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AN OVERVIEW OF THE PRODUCT DEVELOPMENT PROCESS FOR A LOUNGING GROVE CHAIR: THE REBEL LOUNGE

by
Gracey Massengill

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

Oxford, MS
May 2024

Approved by

Advisor: Dr. Jack McClurg

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Reader: Professor Eddie Carr

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I would like to thank my team, Andrew Brady, Brooke Grissinger, Carter Doss, and Karson Wardell. Andrew, you were a great leader, thank you for always listening to everyone's ideas and making sure we were on task. Brooke, thank you for all of your accounting work and being so willing to tackle the sewing machine. Carter, thank you for all of the CAD designs and also being openminded to everyone on the team. Karson, thank you for your guidance in all of our material choices and assembly line ideas, as well as being willing to learn to sew despite your fear of getting your finger caught.

I am so thankful for a team that worked well together and respected everyone.

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ABSTRACT

GRACEY MASSENGILL: An Overview of the Product Development Process for a Lounging Grove Chair: The Rebel Lounge

(Under the direction of Dr. Jack McClurg)

This report focuses on the process of completing my senior capstone project for the Center for Manufacturing Excellence with my teammates, Andrew Brady, Carter Doss, Brooke Grissinger, and Karson Wardell. It explains the development, design and manufacturing of the Rebel Lounge Chair, a comfortable, portable and versatile chair made with the University of Mississippi Grove in mind and the prospective customers that would purchase such a chair. The report describes the phases of brainstorming, market research, prototyping, manufacturing process development, and accounting analysis that the Rebel Lounge capstone team went through to create their product.

Due to out-of-the-box brainstorming and prototyping our team decided on a chair design which we believe is a comfortable, light weight and maneuverable as well as versatile for our target audience. The chair design consists of a wooden frame construction and a fabric seat which is sewn specifically for our chair. Our manufacturing process to create these chairs is a balanced production line with five working cells. The work cells consist of a cutting, two drilling stations, sewing and final assembly, each of which have detailed standard operating procedure instructions to help with quality control and speed of the process.

Using our manufacturing process, we were able to meet the assigned demand of making at least 5 chairs an hour, allocating about 10 minutes per work station to build each chair. The

cost of our Rebel Lounge chair is $113.18 including all material cost, labor cost, and allocated overhead cost. We will be selling the chair for $140 for about a 19% profit margin.

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INTRODUCTION

1.1 THE CME CAPSTONE PROJECT DESCRIPTION

The Haley Barbour Center for Manufacturing Excellence (CME) is a program that allows engineering, accounting and business majors to receive either a minor or an emphasis in manufacturing. In recent years, the CME has accepted a broader range of majors including Integrated Marketing Communications (IMC) which has allowed me to join the program. Throughout the CME college experience, the students are given the opportunity to gain a well-rounded understanding of manufacturing by taking multiple manufacturing related engineering, accounting, and business courses. In these classes, the students learn about business models using strategic management, accounting concepts such as overhead allocations, and lean manufacturing concepts such as line balancing, takt time, and value stream mapping. Once the students have completed all courses, they are asked to create a product starting from an idea and ending with a marketable product using the collected knowledge from their courses in the CME. This project is known as the senior capstone and is fulfilled as a group project with a team of diverse majors.

1.2 TEAM OBJECTIVE

This year the students were given six products to choose from as their capstone project. Students were given the opportunity to rank the projects in the order of interest and teams would be assigned based on the student's majors and their desired products. Unlike in years past, two teams were given the same projects for each of the six products. This added an additional

challenge for each team, for the products manufactured by each team had to be uniquely designed.

Our team consisted of three engineering majors, an accounting major and my IMC major. We were given the task of making a grove chair while creating something different than the second team (Team Two) given the same task.

BRAINSTORMING

2.1 APPLYING CME CONCEPTS

With the newly added task of differentiating from Team Two, our team implemented the strategic management *VRIO -framework* that we learned in the Manufacturing Business class taught by Professor Paik. This framework helped us evaluate our resources and capabilities we could utilize to create a competitive advantage from Team Two by finding a *valuable*, *rare*, *non-imitable* procedure that our *organization* has resources to implement.[1]

The *VRIO-framework* is a set of questions that help an organization assess their resources and capabilities in terms of the resource-based view (RBV) that could be used as competitive advantage, meaning the organization is creating more economic value in its product market than the competitors. "Economic value is the 'difference between the perceived benefits gained by the purchasers of the good and the economic cost to the enterprise."[2]

Our team began brainstorming, searching for a resource or capability within our group using the *VRIO-framework*. We needed a competitive advantage that was *valuable* in the sense that it would improve our efficiency and effectiveness as well as *rare* in the sense that the value-creating strategy that we used was not being implemented by Team

[1] (Barney, Firm resources and sustained competitive advantage)
[2] (Peteraf and Barney)

Two.[3] Although a valuable and rare resource is important, it is imperative that the resource is also *non-imitable* in the sense that "firms without a resource would face a cost disadvantage in obtaining or developing it," as well our group being *organized* with procedures that would support the exploitation of the value, rarity, inimitability of our resource or capability.[4]

2.2 APPLYING IMC CONCEPTS

Furthermore, I was able to implement an IMC concept that complemented the *VRIO-framework*. During my education as an IMC student, I learned the importance of understanding the customers and their needs, then marketing the product to fulfill their needs rather than focusing on how purchasable the product is, such as focusing on the price or the color of the product. This understanding of the customer and their specific needs is known as "customer insights."

"Customer insight is knowledge about customers which meets the criteria of an organizational strength; that is, it is valuable, rare, difficult to imitate and which the organization is aligned to make use of."[5] Customer insights were considered one of the many resources for our team as we went about finding a competitive advantage over Team Two's more traditional approach to building a collapsible chair.

Although we did not conduct specific observational research to uncover our customer insights, we were able to call upon years of experiencing the Grove as children and students. We recalled that some people bring chairs to watch the football game in the Grove rather than go into the stadium while others need a chair to rest their feet after hours of socializing and preparing for the Grove festivities, and still others simply bring chairs for their young children to sit in. In all

[3] (Barney, Firm resources and sustained competitive advantage)
[4] (Barney)
[5] (Smith)

three scenarios our team felt that comfort would be a top priority when considering which chairs our prospective customers would bring to the Grove.

Furthermore, we knew that the Grove on football game days is set up and taken down in about 24 hours. With such a quick turnaround time, a deciding factor on choosing a chair for the Grove would be the physical ability to get it to and from the Grove. We felt that a fully wooden chair would prohibit people from choosing it due to how cumbersome it would be to bring it to and from the Grove on a busy game day. We believed that our customers would prioritize taking light and maneuverable chairs for ease of relocating them to the Grove weekend after weekend during peak football season.

Lastly, we knew that number of people that go to the Grove was a small audience compared to the number of potential customers looking for a comfortable, portable chair. For this reason, we felt our chair would appeal to a larger market, while still focusing on the Grove, if it were versatile. It would meet the needs of those who want to take a comfortable chair to the Grove, but it could also be marketed to a larger audience that does not attend the Grove.

With these customer insights our team prioritized three qualities for our chair: comfort, portability and versatility. For the sake of this project our team considered a comfortable chair to be one that is not rigid and upright, but lounging, lower to the ground and one that conforms to the user's body. We considered a portable chair to be one that was lighter and therefore easier to carry, and finally a versatile chair to be one that could be used for many different activities.

2.3 FINDING OUR COMPETITIVE ADVANTAGE

Once we understood our customer insights and decided on three desired characteristics of our chair, we evaluated our capabilities and resources that would help us attain the desired

characteristics as well as create a competitive advantage over Team Two's more traditional approach.

For this step I was able to apply previous experience with a specific manufacturing process, sewing. As a child living in a small town, I had to find ways to entertain myself, so I learned how to sew. The clothes in the few stores in town weren't my style and nothing fit me anyway, so I made my own. I loved the process of designing and making my own clothing so much that I started selling my designs on Instagram and ran my own social media. This understanding of social media platforms as a marketing tool led me to pursue my degree in IMC, but I wanted to continue developing my entrepreneurial side. When I heard about CME and how I would be given the task to create a product from start to finish, I knew I wanted to be a part of the program.

During my time at the CME, it has grown my understanding of manufacturing using woodworking, metal working, 3D printing and more; however, the CME machine shop floor did not have a textile working lab as one of their many manufacturing processes to learn. The CME did provide an opportunity to land an internship with my dream manufacturer, one that dealt with clothing. It was when I began pursuing an internship through the CME Hearin Foundation that I was exposed to sewing as a true manufacturing process.

I was given the opportunity to intern at Blue Delta Jeans in Tupelo Mississippi during the summer of 2023 where they made custom blue jeans. Their main manufacturing machinery was the sewing machine. I got to see first-hand what it was like to be a part of a clothing manufacturer, something I had dreamed about from the first piece of clothing I made as a kid.

During my time at Blue Delta Jeans, I gained a better understanding of pattern making as I saw the employees create a custom pattern for each pair of pants they made. I watched as the

cutting machine stamped out the fabric, cutting out the legs, pockets etc. for each pair of jeans. I was exposed to a plethora of different sewing machines, each with a specialized process of creating a pair of jeans. One of the coolest things about my internship was I had the privilege of meeting each person that sewed my custom blue jeans for me and thank them for their time. The experience was one I will never forget. It provided me a better understanding of my favorite manufacturing process, leading me to believe that my capstone team could implement sewing into our process.

With this business as an example of sewing as a primary manufacturing process, I revealed my sewing skills to my team. They believed it could be just the solution for making our chair comfortable, portable and versatile, we just had to pitch the idea to our project advisor and get it approved to add a completely new manufacturing process to the CME machine shop floor.

