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Product Realization Capstone: Element Proof Safety Steps for Willie Price Lab School

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PRODUCT REALIZATION CAPSTONE:
ELEMENT PROOF SAFETY STEPS FOR WILLIE PRICE LAB SCHOOL

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

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ABSTRACT

The purpose of this document is to describe the process we took to complete our capstone which paired the Center for Manufacturing Excellence with the Willie Price Lab School. The goal of the capstone was to remake step stools for the students of Willie Price, as the last stools failed to withstand weather damage. However, with the COVID-19 pandemic, plans were hindered, shifting the goal from actually producing the steps to creating instructions so that a younger Center for Manufacturing class could complete the production at a later date. Standardized Work Instructions, a detailed production plan, and engineering drawings were created to the best of our ability with the lack of resources during the crisis. We hope that this document is used to not only produce this single run for Willie Price but to also produce more steps as service to other institutions on campus, the community, and the state.

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I. INTRODUCTION

Capstone Structure and Center for Manufacturing Excellence Background

The capstone project is a yearlong assignment aimed at encapsulating and utilizing the vast library of knowledge gained by CME students' during their time at the CME. It not only involves designing and creating a product, but also devising a large-scale manufacturing process and forming an in-depth business plan. As such, the project combines the engineering, business, and accounting aspects present within the CME curriculum into one all-encompassing project. The Center for Manufacturing Excellence (CME) was created in 2008 with the goal of providing academic and real-world experience in the manufacturing industry.

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Problem Definition

In 2017, the Center for Manufacturing Excellence teamed up with Willie Price Lab School to fix a pressing issue, the lack of a sturdy step stool for the children trying to reach higher surfaces or counters. Willie Price Lab School is The University of Mississippi's only childcare facility. Located on campus in Kinard Hall, Willie Price provides the preschool experience to three and four-year-old children while giving students of the university the opportunity to learn hands-on teaching skills [1]. A previous CME capstone team of five members came up with a solution. Step stools, called “Step Buddies,” were designed and created to be used in front of water fountains, in bathrooms, and in front of doors coming back inside from the playground. The 26”x 16” was the perfect size for water fountains and the outdoors, and the wooden frame of the stool allowed for a sturdy option for rowdy children while keeping the stool light enough for the all-female staff to move.

In August of 2019, Willie Price approached the CME again, but this time with the request for a new and improved Step Buddy. After two years of outdoor element exposure, the wooden frame buckled while in use. Additionally, two large stools, one in front of the toilet and the other in front of the sink, proved to take up too much floor space in the bathrooms. Children were hopping from one step to another because there was not enough room to step down off the stool in front of the toilet and then back up onto the one in front of the sink. This provided a chance for the students to hurt themselves by either falling off the step or hitting the side of the step. Willie Price staff also noticed a lack of Step Buddies in locations that they wished they had them. There were no steps in front of the fish tank, requiring students to stand on their tip toes and hold on to the base of the tank to see the fish. This process also put them in danger of falling or knocking the fish tank down.

On Friday, March 12th, 2020, The University of Mississippi announced its shift to online learning due to the COVID-19 pandemic. Because our production run was scheduled to start the following Monday, March 15th, we had to determine an alternative route to finishing our capstone. Still wanting to complete our project and realizing Willie

Price was still in need of the new steps, we shifted our capstone's focus to be able to work on it remotely. The new focus was to create a detailed description of how to manufacture the step as well as a plan for producing the 22 steps requested by Willie Price. The intention is that the CME use our work to guide the incoming freshman class through completion of the process. The freshman course will use our detailed instructions to produce these 22 steps for Willie Price in their Manf 152 lab course.

Team Introduction

The "Step Buddy" student team consists of Catherine Thomas (Point of Contact), Allan Heuerman (Financial Consultant), Christian Eaves (Lead Engineer), Jared Mumme (Research and Development), and Stuart Gunner (Recording Secretary and Risk Management). Catherine Thomas is a General Business and Biology double major with plans to attend Physician Assistant school. Allan Heuerman is an Accounting major attending Veterinary Medicine school in the fall. Jared Mumme is a Managerial Finance major planning to continue his studies through the Masters of Business Administration program at Ole Miss. Stuart Gunner is also a Managerial Finance major with plans to serve as an intern for Campus Crusades for Christ, and Christian Eaves is a General Engineering major with plans to attend law school at Ole Miss. Our contacts through Willie Price consisted of Assistant Director, Mrs. Alyce Krouse, and Director, Dr. Kenya E. Wolff. The CME Staff that aided our team were Dr. Jack McClurg, Mr. Rick Hollander, Mr. Edward Carr, Mr. Mark McAnally, Mr. Michael Gill, and Mr. James McPhail.

II. DESIGN

Customer Need

As stated earlier, Willie Price staff needed new, waterproof steps due to the fact that the steps that were stored outdoors fell victim to the elements. The staff also requested a smaller step design to be placed in the bathrooms and in front of the fish tank. They requested that all current steps be remade and some current steps be converted to the smaller size. They also requested an additional two steps be made so that they could have steps in all the locations that they already have them and then two in front of the fish tank. Of the original 20 steps, they requested that 14 steps remain the larger size and six steps be converted to the smaller design. They requested that the steps in front of the fish tank also be the smaller design, making a total of eight small steps, 14 larger steps, and 22 steps all together.

The staff noted that they enjoyed the original design of the step other than the lack of element proofing. They noted that the rubber on the top was ideal to prevent the students from slipping. They also noted that the wooden design provided enough weight that the step would not slide around while remaining light enough for the mostly female staff to pick up and move around.

Brainstorming Phase One

After brainstorming solutions as a group, we met with our assigned floor technician, Mr. James McPhail, for additional insight. When we asked Mr. McPhail about potential materials we should look into, he suggested we consider building the stool entirely out of carbon fiber. The basis of the idea was that the carbon fiber could be bent into the shape we desired and then cure. We considered both making the entire stool out of carbon fiber or only utilizing the carbon fiber for the top of the stool. This seemed very promising. The shaping and curing process looked to be relatively easy. Additional pros to using carbon fiber were its durability, lightness, and its water resistance. After performing further research however, we discovered that using carbon fiber would have its cons as well. Carbon fiber is hard to machine, can possibly become uneven during the curing process, would be difficult to attach to the wooden legs, and was actually slippery when wet. On top of all of that, the carbon fiber was highly expensive. Due to this, we decided to look for another alternative.

