Product Development and Mechanical Design

Master in Mechanical Engineering

&

Master in Aerospace Engineering

Smart Trash Can with Odor Neutralization

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Grupo 18

2023/2024 – 1º Semestre, P2

Contents

1 Executive Summary

In this project, we introduce a Smart Trash Can with Odor Neutralization, which aligns with the mission statements outlined. Our product was developed at Instituto Superior Técnico, Lisbon, as part of the Product Development and Mechanical Design course. This all-inclusive design includes need identification, requirement formulation, and mission objective adherence.

A comprehensive knowledge of the product's functionality is provided by the product design, which contains an overview of the architecture and schematic processes. To show the product's component parts and their interactions, the decomposition is described. A separate component is devoted to the thorough design, which uses mathematical models to guarantee the product's performance and dependability. In order to improve different parts of the product, Design for X (DfX) considerations are also taken into account.

Prototyping, testing, and product planning are also covered in the project, illustrating a methodical approach to product development. A financial model and economic judgments are established, offering information on the project's sustainability and viability. The Smart Trash Can with Odor Neutralization was conceptualized, designed, and planned as a comprehensive project, all of which are represented in this work.

2 Mission Statement

Our steadfast commitment revolves around a mission to revolutionize how individuals and households approach organic waste management. Central to this mission is our groundbreaking Smart Odor Neutralization Trash Can, designed to profoundly reshape daily living experiences by addressing the prevalent challenge of unpleasant odors from kitchen waste. Our aim is to elevate overall quality of life, fostering harmony and convenience.

Confronting the environmental concerns tied to organic waste, especially in urban areas where a staggering 39% of waste in Portugal [1] is classified as Organic Waste, our meticulously crafted product seamlessly integrates into daily routines. It offers an elegant and practical solution, going beyond the ordinary to tackle the complex issues associated with lingering odors and contributing to a more pleasant domestic environment.

Our commitment extends to the aesthetic and ergonomic aspects of the Smart Odor Neutralization Trash Can. We strive to maintain the familiar dimensions of a standard trash can while enhancing it with a distinctive and sophisticated design. Lightweight and equipped with handles for easy transportation, our product not only meets but exceeds expected standards, adding practicality and style to every household.

Focusing on intelligence and innovation, our trash can incorporates cutting-edge odor-neutralizing systems. Envisioned as a product that efficiently eliminates unpleasant smells and fosters a perpetually fresh atmosphere, we seek to redefine waste management standards. Our product is versatile, catering to diverse needs in households, restaurants, cafes, food factories, and beyond.

Recognizing potential hesitance in investing in a premium trash can, we emphasize the inherent cost-effectiveness of our system compared to the undeniable benefits it offers. Rooted in the ambition to provide a unique blend of design, elegance, and practicality, our product stands out as an innovation beacon, aiming to pioneer a paradigm shift in the industry.

Our mission is grounded in the belief that a cleaner, fresher, and more stylish home is not just an aspiration but an attainable reality. We are resolutely committed to transforming this belief into tangible experiences, ensuring our Smart Odor Neutralization Trash Can becomes an integral part of every household, transcending the mundane and ushering in a new era of enhanced living.

3 Product Design

3.1 Needs and Specifications

In the field of trash management, the necessity for effective solutions has given rise to the Regular Size Intelligent Odor Elimination Trash Can, a state-of-the-art creation painstakingly designed to meet the changing demands of garbage disposal. This talk will go into detail about the particular specs that support its technological capabilities.

With a volume of 32 liters, this garbage can provides a spacious holding area for organic waste. Its roomy interior strikes the ideal mix between usefulness and spatial economy with careful balance.

The Regular Size Trash Can, with its dimensions of 35x35x64 cm, is a compact design that combines expansive functionality with a small form. Because of its geometric arrangement, it is a prime example of spatial efficiency and can be adapted to a variety of environmental settings.

The automatic lid opening mechanism is the pinnacle of technological innovation and user ease. This feature reduces the risk of cross-contamination by forgoing physical involvement and signaling a paradigm shift toward hands-free waste disposal.

A crucial component of its technology, the filtering system does more than just trap odors; it captures and reduces them in a subtle way. This technique creates a constant improvement in smell, which in turn creates an atmosphere that is completely odor-neutral.

Turning to increased hygienic effectiveness, the garbage can includes a UV LED light element. This innovative technology effectively eliminates harmful microbes and raises the standard of cleanliness. It is a powerful disinfectant.

The charcoal filter system is a notable addition to its arsenal of aromatic mitigation techniques. This outperforms traditional scent removal techniques by effectively entangling and eliminating unpleasant scents, creating an environment that is consistently scented with freshness.

All things considered, the Regular Size Smart Odor Neutralization Trash Can combines a complex array of features. Redefining trash disposal paradigms is made possible by its volumetric expansiveness, spatially thoughtful dimensions, automatic lid operation, advanced filtration system, UV LED light, and charcoal filtration system. This container goes beyond the traditional scope, evolving into a technological marvel painstakingly designed to raise the bar for waste management in a variety of household and business contexts.

3.2 Product Architecture and Schematic Operation of the Equipment

Product architecture is the assignment of a product's functional features to its physical building blocks. This is a critical step since it is here that we describe the basic components of the product in terms of what they do and how they interface with the rest of the device.

There are two key groups that must be considered in the product's architecture: physicality and functionality. Individual operations and transformations that contribute to the overall performance of the group are referred to as functional aspects of a product. The physical elements, on the other hand, are the pieces and components that ultimately implement the product's functionality.[6]

The product architecture can be divided into two types: modular and integral. Each has their merits and downsides, but because we will be including a modular architecture into our product, we will place more focus on this one. The following characteristics define a modular architecture:

- Chunks implement one or a few functions entirely;
- Interactions between chunks are well defined.

The key advantage of this form of architecture is its scalability. Because the chunks implement only one or a few functions, the design team can adjust and focus on one chunk of the product in the future to improve the performance of that specific functionality without interfering with other sections. After some discussion, we obtained the following schematic.