As a team, we pitched the idea to add sewing to the machine shop floor so that we could make a fabric seat. The idea was accepted, and we were given the opportunity to do something that had never been done before on senior capstone project, working with textiles as a major component of manufacturing.

It was my ability to sew that would be our competitive advantage, allowing us to differentiate from Team Two's traditional approach. We knew it was *valuable* because it would improve our efficiency and effectiveness since it was a quick process and I had experience in sewing. It also was *rare* because Team Two was not implementing it. It was *non-imitable* in the sense that it was not a readily available process on the machine shop floor nor was it one that would be desirable for Team Two to learn. Lastly, we had the *organizational* procedures that would allow us to implement sewing into our chair making process.

It was the sewing that would allow us to substitute a wooden seat with a fabric seat. By using fabric, our chair would conform to one's body better and provide a relaxing lounging position more efficiently than a rigid wooden seat would. A wooden lounge chair would require more wood to provide such a lounging position, adding weight to the chair and cost of material. By using fabric, we predicted we would be able to reduce the material cost, weight of the chair and time it took to build the chair.

Furthermore, we believed a fabric seat would increase the comfort of the chair while reducing its weight. The fabric would also allow our chair to fold in half, increasing its portability. Finally, we decided to design our chair like a lounging poolside chair to increase versatility, encouraging our customers to use our chair by the pool, at the beach and in their backyard.

With the help of our customer insights and the *VRIO- framework*, our team was able to find a competitive advantage against Team Two, leading us into the next step of our capstone project, market research.

MARKET RESEARCH RESULTS

With the idea of our Rebel Lounge chair formulated, we needed to receive feedback from our potential customers. In order to do this, I created a survey that was then sent out and recorded 49 potential customer responses.

Our market survey found that a total of 88% of potential customers we surveyed agreed that the lounge design would provide optimal comfort compared to a structured, upright chair. Figure 1 shows that there were a few potential customers that felt neutrally and fewer that disagreed, whereas 54% “strongly agreed” that a lounging chair is more comfortable than an upright chair and 34% “agreed,” giving us 88% of potential customers agreeing.

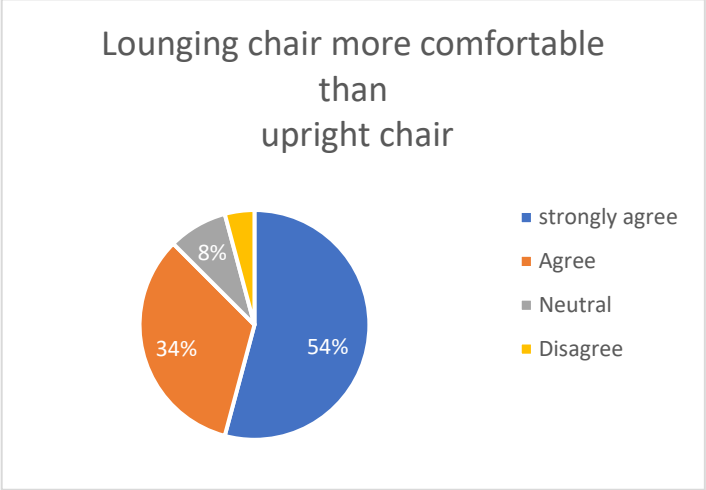


Figure 1: Comfort of Chair

We also believe this type of chair is versatile for the Grove, the beach, a backyard pool and more due to its portability which is an important characteristic according to

Figure 2. Our survey responses presented to us that 42% of our potential customers believe a portable chair is “very important” when choosing a chair to buy and 29% believe it’s “important,” giving us 71% positive feelings toward portability of a chair.

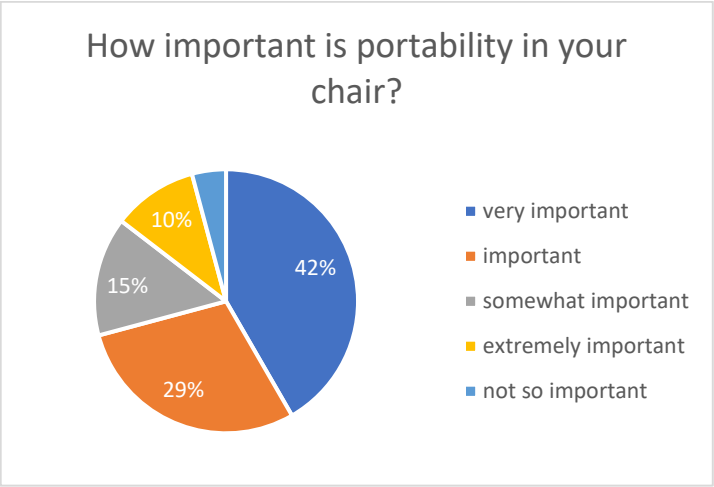


Figure 2: Importance of Portability

Of our survey, only 46% of people currently take chairs to the Grove on game days, however 91% would like the option to sit in a comfortable chair while at the Grove, therefore there is a large opportunity to provide portable Grove chairs on game days. This is apparent in Figure 3 where 16 people who do not currently bring a chair to the Grove “strongly agree” that they would like the option to sit while at the Grove and still 8 more “agree” with this statement. The 91% is made up of all those who “strongly agree” and “agree” regardless of if they currently bring their own chair.

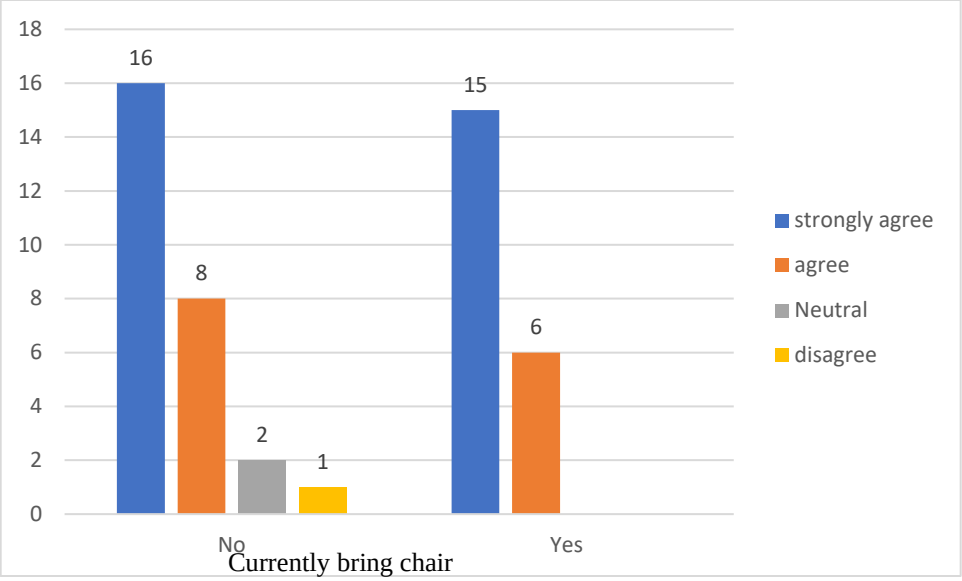


Figure 3: Option to sit at The Grove

It was also helpful to see that although they might not take a chair to the Grove, 77% take their own chairs to the beach, perhaps alluding to the fact that they have yet to find a chair that they would like to bring to the Grove. We can provide the one they are looking for. This number is apparent in Figure 4 when adding all the yes answers about whether or not they take chairs to the beach. Moreover, of the people who do not currently bring a chair to the grove, 70% take a chair to the beach. This shows us that they are still potential customers for our chair because it is versatile for the beach.

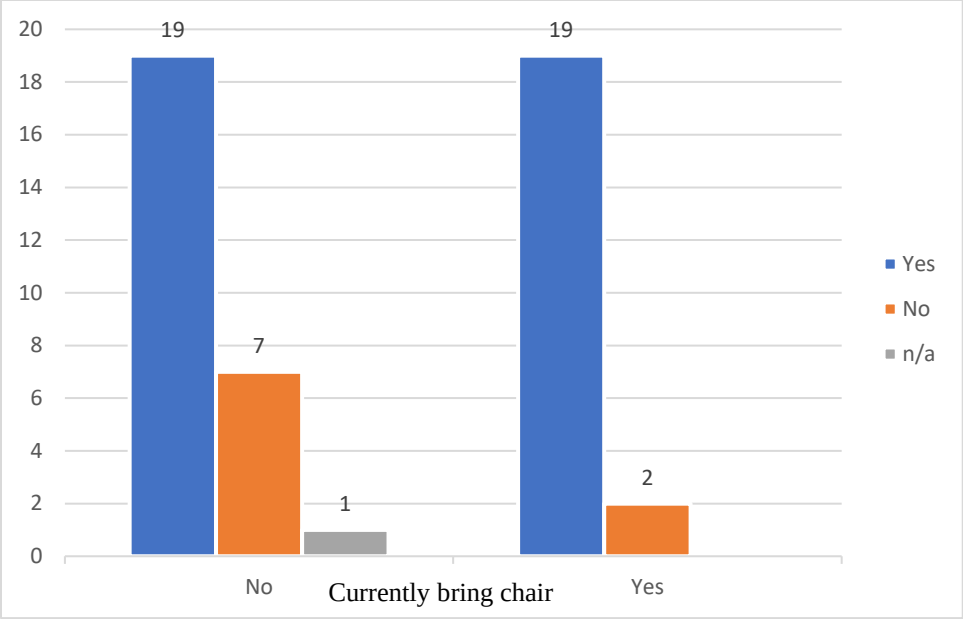


Figure 4: Take chairs to the beach

Further, our target audience is 45-year-olds and above due to their increased interest in having a portable, comfortable chair for outdoor activities over a younger audience. While there are not enough numbers of each age to accurately represent each age group's preferences, within our small survey, we found that 65% of the 45-54-year-olds were interested when adding the "very interested" and "extremely interested" numbers in Table 1 together and dividing it by the total responses from that age group. All other age groups were lower percentages when doing the same equation for each age group.