This led us to pressure treated wood. As a product that must be able to withstand the effect of water, we needed a material that was strong and moisture resistant. Initially, there were worries about if the pressure treated would be dangerous due to chemicals that are used to treat the wood. This concern was of great importance to us because it would affect team members who have long term exposure to the material making the steps as well as the Willie Price students, who as curious children, are prone to touching things and placing their hands in their mouths. However, according to research, the toxic chemical of concern Chrominated Copper Arsenate was phased out of use in pressure treated wood by the Environmental Protection Agency in 2013. However, because pressure treated wood still contains chemicals and repeated, chronic, and long term exposure to wood dust can increase the chance of ingesting or inhaling the chemicals, it is important to take precautions when manufacturing the wood [2]. Because this is a short production run, the risk of prolonged exposure is greatly reduced, but we suggest operators wear gloves and a long sleeve shirt. The possibility of inhaling the wood dust is greatly reduced in the CME facility due to the use of the dust vacuums attached to the sawing and milling equipment, but we suggest wearing a mask during the dust production operations. Additionally, to reduce the possibility of ingesting the wood, operators should not eat or drink on the floor.

Other changes on our initial design from the previous project was the change in size of the Step Buddies. The previous group used a length of 26", but we decided to change that to 24". We are now able to get four cuts out of an 8' cut of wood with little to no scrap.

Also, with Willie Price in need of eight smaller stools, we were faced with the task of determining the sizes for those too. We decided to make the smaller stool exactly ¾ the size of the bigger stool. This will keep the measurements comparable between both stools. Stability would not be affected due to the fact that the step used the same proportion as the previous design. Willie Price needed these stools for areas with less space such as the bathrooms. The initial design incorporated the same rubber as the previous group's project.

Customer and Capstone Feedback

Once the initial design was finalized and the prototype built, we headed to Willie Price to ask the staff for feedback. The staff approved of the size of the smaller variant and were overall pleased. They did however request that we round the corners of the stool for safety purposes and suggested we paint the stools powder blue to match the colorful atmosphere inside the school. These suggestions were implemented in the final design.

Additionally, we received feedback from our professor, Mike Gill. Mr. Gill told us that the prototype looked crude and could use some work aesthetically. Specifically, he noted that the rubber matting on the prototype looked poorly attached. He suggested we look into contact cement or epoxy to achieve flush attachment. In the meantime, he suggested we use exclusively glue to attach the rubber to the top piece and not to use staples. He advised a trial and error approach to determine the best material and method to attach the rubber.

Brainstorming Phase Two

After addressing the feedback from our midpoint presentation and the customer, the Willie Price staff, we went back to the drawing board to fix the major concerns: the rubber's aesthetic, the process of attaching the rubber, and painting the pressure treated wood. Taking the negative feedback of the visual appearance of the rubber on our prototype, we considered alternatives to the rubber topping. The thick rubber material that the previous capstone group used was difficult to cut and difficult to attach, creating air bubbles in the rubber. Additionally, although it was easy to wipe clean, the rubber used held dirt well after someone stepped on it.

The process to put the rubber on the step was also an issue we faced. At first, we attached the rubber using wood glue. We tried to stretch the rubber over the wooden top. The process used a good deal of energy and all 5 members of our group. This process produces the most air bubbles even after we reinforced the rubber's attachment with staples. The stapling also added to the poor visual appearance of the top of the step. Next, we tried a process similar to the previous capstone group's process. We used clips on one end of the step top to attach the rubber and generate tautness in the rubber when we pulled from the other end. This process also used a good deal of energy and was time consuming. The number of air bubbles, however, was dramatically reduced using this method. Staples were also still required using this method, so the visual appearance still did not meet the request of our course instructor.

Under the direction of our floor technician, James McPhail, we researched alternative materials to the rubber. One idea was pre-cut thin abrasive strips, similar to those that would go on the bottom of tubs that do not already have anti slip components. This, however, removed the advantage of the previous rubber's easy cleaning as well as cushioning that the previous rubber provided. After moving on from this idea, we looked into other rubber alternatives. We found Safe Way "Safetrac" tape similar to that used on jet ski steps and the tops of boat trailer wheels. The material was thinner but still provided cushioning. Additionally, the Safe Way product had an adhesive bottom. When we tried to attach the material to a secondary prototype, we were able to simply cut it with scissors and attach it using its own adhesive. The new material was also easy to wipe clean and proved anti-slip resistant when water was poured on the top of the step. Due to all of the overwhelming positives attributes of this material, we settled on this incorporating this material in the final design.

Our final feedback was from the customer and also addressed the physical appearance of the step. The previous unstained and unpainted wood was boring, especially for a pre-school. When we offered color treating the wooden portion of the steps to the customer, the customer was ecstatic. After debating the color, Willie Price staff determined that a powder blue colored paint would meet their needs. Our dilemma was now determining how to paint pressure treated wood. The company of wood we ordered, Yellawood®, provided helpful instruction on how to paint their wood [3]. The process starts with making sure that the pressure treated wood is dry. This is because the wood can still be wet after being treated with the chemicals. They recommend performing a "sprinkle test" to make sure the wood is dry enough to allow the paint to dry without streaking. A sprinkle test includes dropping several drops of water on the piece of wood. If the water beads up, they recommend waiting a few days and then performing the test again, if the water soaks into the wood, the wood is ready to be painted. Then the company recommends using an alkyd oil-based primer followed by two coats of high-quality acrylic latex top coat paint. Both of these products were ordered and the painting of the exposed wooden portions of the step was incorporated in our final design.

Final Design

The final design took into account all the initial changes from the first step to our model while also incorporating the changes made after feedback from our instructor and the Willie Price staff. The final design of the larger step incorporated the powder blue painted pressure treated wooden legs and the pressure treated plywood top covered with the new, Safetrac anti-slip tape. The final design also featured scotch tape anti slip disks on the bottom to reduce wear of the wooden bottom on the day care's tile floor. The smaller step incorporated all the same features but at the smaller size.

Additionally, all cuts made from bulk pieces of wood were decreased 1/16" from the normal measurement, decreasing the amount of scrap left at the end. With this measurement, we were able to account for lost material due to the kerf. With the smaller cut, lost length in the bulk wood is accounted for and therefore the last piece cut from the bulk piece will be a normal length and not deemed as scrap.