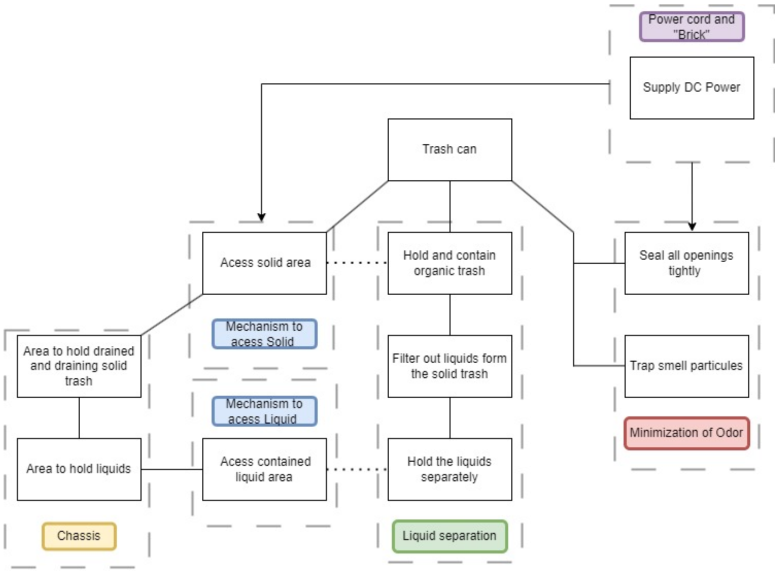

Figure 1: Schematic of the Trash can

Now that we defined the interactions of our product, we proceeded to create a rough geometric layout in order to have and idea what would be our final product.

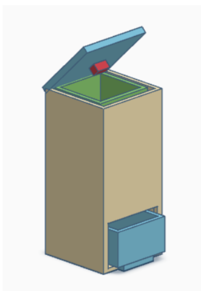

Figure 2: Rough layout of the trash can

3.3 Product Decomposition

We can now proceed to the product decomposition. This is crucial since it will allow us to divide a single problem into multiple subsystems. There are several different sub problems that need to be addressed:

- Overall structure: This is the chassis that will provide structural support to all of our components;
- Solid organic waste storage: This is where the user will input their organic leftovers. This bucket must also be made in a way that separates the liquids that are lost on the trash can from the organic residues themselves;
- Liquid storage: After separating the liquid from the solid leftovers, the product has a container to keep the fluids in.

- Odor decrease system: This system will have two separate subsystems that complement each other: an UV light source that is capable of killing the fermentation bacteria that emerge from the organic waste after a few days, and a ventilation system combined with an active carbon charcoal filter;
- Opening mechanisms: The final user must be able to access both the organic waste area and the liquid area separately.
- Electric circuit: Since we are designing a smart trash can, we need a power source in order to make our components to work.

3.4 Detail Design

3.4.1 Solid storage area - Miguel

All solid organic residue will be stored here by the user. The bucket that remains in the trash container's higher level must have a system that drains the liquid that comes from the organic residue while not allowing the solid parts to flow through. Also, we needed to design a proper handle that does not break while lifting the trash can at full capacity.

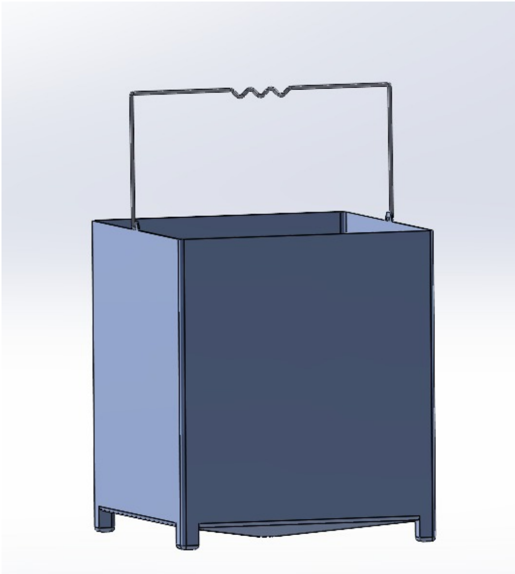

Figure 3: Solid residue bucket

This is the final design that we obtained after thorough consideration. We began by thinking a fairly standard square-shaped bucket that would fit with our chassis, which will support all of the components. We will have an inverted pyramid form at the bottom of the bucket, which will allow all liquid to flow into the middle of the bottom of the bucket, where there will be small holes (figure 4). These openings will allow liquid to travel to the liquid container right beneath the bucket. To support the bucket, we developed four legs, one in each corner of the bucket, so that the pyramid shape would stay in a vertical position into a platform with a large opening to allow liquids to flow through.

It is important first to establish how much solid residues that our bucket can support. We established the following dimensions for our bucket.

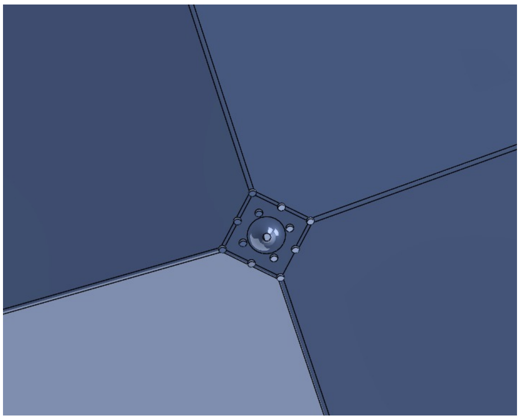

Figure 4: Holes of the solid residue bucket

Part of the bucket	Dimension	Value
Square shaped	Height (dm)	3.2
	Length (dm)	3.1
	Width (dm)	3.1
Pyramid shaped	Height (dm)	0.4
	Length (dm)	3.1
	Width (dm)	3.1
Total Volume (L)		32.03

Table 1: Dimensions of solid organic residue bucket

We can see that our bucket has a capacity of around 32 liters, which is a very standard size for an adequate garbage can. According to "ECO" [3], the average Portuguese individual generated approximately 1.32 Kg of waste per day in 2017. Given that organic residues account for 39% of global trash generated in Portugal, we estimate 0.51 Kg of this sort of waste is generated per day. We must also consider that the average Portuguese household has around three individuals [4], resulting in 1.53 kg of organic leftovers per dwelling. Taking a average density of 1250 kg/m^3 [5] for the organic residues, we can calculate what is the final volume of organic residues how many days does it take to completely fill the bucket.

$$V_{generated} = \frac{\rho_{Residues}}{m_{Residues}} \quad (1)$$

$$Time = \frac{V_{Total}}{V_{generated}} \quad (2)$$

We anticipate that if only one type of waste is organic, the bucket will be totally full after 26 days and when completely full and it will weight around 40 kg. This is presuming that a block of compact trash will be inside the solid residue storage; in a real-world scenario, there will be small areas unfilled by solid residues, hence the real maximum weight will be a lot less, as well as the time to fill completely the bucket.