Table 1:Ages of Interest

Count of how interested in a chair like ours?	age?					
how interested in a chair like ours?	45-54	25-34	18-24	55-64	64 and above	35-44
somewhat interested	5	3	3	3	2	1
very interested	9	2	3	2		
extremely interested	4	2	2	2	1	
not so interested	2	1			1	
Grand Total	**20**	**8**	**8**	**7**	**4**	**1**

Our survey also provides evidence that those who are 34 and older are more willing to spend more on a chair like ours, which costs us $113.18 to manufacture, allowing us to price it within their comfortable price range of $101-$150 at $140.

Overall, our market survey results prompted us to move forward with our design, allowing us to keep our priorities of making a comfortable, portable and versatile chair for the Grove.

FURTHER RESEARCH

4.1 PRICING

We analyzed competitors who also provide comfortable and portable chairs. Again, we are defining comfortable chairs as chairs that lounge, so although a competitor might be the inexpensive sport chairs, we are not considering them in this analysis. Instead, we are comparing ours to other lounge chairs, also known as sling chairs. Many sling chairs are available on Amazon and other websites from anywhere to $20-$250. When considering the craftsmanship, quality and the fact that it is Mississippi made for a Mississippi tradition, we believe consumers will pay for our chair at a market price of $140.

4.2 WEIGHT LIMITS

We believed to have found the strongest wood within our price range; however, we felt there should be a weight limit for our chair. Similar products have weight limitations of 250 lbs. We were able to build 10 chairs, each one tested by staff at the CME, helping us gauge our weight limit. We estimated our chairs to safely hold around 220 lbs.

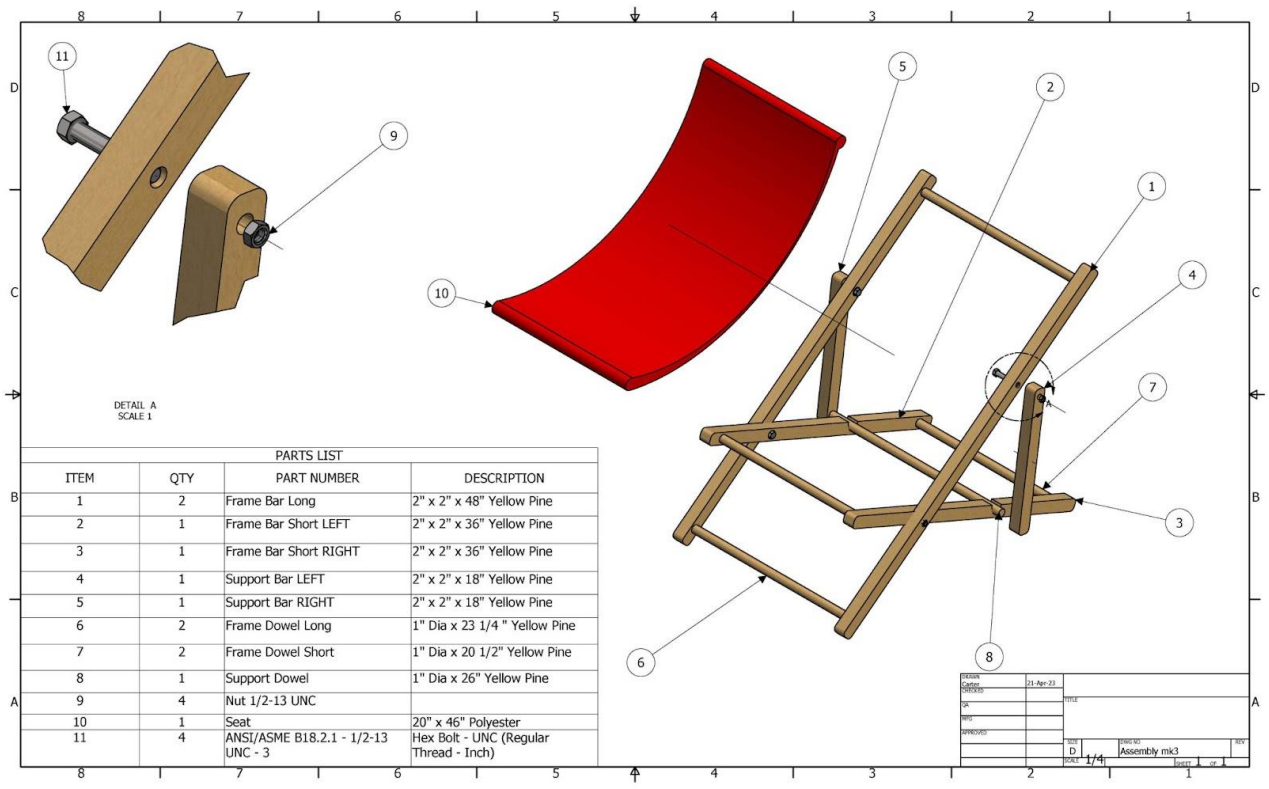
Once we finished our research and had a better understanding of the market for chairs like ours, we took to designing our Rebel Lounge chair. As a team we discussed the desired size of our chair as well as what material we would use to build it. Then, one

of my engineering team members, Carter Doss set out to design our chair using computer-aided design (CAD) software.

DESIGN DRAWINGS

Each piece of our product was first designed in CAD to help us understand what material we needed to create our lounge chair. Once we understood the makeup of our chair seen in Figure 5, we designed each part of our chair individually as seen in Figure 6 through Figure 12.

Once we understood the required material to make our chair, we ordered it and created a prototype. After our first prototype we made minor adjustments. Our initial concept allowed for an adjustable back rest, but we removed that feature prior to prototyping for safety reasons. We added counterbores for the nuts to sit flat with the wood seen in Figure *5* at the #4 and #5 intersections so that the chair could fold. We decided to rout the ends of the wood pieces for aesthetic reasons and we increased the length of our fabric seat for increased comfort. We also moved the 1 ½ inch notches as seen in Figure 7 and Figure 8 further down to create a more comfortable lounging angle.



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	Frame Bar Long	2" x 2" x 48" Yellow Pine
2	1	Frame Bar Short LEFT	2" x 2" x 36" Yellow Pine
3	1	Frame Bar Short RIGHT	2" x 2" x 36" Yellow Pine
4	1	Support Bar LEFT	2" x 2" x 18" Yellow Pine
5	1	Support Bar RIGHT	2" x 2" x 18" Yellow Pine
6	2	Frame Dowel Long	1" Dia x 23 1/4 " Yellow Pine
7	2	Frame Dowel Short	1" Dia x 20 1/2" Yellow Pine
8	1	Support Dowel	1" Dia x 26" Yellow Pine
9	4	Nut 1/2-13 UNC	
10	1	Seat	20" x 46" Polyester
11	4	ANSI/ASME B18.2.1 - 1/2-13 UNC - 3	Hex Bolt - UNC (Regular Thread - Inch)

