PDS Report for SeatEd Storage Unit

Will Campisi, Brandon Carmichael, Evelyn Chiu, Mark Tarazi, and Griffin Weaver

CraftEd (Team 4)

MAE 4341

Table of Contents

3. **Market Identification**
    3.1. Target Market
        3.1.1. Market Size – IBISworld/other market reports
    3.2. Consumer Behavior
        3.2.1. Sociological research
        3.2.2. Historical solutions to stated problem
    3.3. House of Quality (again)
        3.3.1. Focus on Competitor Analysis

4. **Financial Requirements**
    4.1. Financial Executive Summary
    4.2. Pricing Policy
        4.2.1. Derived from Conjoint and other observations
    4.3. Bass Model Forecasting to predict product demand
    4.4. Production Costs
        4.4.1. What manufacturing process will you use?
            4.4.1.1. Ashby charts
        4.4.2. Tooling parameters and costs
    4.5. Cost of Goods Sold
        4.5.1. Materials, labor, off the shelf components
    4.6. Warranties
        4.6.1. Weibull distribution around FEA cyclic loading failure prediction
        4.6.2. How will you handle product mishaps?
    4.7. Capital Investment Required
        4.7.1. How will you buy manufacturing equipment or afford to outsource?
        4.7.2. Pay employees to scale up production

5. **Legal Requirements**
    5.1. Safety & Environmental Regulations
    5.2. Potential Liability Issues
        5.2.1. Prediction of Misuse Cases
            5.2.1.1. Failure Mode and Effect Analysis
    5.3. Intellectual Property Considerations?
        5.3.1. Pursue Utility, Design patents? Why?
        5.3.2. Trade secrets? Why?
        5.3.3. Trademark? Describe
            5.3.3.1. Team name and logo
            5.3.3.2. Other trademark opportunities?

6. **Environmental Targets**

6.1. How will the products reduce environmental impact on production?
6.2. How will the products reduce environmental impact upon end of life?

7. Future timeline

7.1. What are your team's actual future plans?
7.1.1. Formation of an LLC?
7.1.2. Crowdfunding?
7.1.3. Pitch Competitions?
7.1.4. Call it a semester?

8. Sources

8.1. Bibliography
8.2. Appendices

Division of Labor

Will Campisi	1.6, 2.1.3, 2.2.1, 2.2.2, 3.3, 4.4.1, 4.6.2, 8.2
Brandon Carmichael	1.7, 2.1.2, 2.3, 2.4, 2.6, 4.4.1.1, 4.6.1
Evelyn Chiu	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 2.1.1, 2.6, 3.1, 4.1, 4.3, 4.5, 5.1, 5.2, 5.3, 7.1.3, 7.1.4 Reviewed final report
Mark Tarazi	3.1, 4.1, 4.2, 4.3, 4.4, 4.5, 4.7, 6.1, 6.2 Reviewed final report
Griffin Weaver	2.3, 2.5, 7.1.1, 7.1.2

1. Product Description Executive Summary

1.1. **Team Name:** CraftEd (Team 4)

Summary of Participants:
Will Campisi, Brandon Carmichael, Evelyn Chiu, Mark Tarazi, and Griffin Weaver

1.2. **Product Name:** SeatEd Storage Unit

1.3. **Problem You Are Solving:**

Based on the empathy fieldwork that we have conducted, where we targeted the freshman college student demographic, satisfaction in dorm living situations is something that many students struggled with. Students complained often about being able to store items inside their room, as well as having a space to host their friends. Thus, the problem we aimed to address is to design a system that enhances college students' lives in small living spaces, such as a dorm or apartment.

1.4. **Basic Functions of Product to solve the problem**

To solve the problem, our goal was to provide multipurpose furniture that increases storage while encouraging socialization. The product is used in three forms. In one form, the product is a storage ottoman that is sized to easily fit under any dorm bed, which we measured to be 22 inches based on a teammate's dorm bed. In the other, the lid of the storage ottoman includes a flip-up backrest that turns the storage ottoman into a comfortable chair. In the final form, the lid of the storage ottoman is flat, allowing the user to place items onto the top of the unit as a coffee table.

1.5. **Special Features of Product beyond core Problem Solution**

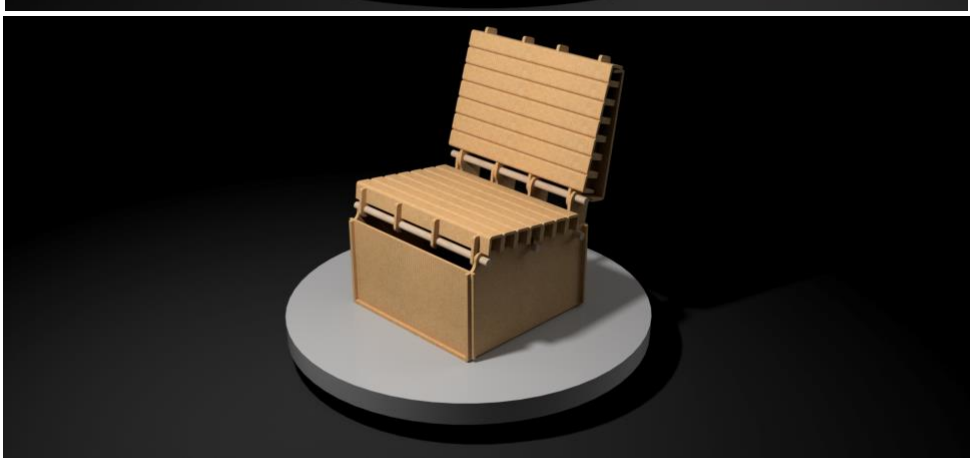
Students typically move several times throughout their college education. This product is made out of cardboard with a sustainable waterproof coating to protect it from liquid damage during usage and transportation. The lightweight cardboard material allows the user to easily lift the product from multiple living spaces. If they no longer have a use for it, the user can also recycle the product at the end of the school year. By recycling our product, users help the environment and save storage space. It also saves students the headache of needing to sell their furniture items when moving at the end of the school year.

To allow for a more comfortable solution for the seat portion of our product, we conducted academic research on the geometrics of the most comfortable chairs. Our seat features a reclined back at 100 degrees, an angle that we researched to be optimal for comfort. The supporting mechanism of the backrest slots into a maple rod to maintain this angle every time the chair is opened to be used. There is also a slant in the bottom portion of the seat base of 5 degrees to maintain ideal comfort for lounging.

1.6. Service Environment Conditions

The product is intended for indoor use assuming a stable temperature of around 70 degrees Fahrenheit. Based on typical room temperature conditions, the low temperature is assumed to be 60 degrees Fahrenheit, and the high temperature is assumed to be 80 degrees Fahrenheit. Due to the small range of temperatures of intended use, it is assumed that the thermal effects on the product will be negligible. The product will include a waterproof coating on the cardboard to prevent damage from occasional spills that may occur. However, the product is susceptible to water damage if continuously exposed to water or due to large spills. Another condition to be mindful of is placing it by a unit heater. Because cardboard is flammable, if the unit is placed too close to a heater, it is possible for it to catch fire.

1.7. Picture of Highest Level CAD Rendering



Figures 1.1 and 1.2 High-level CAD renderings

2. Physical Description

2.1. List of Requirements from Customer

2.1.1. Empathy Field Work

We focused on empathy field work on college freshmen because we felt that they had unique problems and experiences as new students on campus. We grouped our data points into six main categories based on our 204 needs, insights, and surprises. The first was community, where students expressed concerns over fitting into Cornell's community and finding friends. Our second was transportation as understanding the bus system and getting around campus was difficult due to high construction zones on campus. Our third was leisure as maintaining a good work-life balance was important. Our fourth was storage, where students in interviews expressed frustration about being unable to store all of their belongings inside their dorms as they pleased. Our fifth group was academics, where a lot of students were worried about the rigor of a Cornell curriculum, doing well in their classes, and being able to keep up with an overwhelming amount of work. Our last group was centered around meals, where finding good, healthy meals to enjoy on campus was difficult among the crowded dining halls and short hours of operation.

We focused on our storage and leisure categories to develop our problem statement. From our empathy fieldwork, we discovered that students often felt isolated in their dorms and struggled with storing items. Dorm accommodations were usually not up to their standards: closets were narrow, and desks were on the smaller side, making it difficult for freshmen to work on. Many freshmen we interviewed expressed frustration with their current living situations as a result. For instance, we observed a freshman sitting on the floor watching a TV, which he had placed on his floor. We also interviewed a girl who lived in a dorm converted from a lounge who complained about her lack of furniture and storage. Some students were also unsatisfied with finding public spaces on north campus to work or socialize. This was especially a problem that they experienced at night when most freshmen return to north campus.

2.1.2. Analytical Hierarchy Process

The Analytical Hierarchy Process allowed us to visualize the relative importance of the categories that we grouped our emotional data points into. The process starts by completing the Criteria Comparison Matrix using ratings of 1-9, where 1 represents that criterion A and criterion B have equal importance, and 9 represents that criterion A is demonstrated to have much more importance than criterion B. This matrix is then normalized and the average of the row values are taken to obtain the Criteria Weights vector. The consistency is then checked to ensure that the Criteria Comparison Matrix has been set up properly.

	Community	Transportation	Leisure	Storage	Academic	Meals
Community	1.00	1.00	0.33	1.00	3.00	3
Transportation	1.00	1.00	0.33	0.33	3.00	3
Leisure	3.00	3.00	1.00	1.00	5.00	5.00
Storage	1.00	3.00	1.00	1.00	3.00	5.00
Academic	0.33	0.33	0.20	0.33	1.00	5.00
Meals	0.33	0.33	0.20	0.20	0.20	1.00
Sum	6.67	8.67	3.07	3.87	15.20	22.00

Table 2.1 Criteria Comparison Matrix

	Weight Sum Vector	Criteria Weights	Consistency Vector
Community	1.050423224	0.1610721691	6.52144458
Transportation	0.883145153	0.1323365369	6.6734794
Leisure	2.118126435	0.3228469313	6.560776114
Storage	1.618332755	0.2509171068	6.449670872
Academic	0.5548489183	0.08882467121	6.246563154
Meals	0.2743232285	0.04400258465	6.234252618
		average consistency (lambda)	6.447697789
		consistency index (l-n)/(n-1)	0.08953955788
		consistency ratio, CI/RI	0.0716316463
		Consistency:	Consistent

Table 2.2 Checking consistency of the Criteria Comparison Matrix

2.1.3. Conjoint Analysis

In order to get input on what our target demographic desires for multipurpose dorm furniture, we sent out a Conjoint Analysis survey using Sawtooth Software. This analysis allowed us to see what attributes were important to our consumers. The attributes that we included in the survey included price, adjustability, and base material. We varied our price in increments of $50 from $100 to $250. For base material, we asked about corrugated cardboard, engineered wood, plastic, or a composite material; we included photos of each material for the user to reference. The results of the Conjoint analysis are shown below:

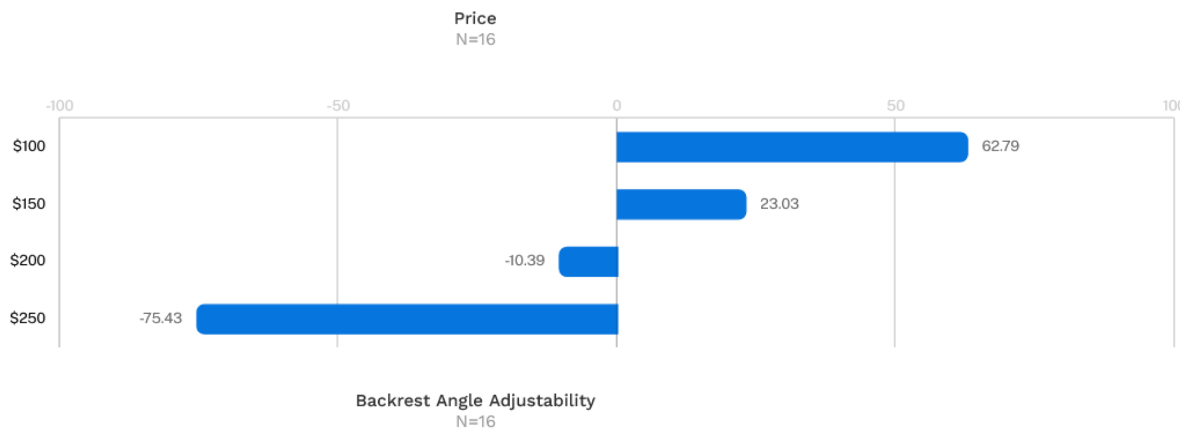


Figure 2.1 Results for Price

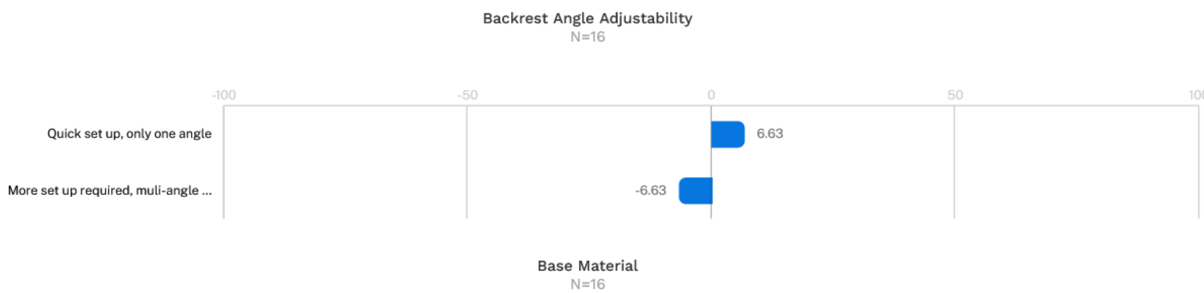


Figure 2.2 Results for Adjustability

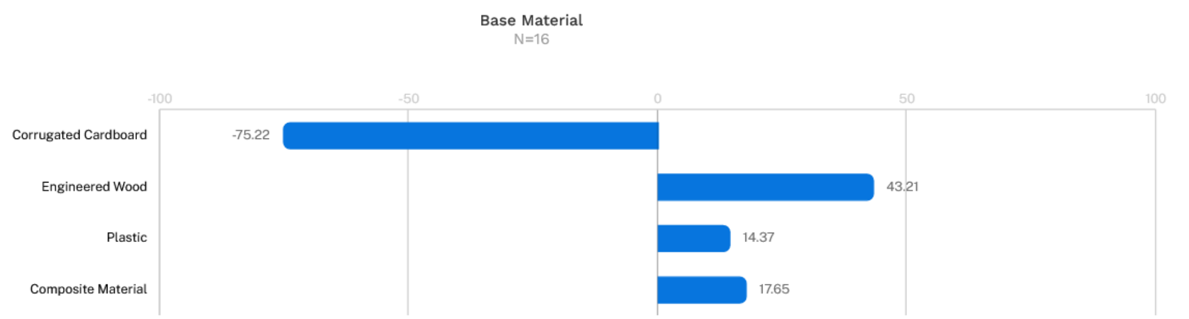


Figure 2.3 Results for Base Material

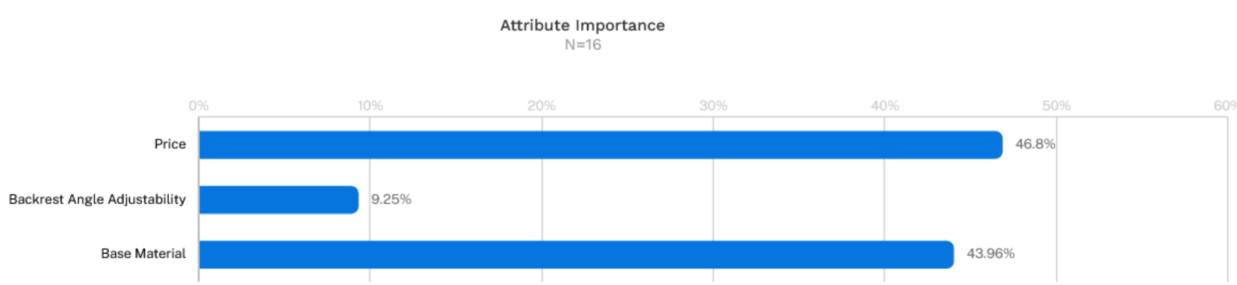


Figure 2.4 Relative Attribute Importance

As shown in the Figures above, our target demographic largely favors cheaper products. They also disfavor our choice of material being corrugated cardboard. It was found that adjustability was not strongly favored either way and was not nearly as important as the other two attributes. Because of this, we decided to omit adjustability from our design as the product was simpler and therefore cheaper without it. The cost of the product was the most important attribute, driving the majority of the decisions that our consumers made. Despite the results of the survey, we decided to make our product out of corrugated cardboard. This allows us to keep the price of the product down, while also reducing the environmental impact of our product. To confirm this choice, we had positive follow-up conversations about cardboard with some of the individuals who completed our conjoint analysis: we specified our reasoning for using cardboard, showed a more developed design, and asked for their opinions.

2.2. Engineering Characteristics of Concept

2.2.1. What manufacturing and assembly methods did you use and why?

After reviewing all options for manufacturing, we found that laser cutting would by far be the easiest, fastest, and most efficient method available to us. The laser cutter provides clean accurate cuts with minimal tolerance. Furthermore, we had a lot of experience operating the laser cutter as one of our team members is the manager of the Rapid Prototyping Lab. We designed our product to be made of flat laser cut parts that slot together with ease for quick assembly. This would allow us to mail our product in flat packaging, which would improve space efficiency and reduce our carbon footprint.

We decided to glue single ply cardboard together to create double and triple ply cardboard as buying it reinforced was costly. We created bends in the flat parts using a press brake to get accurate and straight folds. In the future, when mass producing the product, it would be more cost effective to simply buy double and triple ply cardboard in bulk from a sourcer like Alibaba. We would also likely buy or outsource a die cutter to increase the speed of production.

2.2.2. House of Quality

We used a House of Quality matrix to determine the most important quality characteristics (functional requirements) and demanded qualities (customer requirements). The chosen quality characteristics were expected life, weight, material rigidity, load capacity, cost of production, and comfort. The chosen demanded qualities were, cost, aesthetics, adjustability, user-friendliness, storage capacity, waterproofness, size, ergonomics, and mobility. The relative importance of these was ranked based on user feedback from testing, as well as our conjoint analysis. When conducting user testing, we found that user friendliness and ergonomics were important to our target demographic. Similarly, when conducting conjoint analysis we found that cost was the most important consideration to our users. We then ranked our product against five competitor products to see how our product compared to those already on the market. The House of Quality is shown below:

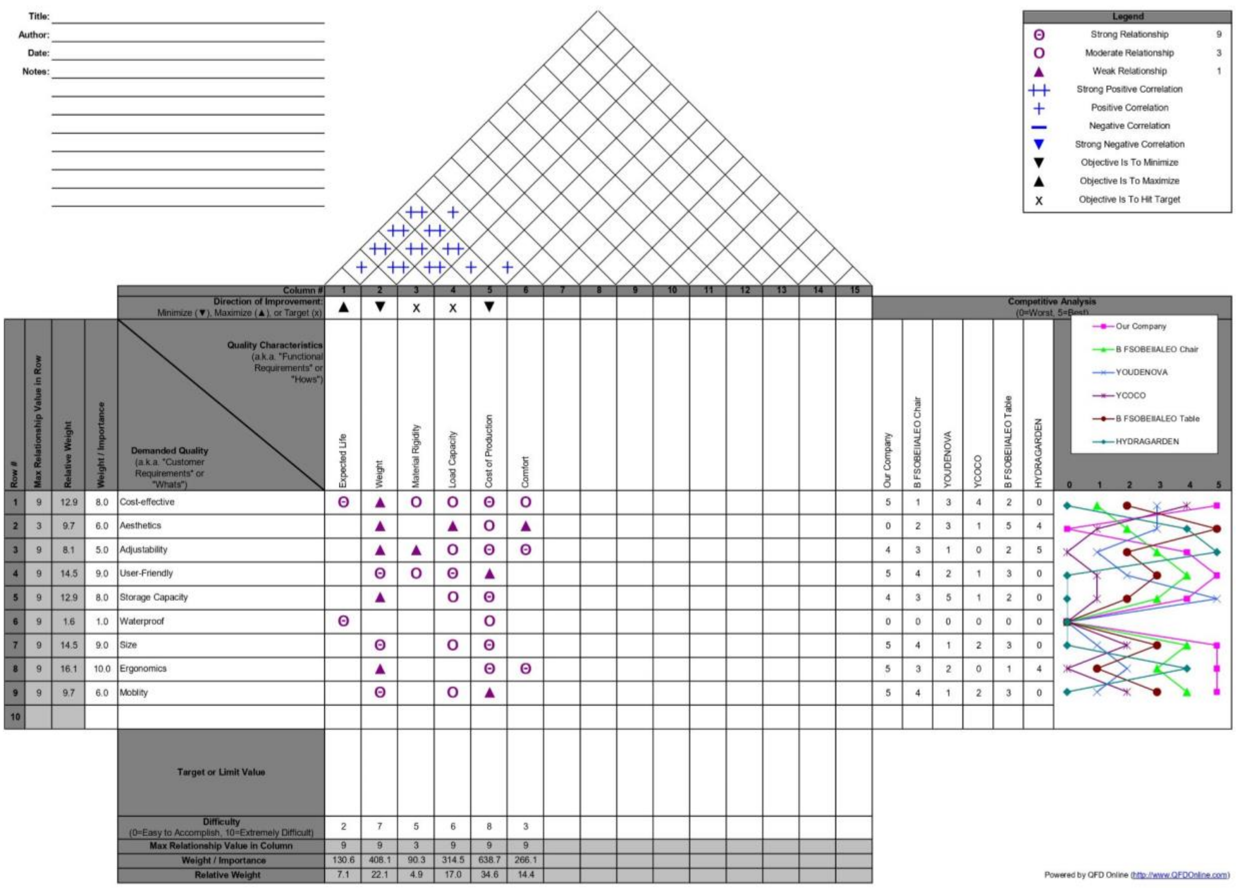


Figure 2.5 House of Quality Matrix

As shown in Figure 2.5, we found that the most important quality characteristics were cost, comfort, and weight. When comparing our product to ones already in the market, we found that our product (the pink line in Figure 2.5) ranked highly among competitors for most of the demanded qualities by consumers. This indicates that our product has the potential to perform well on the market, and gives us direction on areas of improvement for future iterations of our product. More details on the competitor analysis are given in Section 3.3.1.