The final design incorporated the following measurements. Due to the COVID-19 pandemic, our engineer lacked the resources to complete CAD drawings of our design on a computer, therefore the following hand drawings represent the parts and dimensions. The sketches for individual parts as well as the assembled product are illustrated in Figures 1-6.

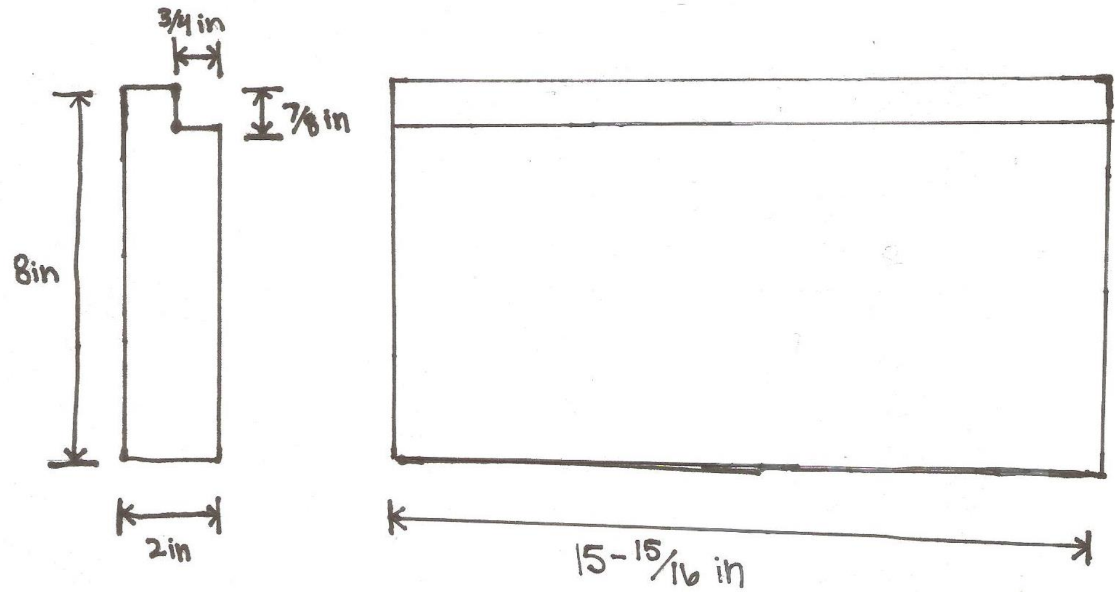

Figure 1: Large Step Leg Dimensions

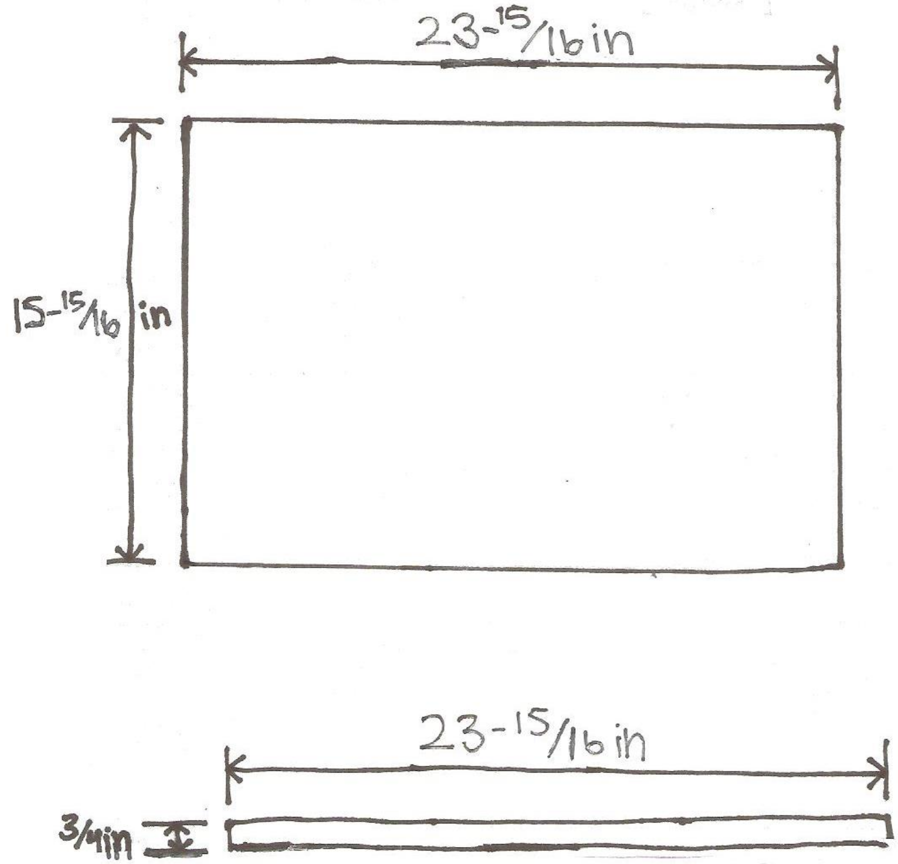

Figure 2: Large Step Top Plywood Dimensions

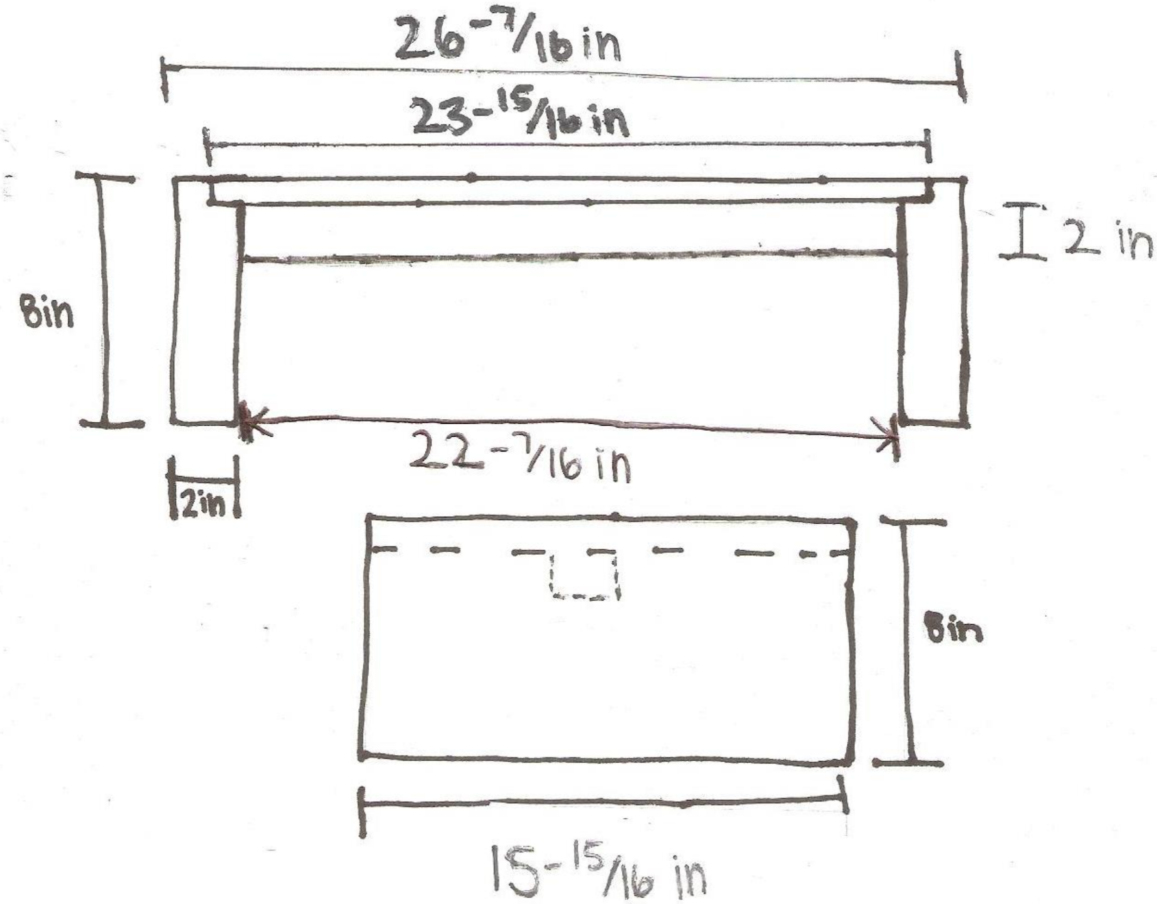

Figure 3: Large Step Assembly

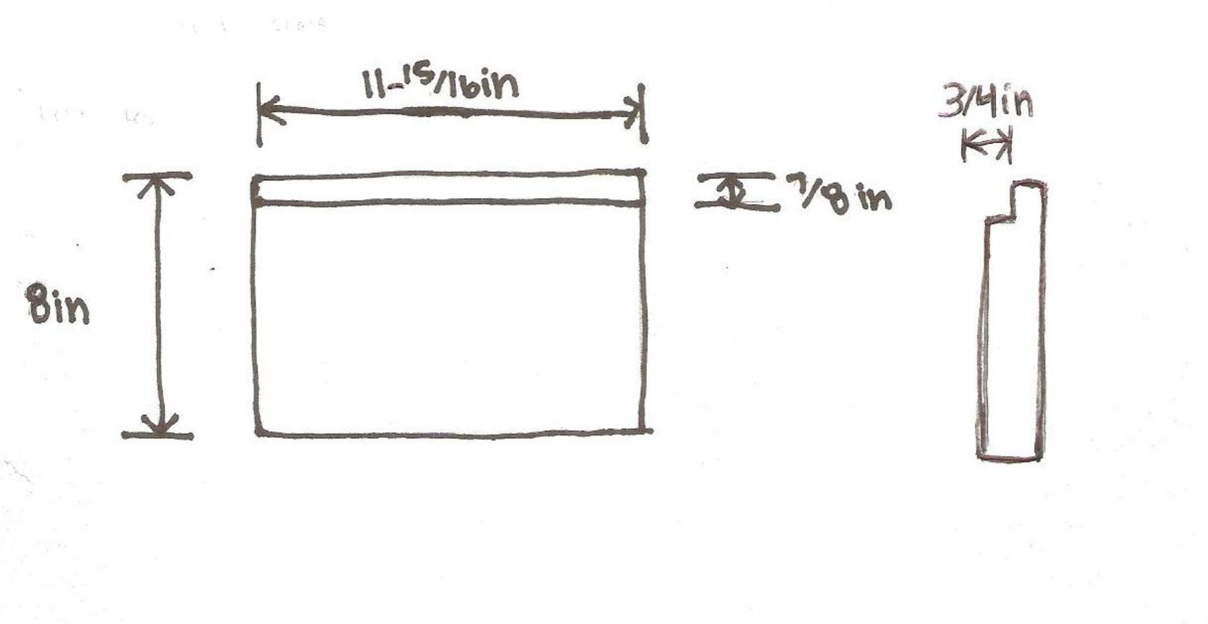

Figure 4: Small Step Leg Dimensions

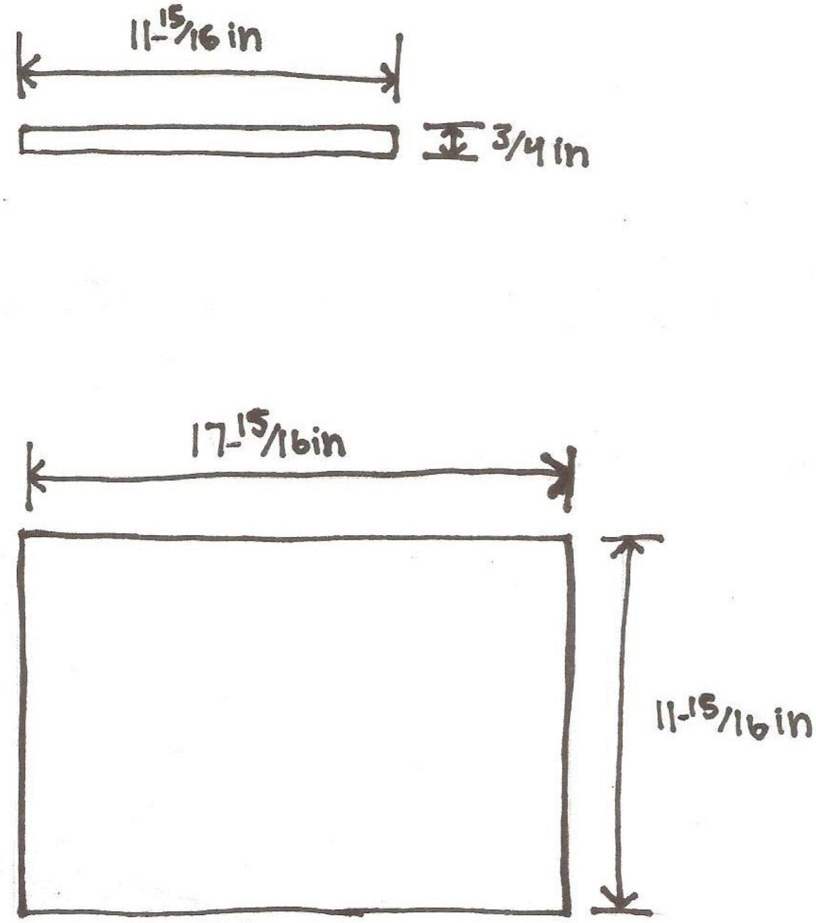

Figure 5: Small Step Top Plywood Dimensions

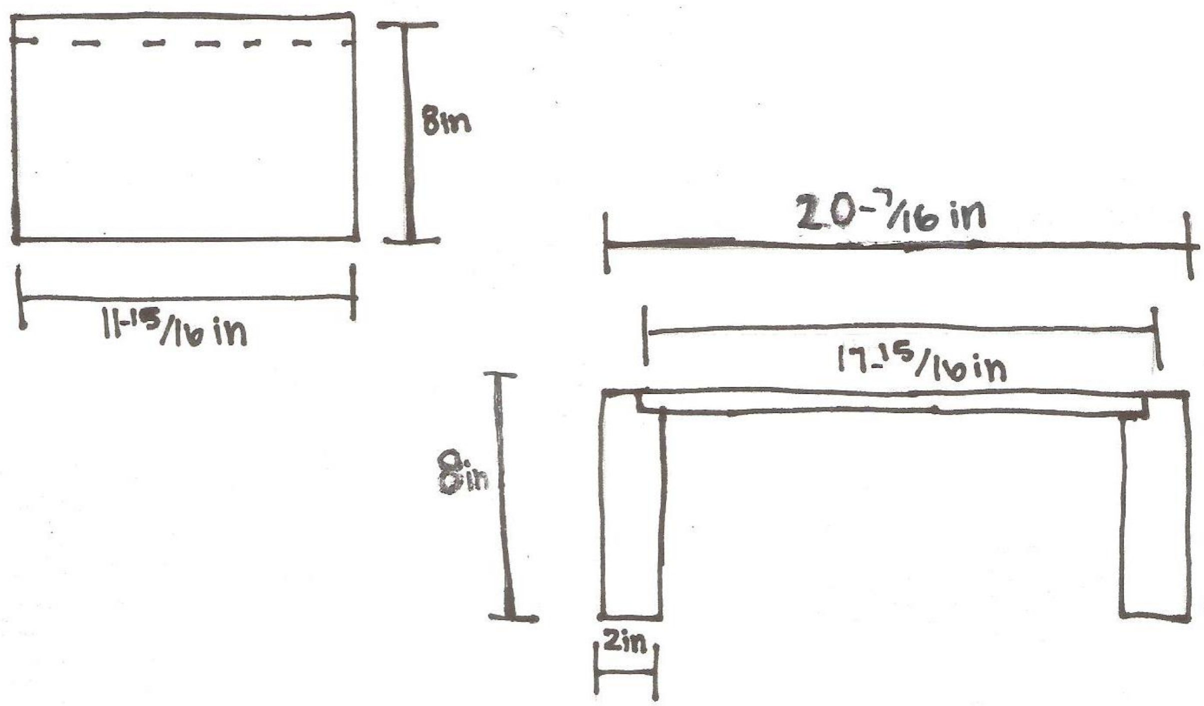

Figure 6: Small Step Assembly

Design Calculations

Because the step did not fail structurally, we were able to use the last group's design calculations. Because of this, we were able to ensure that the step was sturdy and could withstand a weight of 300 pounds. Although the step was able to adequately withstand