Figure 5: Assembly and Parts List

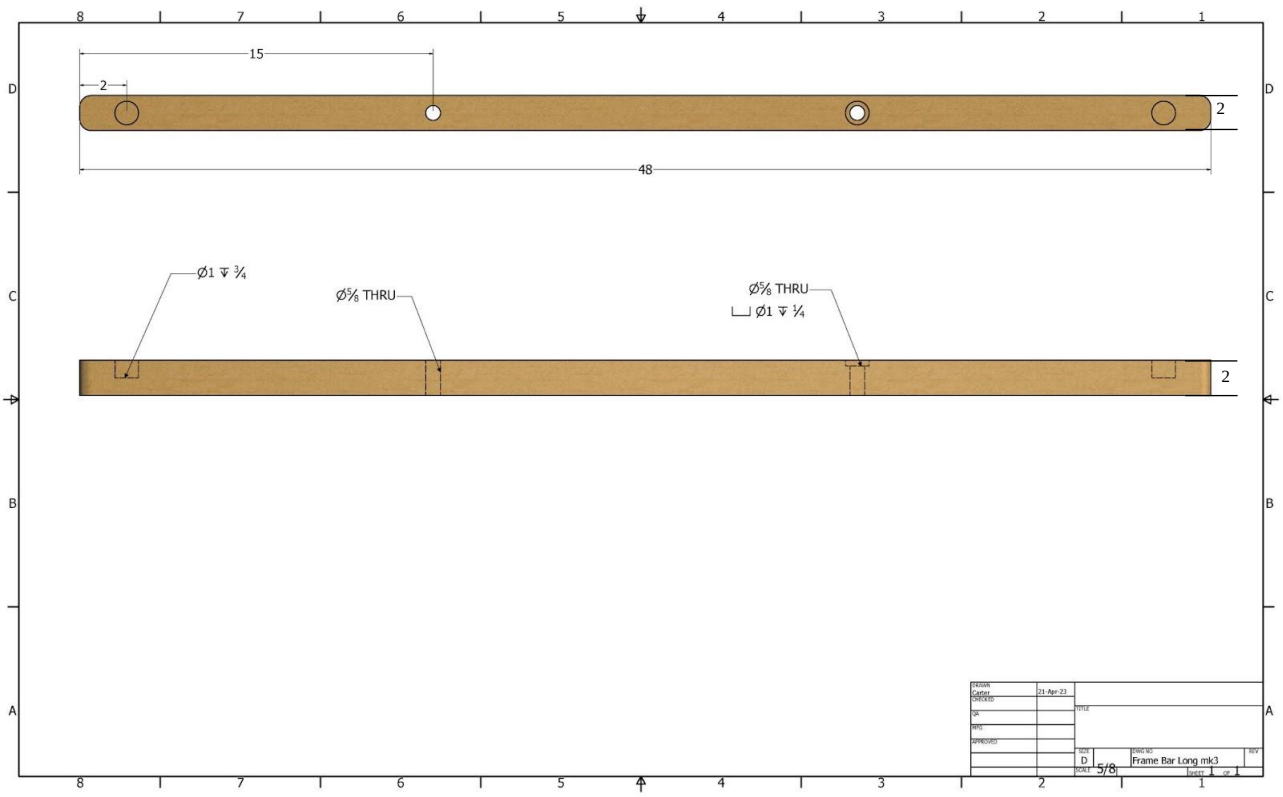


Figure 6:Frame Bar Long

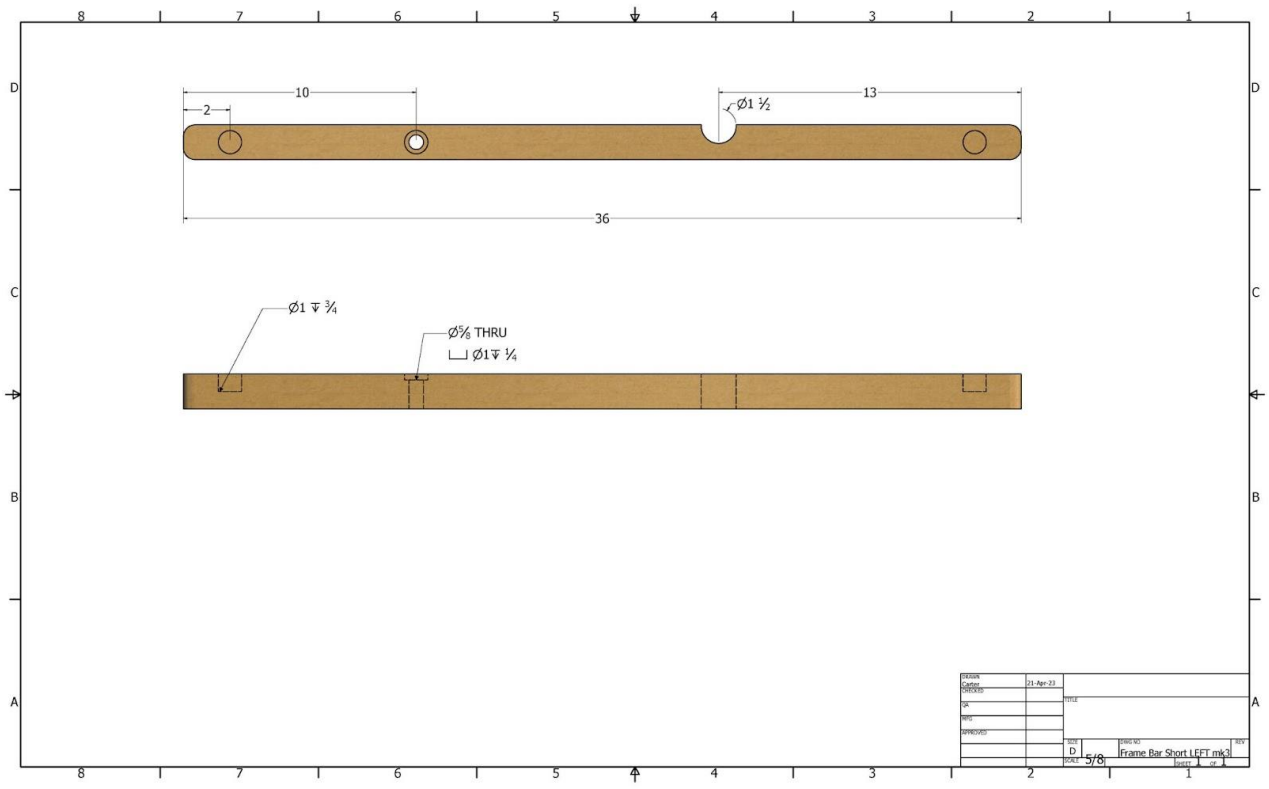


Figure 7:Frame Bar Short Left

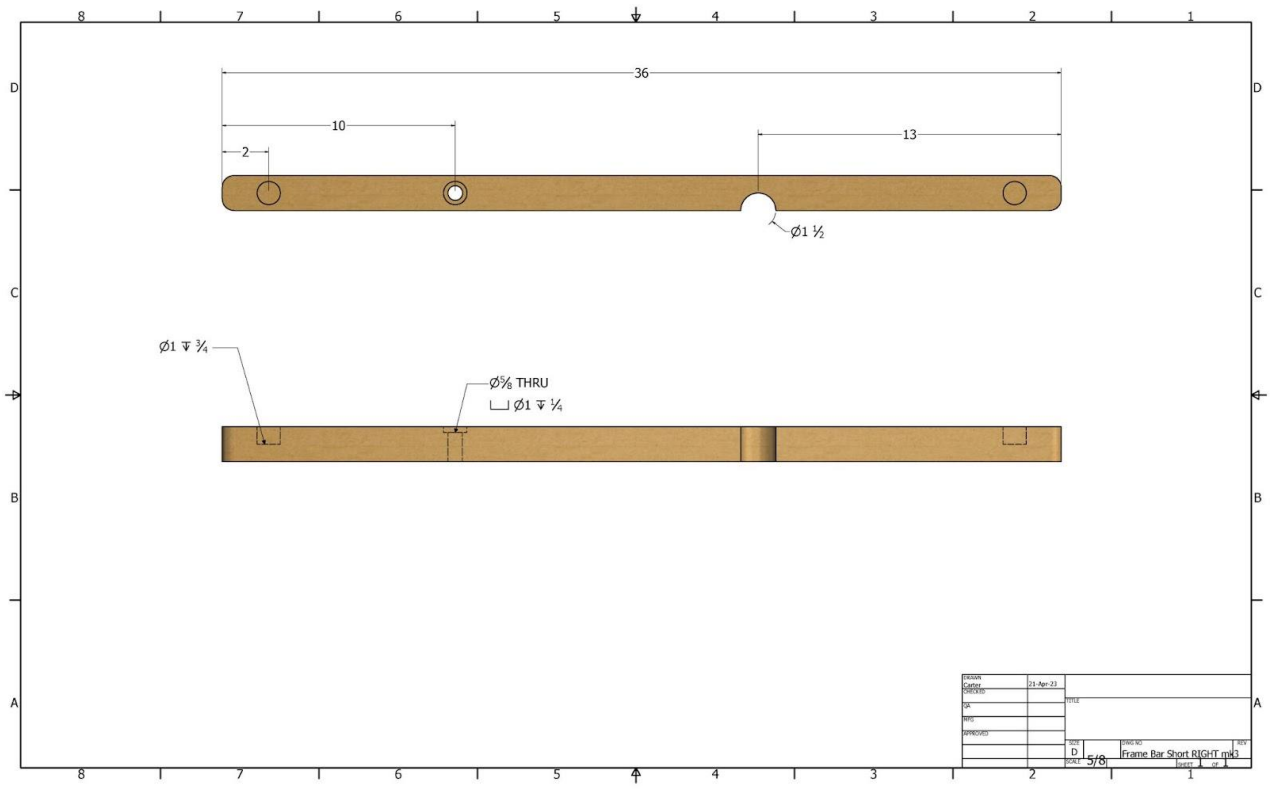


Figure 8:Frame Bar Short Right

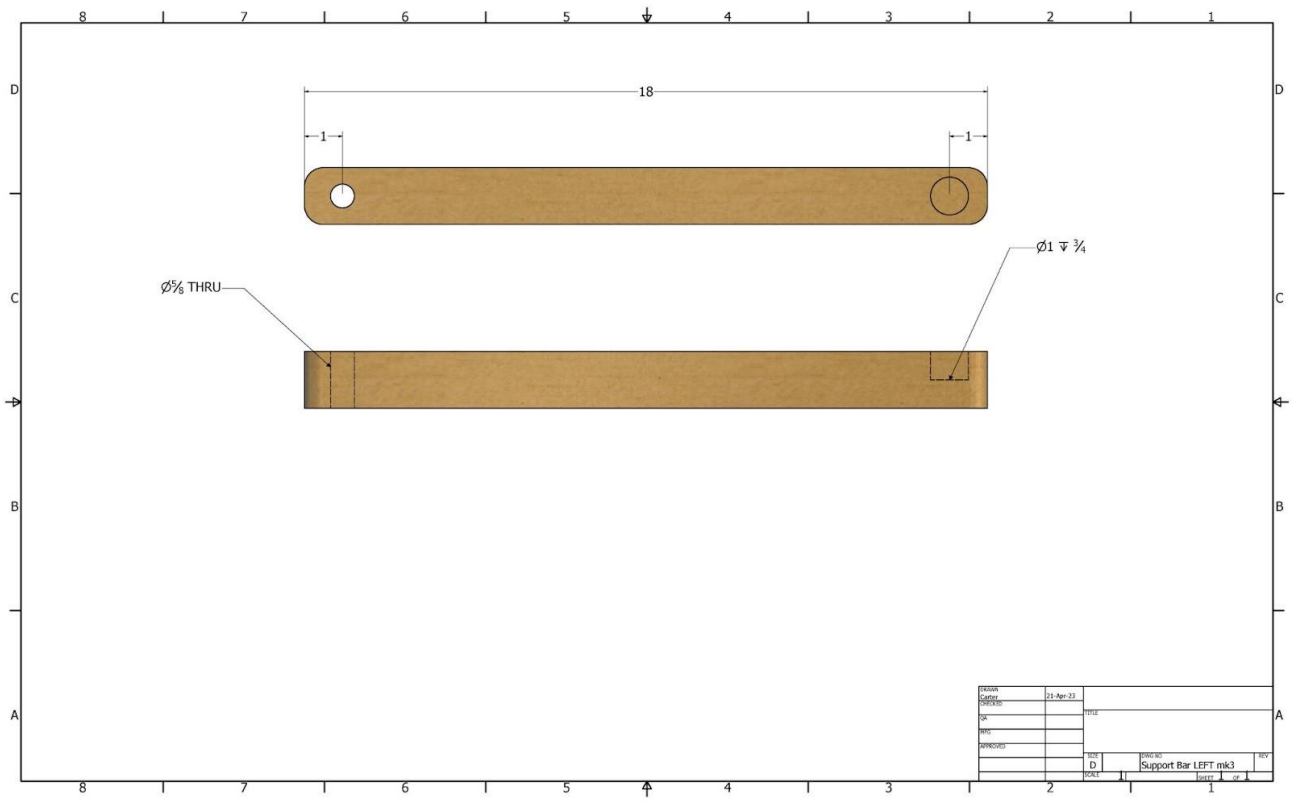


Figure 9:Support Bar Left

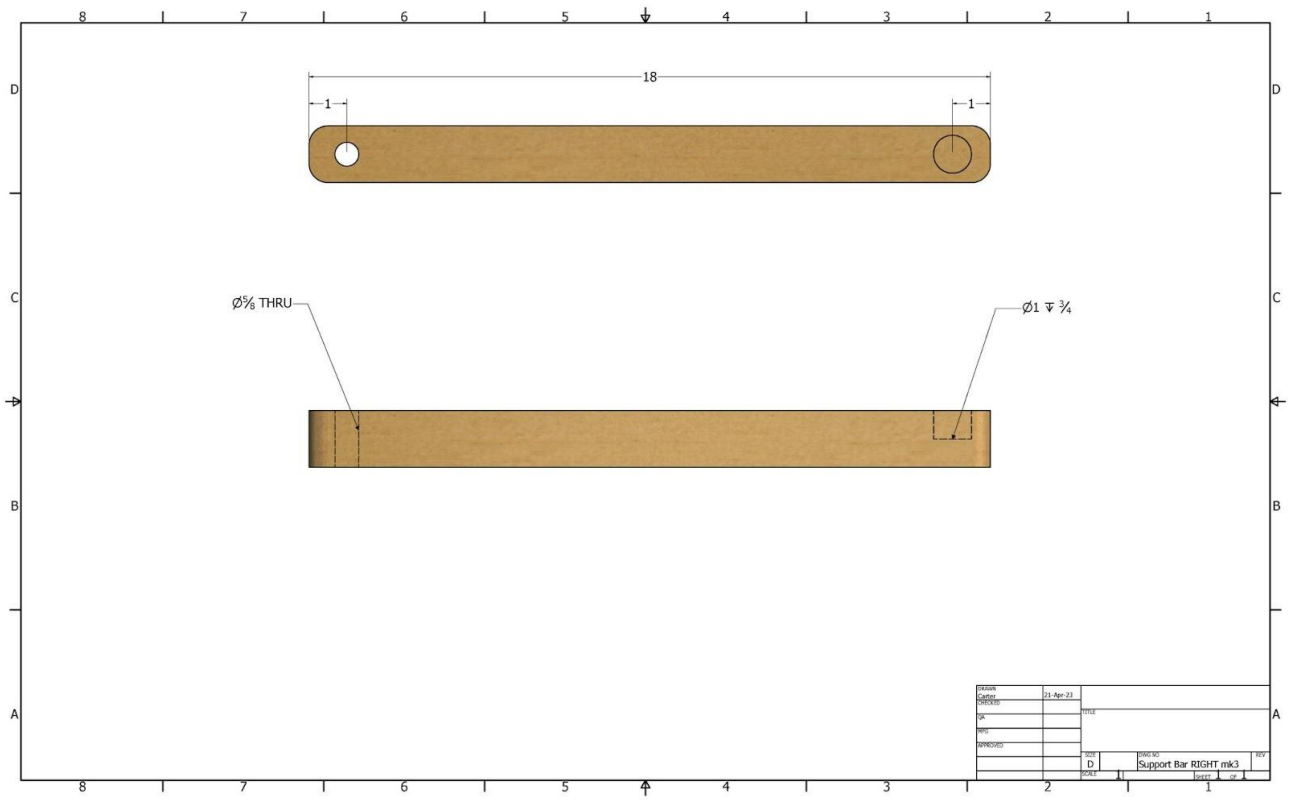


Figure 10:Support Bar Right

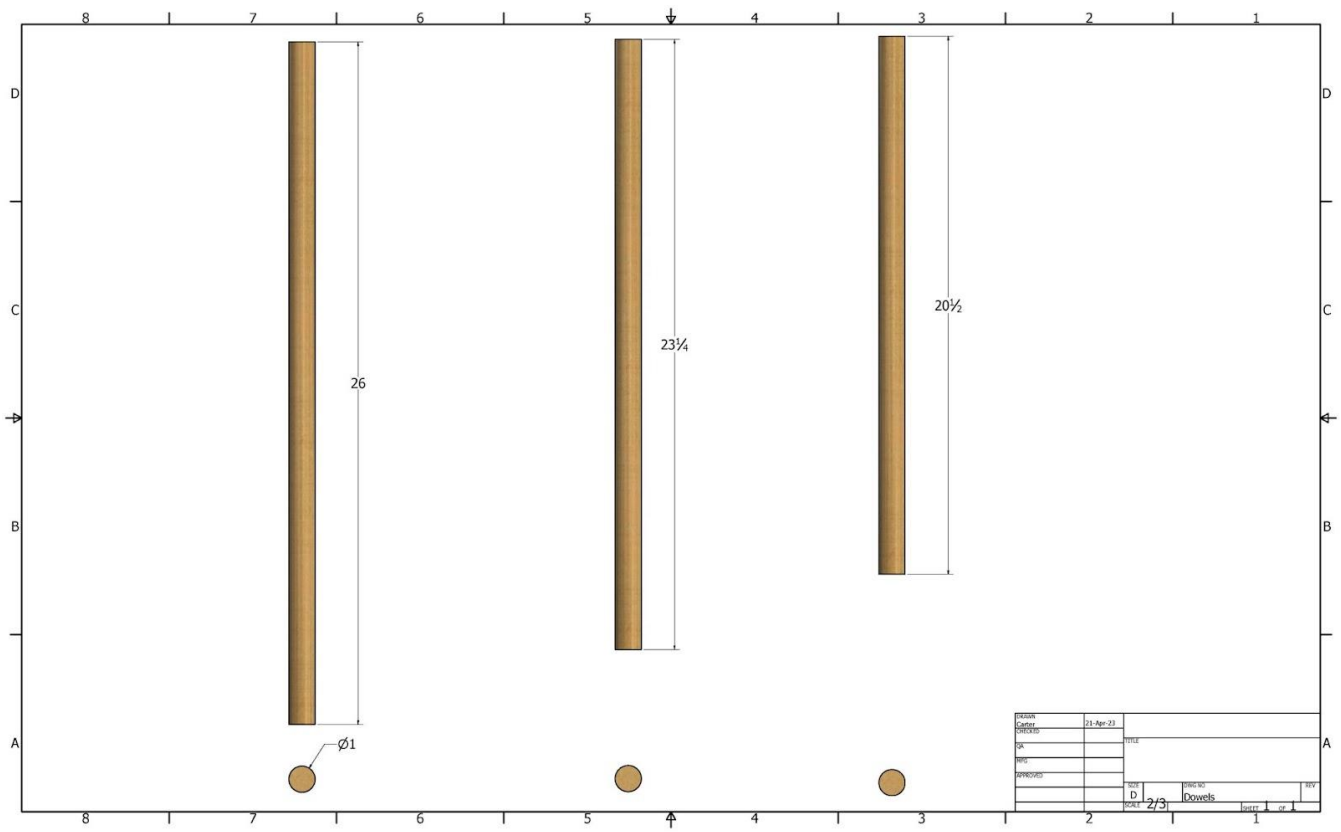


Figure 11:Dowels

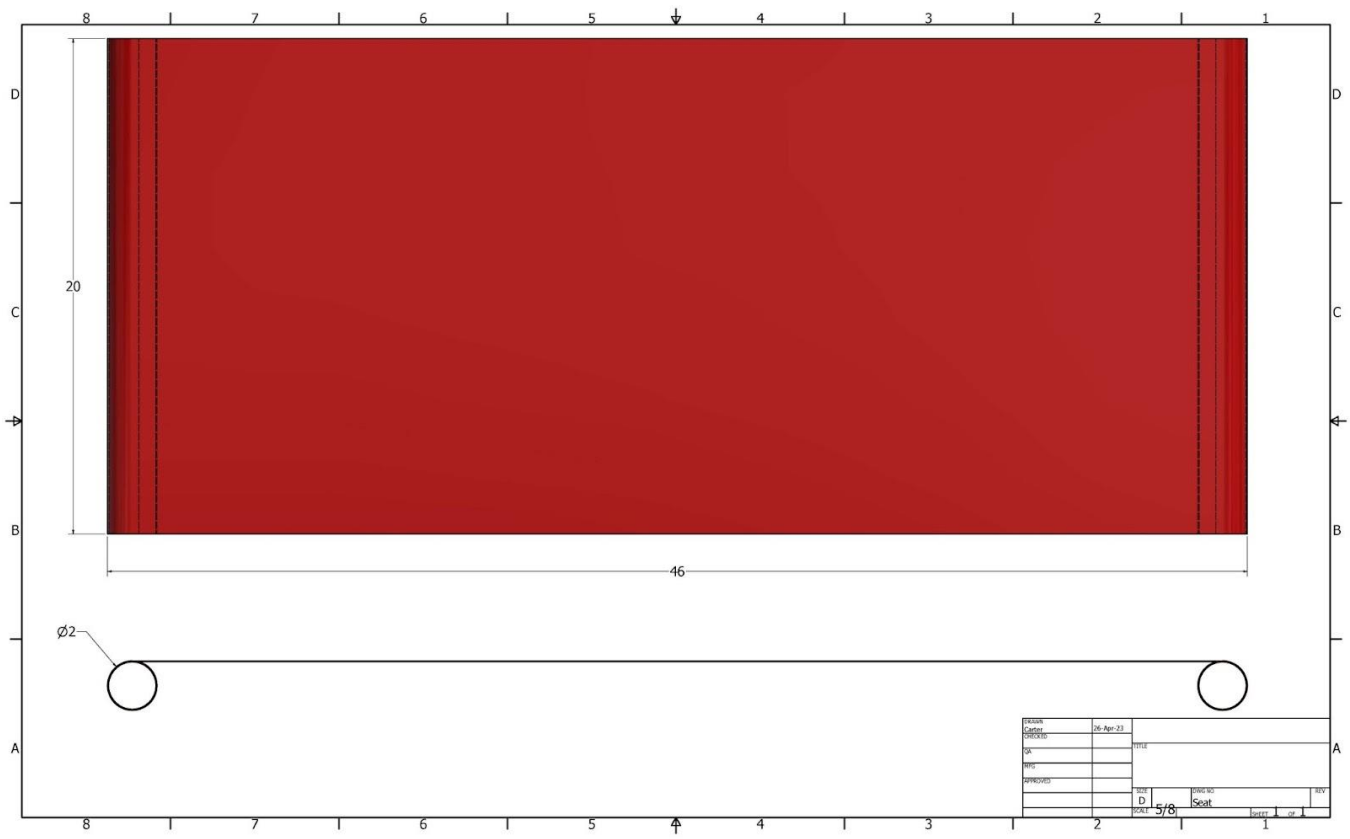


Figure 12:Seat

MANUFACTURING EQUIPMENT

We decided the wood for the Rebel Lounge chair would be pre-cut 2 x 2 pine construction with hardwood dowels found at The Home Depot. We used a red, PVC-coated polyester fabric for its strength and weather tolerance. Our first machining process was using a miter saw to cut the chair legs, spacers, and wooden dowels to the desired size. We then used a routing machine to round off all of the edges of the 2 x 2 pieces of pine to create a cleaner finish and increase the friction surface area between the chair and the ground.

We used two different drill presses, one with a one-inch forstner bit and the other with a 5/8ths drill bit to create the counter bore for the dowels, bolt holes, bolt heads, nuts and the notches on the adjustable backing. A pneumatic brad nail gun along with wood glue and a mallet were used to secure the wood dowels to the rest of the chair. We tightened the hardware using two 3/4-inch socket wrenches. Finally, scissors were used to cut the fabric and a sewing machine was used to sew the fabric together.

STANDARD OPERATING PROCEDURES

We believe that our Standard Operating Procedures (SOP) are the simplest way to do each step. We found that each individual step took around 10 minutes to complete and having a SOP made it easy for each member of our group to know how to do every step in the process. The SOPs also allow for someone unfamiliar with the process to quickly follow along with what our workers are doing at each step. The SOPs for each of the five workstations are as follows

Table 2:Sewing SOP, Table 3: Cutting SOP, Table 4: Drilling SOP- 5/8", Table 5: Drilling 2 SOP-1", Table 6: Final Assembly SOP. The original SOPs had accompanying photographs to make the steps even clearer, but the photos were removed for formatting purposes in this report.

Table 2:Sewing SOP

1	Make sure the bobbin (the circle piece that provides the bottom thread) has thread and thread the top needle.
2	Cut fabric using the paper pattern.
3	On one of the 48" sides, fold over fabric with the shiny side facing you and the rough side (the side you sit on) folded in by 1."
4	Begin sewing, after an inch of sewing, hold the reverse handle down and sew one inch backward. Let go of the handle and continue sewing forward the length of the fabric and reverse stitch one inch at the end.
5	Repeat steps 3 and 4 on the other 48" side of the fabric.
6	On the 20" sides, fold over fabric with the shiny side facing you and the rough side folded in by 2 1/2" (this will be the hole for the dowels).
7	Repeat step 4.
8	Repeat steps 6 and 4 on the other 20" side of the fabric.

Table 3: Cutting SOP

