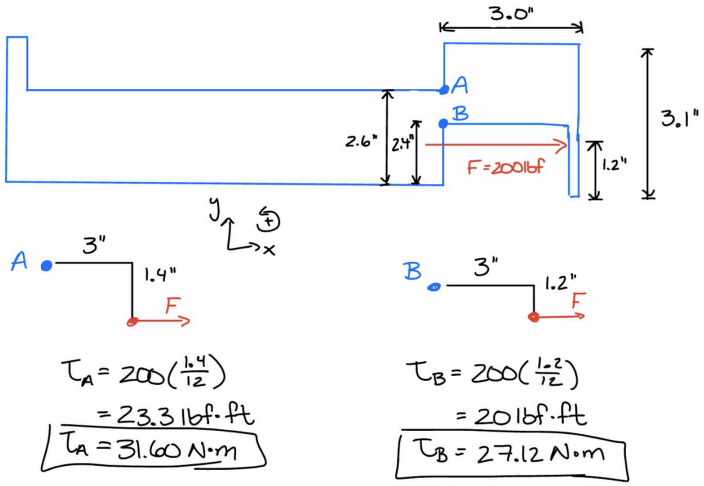
Methods:

1. Mechanical Analysis:
    - Evaluates the force and torque required by the linear actuator to cut and crush bottles.
    - Assesses stress on the pipe weak points and structural integrity of the machine.
2. Water Bottle Crushing Analysis:
    - Most water bottles deform and crush under pressures around 150 psi.
3. Environmental Impact Analysis:
    - Quantifies the environmental footprint of materials and energy use.
    - Assesses recyclability and end-of-life considerations for the machine.

Assumptions:

- Bottles are made of plastic and crush under 150 psi.
- A user inserts a single bottle at a time, with a maximum diameter of 3 inches.
- The actuator operates at full efficiency and has a linear force capacity of 200 lbf.

Free Body Diagram:



Conclusions and Implications for Design:

1. Mechanical Performance:
    - The analysis confirms that a 200 lbf actuator applied torque will be well below the ABS requirement for torque on a single spot.
    - We find that the Fmax of the actuator is 1.25x enough power to crush a water bottle.
    - Blade material (hardened stainless steel) resists wear and maintains sharpness over repeated cycles.
2. Environmental Responsibility:
    - Material choices, including ABS for the chute and recyclable housing, minimize environmental impact.
    - Efficient drainage prevents contamination and ensures cleaner recycling streams.

Justification of Design Choices:

This analysis validates that the machine meets its functional and environmental goals while ensuring user safety and manufacturability. Key design choices, such as the use of a linear actuator, hardened steel blades, and modular construction, are justified by the findings, which demonstrate sufficient performance, reliability, and cost efficiency.

The results of this analysis provide confidence in the viability of the design, reinforcing its suitability for deployment in high-traffic areas to enhance recycling efforts. Detailed calculations and additional diagrams are included in the appendix to support these conclusions.

Prototype Documentation

The final prototype resembles the majority of the final design components. However, the production process for the final product would be different. First, the materials used in the prototype, such as PVC and 3D-printed components, were selected for ease of proof of concept and cost-effectiveness during the development phase. For mass production, we've created a table to show the details of mass production processes.

Component	Prototype	Final Product [Suitable for Mass Production]	Reason
Linear Actuator	Basic off-the-shelf component	Customized actuator	Optimized for durability, cost, and specific application
PVC Pipes	Off-the-shelf pipe	Injection Molding	Consistency in size, shape, and durability
Blades	3D-printed prototype / Manufactured blades from stainless steel tube	Stainless steel blades	Enhanced strength and longevity
Chute	PVC pipe	Molded composite material	Lighter, stronger, and better suited for mass production
Frame	Assembled using acrylic	Integrated metal frame	Improved rigidity and reduced manufacturing complexity
Bin with Filter	Plastic container with basic mesh	Reinforced bin with integrated filter	Enhanced durability and hygiene
Controls	Manual switch	Embedded microcontroller with touch interface	Improved usability and automation

Some users suggested adding visual instructions or indicators to guide first-time users, which will be incorporated into the final design. Feedback also highlighted the importance of ensuring noise levels remain low, particularly for use in indoor settings.