this load, we followed the advice of the last group saying that the prototyping process revealed the need for a crossmember to increase the lateral stability of the step and to compensate for deviations in the plywood's quality. Because of this, the larger step still incorporated the crossmember. The smaller step, being only utilized by children in the restrooms and for viewing the fishtank, would only realistically need to support a load of 50 lbs, the CDC's measurement for a 4 year old with a Body Mass Index (BMI) in the upper range of the obese category [4].

III. STANDARDIZED WORK INSTRUCTIONS (SWI)

Introduction

Because of our change in the capstone design, Standardized Work Instructions (SWI) were created to ensure the steps were built taking all of our research and brainstorming into account. Standardized work instructions are used in manufacturing processes to ensure that each step in the process is done in a timely, consistent, and repeatable manner.

Step Buddy SWI

1. Cutting the Legs

- For the full-size stool, cut the 2"x8"x8' lumber into six 2"x8"x15-15/16" pieces with a miter saw. This should make 6 individual legs for the full sized stool.
- For the ¾ size stool, cut the 2"x8"x8' lumber into eight 2"x8"x11-15/16" pieces with a miter saw. This should make 8 individual legs for the ¾ sized stool.
- For this process, it is easier to use a stopper to mark cuts at either 15-15/16" (for the full-size stool) or 11-15/16" (for the ¾ size stool) when feeding the

wood through the miter saw. The stopper allows for speed and accuracy through the cutting process.

2. Groove in Leg

- For both stool sizes, use the table saw to make a cut into each leg.
- Place the 2”x8” lumber onto the table saw so that the 8” side is on top of the surface. Make the width of the cut ⅞” and the height ¾” using a dado cutting blade with the table saw.
- Refer to Figure 7 to make the groove.

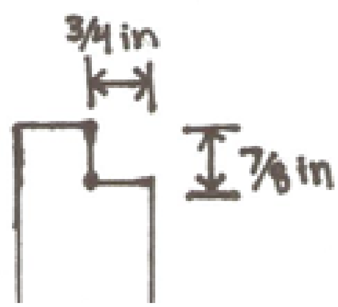

Figure 7: Groove in Leg

3. Rounding edges/sanding

- Use the industrial belt sander with 100 grit to round the edges of the legs.
- Use Figure 8 as a reference of how the edges should be sanded. The dashed line indicates the corner that has been sanded smooth.