1	Set up miter saw with fences for each chair leg length.
2	Pick up 2x2 wood stock and measure and mark 48” leg using leg jig. Cut leg using miter saw.
3	After two long legs are cut, bring them to the router table and round off the ends. Make sure to round off the ends in the same direction.
4	Hand off the completed round legs to Drilling 1 station.
5	Repeat step 2 for two short legs using 36" measurement.
6	Repeat steps 3 and 4 for short legs.
7	Repeat step 2 for two spacers using 18" measurement.
8	Route spacers and hand spacer off to Drilling 1 station.
9	Pick up wooden dowel stock and cut one long dowel using 26.5" measurement on dowel jig.
10	Pick up wooden dowel stock and cut two medium dowels using 23.5" measurement.
11	Pick up wooden dowel stock and cut one short dowels using 20.5" measurement.
12	Place all wooden dowels in final assembly area.

Table 4: Drilling SOP- 5/8"

1	Drill press has a 5/8" diameter drill bit set up to allow for full thru holes.
2	After receiving the **long legs** from the cutting station mark the hole locations of the **two** 5/8" holes using the marking jig and a punch. The piece will need to be turned 180 degrees longways to mark a hole location on each side. Mark holes with rounded edge perpendicular to the table.
3	Drill the thru holes for the long legs and pass them forward to Drilling 2 Station.
4	After receiving the **short legs** from the cutting station mark the hole location of the **one** 5/8" hole using the marking jig and a punch. Mark holes with rounded edge perpendicular to the table.
5	Drill the thru holes for the short legs and pass them forward to Drilling 2 Station.
6	After receiving the **spacers** from the cutting station mark the hole location of the **one** 5/8" hole using the marking jig and a punch. Mark holes with rounded edge perpendicular to the table.
7	Drill the thru holes for the spacers and pass them forward to Drilling 2 Station.

Table 5: Drilling 2 SOP-1"

1	Drill press has a 1" diameter forstner bit set up to allow for only 0.7" of downward travel. The table of the drill press should be set so that there is as little space between the bit and the wood as possible.
2	After receiving the long legs from Drilling 1 Station mark the hole locations of the two 1" holes using the marking jig and a punch. The piece will need to be turned 180 degrees longways to mark a hole location on each side. Mark holes with rounded edge perpendicular to the table.
3	Drill the blind holes for the long legs.
4	Countersink **one** of the 5/8" thru holes by drilling until the top of the drill bit is flush with the part. Countersink on the same side as the blind holes.
5	Bring long legs to the final assembly station.
6	After receiving the **short legs** from Drilling 1 Station mark the hole locations of the **two** 1" holes using the marking jig and a punch. The piece will need to be turned 180 degrees longways to mark a hole location on each side. Mark holes with rounded edge perpendicular to the table.
7	Drill the blind holes for the long legs.
8	Countersink the **one** 5/8" thru hole by drilling until the top of the drill bit is flush with the part. Countersink on the same side as the blind holes.