Keeping this in mind, we will need to design a proper handle that is capable of supporting this amount of weight. For these calculations, we need also to consider the weight of the bucket and of the supports. We estimated a 1.5 mm thickness in our bucket, which will be built of polypropylene (PP), which has a density of roughly 900 Kg/m^3 (table 11). So, the bucket will contribute around 0.54 kg to the final mass, and we can use that to determine the weight due to gravitational force (equation 3).

$$F_g = m * g \quad (3)$$

A maximum force of around 398 N is applied into our bucket. With this information, we can now design our handle.

Type of material	SAE 304 SS
Type of handle	Circular
Tensile Strength (MPa)	550
Diameter of the handle (mm)	4
Area of the handle (mmˆ2)	12.57

Table 2: Handle design

We need to compute the maximum strength that is applied when the bucket is full. We can do that by equation 4, where A_{handle} is the area of the cross section of the handle. Since it will be supported by two sides, we need to divide the final value by 2.

$$\sigma = \frac{F_g}{2 \times A_{Handle}} \tag{4}$$

We concluded that the maximum strength applied is around 15.8 Mpa, a value that is far off from the Tensile strength of our material for the handle. To complement this information, we performed a numerical simulation using Solid Works.

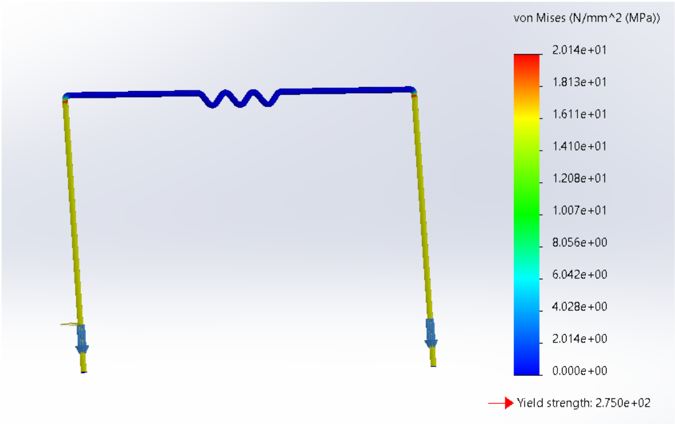

Figure 5: Stress apllied on the handle

Despite using a simple formula, we can see that in the vertical bars we achieved a similar outcome when comparing with the analytical solution.

3.4.2 Odor Neutralization System - Bárbara Ribeiro

The calculations presented are related to the filtering system, exploring the potential use of ultraviolet light for efficient bacteria elimination and suggesting the implementation of a charcoal filter to diminish odors. This system will significantly influence the planning and manufacturing of the waste component, as it is imperative for space conservation and ensuring optimal functionality. These elements are situated within the dustbin, as illustrated in Figure 5.

Both systems will use the same capacity sensor and the same timer.

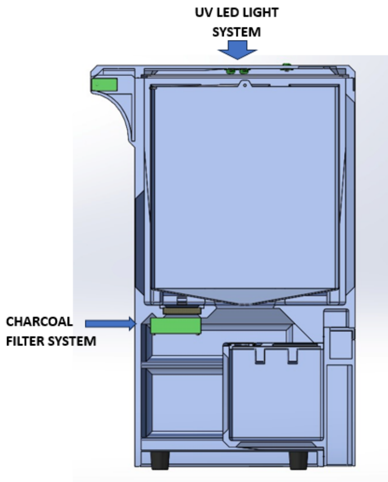

Figure 6: Odor Neutralization System

Ultraviolet LED system

The LED light will act on top of the solid container and this will only elimate the bacterias of the most recent trash added to the bin. The first step is to ensure that the chosen LED light has direct reach to organic waste.