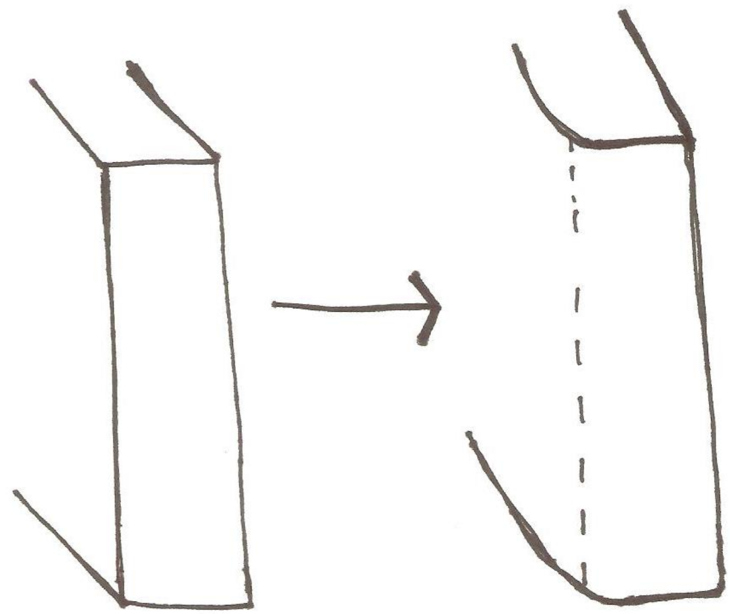

Figure 8: Rounded Edge Instruction

4. Priming and Painting

- Before priming the legs, perform a sprinkle test. Drop a few drops of water onto the wood. If the water beads up, wait a few more days to prime, but if the water absorbs into the board, it is good to paint. This is done to make sure the pressure treated wood is dry enough to paint.
- Start with one coat of white alkyd oil-based primer, using the paint roller. This type of primer is used on woods that are prone to extractive bleeding, or discoloration caused by the elements, so it is ideal for the dried pressure treated wood.
- Clean the paint roller after use and let dry.

- Once the primer has dried, follow the instructions from the acrylic latex paint can and apply two coats allowing each coat to completely dry before you apply the next coat. Also, use the paint roller for this step. Acrylic latex paint is an exterior paint designed to withstand elements and is therefore also ideal for our element proof step.
- Let paint completely dry before moving on to the next step.

5. Cutting the Top Board

- For the full-size stool, cut the ¾”x4’x8’ plywood into twelve separate 23-15/16"x15-15/16" pieces with a panel saw. One plywood sheet should make twelve tops.
- For the ¾ sized stool, cut the ¾”x4’x8’ plywood into twenty-one 17-15/16”x11-15/16” pieces with a panel saw. One plywood sheet should make twenty-one tops. As previously explained, the width of the saw cut must be accounted for.

6. Cutting Anti-Slip Tape

- Cut the anti-slip tape for the full-size stool to a length of 20”.
- The anti-slip tape comes packaged in the width of the full-size stool (24”). This creates a common measurement with the top board. Because of this, no cuts need to be made for the full-size model to account for its width.
- Cut the anti-slip tape for the ¾ size stool to a length of 16”.
- The ¾ size model has a width of 18”. Because of this, an additional 6” vertical cut needs to be made after.

- Note: The 20” and 16” cuts are longer than the length of each respective stool to allow for tape to cover both sides of the board and attach to the bottom of the board.

- Reference Figures 9 and 10 to see how the anti-slip tape should be cut. Figure 9 shows the full-size cutout dimensions, while the Figure 10 shows the ¾ cutout dimensions. The left hand line represents where each cut will take place on the roll of anti-slip tape whereas the right hand land represents the end of the roll of tape.

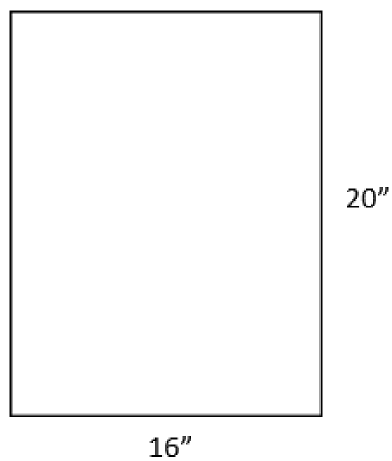

Figure 9: Tape Cut Dimensions for Small Step

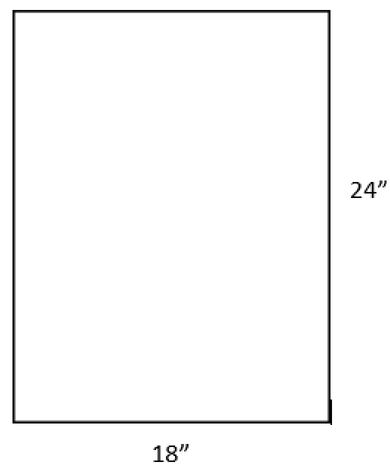

Figure 10: Tape Cut Dimensions for Large Step

7. Attaching Anti-Slip Tape to the Top Board

- When placing the piece of anti-slip tape on the top board, remember to use the 20" x 24" cutouts for the full-size model and the 16" x 18" cutouts for the ¾ size model.
- Make sure the top board is completely dry and free of debris.
- On the bottom of the board, use a ruler to measure out 1 ¼". from the edge. Mark this with a pencil. This is where you will start attaching the tape as seen in Figure 11.
- Peel off about ½" of the tape's paper backing. Once the paper is peeled back, avoid touching the adhesive with your fingers.
- Place the adhesive starting from the mark on the bottom and wrap it around the board. Remove paper backing gradually as you attach the adhesive. Press down firmly on the tape with your hands or use a rubber hand roller as you go to remove any air pockets or bubbles that may form.

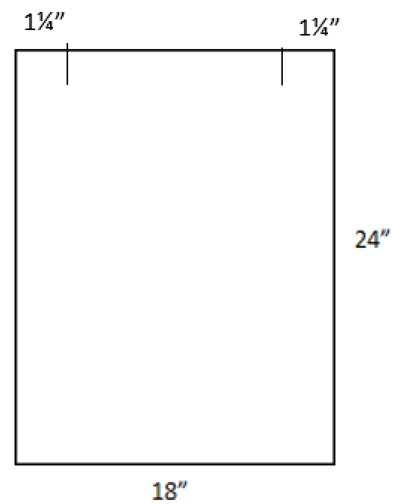

Figure 11: Top Board Placement on Anti-Slip Tape

8. Assembly

- The final assembly begins with using a jig to stand the legs upright as if they were functional legs for the step. A jig can either be purchased or 3D printed in the maker space. A team member then places a line of wood glue in the corner of the leg groove.
- Then, the top of the step is placed in the leg cut out. The first two steps are repeated for the other side of the stool.
- After, the legs and top portion of the stool need to be reinforced with 2" long 18-gauge brads along the top of the overlap of the top and leg cut out. Use a brad gun and make sure to use enough force so that the brads are flush to the top of the step. The brad gun should be used perpendicularly to the step. There should be 5 brads on both sides. Start by placing one brad on each of the step

and one brad in the middle. For the last 2 brads, place them equal distance between the middle brad and the end brad.