2.3. Use of TRIZ throughout iterations

2.3.1. Functional Decomposition

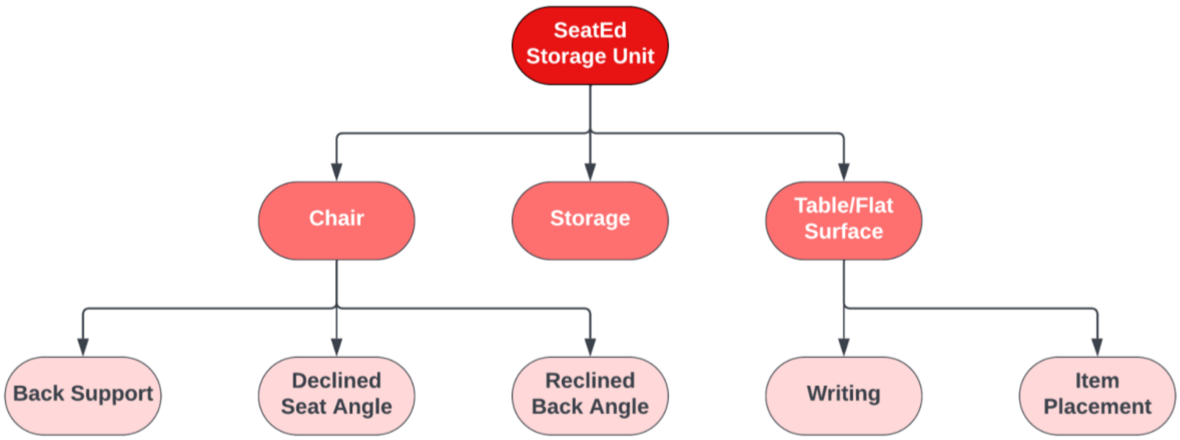


Figure 2.6 Functional Decomposition Flowchart

The functional decomposition analysis allowed us to break down the individual features of the SeatEd Storage Unit. It helped us to easily comprehend the sub-functions of the storage unit to gain a better understanding of the entire system.

2.3.2. Substance Field Analysis

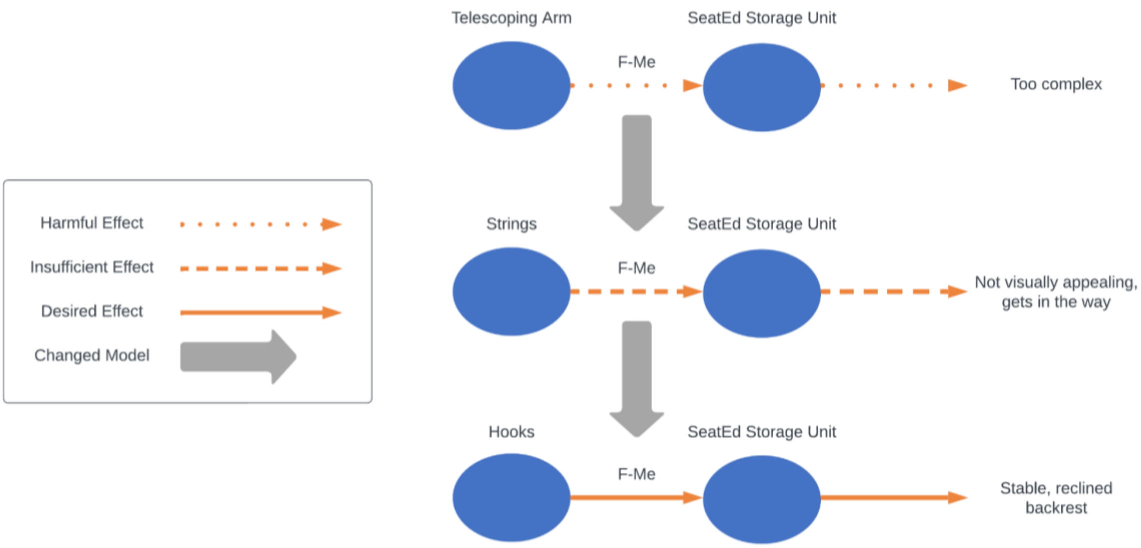


Figure 2.7 Substance Field Analysis

The substance field (Su-Field) analysis allowed us to visualize the efficacy of the backrest of the SeatEd Storage Unit. The first set tool was the telescoping arm used in Design Zero, which ended up having a harmful effect on our product due to its complexity. The second tool was using strings or chains to hold open the backrest, used in Design One. While this tool effectively kept the backrest at a fixed angle, the strings often got in the way and looked out of place, so its effect was insufficient. The third tool was using hooks that were fixed to the backrest and could latch onto one of the dowel rods, used in the final prototype. This was an effective solution to creating a stable fixed-angle backrest while reducing the number of materials used and promoting sustainability.

2.3.3. What engineering contradictions are you solving for?

The engineering contradictions that we are solving for include improving the durability of a moving object while preserving strength and improving the durability of a moving object while preserving ease of manufacture. In our case, the "moving object" refers to the hinges that allow the seat to lift and the backrest to open, and we are aiming to preserve the strength of the cardboard as well as how easy it is to manufacture the storage unit.

2.3.4. What are your historical solutions?

The historical solutions for the first engineering contradiction include cheap short-living objects, segmentation, and asymmetry. The historical solutions for the second engineering contradiction include cheap short-living objects, local quality, and preliminary action.

2.3.5. What is your proposed solution?

The proposed solution is to use cheap short-living objects such as cardboard and maple dowel rods, which will allow us to manufacture the storage unit sets easily. Additionally, the double and triple-thickness cardboard will make the storage unit durable enough to last a couple of years.

2.4. What is the embodiment of your solution?

2.4.1. Static renderings



Figures 2.8, 2.9, and 2.10 Static renderings demonstrating different configurations

2.4.2. Link of dynamic renderings

https://tinyurl.com/5n7ndhtm

2.4.3. Pictures of physical prototype iterations



Figures 2.11, 2.12, and 2.13 Design Zero Physical Prototype

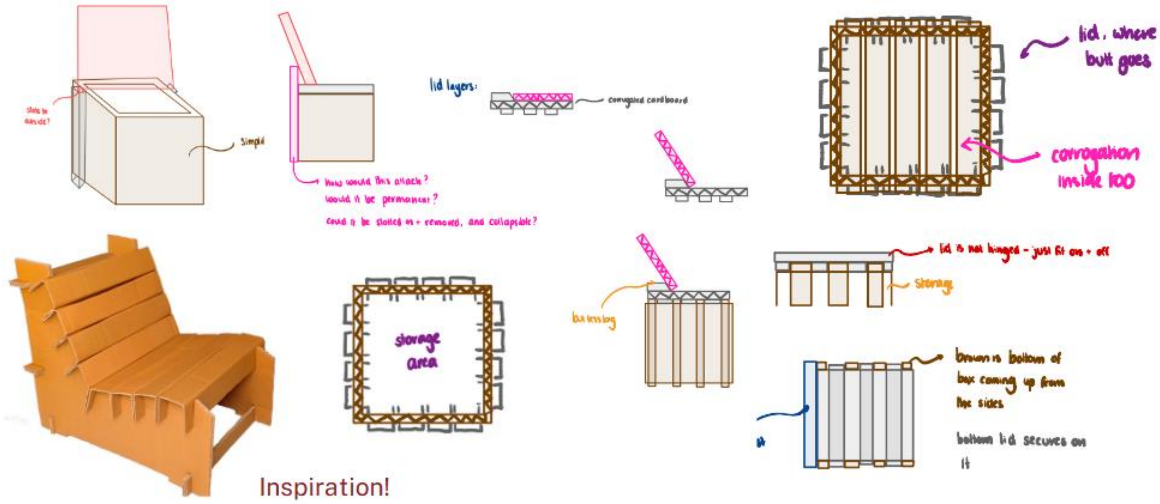
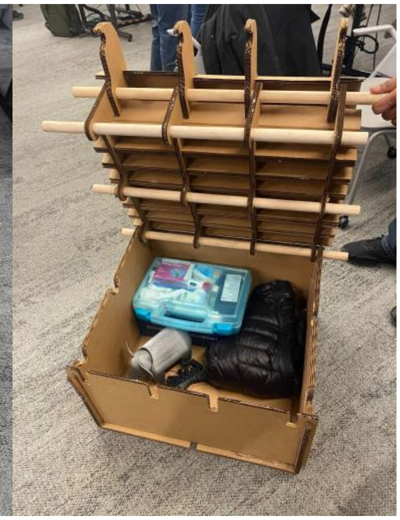


Figure 2.14 Design One Brainstorming

Figures 2.15, 2.16, and 2.17 Design One Physical Prototype

2.4.4. Final works like prototype



Figures 2.18, 2.19, 2.20, and 2.21 Final Prototype

2.5. Mechanical Analysis

Our primary building material is corrugated cardboard. This material seriously complicates our mechanical analysis as it is a sandwich structure made of multiple layers. These layers include the straight walls, called the liners, and between these walls are the corrugated pieces, called flutes. This sandwich structure makes mechanical analysis far more difficult than a homogeneous material. Corrugated cardboard is an anisotropic structure. Additionally, the actual cross sectional area of the material is difficult to determine as it varies slightly with the fluting and is much thinner than the area appears to be (hereafter called the "projected area") because of the fluting that expands the structure.

In order to make this an achievable project, we assumed that the majority of the stress in the loading of the cardboard will be along one of the principal directions. With this assumption, we treated it as an isotropic material with the material properties of the strongest direction. We chose the strongest direction—which is along the flutes—as we could cut the part in such a way that the majority of the stress will be in the way that it is strongest. Another assumption is that the cross-sectional area of the material is the same as the projected one created by the fluting. This assumption is far from the truth, but it is difficult to get true cross-sectional area, and the added structural support from the fluting shape makes it so it would also not be accurate to merely treat the fluting as a single sheet of material at a certain thickness. With these two assumptions, we will be able to solve the system.