9	Clamp the two short legs together and mark a line for the half holes onto the clamped short legs using the marking jig, making sure that the blind holes are facing down towards the table. Also verifying that your mark is on the opposite end of the piece from the one 5/8" thru hole.
10	Drill two half thru holes by drilling through the center of the two clamped short legs. Bring the short legs to the final assembly station.
11	After receiving the **spacers** from Drilling 1 Station mark the hole location of the **one** 1" hole using the marking jig and a punch. Mark hole with rounded edge perpendicular to the table.
12	Drill the blind holes for the spacers. No countersinking is needed on the spacers.
13	Bring spacers to the final assembly station.

Table 6: Final Assembly SOP

1	Using two long legs (48"), fabric seat, and two medium dowels (23.5") place one of the long dowels through the pocket in the seat fabric. Using a mallet and wood glue press the dowel with the fabric on it inside the end of each long leg (this is the top of the chair back). Place the remaining dowel on the other end of the legs creating a rectangle. ensure the use of wood glue in all dowel holes. Brad nail the dowels to the legs using one nail per hole. Note: apply wood glue to the inside of bore holes to prevent glue from getting on fabric.
2	Using two spacers, one long dowel (26.5"), two bolts, two nuts attach the back rest to the long legs. Use a mallet to press the long dowel into the spacers secure with wood glue and brad nails. Then attach the back rest assembly to the long leg assembly with the two bolts and two nuts ensuring the bolt heads are on the inside of the large legs and the nuts are on the outside. Tighten using two 3/4" sockets and ensure proper rotation. note: if it does not swivel easy loosen nut a quarter turn.
3	Using two short legs (36"), two short dowels (20.5"), two bolts, two nuts, and the assembly made in the previous steps, with one short dowel pass it through the end of the fabric seat. Using the two short legs and a mallet pass the short legs through the center of the large assembly and press short dowel passed through fabric seat into the short legs using wood glue and brad nails. Use the two bolts and nuts along with a 3/4" socket to secure the short leg assembly to the long leg assembly. Ensure the bolts are not so tight the keep the chair from folding.
4	Test the chair and ensure it folds easily and it can be propped up correctly.

FIRST PRODUCTION RUN REFLECTION AND IMPROVEMENTS

Throughout the past two semesters, our manufacturing process went through many iterations. Almost every time we built a chair, we found something we wanted to optimize or a new idea of how to make our process easier. This concept is called improvement or kaizen and is used when implementing lean production in manufacturing. The Japanese word "kaizen" means "change for the better" and is considered continuous improvement, meaning there is no end to improving a process[6]. The CME introduced "kaizen" by teaching us how to identify and remove non-value-added actions.