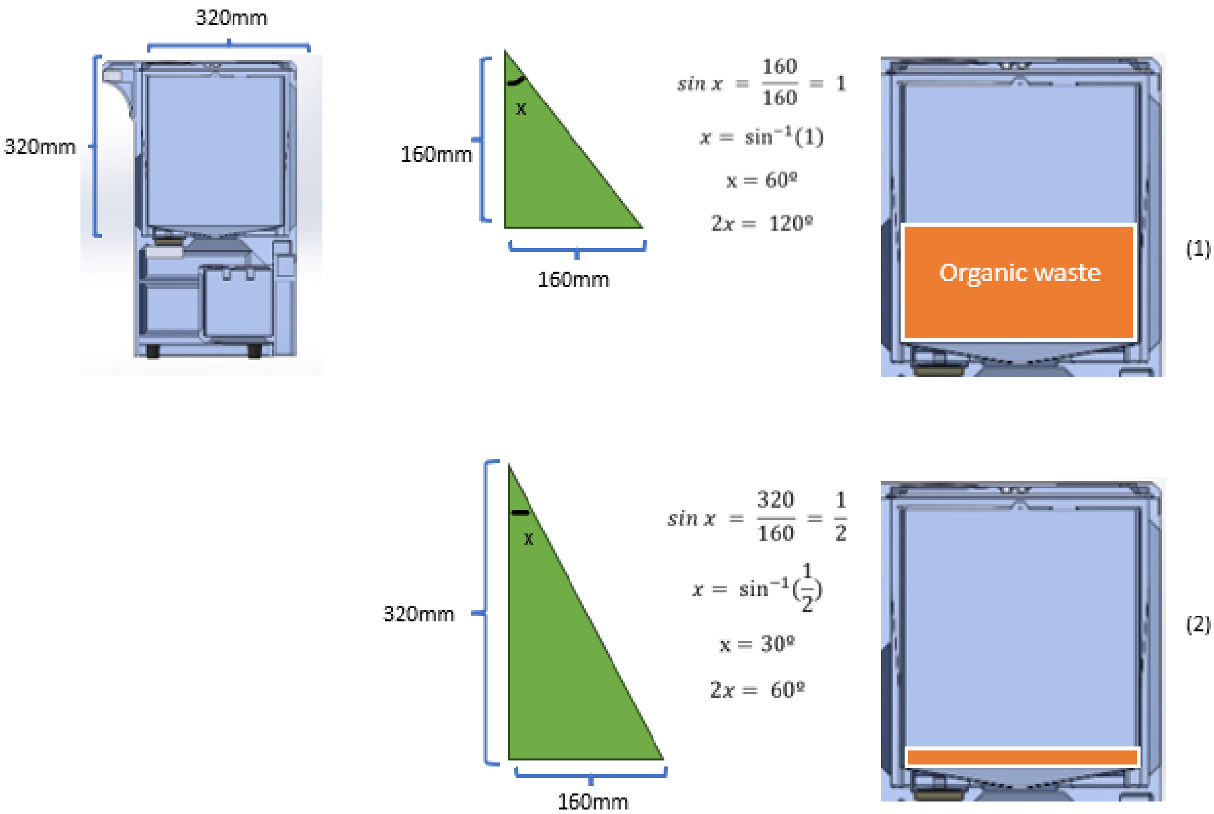

Figure 7: Calculation of the UV LEAD Angle to a dustbin at its middle capacity (1) and to a trash can at his lowest capacity (2)

Caracteristics	Value	Unit
Input Voltage	12	V
Input Current	100	mA
Power Output	0,1	W
Incident Angle	120	º
Wavelenght	275	mm
UV type	C	
Diameter	13	mm
Lenght	8	mm

Table 3: UV LED Light caracteristics

Therefore, considering the dimensions of the trash can and the condition to ensure the smallest possible dead angle for the UV LED light, we need to select an LED lamp with an incidence angle of 120º.

The UV LED light effectively eliminates organic residues if it has an required UV dose of 20mJ/cm2. The dustbin electrical circuit is 12V, so the input voltage of the UV LED lamp is 12V. The power output of the UV LED light is 0,1W, so we will implement 2 UV LED lights to increase the power of the system to 0,2W. The caracteristics of the UV LED light choosen are in Table 3. [2]

The area of the organic solid waste that we need to elimate the bacterias is calculated by the equations 5 and 6.

$$A_s = Base * Lenght \tag{5}$$

$$A_s = 320 * 320 = 1,024 * 10^5 mm^2 = 0,1024 m^2 \tag{6}$$

The exposition time is calculated with the required UV dose and power output as the equations 7 and 8.

$$ExpositionTime = \frac{UVDoseRequired}{UVPowerlight} \tag{7}$$

$$ExpositionTime = \frac{200\frac{J}{m^2}}{\frac{0,2W}{0,1024m^2}} = 102,4s \tag{8}$$

To sum up, with these calculations, we estimate to have the LED light switch on for 2 min each time after the trash can is closed. So, the timer has to be programmed for 2 min. Considering that one family opens the dustbin around 10 times by day, the UV LED light is switch on 20 min per day.

The ultraviolet LED system will be encased in UV safe acrylic to safeguard it against potential dirt or contaminants that may compromise its components. This protective measure ensures the consistent passage of light, maintaining its high-quality bacteria elimination capabilities. We will consider energy losses to be negligible and a lamp with 100% efficiency. [7]

Caracteristics	Value	Unit
Input Voltage	12	V
Input Current	200	mA
Power	2,1	W
Nominal Velocity	2800	RPM
Air Flux	0,02	m3/s
Lenght	15	mm

Table 4: Fan Properties

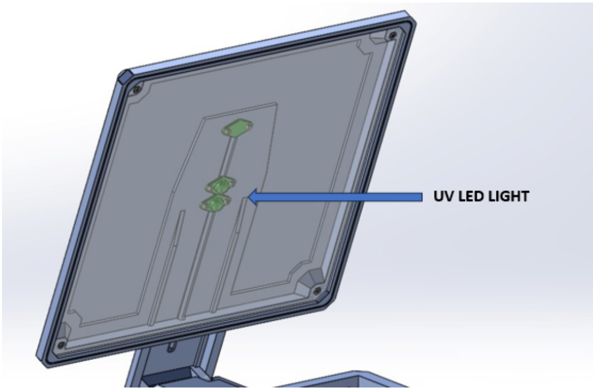

Figure 8: UV LED light in the dustbin

Charcoal filter system

The charcoal filter system is placed between the solid container and the space behind the liquid container. There are one charcoal filter and one ventilator.

It is difficult to have a number that indicates the amount of odors that organic waste produces since organic compounds have very different characteristics.

The charcoal filter choosen has 95 of efficiency. This means that 95 of the odores particules that passes throught the filter are retained. And, consequentely, the odors are reduced up to 95%.

In order for the air to pass effectively through the filter, it is necessary to install a fan. The chosen fan characteristics are in table 4.