- For the larger step, the crossmember is cut from the bulk 2”x2”x8’ bulk piece into four 22-7/16” pieces using a miter saw.
- The crossmember is attached to the middle of the bottom of the step using wood glue. If needed, the glue should be reinforced 2” 18 gauge brads placed from the side of the legs into the cross member.
- For both size stools, place a scotch non-slip circle on each of the four corners of the bottom of the legs. Use Figure 12 as a reference for the crossmember location on the larger stool as well as scotch pad placement.

Figure 12: Crossmember and Scotch Tap Location

IV. PRODUCTION PLAN

Floor Layout

The floor layout, as seen in Figure 13, consists of two phases. The first phase, indicated in blue, encompasses all the steps needed to create the legs of the Step Buddy. The second phase, indicated in purple, entails the steps required to create the top board and assemble the final product. The manufacturing process and floor layout are split into these two phases due to the inherent waiting time required for the paint on the legs to dry. Because of this, we will have to stock the assembly station in the second phase with dried, painted legs before we can begin the second phase of the manufacturing process.

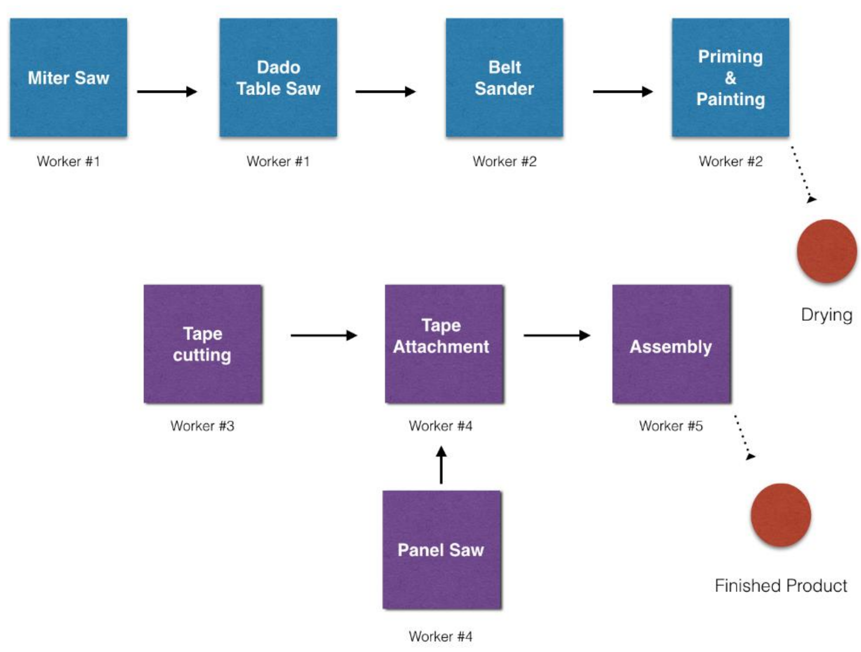

Figure 13: Production Layout

Number of Workers

Under normal circumstances, the number of workers needed for a production cycle would be calculated as a function of takt time (the rate at which finished products leave production) and cycle time, (the actual amount of time it takes to complete a specific step of the process). Due to the fact that school closed due to the coronavirus, our group was never able to record cycle times. Therefore, we had to make a rough estimate on the number of workers a production run would require. As such, we project that 5 workers are needed.

Roles of Workers

Worker #1 will operate the miter saw, cutting the legs from their larger stock pieces and then move over to the table saw with the dado blade to cut the groove in the leg where the top will rest. Those legs will be passed to Worker #2. Worker number #2 will sand the legs with a belt sander, apply one coat of primer to the leg, and then paint the legs. Worker #2 will move the painted legs to the drying zone. Upon drying, the legs will be loaded into inventory.

Worker #3 will cut the tape and then pass the tape to Worker #4. Worker #4 will cut the plywood tops using the panel saw and apply the anit-slip tape to the plywood. Then, the tops will be passed to Worker #5 for final assembly. Worker #5 will take prepainted legs from inventory and stand them up using a jig. They will use the plywood tops they received from Worker #4 to assemble the finished product.

Total Run Time Estimate

According to the original guidelines for this capstone project, our group was allotted two one-hour sessions to perform production. Our group decided to use one session to produce the fourteen large steps and the other session to produce the eight small steps. In order to produce fourteen of the large steps in one hour we would need to build one step every 4.28 minutes. In order to produce 8 of the small steps in one hour we would need to build one step every 7.5 minutes. Therefore, 4.28 and 7.5 are the takt times for our production plan.

V. BUSINESS

Marketing

Pairing with Willie Price for this project was a mutually beneficial cause. As students, we were able to solve a real world problem on our campus. We were able to meet other members of the university community and interact with not only Willie Price but also the school of education. This project of course met the needs of Willie Price as we were able to improve the steps they had and build steps that they needed. The Center for Manufacturing Excellence and Willie Price were both able to increase their names' presence on campus.

Through this pairing, the Center for Manufacturing was able to spread their presence on campus. Because the program is still new and is continually growing it benefited the program to interact with other schools and programs on campus. This opens up the opportunity for the CME to work with Willie Price on other projects they requested, such as a personalized sandbox and various wheelchair ramps.

The Center for Manufacturing Excellence can also further benefit from this project by using the same philanthropic spirit of this project to start other projects for nonprofits around Mississippi. This would allow the Center for Manufacturing Excellence to improve not only the manufacturing community of the state but also the entire state.

Accounting

The first step in accounting for this project was creating a budget for our prototype. This budget can be seen in Table 1. The Center for Manufacturing Excellence allowed for one thousand total dollars of expenditures for the project. Due to the fact that the CME factory floor had many of the materials we were originally planning on ordering available to use, our actual research and development expenses for the prototype were less than budgeted. This allowed for the additional purchase of the anti-slip safety tape that would ultimately be implemented in the final design. Even with this additional purchase, we were left with a budget surplus of $7.11 as can be seen in Table 2.