Design Process

Our team's design process emphasized effective communication, clear role allocation, and iterative development to ensure the successful completion of the project. The process began with brainstorming sessions to outline the problem statement and identify key features for the machine. Tasks were then distributed among the four team members based on their expertise:

- Sense: Led the prototype development and facilitated communication and coordination among team members to ensure seamless progress.
- Betty: Focused on electronics and assembly, ensuring that the machine's electrical components and mechanical parts worked in harmony.
- Melody: Took responsibility for computer-aided design (CAD) and prototype construction, producing detailed models and overseeing the physical assembly of the machine.
- Ella: Conducted market analysis and performed hand calculations to validate the machine's feasibility and optimize its performance.

The team maintained regular meetings to monitor progress, address challenges, and refine the design. Updates and feedback were shared through collaborative tools, enabling iterative improvements at each stage. This structured approach ensured alignment with project goals and timely completion of milestones.

Design Status

The product is nearing production readiness, with a functioning prototype that successfully performs the cutting, draining, and crushing of plastic bottles. The following outlines the current status and future steps:

- Production Readiness: The design uses standard components such as linear actuators and PVC pipes, ensuring affordability and ease of scaling for manufacturing. Minor refinements to the assembly process are ongoing to enhance reliability and streamline production.
- Required Additional Testing: Further testing will focus on long-term durability, efficiency under continuous use, and handling variations in bottle size and material. These tests will help identify potential wear and tear and optimize maintenance schedules.
- Future Market Research and User Feedback: Pilot deployments are planned on college campuses and public spaces to gather user feedback and identify areas for improvement.

Surveys and observational studies will help refine the user interface and overall performance.
- Intellectual Property (IP) Assessment: A preliminary review of existing patents in the recycling and waste management space is underway to ensure that the machine's design and functionality are unique. Pending confirmation, we aim to secure a patent for the cutting and crushing mechanism to protect the innovation.

Overall, the project is on track to transition from prototype to full-scale production, with a clear roadmap for addressing remaining challenges and expanding market reach.

Patent Documentation

Invention Description: The Plastic Bottle Recycling Machine is an innovative device designed to automate the recycling preparation process by integrating the cutting, draining, and crushing of plastic bottles into a single, user-friendly system. The machine is tailored for deployment in high-traffic public areas, such as college campuses, parks, and office buildings, to increase recycling rates and streamline waste management. Its compact design ensures efficient operation while maintaining safety and ease of use for all users.

Key Features and Operation:

- Cutting and Crushing Mechanism: The device uses a linear actuator connected to two hardened stainless steel blades. Upon activation, the actuator drives the blades to simultaneously cut and crush the plastic bottles, reducing waste volume and optimizing recyclability.
- Integrated Liquid Drainage System: A slanted ramp with a filter efficiently drains and separates leftover liquid from the crushed bottles, maintaining hygiene and preventing contamination.
- User-Friendly Interface: A single-button operation initiates the cutting and crushing process, making the machine accessible to users of all ages and abilities.
- Sustainable Design: Constructed using recyclable and fire-resistant materials, the machine is energy-efficient and environmentally friendly.
- Modular Construction: The use of standardized components facilitates maintenance, repair, and potential upgrades.

Novelty: The Plastic Bottle Recycling Machine introduces a unique combination of features that distinguish it from existing recycling solutions:

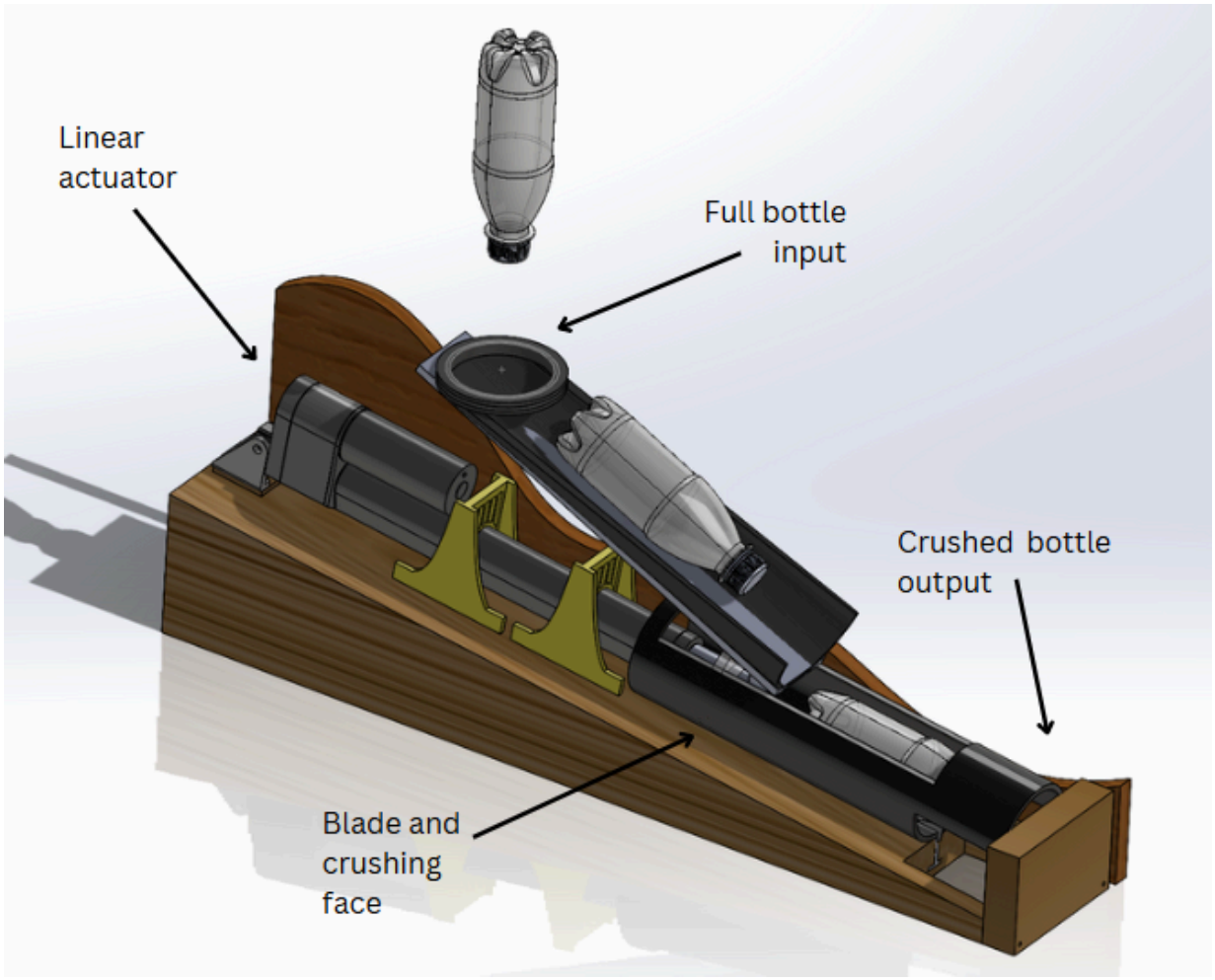
1. Multi-Functionality: Unlike competitors that focus solely on crushing, this device integrates cutting, draining, and crushing into one streamlined process.
2. Automation: The machine eliminates the need for manual preparation, such as removing caps or emptying liquids, significantly enhancing user convenience.

3. Compact and Hygienic Design: Its slanted drainage system and enclosed cutting mechanism ensure clean and safe operation, which is not commonly addressed in competing solutions.
4. Energy Efficiency: Designed for minimal power consumption, the machine uses a low-power linear actuator optimized for durability and cost-effectiveness.

Preliminary Patent Claims:

1. A machine for recycling plastic bottles, comprising:
    - A cutting and crushing chamber equipped with at least two blades connected to a linear actuator for simultaneously slicing and compressing plastic bottles.
    - A PVC chute for bottle insertion, guiding bottles into the cutting and crushing chamber.
    - A slanted drainage ramp with a filter to separate and collect liquid waste from crushed bottles.
    - An integrated waste bin for retaining crushed plastic bottles.
    - A user interface featuring a single-button operation to activate the machine.
2. The machine of claim 1, wherein the cutting and crushing chamber is enclosed to ensure user safety.
3. The machine of claim 1, wherein the components are constructed from fire-resistant and recyclable materials.

Sketch:



Potential Applications:

- Deployment in college campuses, parks, malls, corporate offices, and municipal recycling programs.
- Educational settings to promote awareness of recycling and environmental sustainability.
- Integration into sustainability initiatives led by corporations and government agencies.