So, the clean volume of air is calculated by the equations 9 and 10.

$$CleanVolume = Airflux * FilterEfficiency \tag{9}$$

$$CleanVolume = 0,02 * 0,95 = 0,019\frac{m^3}{s} \tag{10}$$

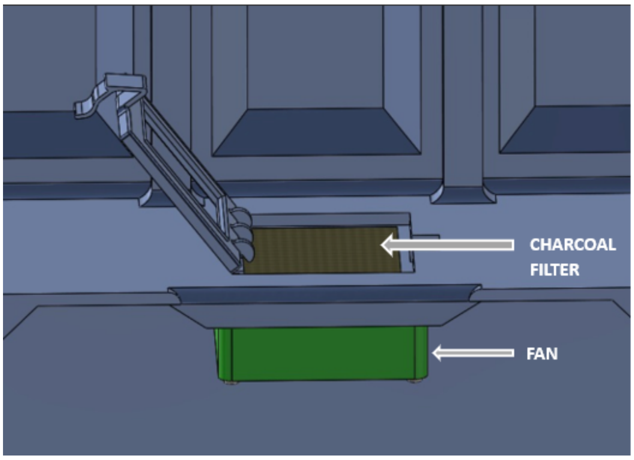

Figure 9: Charcoal Filter system (charcoal filter and a fan)

3.4.3 Liquid storage area - João Morais

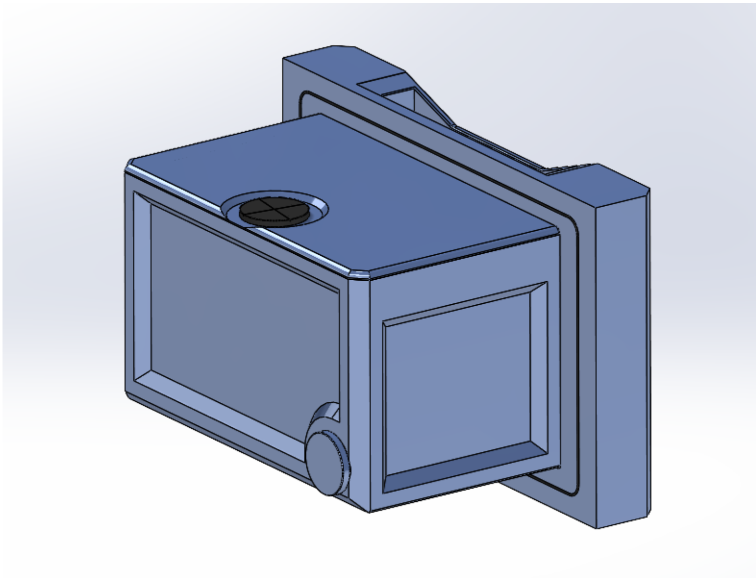

Figure 10: Liquid Storage Area

As explained above, the Smart Trash-can can separate liquids from the trash, and with this in mind, a specialized zone was created to contain all the liquids generated by the trash above. this apparatus consists in a "drawer-like" component, accompanied by a clip-on cover with a rubber entrance seal, and a screw-on cap at the bottom to ease emptying said container. With this assembly in mind, some calculations regarding it's volume, and accompanying components were made, to guarantee a coherent use between all the trash-can´s subsystems.

	Value
Amount of trash per day	1,53 Kg/day
Average moisture content	5 %
Liquid produced per day	0,077 Kg/day
Liquid Density	1,3 g/cm^3
Liquid produced per day	0,059 dm^3/day

Table 5: Amount of liquid coming from organic trash

Knowing the amount of liquid produced by household trash everyday, it is then possible to have a better understanding of the required size for the drawer. As seen above, the Solid trash container, will be emptied every 26 days, and this means that every time the bucket is returned, it has the possibility to be cleaned in-situ, and for this, some more calculations can be made to determine the amount of water dispensed.

	Value
Kitchen tap volumetric flow	0,059 dm^3/s
Average time to clean	10 s
Volume of cleaning water	0,589 dm^3

Table 6: Amount of liquid coming from cleaning solid trash compartment

For a more user-friendly service, 2 cycles of 26 days were considered, leading to a necessary volume of 4,24 dm^3, and with a user-friendly experience still in mind, a coefficient of fullness of 0,75 was implemented, taking the necessary volume to a value of 5,63 dm^3. With this volume in mind and the overall size constraints, the following values were determined.

Inner dimension	Value
Height	150 mm
Depth	150 mm
Width	250 mm
Volume	5,625 dm^3

Table 7: Dimensions of the drawer

Another important component to be analyzed, is the silicone cap, that prevents visual contact with the liquids, inside the drawer, and that provides some safety for the user when dumping the liquids. This cap has to be able to deform when hit by a liquid trash droplet, and to maintain its integrity when not being forced on. To achieve this, we proceeded to calculate the force applied by a liquid trash droplet, which values are presented on table 8, that were then applied through SolidWorks on one of the parts flaps, allowing for the confirmation that the part can deflect when applied by the weight, and behaves as designed to, as can be seen on figure 11. The maximum deflection is also to be expected, and for the application at hand serves the exact purpose necessary.

	Value
Average water droplet size	0,05 ml
Liquid trash droplet weight	$6,5 \times 10^{-5}$ Kg
Gravitational acceleration	9,81 m/s^2
Droplet Force	$6,38 \times 10^{-4}$ dm^3

Table 8: liquid trash Droplet information

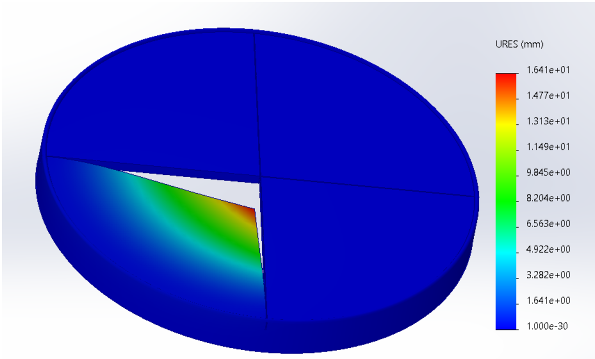

Figure 11: Deformation of Silicone Cap

3.4.4 Automatic Opening - João Gaspar

Considering the use of an automatic opening system, several considerations regarding the operation and sizing of this system need to be made. The intention is to use a general controller to operate a servo motor that will facilitate a 90º opening. Figure 12 illustrates the profile of the mechanism intended for implementation. Therefore, this section will present all the calculations performed for the automatic opening of the trash bin lid.