Value-added actions are that which directly add to the product. For example, a worker sewing the fabric together, or actively drilling the holes in wood. Whereas non-value-added actions do not directly add positive impact on the product and is considered action that the customer should not have to pay for or considered waste[7]. For example, non-value-added actions would be excessive walking in between stations such as sewing and drilling. There is no processing happening in between the station, therefore there is no value added to the product in the time it takes to walk the work in process (WIP) from the sewing machine to the drill press. When implementing kaizen, these non-value-added are identified and reduced as much as possible.

[6] (Baudin and Netland) pg 33.
[7] (Liker) pg. 27

With an understanding of lean manufacturing and removing as much non-value-added processes as possible, our team continued to remove waste practices with each production of our chair. One process we could optimize was at the sewing station. If we were to mass produce these chairs, we decided we would invest in an industrial fabric cutting machine to reduce the time it takes to cut out each piece of fabric for the seat as well as create a more consistent cut. Another improvement we made was at the cutting station where we decided to identify any material that was not to our standards. Some pieces of wood were not to our standards, so we discarded them and included that in our final cost as overhead.

At the drilling stations, we realized that we passed our material back and forth between stations, creating non-value-added processing. We made two jigs, or devices that help facilitate a production process[8] to ensure that the product flows in one direction throughout the process and we allocated different procedures to each drilling station. During final assembly, we made a few changes such as getting rid of the glue bottle and having the glue in a cup while we used a paint brush to apply the glue in the holes for the dowels to adhere to.

We also created a factory layout where our working cells were close to each process and implemented another manufacturing concept known as line balancing. Line balancing is the practice of using the takt time, or the time needed to meet customer demand, to discern how much work each station has[9]. For example, our takt time was 12 minutes, meaning we needed to allocate up to 12 minutes worth of work to each workstation to be as efficient as possible.

We also determined our cycle time while line balancing our production line. The cycle time is "the actual time it takes to process the piece[10]." We timed each workstation to understand how

[8] (Radhwan, Effendi and Rosli)
[9] (Baudin and Netland)
[10] (Baudin and Netland)

long it took each process to complete. We were then able to reallocate certain steps to different workstations in order to balance the time it took one worker to finish a process. For example, we found our longest task to take 10 minutes to complete, so we allocated responsibilities to the rest of workers to meet the set standard of 10 minutes worth of work. This way, no worker was waiting for a process to finish, and no WIP was sitting between workstations, creating waste from waiting time.

7.1 TAKT TIME AND VALUE STREAM MAP

After our first production run, we implemented our adjustments and went about determining takt time for our process. We did this to better understand our capacity, how many workers we needed to meet our demand, and the time restrictions we would be under in order to meet our demand. "Takt time is the amount of time that must elapse between two successive piece completions in order to meet the customer demand."[11] It is calculated by dividing net available production time by demand.[12] We used it to better understand how quickly we needed to finish each process in order to meet our demand. Knowing our takt time also helped us discern how many workers we would need to be working within the hour limit we were given to meet our demand of five chairs and hour. We decided to have five workers and put one worker at each station. Our net available production time was 60 minutes, divided by five chairs, giving us a takt time of 12 minutes. We knew we needed to finish a chair every 12 minutes in order to achieve our goal of producing five chairs an hour. While our goal was to produce a chair every 12 minutes, we were able to produce one every 10 minutes, putting us under our takt time. Future

[11] (Baudin and Netland) pg 105
[12] (Baudin and Netland) pg 105

modifications to create a more efficient line balancing and adherence to our takt time is discussed later in this report.

Another manufacturing tool that the CME focusses on that we used is known as the value stream map (VSM). It is a flowchart that helps develop the lean process by visualizing the flow of product and information through the processing steps.[13] Our VSM helped us understand what our production processes, our material flows as well as information flows would be if we were mass producing our Rebel Lounge chairs. It also helped us recognize our value-adding processes and identify non-value-adding processes. Ultimately our map in Figure 13 helped us identify wasteful processes and flows that could be modified to make our system more productive.

Our VSM helped us by representing our workstations and identifying which processes fed into other processes. It showed us our cycle time per station, helping us better understand how long it took us to meet our given demand of five chairs an hour. It showed us that we were under takt time, exceeding our demand at 40 minutes with minimal amount of waste.

[13] (Jacobs and Chase) pg. 402

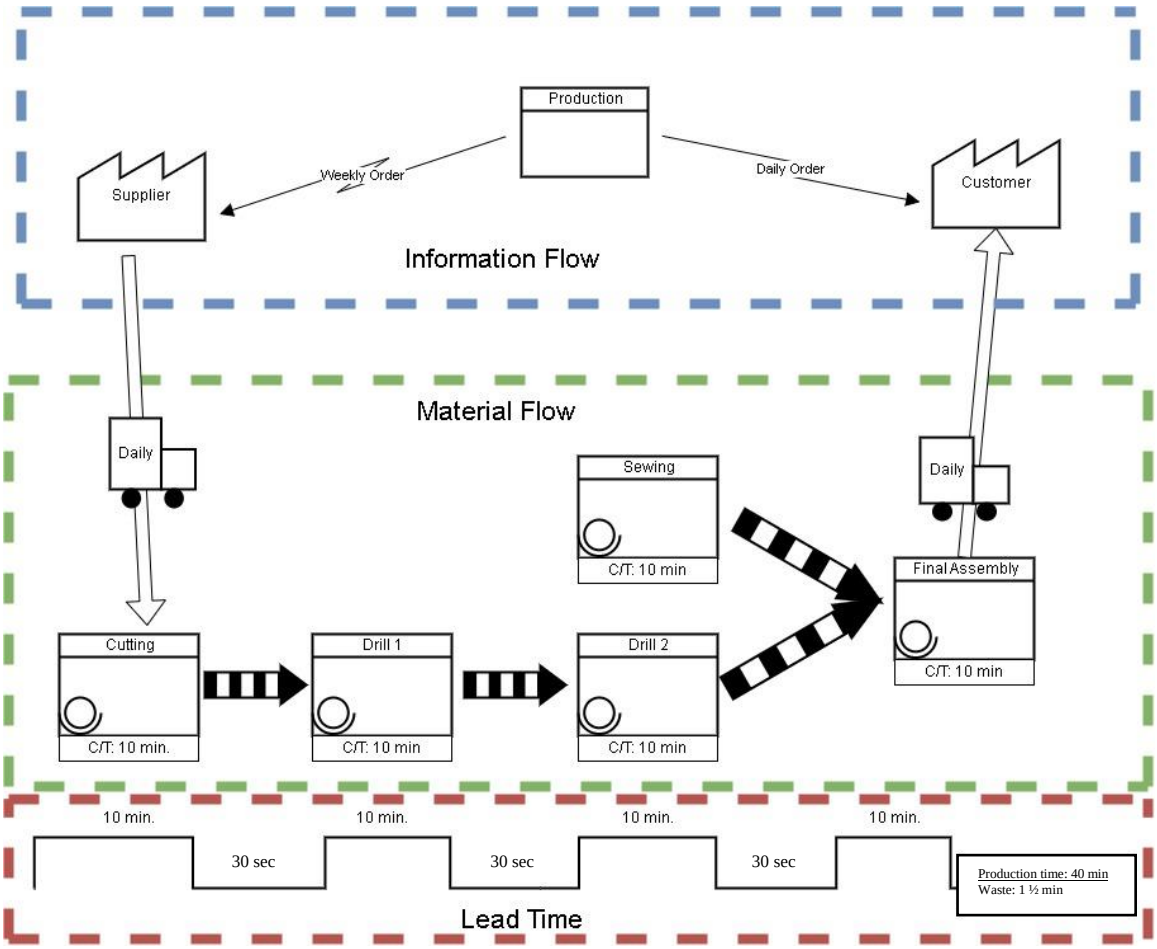


Figure 13:Value Stream Map

POKA-YOKE IDENTIFICATION

Another manufacturing tool we used is the Japanese term, poka-yoke. Poka-yoke is an error-proofing tool to help reduce mistakes in production[14]. We felt by creating a fixture, or a tool, to measure quickly it would help reduce error and increase efficiency because the legs of our chair and the spacer are three different lengths and require holes drilled in different positions. The use of a fixtures for each pair of legs and spacer was used to ensure the correct length of the legs could be cut quickly. The fixtures as seen in Figure 14 and Figure 15 were designed to make measuring the length of each cut for the three legs easier by not requiring the use of a tape measure. Figure 14 is a piece of plywood with drilled holes that allows the worker to place it on top of each chair leg and correctly mark where the holes go in the legs each time.

The legs also used the same jig as the drill press jig for the back adjustment notches as seen as the top fixture in Figure 15. A line was drawn on the legs to determine where the two pieces needed to be cut using this fixture. This is done with a pair of legs at a time to reduce the time needed drilling. The wood dowels also have a fixture to ensure the correct length is cut due to the three lengths required for the chair as seen as the bottom fixture in Figure 15. The fabric uses a paper pattern to ensure the material is cut in at the proper size and the pockets are sewn with the correct diameter. In total the chair will need two fixtures, two jigs, and one pattern.