Finding material properties for the cardboard was also somewhat difficult. Based on the article titled "Investigating the Mechanical Properties of Paperboard Packaging Material for Handling Fresh Produce Under Different Environmental Conditions: Experimental Analysis and Finite Element Modelling", we approximated the grammage of the paper our prototype's cardboard is made out of to be around $175\frac{g}{m^2}$. We did this by weighing a piece of cardboard and using Fusion 360 to find the surface area of the two liners on it. To find the approximate surface area of the flutes, we started by first finding the approximate length of the flute, if it were unfolded, then multiplying by the width of the piece of cardboard to get the total surface area. To get the length of the fluting, we measured the approximate wavelength of the flutes in the cardboard with calipers to find a sinusoidal equation representing the flutes, then used the arc length integral —$l = \int_a^b \sqrt{1 + (\frac{dy}{dx})^2} dx$ — to find the total length. The values from the paper gave us the Young modulus, $E = 2155.57\ MPa$. We found the rest of the material properties from Granta EduPack 2023 R2. The material properties for the maple rods were also found from Granta EduPack.

To simplify our analysis, we focused our analysis on parts which are under the most load and likely to fail. These parts include: the maple rods, the seat bottom skeleton frame, the back skeleton frame, and the main base. We did not analyze: the table top, the slats, or the cross support pieces. These parts are under considerably less load than the others.

When determining the forces to apply on the model, we based our calculations on a 74 kg person sitting in it. To get the force on the seat portion, we used a constant pressure applied to all faces of the seat skeleton frame. The force on the backrest depends on many factors, including the angle of the seat pan with respect to horizontal—which is 7° for our model—and the angle of the backrest with respect to the seat pan—which is around 10° for our model. We obtained the force on the backrest from the paper titled "Free shoulder space requirements in the design of high backrests". This paper tells us the force placed on the back rest if the back rest were only two supports, one at the base of the chair and one at the top of the backrest, based on the seat angle and the horizontal distance between the two back supports. Using a chart in the paper, we found the total force on the back rest should be about 170N with 80% of that being on the lower support.

Our chair has a full back, not just two supports, so we changed these point loads into distributed loads on two different regions. The lower region has 80% of the total weight and the top region has the other 20%. To model this in Ansys, we converted the two distributed loads into pressures such that each of the four back skeleton frame parts had a fourth of the total load.

2.5.1. Analytical

The shapes of our cardboard make doing accurate hand calculations far too complex. To get estimates using hand calculations, we had to greatly simplify the geometry of our chair.

Due to the way we set the distributed load on the seat frame structure, each of the three dowels will put the same force into the base.This means each half of the base will take half of the weight of the person sitting on it. The width of the base is 0.524m long and the material is 0.013m thick. Assuming the force is evenly distributed through the cross section, this gives an approximate stress of 803.48 Pa.

Treating the dowel as a simply supported beam with a uniform distributed load which has a sum of one-third of the weight of the person, we used Euler-Bernoulli beam theory to find the maximum stress. The dowel is 0.555m long and has a diameter of 0.025m. The distributed load is 436N/m. The maximum moment for a simply supported beam with a uniform distributed load occurs at the center with the value $m = \frac{wl^2}{8}$ with w being the distributed load and l being the length of the beam. For our beam, this value was m=16.79Nm. Using the equation $\sigma = \frac{mr}{\pi r^4/4}$, we found the maximum stress in the beam to be 1.37MPa.

Each seat structure part has two sections supported between dowels. We modeled half of one structure by using symmetry about the middle dowel support. We used beam theory with one roller end and one fixed end to model this. The fixed end simulated the symmetry condition. The maximum absolute value of moment for this type of beam is $m = \frac{wl^2}{8}$. For this beam the length, l, is 0.224m and the distributed load, w, is 405.1N/m. This gave a maximum moment of m=2.54Nm. To find the maximum stress from this, we simplified the bar's geometry to just be the lower portion with thickness b=.013m and height h=0.025m. Here, the second moment of area is $I = \frac{bh^3}{12}$. To find the maximum stress, we used the equation $\sigma = \frac{m\frac{h}{2}}{I}$. This gave a maximum stress in the beam of 1.88MPa. This, however, did not take stress concentrations into account.

For the seat back structure, we only focused on the portion holding the slats, ignoring the hook on the other side. This is a very difficult part to model as, along with the cutouts for slats, the bar is tapering. However, because we focused on stress for this analysis, we used a uniform cross section which is the same as the one at the base. We also only considered the beam below the cutouts, therefore ignoring the stress concentrations. This cross section has a thickness of t=0.014m and a height of h=0.07m. The maximum moment will occur at the base. To find this moment, we used the distributed load as previously described. We found equivalent force on the lower portion of the back to have a magnitude of 34N and be 0.135m away from the fixed edge. We found the equivalent force on the upper portion of the back to have a magnitude of 8.5N and be 0.226m away from the fixed edge. The maximum moment applied by these two equivalent forces was 2.54Nm. Using $\sigma = \frac{m\frac{h}{2}}{I}$, we found the maximum stress to be 0.32MPa.

2.5.2. FEA

We used Ansys to perform the finite element analysis on the parts. To ensure accurate results, we made sure the displacements converged such that they only changed a maximum of 0.25% between meshes for the backrest simulation and 0.63% for the system containing the rest of the objects we were simulating. However, we are not certain that these analyses are completely mesh independent. There are several stress concentrations present in our model, for example, the corners where the slats slot into the skeleton frames. Originally, we had fillets to prevent these stress concentrations, but such fillets would prevent the product from fitting together properly as the fillets would prevent the slats from being inserted all the way. Ansys solved these problems with 3D elasticity. In 3D elasticity, these stress concentrations are stress singularities. Stress singularities do not converge and generally just keep increasing with mesh refinement, so we accepted the convergence of the displacements as sufficient.

2.5.2.1. Static

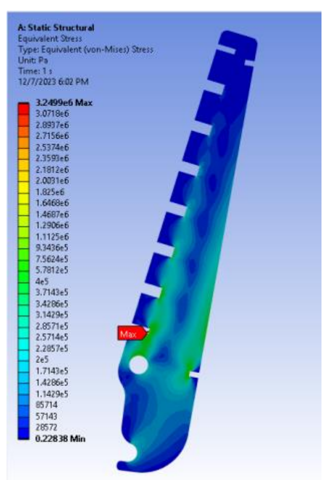


Figure 2.22 Ansys Stress Results for the Back Structure

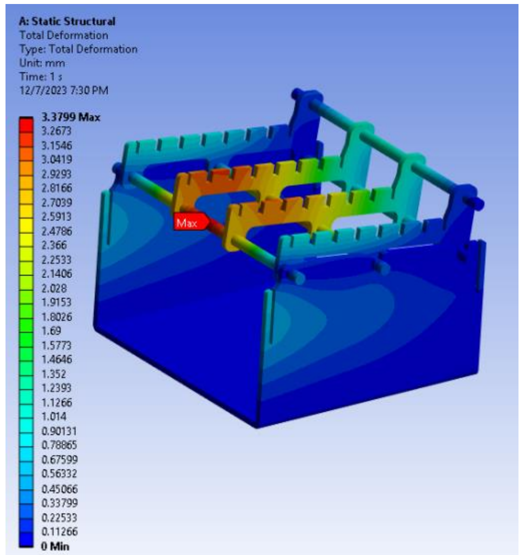


Figure 2.23 Ansys Displacement Results of the Base, Seat Structure, and Dowels

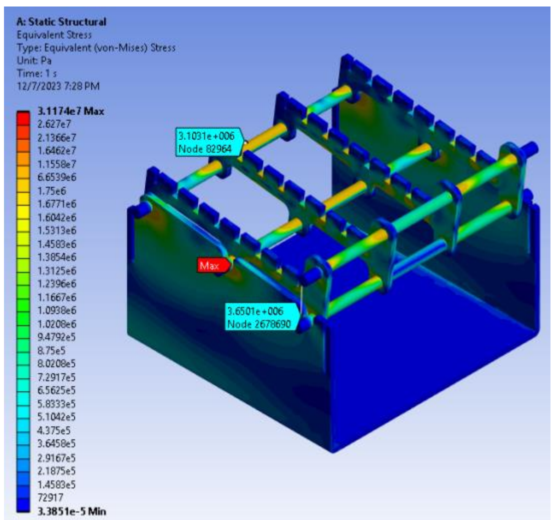


Figure 2.24 Ansys Stress Results for the Base, Seat Structure, and Dowels

Figure 2.22 shows the Ansys result for the back skeleton frame. The stress is highest at the cutouts, at 3.25MPa. However, the stress is significantly lower than the ultimate strength of cardboard, σ_U=24.5MPa. Therefore, we were satisfied that this part was sufficiently strong for our purposes.

Figures 2.23 and 2.24 show the Ansys results for the combined system of the base, the seat structure, and the dowels. The maximum stress is high at 31.17 MPa. This value, however, is at a stress singularity where the dowel interacts with the base. The highest real stress in the cardboard is around 3.65 MPA and occurs in two locations. The first location is in the base directly below and around the front two dowels. The second location is the corner in the slat slot in the seat structure at the slot closest to the chair back hinge. These high real stresses are well below the ultimate strength for cardboard. Thus, we were satisfied that the cardboard parts would be strong enough for our purposes. The highest stress in the maple dowel rod occurs in the middle of the front dowel. It has a stress of 3.1MPa. This is below the longitudinal ultimate strength of maple, $\sigma_U = 60.8MPa$.

2.5.2.2. Cyclic Loading

From Granta, for zero mean stress, cardboard can last for 10^7 cycles at 19.3MPa and maple can last for 10^7 cycles at 34.75 MPa. However, this value is for alternating stress with a mean stress of zero. Our loading condition does not have zero mean stress. To accommodate this fact, we used the Soderberg method, $\sigma_{corrected} = \frac{\sigma_{alternating}}{1-(\frac{\sigma_{mean}}{\sigma_{yield}})}$, to find the corrected alternating stress, which we then compared to the listed value on Granta. Doing this conversion, we found the corrected stresses to be $\sigma_{cardboard} = 3.94MPa$ and $\sigma_{maple} = 3.18MPa$. Both of these values are much lower than their corresponding strength to last ten million cycles. Therefore, based on our Ansys model and our assumptions, our product should last ten million cycles. This analysis, however, has many limitations. This cyclic loading assumes a sinusoidal loading, while in actuality it will be more like a step function, either zero stress or full stress.

2.6. Project Deadlines

2.6.1. GANTT Chart

[MAE 4341: Gantt Chart.xlsx]

Gate review dates are highlighted in red. The overall completion timeline is broken up into four big sections: Empathy Fieldwork, Brainstorming and Modeling, Rough Prototyping and Testing, and Iterating and Refining Product.