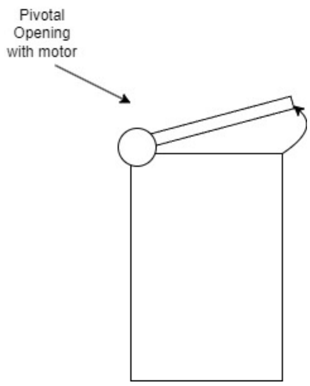

Figure 12: Automatic opening system

The first step in creating this system is to determine the mass of the lid. The base prototype has a lid weighing approximately 750 grams and a length of about 350 mm. This prototype is shown in Figure 13, and as can be seen, it has a protrusion to allow rotation when attached to the servo motor, with a length of about 60 mm.

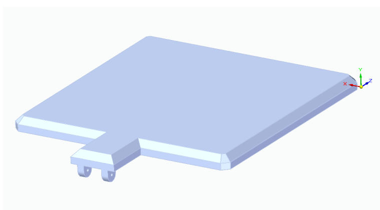

Figure 13: Trash can lid prototype

Now that it is possible to summarize the most important geometric properties, table 9, we can determine the forces applied to the lid and the motor requirements. To do this, we will consider the gravitational force determined by equation 11, where m is the mass and g is gravitational acceleration

$$F_g = m \cdot g \tag{11}$$

Dimension	Value	Unit
Length	0.41	m
Mass	0.75	kg
Gravitational Acceleration	9.81	m/s2
Inertia	0.00735	kg/m2

Table 9: Geometric proprieties and Constants

Next, we will calculate the mechanical frictions of the motor, considering a loss factor.

$$F_T = F_{requidered}(1 + \epsilon) \tag{12}$$

where ϵ are the estimate losses for servo motors. Since the lid will rotate in a fluid, it is necessary to understand the drag effect that the lid undergoes during rotation and its implications for the force required from the motor.

$$F_D = \frac{1}{2}\rho A C_D V^2 \tag{13}$$

where rho is air density, A is the area, C_D the drag coefficient and V the opening velocity. To calculate C_D the trash lid can be considered as a flat plat and is is possible to consider eq. 14 as model

$$C_D = \frac{1.328}{\sqrt{Re}} \tag{14}$$

The Reynolds number (Re) and the motion forces, which include kinetic and static friction constants, are crucial parameters for computations

$$F_k = \mu_k F_N \tag{15}$$

$$F_s = \mu_s F_N \tag{16}$$

where μ is the coefficient and F_n is the normal reaction force. To determine Re and F_D, knowledge of the lid velocity is necessary. However, since the lid undergoes rotational movement without a linear velocity, it becomes necessary to consider the mean velocity at the midpoint of the lid. To achieve this, we assume that the lid completes a quarter of a revolution.

Gravitational Force		
F_g	7.3575	N
Motor's Mechanical Friction		
μ	0.1	
F_N	7.3575	N
F_f	0.73575	N
Air Drag		
ρ	1.225	kg/m^3
V	0.18326	m/s
L	0.35	m
μ	1.81E-05	Pa
Re	4.34E+03	
C_D	2.02E-02	
A	0.1225	m^2
F_D	4.15E-05	N
Static Friction		
μ_S	0.3	
F_N	7.3575	N

F_S	2.20725	N
Kinetic Friction		
μ_K	0.12	
F_N	7.3575	N
F_K	0.8829	N

Table 10: Applied forces in the Trash can Lid

Summing all the forces, it estimated that it is necessary to apply 11.18 N force. Considering a tolerance for the applied as 12 N, the motor needs to provide at least 4.2 Nm of torque. Once this servo motor is attached to the trash can lid, its necessary to check if the supports can hold with this force.

So, a finite element analysis (FEA) was done to understand how the lid behaves with the forces. The simulation was done in SolidEdge, a CAD software with FEA capabilities. Figure 14 shows the used mesh with a base size of 4 mm, the total number of elements is 107430 and the total number of nodes is 190098.

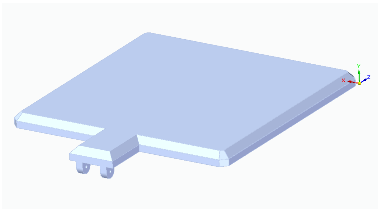

Figure 14: Trash can lid prototype

This simulation was run considering a polypropylene, general purpose, material which data is provided in tabel 11. also, it was considered that the motor suported was pinned and the lid is under a applied force of 20 N.

Property	**Value**
Density	913.000 kg/mˆ3
Coef. of Thermal Exp.	0.0001 /C
Thermal Conductivity	0.002 kW/m-C
Specific Heat	1884.000 J/kg-C
Modulus of Elasticity	1103.161 MegaPa
Poisson's Ratio	0.350
Yield Stress	33.095 MegaPa
Ultimate Stress	0.000 MegaPa
Elongation %	0.000

Table 11: Polypropylene data for FEA

As it is possible to see, the lid is well constructed to hold this load. Figures 15 shows a little defletion which is not significant to the applications, as the deflection value is less than a 0.1mm. Similiar, figure 16 shows the bottom view from the FEM method. The more concerning region is near the support holes in figure

In conclusion, this section has detailed the calculations involved in the automatic opening mechanism of the lid, with a focus on determining the necessary motor torque. Additionally, a Finite Element Method (FEM) simulation was conducted to ensure the structural integrity of the lid, affirming its capability to function effectively. Even under extended periods of operation, it is anticipated that the lid will continue to operate reliably.