[14] (Liker) pg. 133

Figure 14:Drill Press Jigs

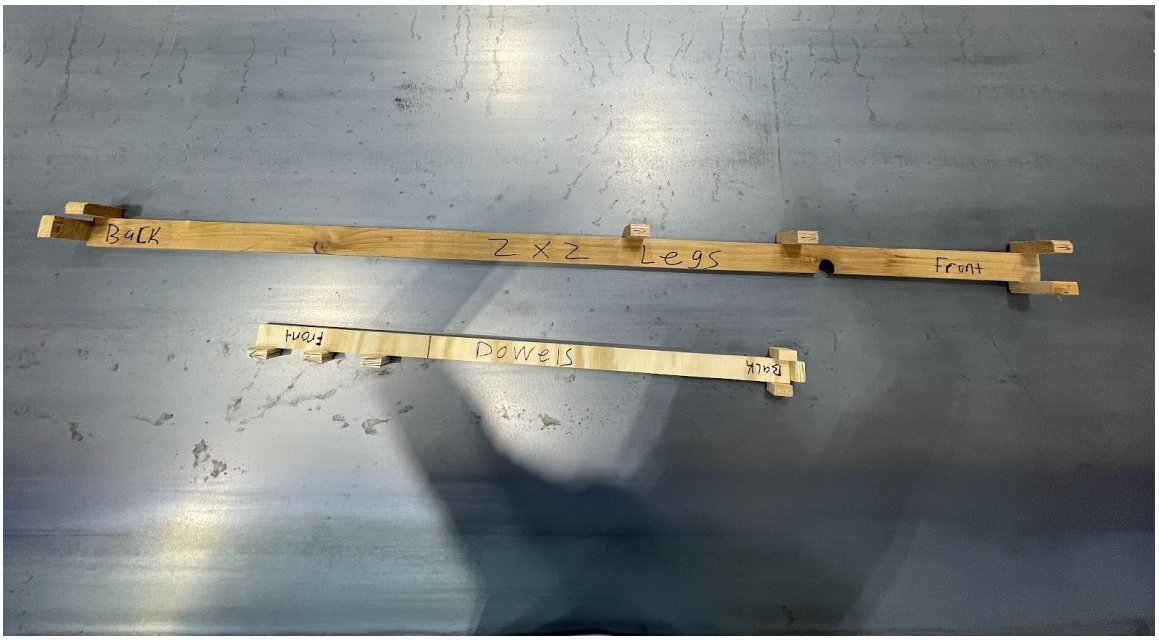


Figure 15:Fixture of Legs and Dowels

COST ANALYSIS

9.1 INITIAL COST ESTIMATE VS. UPDATED COSTS

Table 7 represents our expected cost per unit in the spring of 2023. Our material cost was too high because we were using the cost of about 10 chairs worth of material rather than considering wholesale prices as if we were mass producing the product. In our initial cost analysis, we did not allocate overhead correctly either. With our machine cost we should have included a portion of all other expenses such as salaries, rent and material. Our labor cost was also too low, putting our expected cost per unit at $68.74 which we would soon find out was not an accurate cost.

Table 7: Initial Cost Per Unit

Material Cost	$51.95
Machine Cost	$10.00
Labor Cost	$6.79
Cost Per Unit	$68.74

Our initial material cost analysis is represented in Table 8. Again, we were not considering wholesale prices so items were higher in price than they would be if purchased in bulk. By using the actual costs of our materials from hardware stores in

Oxford to create our 10 assigned chairs, out total material cost came out to be $51.95 per unit.

Table 8: Initial Material Cost

Material	**Price per Piece**	**Quantity per Chair**	**Cost per Chair**
2in x 2in x 8ft Wood	$4.98	3	$14.94
1 x 48 in Wood Dowel	$7.99	3	$23.97
½- 13 UNC-3 Bolt	$2.19	4	$8.76
½- 13 UNC-3 Nut	$0.47	4	$1.88
Red PVC Coated Fabric	$2.50 (yard)	.56	$1.40
Overhead per Chair			$1.00
Total			**$51.95**

When comparing our initial material costs to our updated material cost found in Table 9, one can see the difference that wholesale pricing made on our total material cost. Once we re-evaluated and considered wholesale pricing, we were able to reduce cost of material by 24%. With the wholesale pricing, our chair cost us $33.58 in material.

Table 9: Updated Material Cost

Material	Price per Piece	Quantity per Chair	Cost per Chair
2in x 2in x 8ft Wood	$2.04	3	$6.12
1 x 48in Wood Dowel	$5.14	3	$15.42
½-13 UNC-3 Bolt	$2.19	4	$8.76
½-13 UNC-3 Nut	$0.47	4	$1.88
Red PVC Coated Fabric	$2.50	0.56	$1.40
Total			**$33.58**

Our initial labor cost seen in Table 10 is lower than our actual costs. We did not know the exact time it took for each station to complete their process before we made our chair, therefore we underrepresented the hours for each station. We also chose to pay our employees $13.57 an hour because it is the minimum wage for Mississippi manufacturing.

Table 10: Initial Labor Cost

Direct Labor Budget	Total # of People	Hours	Labor per Hour	Total
Sewing	1	0.083	$13.57	$1.13
Cutting	1	0.083	$13.57	$1.13
Drilling 1	1	0.125	$13.57	$1.70
Drilling 2	1	0.125	$13.57	$1.70
Assembly	1	0.083	$13.57	$1.13
Total	**5**	**0.500**		**$6.79**

Once we timed each process, we correctly allocated the time it took for each process and were able to pair it with a number value for the cost of labor. I also decided to pay $20 hourly wages. I did this because we want skilled workers to build our chair and we care about our employees, and our chair can still fit nicely in the middle of the market price range at this wage.

Table 11 represents the correct pay for each station, putting our labor cost allocation at $15.34 per chair and our cost per unit at $113.18.

Table 11: Updated Labor Allocation

Direct Labor Budget	**Total # of People**	**Hours**	**Labor Per Hour**	**Total**
Sewing	1	0.133	$20.00	$2.66
Cutting	1	0.150	$20.00	$3.00
Drilling 1	1	0.150	$20.00	$3.00
Drilling 2	1	0.167	$20.00	$3.34
Assembly	1	0.167	$20.00	$3.34
Total	**5**	**.767**		**$15.34**

In the fall of 2023, our final cost per chair was $113.18 as indicated in Table 12. The material price of our chair dropped because we used wholesale pricing. Our labor costs went up because we reallocated the correct amount of time for each station and increased the wages. Our overhead costs went up as well because we included salaries, rent, equipment etc.

Table 12: Updated Cost Per Unit

Material Cost	$33.58
Labor Cost	$15.34
Overhead Cost	$64.26
Cost per Unit	**$113.18**

Table 13 shows the costs of buying our machines which we believed would be more economically viable than renting them since they are relatively inexpensive. We included the cost of our machines in our overhead costs. Further explanation of our overhead will be discussed later in this report.

Table 13: Machine Costs

Machine	**Quantity**	**Purchase Price**
Miter Saw	1	$300.00
Drill Press	2	$3,998.00
Router Table	1	$150.00
Sewing Machine	1	$100.00
Total		$4,548.00

9.2 PRICE JUSTIFICATION

The majority of our cost comes from overhead. Our overhead is currently allocated at 200% of material and labor costs. Overhead costs will be this high because it encompasses machine costs, salary expenses, rent expenses, utilities expenses, marketing expenses, materials such as a nail gun, thread, and glue, and other various expenses. The salary expense is what creates most of the cost because it includes the salaries of the manager, accountant, marketing employees, engineer technicians, and custodial staff. All of those salaries could add up to over 50% of our overhead for a year. While we might not want overhead to be so high, it is necessary to cover all of the costs that come with running a manufacturing plant.

9.3 SELLING PRICE OF CHAIR

We plan to sell our chair at around $140. At this amount, the profit per chair will be around $26.82, which is about a 19% profit. The prices of similar chairs on Amazon are anywhere from $20-$250, allowing us to sit comfortably within the market in regard to our pricing. As stated in our market research, $140 is also within the range our target audience is willing to pay. We can also justify our price by saying that our chair is handcrafted, good quality, and manufactured in Mississippi for a Mississippi tradition.

9.4 SALES FORECAST

As displayed in Table 14, in our first year of production, we expect to sell 10,000 chairs. We came up with this number because of the demand of our capstone project was to make 5 chairs per hour. Our total revenue in one year would be $1,400,000 and our total cost would be $1,131,800.00. We would make a profit of $268,200.00.

To reach our optimistic goal, of producing 12,000 chairs a year we would have to decrease our takt time to 10 minutes. This seems attainable since each workstation took about 10

minutes to complete a task, therefore allowing us to make six chairs an hour. We believed that with further modifications we would be able to achieve this optimistic goal.

Table 14: Sales Forecast

Sales	**Pessimistic**	**Expected**	**Optimistic**
Units	8,000	10,000	12,000
Price per Unit	$140.00	$140.00	$140.00
Total Sales	**$1,120,000.00**	**$1,400,000.00**	**$1,680,000.00**
Costs			
Materials	$268,640.00	$335,800.00	$402,960.00
Labor	$122,720.00	$153,400.00	$184,080.00
Variable OH	$514,080.00	$642,600.00	$771,120.00
Total Cost	$905,440.00	$1,131,800.00	$1,358,160.00
Gross Profit	**$214,560.00**	**$268,200.00**	**$321,840.00**

FINAL PRODUCTION AND FUTURE IMPROVEMENTS

Our final production run was an overall success. Again, for the sewing operation a cutting table would reduce the time for cutting, but we decided against it for the final production run. The cutting operation went well, and there was great communication between drilling and cutting when drilling needed an additional piece made. Drilling 1 had a buildup of materials from cutting, causing a bottleneck. One way to solve this would be to line balance more effectively. Once the jig was set for drilling 2 the operation went smoothly.

Our biggest area for further improvement was at final assembly. Our operator, Karson, had too large of a load and the station was ill equipped to help him assemble such a large chair alone. Despite this, he still managed to stay within takt time. Going forward, we would have a jig that keeps the chair off the ground while assembling it. We would also allocate more floor space to help with mobility while building the chair. We could also line balance more efficiently, reallocating certain processes to different workers and designating two workers to help each other with the final assembly.

Overall, our team worked well together, communicating when necessary and coming together to create five complete chairs within an hour. I am so thankful to have had such a great team during this whole process. We created a friendship which made the long hours of discussing plywood, nuts and bolts enjoyable. Everyone was more than willing to take on any task asked of them while we helped each other cross the finish line.

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