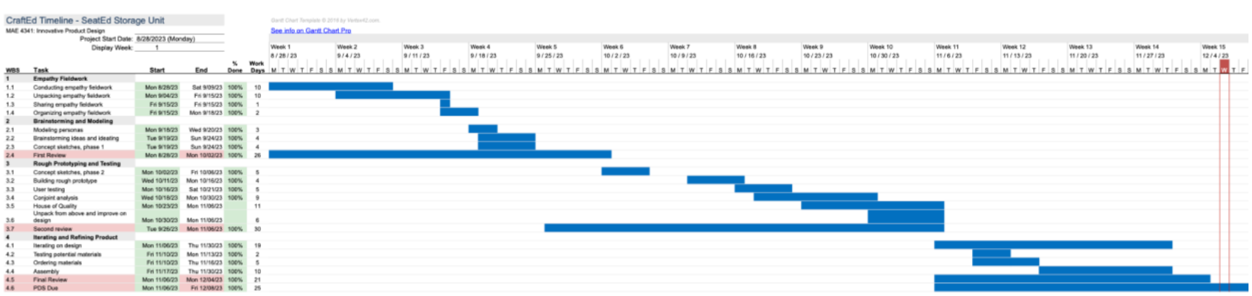


Figure 2.25 Gantt Chart

3. Market Identification

3.1. Target Market

3.1.1. Market Size – IBIS World or other market reports

The Total Addressable Market (TAM) is the opportunity of our product for all the individuals who could potentially find value in our product. In a report published by Forbes, the TAM for dorm furnishings is $10 billion in annual sales in the United States.

For the Serviceable Addressable Market (SAM) for the SeatEd Storage Unit, no direct statistics have been published online regarding a student's tendency to purchase dorm seating. Based on a report published by Statista, there are 5.08 million students enrolled in private colleges and 13.86 million students enrolled in public colleges in the United States. Out of those students, Urban Institute states that 60% of private school students and 36% of public school students live on-campus. Therefore, there are a total of 8.04 million students who live in on-campus housing. Based on another report by Statista, back-to-college shoppers planned on spending an average of $190.80 on dorm furnishings. Multiplying this average by the number of college students in dorms on campus, the SAM is roughly $1.53 billion.

Finally, in our Serviceable Obtainable Market (SOM), we will use freshmen enrollment numbers from 2022 from Insider Higher Education, which said that 2.34 million students enrolled as freshmen in United States universities. After conducting a survey of students living in dorms, 1 out of 10, or 10% students have an ottoman storage seated unit similar to our product. With these two numbers, assuming that 3% of these incoming freshmen students (46,800) purchase our product for $84.99, our annual SOM is $6 million. However, it is important to note that these values are optimistic. Based on the Bass Forecasting Model, it is highly plausible that sales will not be consistent every year. Furthermore, creating a product like this and having it be successful is a difficult feat as well.

3.2. Consumer Behavior

3.2.1. Sociological Research

When conducting empathy field work, we found a large number of students who complained about lacking storage space in their dorms. Students also complained about finding the dorms isolating, with little to no seating for friends. Our product aims to address both of these issues by combining storage with a seat and coffee table. We also found that many college students are highly concerned with environmental issues and their environmental footprint. We decided to make our product as sustainable as possible to appeal to this demographic. Many college students also complain of lacking money for large purchases. In order to allow students to buy our product we aimed to create an affordable product.

3.2.2. Historical solutions to stated problems

Multi-purpose furniture is not a novel idea. Historically, ottomans have provided both seating and storage in many homes. Some ottomans have added features, where the lid can be turned around and converted into a coffee table. However, most ottomans in the market lack a backrest leading to uncomfortable seating positions.

Similarly, there are other examples of sustainable cardboard furniture, but overall very few in the market. Often the cardboard chairs are just lounge chairs, and these chairs lack storage that college students need. Our product solves all aspects of the problems that we identified in our empathy field work.

3.3. House of Quality (again)

3.3.1. Focus on Competitor Analysis

As shown in Figure 2.5, we used the House of Quality matrix to compare our product to its competitors. The competitors we chose in our House of Quality were as follows and pictured below: B FSOBEIIALEO Velvet Storage Ottoman, YOUDENOVA Folding Storage Ottoman, YCOCO Square Ottoman, B FSOBEIIALEO Storage Ottoman with Tray, and HYDRAGARDEN Convertible Sofa Bed. The products were ranked for each demanded quality. As we did not have access to these products, the rankings of these qualities were determined from customer reviews, product specifications, and the available pictures of the products. The outcome of this ranking is shown in Figure 2.5. As shown our product (the pink line) ranked highly among its competitors for most quality characteristics. Furthermore, our product is made of cardboard, which makes it much more sustainable than the competitors we ranked against. While we didn't rank other cardboard products against ours in the house of quality matrix, our product is the only cardboard product that we have seen in the market to include both seating and storage.

Figure 3.1 YCOCO Square Ottoman
Price: $24

Figure 3.2 B FSOBEIIALEO Velvet Storage Ottoman
Price: $50

Figure 3.3 YOUDENOVA Folding Storage Ottoman
Price: $40

Figure 3.4 HYDRAGARDEN Convertible Sofa Bed
Price: $170

Figure 3.5 B FSOBEIIALEO Storage Ottoman with Tray
Price: $30

Figure 3.6 Chairigami Cardboard Lounge Chair
Price: $145

As shown in the above figures, the YOUDENOVA Folding Storage Ottoman, YCOCO Square Ottoman, and B FSOBEIIALEO Storage Ottoman with Tray, are ordinary ottomans with storage and a flat seat without a backrest. The only ottoman with storage and a backrest is the B FSOBEIIALEO Velvet Storage Ottoman. The Chairigami Lounge Chair and HYDRAGARDEN Convertible Sofa Bed, don't include any storage and are simply seating. Our product differentiates itself from all of these products, by combining the comfortable backrest and lounge chair design, with a storage ottoman, and coffee table. Furthermore, our product is made of cardboard which allows it to be extremely sustainable, giving our consumers peace of mind. While our product is a bit more expensive when compared to the simple storage ottomans, it is still cheaper than the Chairigami Cardboard Lounge Chair. We also believe that our consumers would be willing to pay a slight premium to know that they are helping to reduce environmental harm while furnishing their living space.

4. Financial Requirements

4.1. Financial Executive Summary

Costs	Price (USD)	Time
Development Cost and Timing	150,000	per 1 year
Testing Cost and Timing	20,000	per 1 year
Tooling Investment and Timing	180,000	per 1 year
Ramp-up Cost and Timing	30,000	per 3 months
Marketing and Support Cost and Timing	150,000	per 1 year
Unit Production Cost (Materials)	33.62/unit	
Unit Production Cost (Labor Cost)	13.33/unit	

Table 4.1 Cost of Operation

To justify these numbers, according to our Bass Model Forecasting projections, in our first year, we estimate to manufacture a total of 15,000 units. This means that 7 units need to be die-cut, stamped, and packaged within an hour. In order to meet this goal, we will implement two assembly lines in which each would have an output of roughly 3.5 units per hour, or one unit roughly every 9 minutes.

Both assembly lines would require a total of 5 people. If the average production worker makes $15.00 an hour, the total production costs per year would be $150,000. If we intend to make 15,000 units, then the production cost per unit is $10.

The estimated overhead costs considering the four machines that we need will be roughly $50,000. This projection was based on the average overhead costs that manufacturing plants need coupled with the 4 pieces of manufacturing equipment that need to be maintained. If we have 15,000 units within our first year, the overhead cost per unit would be $3.33 per unit. If we add the production cost to the overhead cost, the total production cost would be $13.33.

This justifies our selling price of $84.99. With an overall production cost of $46.95 including the materials and labor costs for our unit, we aim to earn 75% of it back for our profit and to cover additional costs we incur as we grow our business over the course of time.

To determine our Net Present Value (NPV) with the production of the SeatEd Storage Unit, we will use the Bass Model (see section 4.3) to determine our profit margins. Since the Bass Model is an optimistic model of the number of adopters we will get in a year, we took around 70% of the projected adopters from the Bass Model into our NPV analysis to determine the number of adopters who would purchase our product once.

Year	**Adopters** (Bass Forecasting)	**Profit** (Selling Price: $84.99)	**Costs**	**Cash Flow** (Profit - Costs)
1	15,000	1,274,850	1,504,250	-229,400
2	50,000	4,249,500	3,147,500	1,102,000
3	100,000	8,499,000	5,495,000	3,004,000
4	200,000	16,998,000	10,190,000	6,808,000
5	175,000	14,873,250	9,016,250	5,857,000
6	100,000	8,499,000	5,495,000	3,004,000
7	40,000	3399600	2,678,000	721,600
8	10,000	849,900	1,269,500	-419,600
9	0	0	800,000	-800,000
10	0	0	800,000	-800,000

Table 4.2 Cash Flow over a Ten Year Period

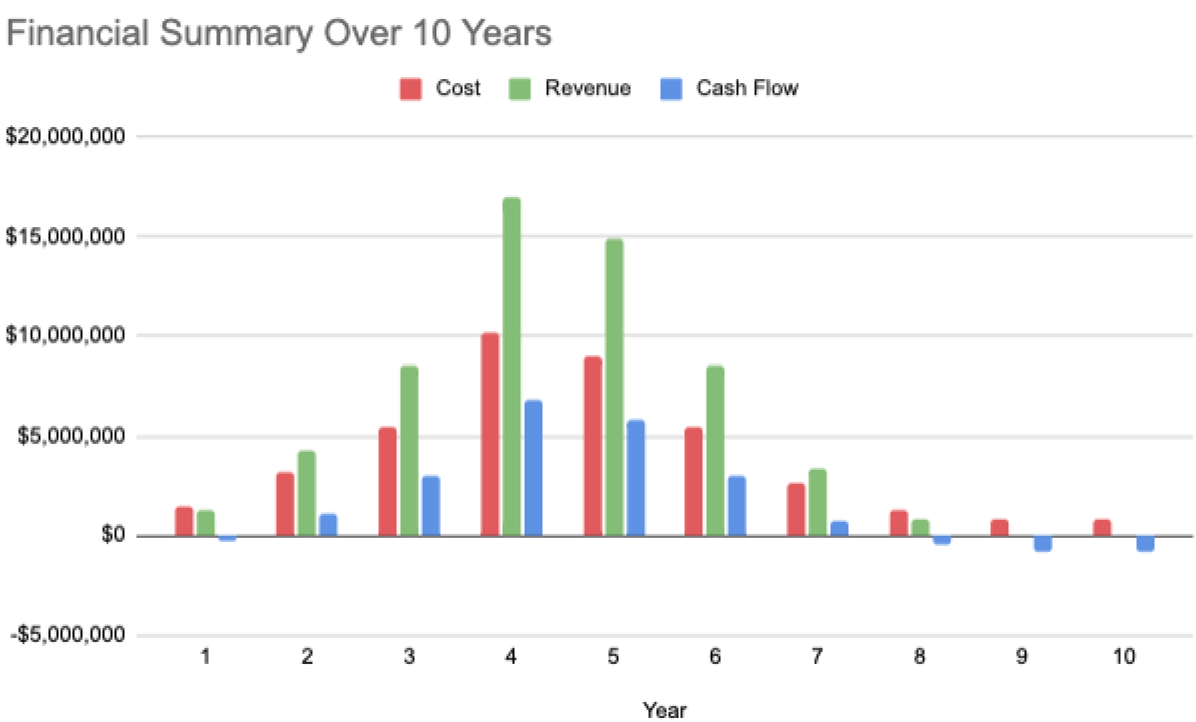


Figure 4.1 Financial Summary Over 10 Years

With a discount rate of 10% a year, the NPV over a ten year period is $12.4 million. This is a value that indicates that our company has potential. However, the harsh reality of the startup industry is that finding success is very difficult; just because our models indicate a profitable turn-out does not mean that our success will be found and we will be making $12.4 million within ten years.