3.5 DfX Implications in Design

"Design for X" (DfX) has evolved as a powerful paradigm in the mechanical engineering field, encompassing an abundance of design concepts aimed at maximizing certain areas of the design process. In this context, "X"

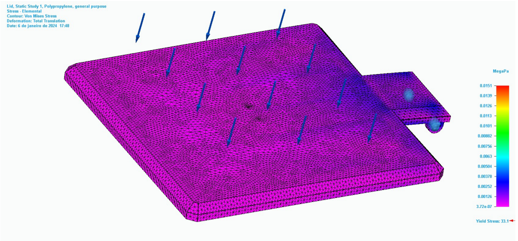

Figure 15: Top view results FEA

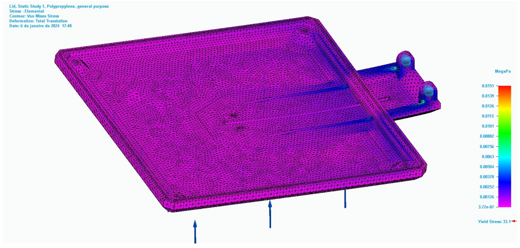

Figure 16: Bottom view results FEA

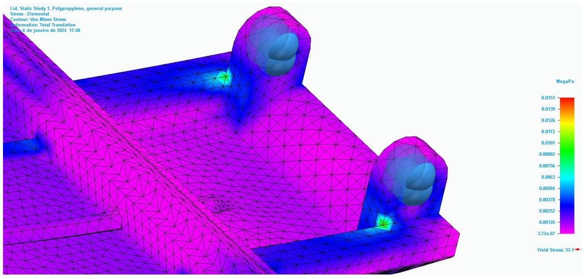

Figure 17: Motor support

might refer to a variety of aspects such as cost, sustainability, assembly, and many more.

One of the main variables is design for value (Dfv), where the type of design is more focused on understanding and meeting the requirements and wishes of the user, rather than the cost of the final product, to provide the best possible experience to the the final costumer. The key point of value engineering is that is not sufficient to only find cost, it is necessary to find the value of each feature, component, and assembly to be manufactured. [8]

The trash can integrates user-friendly features, including:

- A touchless sensor enabling the user to open and close the upper portion of the garbage can without physically touching it, resulting in a more sanitary operation.

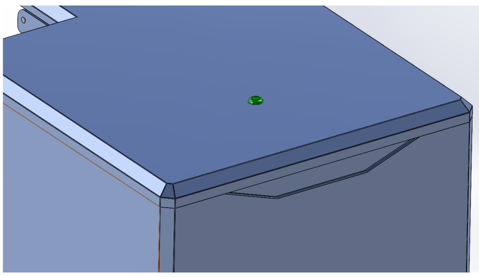

Figure 18: Sensor for opening the trash can

- A programmable timer controlled by a micro-controller allows customers to customize the frequency and duration of bacteria removal, through the use of the inboard UV lights, and fan, removing the need for manual intervention. For safety of the consumer, and minimization of wasted energy, a pressure sensor was installed on the lid opening mechanism, so that the ventilation and UV lights system only works for a certain period of time, and only starts after the lid closes itself.
- An opening mechanism to facilitate the replacement of the carbon filter when it reaches its operational limit. It resembles, both in use and in aspect, the opening mechanism used on the back of TV-remote controllers, used to change its batteries.

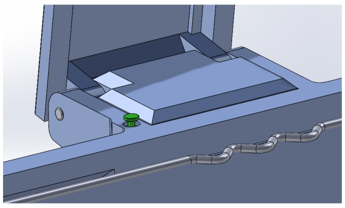

Figure 19: Pressure Sensor

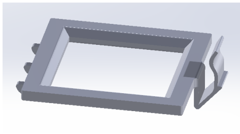

Figure 20: Filter replacement opening system

- The implementation of guide rails, to facilitate the user when placing back said components, that also benefit the user by requiring less force to be opened and slide across each other more easily.

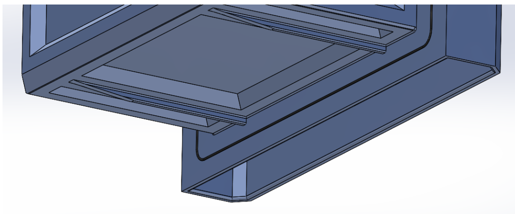

Figure 21: Sliding rails present at the bottom of the drawer

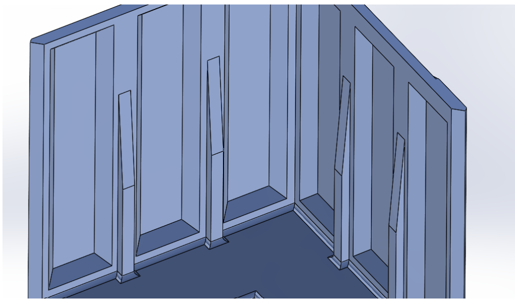

Figure 22: Guide rails on the interior of the upper portion of the chassis

3.6 Prototyping

To gain a sense of what the product would be like, we chose to develop two sorts of prototypes: a physical "looks-like" prototype made of cardboard on a 1:1 scale, and a virtual prototype designed in Solid Works. A prototype is a tangible manifestation of our ideas and it is used to approximate our product into one or more dimensions of interest. [6]

We picked cardboard for our prototype because it is inexpensive and allows for quick conceptualization and customization, making it a useful tool in the early stages of product development.

This prototype was created with the express purpose of gaining a feel for the proportions we chose and communicating with possible customers. We designed a real-scale trash can to communicate our thoughts and concepts in a way that was easy and accessible to our audience, as well as to align potential stakeholders behind a common vision.

This was undeniably beneficial because it allowed our communicators to identify potential issues and misunderstandings about our concept ideas, allowing us to make adjustments and refinements in the future for a better final product, ensuring a smoother path to the desired outcome.

Figure 23: Components of our product

Figure 23 illustrates the many subsystems. The electric circuitry and components were not incorporated into our physical prototype. Cardboard and painters tape were used for all of the components, and we finished with spray paint to make them more visually appealing for presentation, and provide a more uniform surface.

In order to complement our physical prototype, we also designed a virtual prototype. We already presented some pictures in the previous sections, and in 24 we can see a global representation of the product that we imagined.

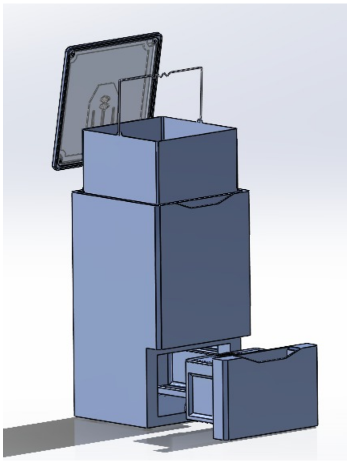

Figure 24: Components of our product

3.7 Testing and Production Planning

Our production approach includes the process of injection molding, which is used to make all non-purchased components of our product. A CNC cutting process is used to precisely construct the molds, which are essential to this process. The precise and effective fabrication of molds that comply with our design standards is ensured by this computer-controlled machining. We use thermoplastic polymer polypropylene, which is robust and adaptable, for the actual molding process. The selection of polypropylene not only satisfies the particular material needs of our product but also demonstrates our dedication to choosing materials that provide a balance between strength, flexibility, and affordability. Our commitment to quality and efficiency in the manufacturing of our components is demonstrated by this injection molding technique, which is combined with CNC accuracy and the use of polypropylene.

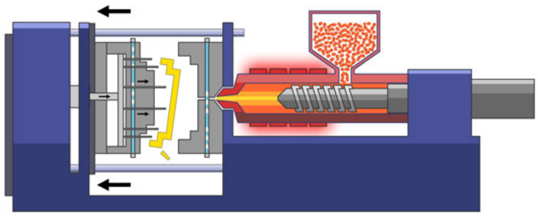

Figure 25: Injection Molding Process

Most of the parts are finely engineered to fit together seamlessly, with interlocking forms providing a snug fit. The electrical parts, on the other hand, are one exception. They are fastened to the assembly using screws. This technique guarantees a strong and reliable connection, making access and maintenance simple when needed. Furthermore, purchased materials are screwed into the molded components to strengthen the final product's structural integrity. In addition to streamlining the assembly process, this combination of exact fits and well-placed screw fastening improves the product's overall longevity and dependability, matching the high standards of quality we strive to achieve.

3.8 Economical Decisions

Table 12 shows the materials required to manufacture the final product, including quantity and cost. The prices provided are from websites such as Alibaba, Aliexpress and so on. Two total costs are shown: one for individually buying parts, and another for bulk buying large quantities. The Bulk Buy value was used for further calculations, as it is lower, and because given the quantity we aim to produce, this would be the only viable option.

Materials	Quantity	Total (€)
UV LED	2	13.02
Timer	1	3.98
Lid switch	1	0.69
Fan	1	3.08
Carbon Filter	1	0.56
Acrylic plate	1	1.68
Servo Motor	1	4.12
Wire	1	2
Micro-controller	1	0.7
Movement Sensor	1	1.92
Power brick	1	3
	Total (€)	34.75
	Bulk Buy (€)	20.85

Table 12: Price and materials bought

The price for the assembly and finishing touches is considered in table 13. A 30 minute period was determined for these actions, based on personal experience, and the ease of assembly/maintenance designed into the product, leading to a total of 9€ per product.

Finishes		
Operator time	Min	30
Other costs	Euros	3
Costs	Euros	9

Table 13: Finishes

The total variable costs is calculated by the sum of the manufactured components, the purchased components and the finishes, as we can see in table 14.

Manufactured Components (Euros)	11.34
Purchased Components (Euros)	20.85
Finishes (Euros)	9
Total Variable Costs (Euros)	41.19

Table 14: Total Variable Costs price

To determine the Total cost, and Selling price, the following relations, present in Table 15 gathered from a thriving product were used on our previously calculated Total variable costs, providing the values shown on Table 16.

Selling Expenses	0,012
Fixed Costs	0,111
Variable Costs	0,877

Table 15: Relation between costs

Total Cost	46,99
Selling price	70,49
Selling Mark-Up	1,5
Margin	0,333

Table 16: Total cost and Selling Price

As shown above, the selling price to the customer came to about 70€, but given the characteristics present in the product, this value could be expected to rise, therefore raising the profit per sale, as the market for this product is not the same as the one for simple trash cans.

3.9 Financial Model

To tackle a financial analysis on our product, the first step was to determine some financial statistics, which were achieved by using values from companies that would be our direct competitors. For this, it was determined that our product belongs in the consumer electronics sector's, household durables category, while creating the financial model. Our estimations and projections were based on this classification. In order to determine an appropriate reference firm, we conducted an analysis of the PulteGroup, a well-known player in the home building market, and from said analysis we were able to produce the following data.

Operating Margin (OPM)	0.2071
Return on Assets (ROA)	0.151
Beta	1.54
r	0,1686

Table 17: Similar Company

With the values above, and assuming a production of 100k products over the course of 7 years, we were able to determine the following values for our operation:

Internal Rate of Return (IRR)	54.14 %
Payback time	3 years
Net Present Value (NPV)	14.9 Million€

Table 18: Financial Model

And with all the values above presented, we can ascertain that this would be a profitable venture.

r	t	0	1	2	3	4	5	6	7	
	CFt (*10^5)	-64.61	12.34	20.98	35.67	60.63	103.08	175.52	49.11	NPV
0.1686	PVCF (*10^5)	-64.61	10.56	15.36	22.35	32.51	47.3	68.81	16.5	14.877
0.5413	PVCF (*10^4)	-64.61	80.07	88.32	97.41	107.43	118.5	130.7	23.76	587.28
0.5414	PVCF (*10^4)	-64.61	80.06	88.31	97.39	107.41	118.46	130.65	23.75	-1048.54

Table 19: NPV

4 Conclusions

To summarize what has been said so far, we have undoubtedly learned and improved our approach to the product design process during the course. We began by identifying real-life issues, such as the smells produced by the fermentation of organic waste after a few days and bag leaking while taking out the garbage.

From here, we attempted to determine how we would address each of these difficulties. We started by breaking down our product into multiple subsystems, and then we created a requirements list and a specification list for our product to meet. After several brainstorming sessions and a very helpful community sketch session, our idea began to take shape. We also performed calculations on our various subsystems to determine whether the models we were creating were viable in real life.

Finally, we created two prototypes, one physical and one virtual, so that we could offer a visual depiction of the product to potential stakeholders. We also conducted an economic and financial analysis to gain a sense of the impact of the design decisions that we made along the design process. We came to the conclusion that the product is economically viable using the templates available on the course web-page.

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Anexos