4.2. Pricing Policy

The sustainability of our product coupled with the do-it-yourself assembly made it possible to minimize cost for the user to incentivize them to purchase the product. The main consideration when pricing our product was the budget of the intended user. Since college students typically have lower disposable income and want to cut down on costs while having an attractive product in their room, we made the cost $84.99.

4.2.1. Derived from Conjoint and Other Observations

Although this price is significantly higher than our ottoman storage seated units, we discovered through user testing that the user was willing to pay more if a product was better for the environment. Our product is 100% recyclable and does not harm the environment. Also, the unique design of the cardboard has attracted our users to our product. It will serve as a talking piece whenever their guests enter their rooms.

After doing a competitor analysis on companies who sell similar to us, we discovered our competitor Chairigami, who also sell cardboard furniture. They price their cardboard lounge chairs at $150 that do not include storage. With our product, which will be sold for a cheaper price of $84.99, the user will get storage capabilities in their dorms while retaining the same marketing points of the company. As a product brand built by students for students, users are more likely to purchase our product.

4.3. Bass Model Forecasting to predict product demand

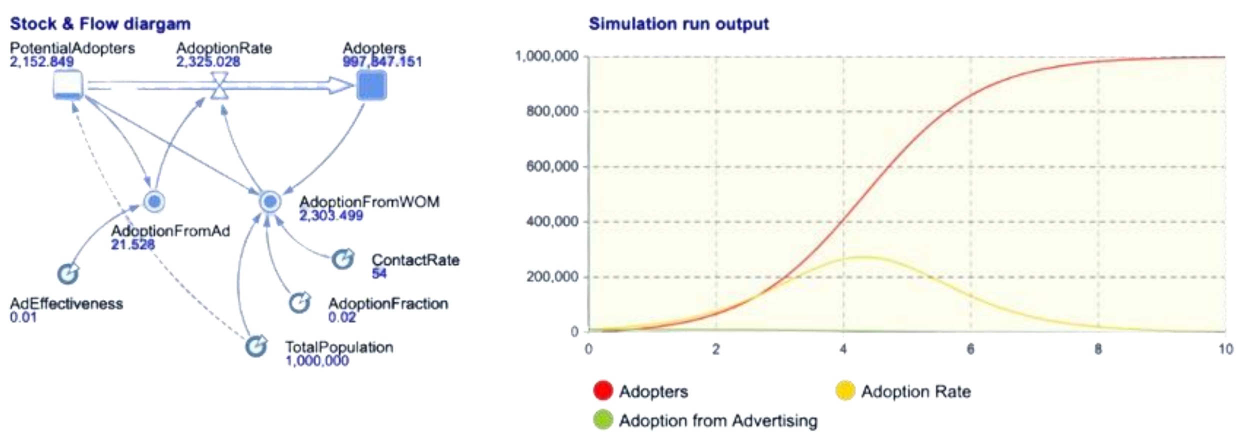


Figure 4.2 Bass Diffusion Model

To create the Bass Diffusion model on AnyLogic, we followed the idea that our product is more likely to spread via word of mouth. Seeing a cardboard chair as an ad online may only be effective for people who truly care about the environment, and marketing it via advertisements may be difficult without direct contact for the users. However, we feel that the contact rate is something that is important for our product – from user testing, we found that people were initially unconvinced about the product, but when they had a chance to use it, found it really interesting and saw it as something they would be able to use. We carried this idea over to the parameters we inputted inside our Bass Model forecast with a contact rate of 54. The adoption fraction utilized was 0.02, a fairly low number that represents how the word of mouth could spread. Our advertising effectiveness is 0.01, as it covers people who are passionate about the environment and is less effective towards everyone else. This is shown in the Bass Model Forecasting, with a flatter curve that increases upwards at a smooth rate as the recommendation and use of our product begins to spread.

The average product life of our unit is 2.521 years, with only 1 initial sale per adopter based on how the item is meant to be recycled at the end of its use. The average consumption per adopter is 0.42, a parameter that reflects how the item is likely to be in use often due to its multifaceted nature: that is, if the person is not actively sitting or resting items on top of the unit, they are most likely still passively using it by storing items inside of it.

4.4. Production Costs

4.4.1. What manufacturing process will you use?

The manufacturing process used to produce our prototype was laser cutting sheets of corrugated cardboard which were then glued together with a glue spray adhesive. A press brake was used for parts that needed a 90 degree bend. After that, everything was easily assembled, and the water resistant coating was applied to the outer surfaces.

For bulk manufacturing, die cutting and stamping could be used. Laser engraving is a viable option but very time-intensive so labor costs would be high. All the pieces in the assembly are fairly similar to each other which would make die-cutting cheaper and easier as only a few dies are required to make the product. Stamping would be used to make the angled back rest pieces which is also an efficient method.

4.4.1.1. Ashby Charts

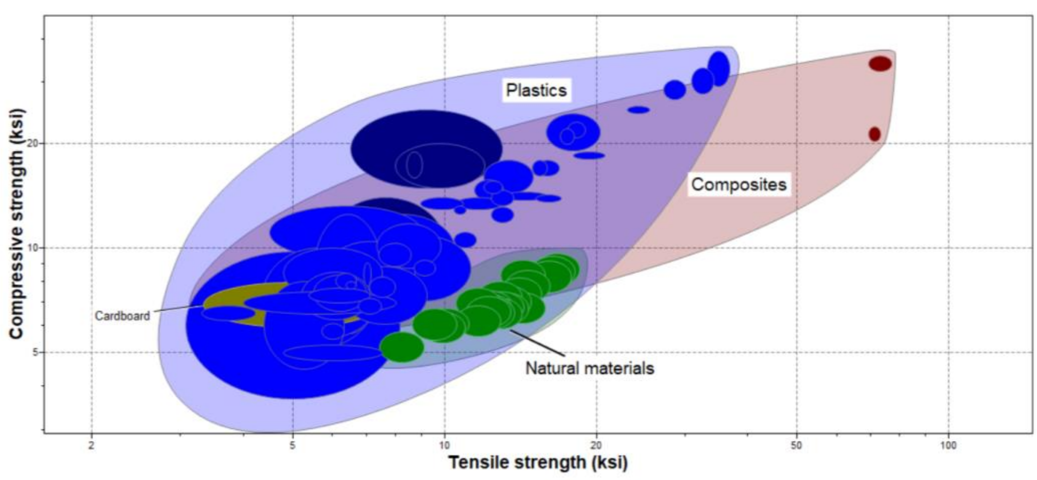


Figure 4.3 Ashby Chart Comparing Compressive Strength to Tensile Strength

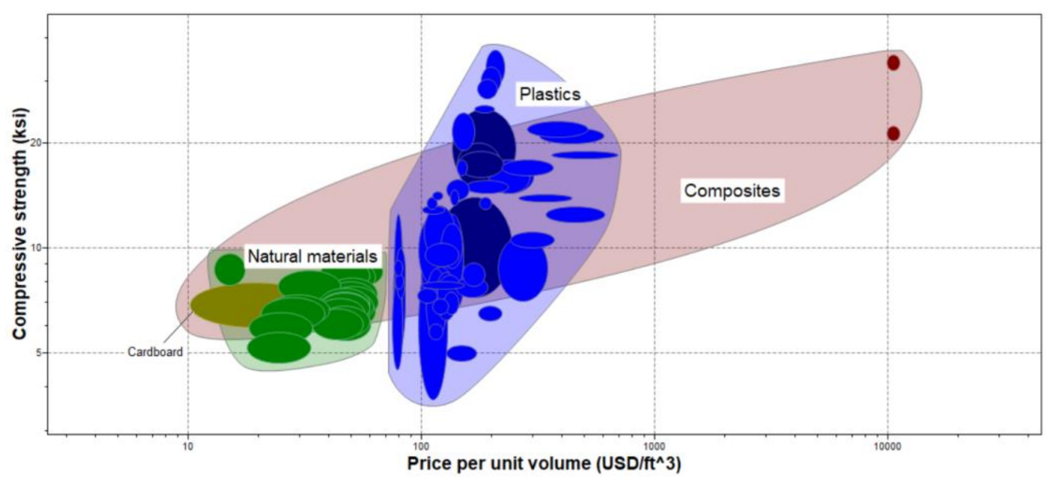


Figure 4.4 Ashby Chart Comparing Compressive Strength to Price per Unit Volume

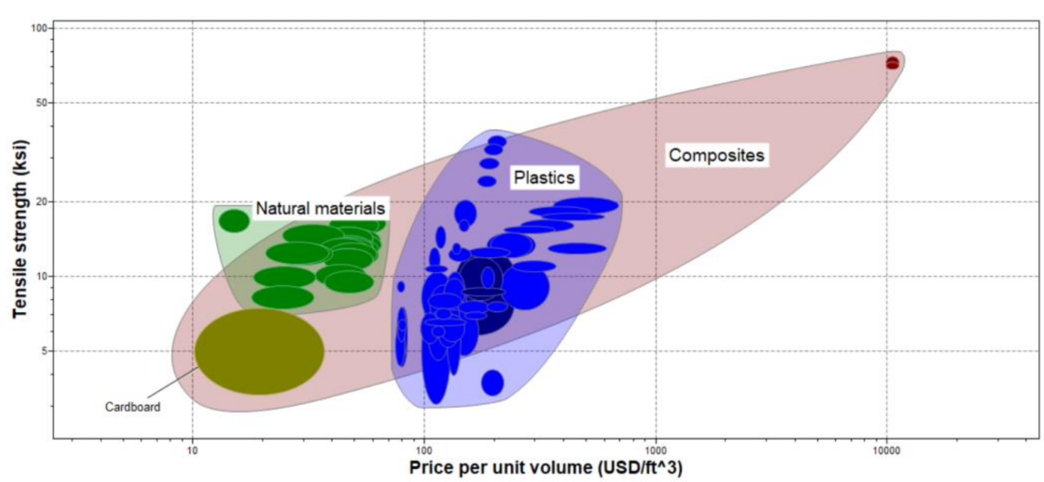


Figure 4.5 Ashby Chart Comparing Tensile Strength to Price per Unit Volume

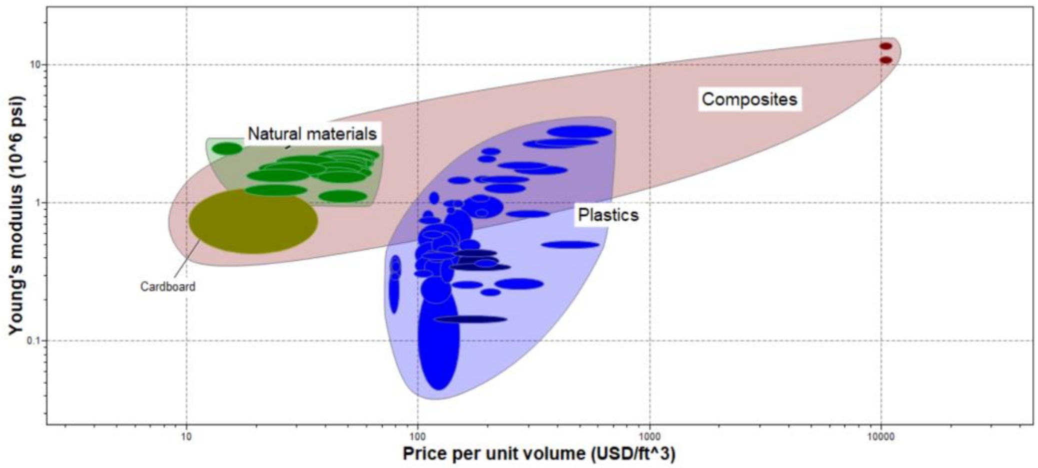


Figure 4.6 Ashby Chart Comparing Young's Modulus to Price per Unit Volume

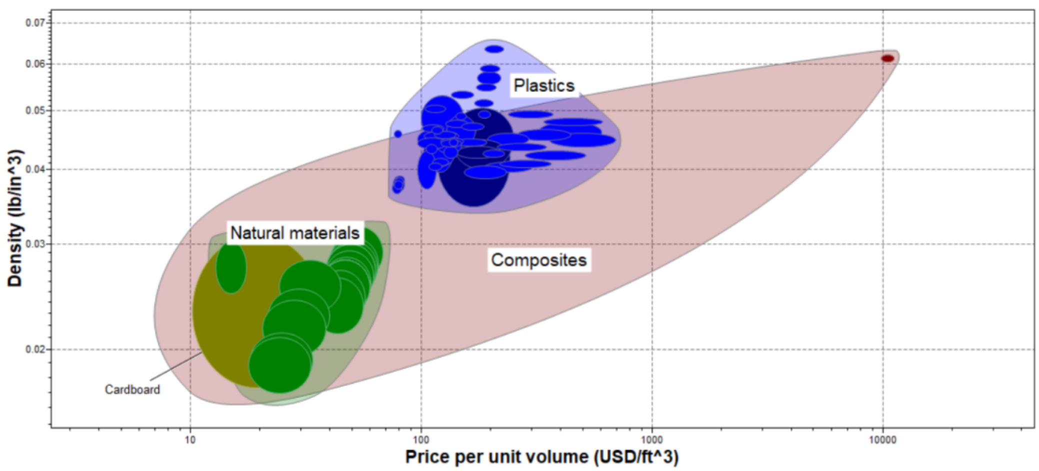


Figure 4.7 Ashby Chart Comparing Density to Price per Unit Volume

Figures 4.2 through 4.7 visualize the mechanical properties of the proposed materials for our seated storage unit. The natural materials used included oak and maple wood, the plastics used included those commonly used in 3D printing such as ABS, PLA, PETG, resin, and TPU, and the composite used was carbon fiber. In general, the composites demonstrated the highest values of composite strength, tensile strength, and Young's modulus, and were the most expensive materials. Cardboard tended to be the least expensive material but also demonstrated some of the weakest material properties. Additionally, the properties of cardboard tended to be similar to those of wood, which makes cardboard a somewhat suitable substitute for wood. This is beneficial because wood was the top choice for the desired material of our storage unit according to our Conjoint Analysis, and so we can use cardboard as a wood-like material that costs and weighs less than wood.

4.4.2. Tooling parameters and costs

To manufacture our current working prototype with the laser engraver machine, tool parameters needed to be set to effectively cut the desired shape of the pieces. The laser engraver has three parameters: frequency, power, and speed. For cardboard, the tooling parameters are, 500 Hz, 20% power, and 50% speed. As cardboard is susceptible to burning up, multiple passes were performed by the laser. We tested that 2 passes were sufficient as the sheets were approximately 3/16”. Engravings such as the logo were performed by the laser using the respective engraving settings.

Another consideration for tooling costs is dependent on our desired tolerances, especially for the slots in the cardboard pieces. After performing product testing, we discovered that a tolerance of 0.02” is needed for all cardboard pieces so that the slots fit in together with a tight fit. Also, the dowel rods have a tolerance of 0.01” which is accounted for in the holes.

4.5. Costs of Goods Sold

4.5.1. Materials, labor, off the shelf components

We experimented with a few cardboard sheets that we purchased to determine the most effective tolerances and ensure functionality of our product:

Vendor	Item Name	Unit Price	Quantity	Total Price	URL	Description
McMaster-Carr	Corrugated Box	$13.37 (per 5 sheets)	7	$93.59	Link	Corrugated cardboard for assembling chair
McMaster-Carr	Maple Rod	$15.52	4	$62.08	Link	Maple dowel rods to act as supports
Amazon	Eco Coating	$24.97	1	$24.97	Link	To coat chair and waterproof it
Amazon	Cement Glue	$22.97	2	$45.94	Link	Adhesive for cardboard pieces to strengthen it
Amazon	Gorilla Glue	$30.79	1	$30.79	Link	Wood glue to attach cardboard together
			Total	**$258.09**		

Table 4.3 Prototyping Materials Ordered (everything we purchased)

After experimentation, we narrowed down the items to exactly what our product required:

Vendor	Item Name	Unit Price	Quantity	Total Price
McMaster-Carr	Corrugated Box	$2.67	24	$64.08
McMaster-Carr	Maple Rod	$15.52	4	$62.08
Amazon	Eco Coating	$24.97	1	$24.97
Amazon	Cement Glue	$22.97	2	$45.94

	Total	**$197.07**

Table 4.4 Actual Materials Used (everything we used in the prototype)

During production, the corrugated cardboard boxes will be attached to each other as the stock comes in bulk so that no adhesive is needed to attach everything:

Vendor	Item Name	Unit Price	Quantity	Total Price	URL	Description
Alibaba	Corrugated Cardboard Sheets	$0.15/sheet	32	$4.20	Link	Corrugated cardboard for assembling chair
Bearwood	Maple Rod	$6.61/2 rod	2	$13.22	Link	Maple dowel rods to act as supports. This is sold in 48" sizing, so will be cut in half.
American Products, Inc.	Minwax Polyurethane	$0.27/oz	64 oz	$16.20	Link	To coat chair and waterproof it
			Total	**$33.62**		

Table 4.5 Production Materials Used (estimated cost if mass produced)

We used the production materials for a total of $33.62. Considering overhead costs like the cost of labor, the cost of packaging, and the cost to own and operate the machinery required for the mass production of our product, our product will be priced at $84.99.

4.6. Warranties

4.6.1. Weibull distribution around FEA cyclic loading failure prediction

Based on the results of our cyclic loading analysis using ANSYS, our cardboard chair demonstrates a remarkable ability to withstand a substantial number of cycles, exceeding ten million. With this information, we can confidently assert that our product is well-equipped to endure our intended two-year life cycle.

In an extreme scenario where the chair is subjected to 50 load cycles per day over a span of 4 years, the total number of cycles would reach 73,000. In this context, one load cycle refers to a person sitting down on the chair one time. This figure is significantly below the ten million cycles indicated by our analysis. Consequently, it is evident that material fatigue poses no significant concern for the structural integrity of our product.

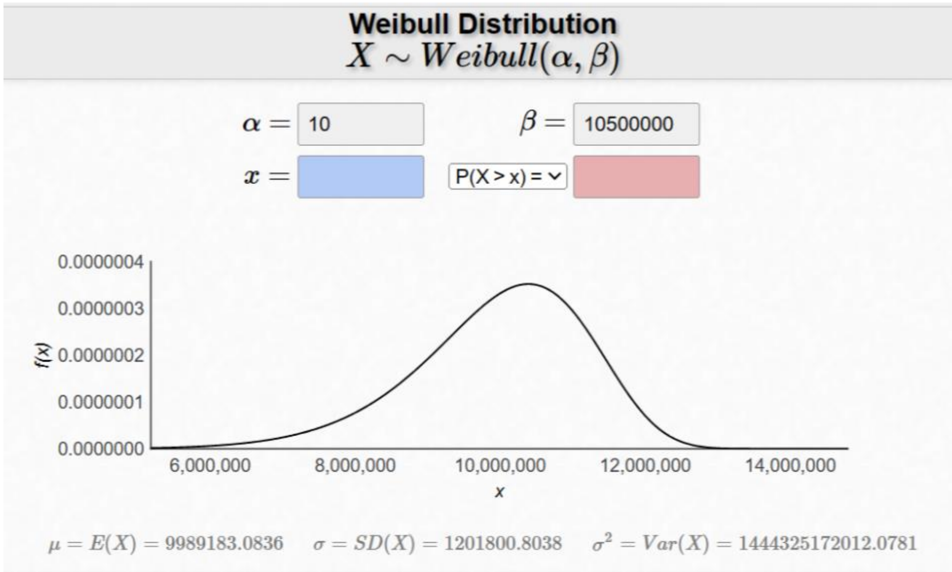


Figure 4.8 Weibull Distribution for Cyclic Loading Failure Prediction

Figure 4.8 visualizes the cyclic loading failure prediction for our chair. The probability that our chair will fail under 73,000 load cycles is 2.6368E-22, or effectively zero. There is a possibility that the estimation for the expectance of this distribution is too large due to inaccuracies with the FEA modeling, and so a more in-depth analysis will need to be performed in the future. However, we still believe that our chair will be able to withstand at least 73,000 load cycles.

This promising outcome further validates the robustness and durability of our cardboard chair, providing assurance that it meets or exceeds the required performance standards for the intended usage over its projected lifespan.

4.6.2. How will you handle product mishaps?

We will uphold a warranty for typical product mishaps for the duration of a year. Typical mishaps include anything that occurs under typical operating conditions. Warranties will be voided for things like, outdoor use, exposure to large quantities of water, and unrealistic load cases such as multiple people. Given that our product is assembled by the consumer we will provide replacement parts for any damaged parts. As our product is made of cardboard we are anticipating a relatively short life cycle (around two years) which is why our product's warranty is only one year.

4.7. Capital Investment Required

4.7.1. How will you buy manufacturing equipment or afford to outsource?

We will start a kickstarter for crowdfunding to get initial capital. We will also seek out investors, and participate in pitch competitions in order to acquire enough capital. With this initial money, if we have enough capital to buy a die-cut machine, we will do so. If buying our own equipment proves to be too expensive we can outsource an initial run or two of production, with capital we managed to raise.

4.7.2. Pay employees to scale up production

We will keep all of our production workers on the floor to manufacture the pieces of the assembly. For expansion, we will pay a production floor manager roughly $21.06, which is the national average, so that they could scale up production every year according to our financial projections. They will coordinate with the equipment manufacturers to transport and install the tools in our production facility.

5. Legal Requirements

5.1. Safety & Environmental Regulations

Given that we are purposely engineering our product out of sustainable materials, our product abides by safety and environmental regulations. In order to determine whether our product was the most environmentally friendly as possible, we scheduled a call with Cornell's Environmental Health and Safety department to speak about our materials with them to confirm they were recyclable. However, we used cement glue to turn our single corrugated cardboard pieces into triple corrugated because we couldn't find non-bulk amounts of triple corrugated cardboard for a reasonable price. The cement glue isn't recyclable, but in our final product it wouldn't be included in the product because we would be buying cardboard that has enough walls of corrugation for assembly. Our largest obstacle in keeping this product environmentally friendly revolves around the decision we will make to waterproof our product.

5.2. Potential Liability Issues

5.2.1. Prediction of Misuse Cases

From the perspective of college students using a cardboard box as a chair and an ottoman, there is a large potential for misuse cases. If a student very forcibly pushes the backrest and/or presses their back against it, there is a possibility that the backrest will bend at the top and break. Furthermore, there is a potential misuse case regarding unrealistic load cases. If a student stands and jumps on the unit or if multiple students sit on the unit, the unit may bend. Due to the nature of our material choice, any extreme user who exposes the unit to extreme conditions, whether attempting to use the unit in outdoor conditions or exposing the unit closely to heat (space heaters, fire) or to large amounts of water, could all be detrimental to the unit.

5.2.2. Failure and Effect Analysis

Component	Functions	Damage Cause	Consequence	Likely? (1-10)	Possible Countermeasures
Seat	Support the user's weight evenly	Deformation in shape, bending, collapsing under pressure	Uneven weight distribution, causing discomfort	4	Increasing thickness of the cardboard, or a more rigid material, designing with an curved ergonomics that follows natural body contours
Backrest and Support	Provide comfort and stability	Collapses under pressure, bending towards the top	Disconnection, affecting the overall stability of the chair	6	Adding additional reinforcement structures into the backrest design
Storage Base	Supports the weight of	Bending from excessive weight	User falls through the seat, product	8	Increasing thickness of the cardboard, using a more

	the upper seat	on top, buckling, deterioration from friction	falls apart and collapses		rigid material, adding additional reinforcements
Dowel Rod	Provides structural support and connects the different parts of the unit	Excessive loading could cause the rod to bend	Backrest doesn't have a support system	2	Increasing thickness of the rod, adding multiple rods to the design to support the backrest

Table 5.1 Failure and Effect Analysis

5.3. Intellectual Property Considerations

5.3.1. Pursue Utility, Design Patents? Why?

If we were to pursue intellectual property, pursuing a design patent would be the most reasonable for our product. The pieces that we use to assemble our product are relatively simple and the design has taken much consideration. It is something that would be easily copied by another person, and to protect our design, pursuing a patent would be worth it. However, there are compromises to pursuing a patent. Pursuing a patent may increase our operating costs and to make up for those profits, we would need to further increase the price of our product to allow for this patent. It is also something that would require a decent amount of time to pass and work on. The industry of cardboard furniture is not very competitive yet, so developing a patent to protect our designs may not be worth it to pursue for the cost and time it takes.

5.3.2. Trade Secrets? Why?

Because this product comes in pieces that will be assembled by the student out of cardboard, keeping this product a secret would be difficult. From the perspective of someone who is trying to copy the product, all they would need to do is analyze the product put together to understand the mechanisms behind it to copy it easily. Maintaining it as a trade secret would be difficult due to the simplicity of our parts.

5.3.3. Trademark?

5.3.3.1. Team name and logo

Our team name was CraftEd. Our motto is *"Our products are CraftEd with students in mind"*

Figure 5.1 CraftEd Logo

5.3.3.2. Other trademark opportunities?

Another trademark opportunity that could come to identify our product and brand revolves around the play in words that our product offers. Circling around the company name, CraftEd, we played with our team’s product in naming it SeatEd Storage Unit to match the play on letters that the “Ed” indicates as a shorthand for education. There is an opportunity to expand in that direction: for example, one of our previous product ideas was a lecture hall desk extender. By creating a product with the name ExtendEd Lecture Hall Desk, we can keep the “Ed” as a trademark within our company.

6. Environmental Targets

6.1. How will the products reduce environmental impact on production?

The only two materials used in our product are cardboard and the wooden dowel rods. Since our product's assembly is do-it-yourself, there is virtually no environmental impact, which is a great selling point for our product. The only environmental impact made is from the operation of manufacturing equipment such as die cutting, stamping, and laser cutting, which barely contribute to pollution in the environment.

6.2. How will the products reduce environmental impact upon end of life?

One of the main selling points of our product is that it is easily recyclable because it is entirely assembled from cardboard. Our product being recycled is critical to our selling points as users do not have to worry about the environmental impact of it. Oftentimes, many students in dorms dispose of furniture in the trash which contributes to compost. The four wooden dowels can also be recycled at a center, although not as common as recycling cardboard.

One main consideration from our stakeholders from designing this product is that it should be water resistant in case any liquid were to dampen the cardboard pieces. For this reason, we decided to apply a water resistant coating to the exterior cardboard pieces to avoid this. We contacted the environment, health, and safety department at Cornell in order to choose a coating that had chemicals that were environmentally friendly. We narrowed down to two coating options which were then presented to an EHS specialist who reviewed the chemical compounds in each coating.

She proceeded to recommend one over another, although she had another reservation about both coatings: they may not be recyclable. After contacting the Tompkins County Recycling Center, we learned that the cardboard is recyclable as long as the coating is not glossy. The polyurethane option we decided on satisfied both of our stakeholders in that it's environmentally friendly and not glossy so that the product is 100% recyclable.

7. Future Timeline

7.1. What are your team's actual future plans?

While our current design works fairly well, we plan to make some improvements to it. We will continue to investigate how to make the folding back work, with the goal of removing the hooks to create a better method to keep the back at the proper angle. Additionally, based on comments we received at our final presentation, we plan to add wheels to our product to make it easier to use.

Our product is reasonably simple to manufacture, with cutting the cardboard itself being the primary manufacturing objective. As mentioned previously, we believe that die-cutting will be the best method to produce our cardboard shapes in the quantities we need to turn this into a viable business. At least initially, everything we need—such as the cardboard sheets and Minwax— is easy to obtain, with the major exception of the custom die-cutters. Based on this, our primary focus as we begin to build the business will be to obtain the die-cutters.

7.1.1. Formation of an LLC?

We believe we have a product that has the potential to be successful given the proper marketing and manufacturing. Based on this, forming an LLC would be possible, centering it around creating sustainable dorm furnishings.

7.1.2. Crowdfunding?

There are several means we are considering to raise the necessary funds to commission the needed machinery, including crowdfunding and finding investors. While Cornell has many resources to help startups find funding, we believe that crowdfunding may be a better option for us. Crowdfunding will allow us to keep all of the equity in our company, which is important for what we expect to be a modest company that will already be split five ways. Additionally, during class lectures we saw how crowdfunding can also be used as an effective advertising pitch. These two factors lead us to believe that we should use crowdfunding to raise the funds necessary to purchase our manufacturing equipment. Ideally, those who support our crowdfunding campaign will enjoy the product and tell others they know about it.

Since we would be an early stage startup without a patent and unable to keep our product as a trade secret, crowdfunding would be a good way for us to protect our intellectual property. With crowdfunding, we can showcase our product without fully revealing the mechanical details of the product.

7.1.3. Pitch Competitions?

While pitch competitions are enticing, it may not be a route that would be best for our business. As an early stage startup without a true patent and without being able to maintain our product as a trade secret, pitch competitions could be risky. In a pitch competition, we may need to disclose information about our mechanical design, making our product idea vulnerable to getting stolen. It could also cause us to divert resources away from the development of our product, as we would need to prepare for the competition and make sure our product has good publicity.

7.1.4. Call it a semester?

However, despite the opportunities present in forming a startup out of CraftEd, we will be calling it a semester. We are well aware about the difficulties of pursuing a startup, and especially in our SeatEd Storage Unit, we would need a large amount of initial investment to even create our first real prototype (beyond the one that we made for the final presentation that was held together by cement glue). We learned a lot from this process, both mechanically and business-wise, and look forward to developing new product designs in the future.

8. Sources

8.1. Bibliography

8.1.1. Chair Comfortability

- **8.1.1.1.** Chair Comfortability Research Paper

8.1.2. NPV

- **8.1.2.1.** NPV Calculation

8.1.3. Employee Salaries

- **8.1.3.1.** Cost of a Production Worker per Hour
- **8.1.3.2.** Floor Manager Salary

8.1.4. Market Size

- **8.1.4.1.** TAM Study 1
- **8.1.4.2.** SAM Study 1
- **8.1.4.3.** SAM Study 2
- **8.1.4.4.** SOM Study 1.

8.1.5. Financial Requirements

- **8.1.5.1.** CAGR Rate

8.1.6. Links to Competitor Products

- **8.1.6.1.** YCOCO Square Ottoman
- **8.1.6.2.** B FSOBEIIALEO Velvet Storage Ottoman
- **8.1.6.3.** YOUDENOVA 30 inches Folding Storage Ottoman
- **8.1.6.4.** HYDRAGARDEN Convertible Sofa Bed
- **8.1.6.5.** B FSOBEIIALEO Storage Ottoman with Tray
- **8.1.6.6.** Chairigami Cardboard Lounge Chair

8.1.7. Links Mechanical Analysis Resources

- **8.1.7.1.** Investigating the Mechanical Properties of Paperboard Packaging Material for Handling Fresh Produce Under Different Environmental Conditions: Experimental Analysis and Finite Element Modelling
- **8.1.7.2.** Free shoulder space requirements in the design of high backrests
- **8.1.7.3.** Granta EduPack 2023 R2

8.2. Appendices

- **Section 1**
  - **Figure 1.1** High-level CAD renderings
  - **Figure 1.2** High-level CAD renderings
  - **Miro Link**
- **Section 2**
  - **Table 2.1** Criteria Comparison Matrix