The next step in the accounting process was the creation of the bills of materials for both variations of the Step Buddy. These statements show the materials, quantity of materials, and cost to make each respective type of stool. They can be seen in Table 3 and in Table 4. In addition, Table 5 shows the quantity and cost of the resources needed to fulfill Willie Price's special order of fourteen full size stools and eight three quarter size stools. In addition, it shows that our group successfully stayed below the one thousand dollars in expenditures, the cap set by the CME for this project.

Table 1: Research and Development Budget

Part	Parts Needed / Prototype Full Size Prototype	 3/4 Size Prototype	 Total Parts Needed	Full (3/4) Parts / Unit RM	 Order Qty	 Cost / unit RM
Side Boards (Legs)	2	2	4	6	1	$7.96
Crossmember	2	2	4	4 (5)	1	$3.77
Top Board	1	1	2	12 (21)	1	$15.99
Non-Slip Covering	1	1	2	12 (21)	1	$53.82
Scotch Grip Pad Packs	1	1	2	8	1	$6.27
Construction Adhesive	1	1	2	6	1	$6.97
Sealant	1	1	2	4	1	$3.86
Staples	1	1	2	24	1	$3.22
Nails	1	1	2	143	1	$4.95
Screws	1	1	2	121	1	$7.97
Total						**$114.78**

Table 2: Research and Development Expenses

Part	Material	Size	Qty	Supplier	Cost
Legs	Pressure treated lumber	2" x 8" x 8'	1	Home Depot	$7.96
Topboard	Pressure treated plywood	3/4" x 2' x 4'	1	Home Depot	$15.99
Crossbeam	Pressure treated lumber	2" x 2" x 8'	1	Home Depot	$3.77
Matting	Anti-slip safety tape	24" x 10'	1	Amazon	$79.95
Matting	Rubber Matting	1/8" x 4' x 9'	1	CME	$0.00
Adhesive		-	1	CME	$0.00
Staples		3/8"	1	CME	$0.00
Nails		3/4"	1	CME	$0.00
Screws		2"	1	CME	$0.00
Total					**$107.67**

Available Funds	$1,000.00	R&D Budget	$114.78
R&D Expenses	$107.67	R&D Expenses	$107.67
Remaining Funds	**$892.33**	**Budget Surplus**	**$7.11**

Table 3: Bill of Materials - Full Size

Material	Size	Price	Qty	Unit Cost	Description
Pressure Treated Pine	2" x 8" x 8'	$8.27	0.33	$2.76	Side Boards (legs)
Pressure Treated Pine	2" x 2" x 8'	$3.77	0.25	$0.94	Crossmember
Pressure Treated Plywood	3/4" x 4' x 8'	$31.57	0.08	$2.63	Top Board
Anti-Slip Safety Tape	24" x 10'	$79.95	0.17	$13.33	Non slip covering
Scotch Grip Pad Packs	3/4" - 1"	$6.27	0.50	$3.14	Non-slip feet
Primer	1 gal	$67.14	0.05	$3.20	To prime legs
Paint	1 gal	$57.96	0.05	$2.76	To paint legs
Nails	1 - 3/4"	$7.97	0.05	$0.38	To connect joints
Screws	2"	$7.97	0.05	$0.38	To connect joints
Total				**$29.51**	

Table 4: Bill of Materials - 3/4 Size

Material	Size	Price	Qty	Unit Cost	Description
Pressure Treated Pine	2" x 8" x 8'	$8.27	0.125	$1.03	Side Boards (legs)
Pressure Treated Plywood	3/4" x 4' x 8'	$31.57	0.048	$1.50	Top Board
Anti-Slip Safety Tape	24" x 10'	$79.95	0.143	$11.42	Non slip covering
Scotch Grip Pad Packs	3/4" - 1"	$6.27	0.50	$3.14	Non-slip feet
Primer	1 gal	$67.14	0.04	$2.80	To prime legs
Paint	1 gal	$57.96	0.04	$2.42	To paint legs
Nails	1 - 3/4"	$7.97	0.04	$0.33	To connect joints
Screws	2"	$7.97	0.04	$0.33	To connect joints
Total				**$22.97**	

Table 5: Purchase Order - Willie Price Lab School

Material	Size	Price	Quantity (Full Size)	Quantity (3/4 Size)	Quantity (Total)	Total Cost
Pressure Treated Pine	2" x 8" x 8'	$8.27	5	2	7	$57.89
Pressure Treated Pine	2" x 2" x 8'	$3.77	4	0	4	$15.08
Pressure Treated Plywood	3/4" x 4' x 8'	$31.57	2	1	3	$94.71
Anti-Slip Safety Tape	24" x 10'	$79.95	3	2	5	$399.75
Scotch Grip Pad Packs	3/4" - 1"	$6.27	7	4	11	$68.97
Primer	1 gal	$67.14	0.67	0.33	1	$67.14
Paint	1 gal	$57.96	0.67	0.33	1	$57.96
Nails	1 - 3/4"	$7.97	0.67	0.33	1	$7.97
Screws	2"	$7.97	0.67	0.33	1	$7.97
Total						**$777.44**

Available Funds	$	892.33
Purchase Order	$	(777.44)
Remaining Funds	**$**	**114.89**

Per the capstone projects requirements, we made projections on our team's potential profit if we were to produce Step Buddies at a full production scale. When performing our revenue determination, we decided that we would only take into account the costs of producing the full size Step Buddy and would consider the ¾ size model a one time special order by Willie Price.

The sales price for the Step Buddy was set at $110.00, the same price as the original Step Buddy. Due to the fact that the nature of this project was to fix problems that existed in the original product, we saw no need to change the sales price. This price was determined by looking at the prices of competing products [5]. Therefore, based on an estimated annual sales volume of 20,000 units, the annual revenue produced by the Step Buddy would be $2,200,000.00.

The total cost of direct materials was calculated to be $590,200.00 based on a per unit cost of $29.51 as seen in Table 3 and a production volume of 20,000 units. As showcased in Table 6, assuming a 40 hour work week and a $20.00 per hour wage, the average annual wage per worker would be $40,000. Multiplying this wage by a total of five workers accounting for social security and Medicare taxes (7.65% combined) yields a total annual direct labor cost of $214,490.00. The variable manufacturing overhead was estimated to be $241,347.00 by taking 30% of direct material and direct labor costs. Variable overhead includes items that vary in relation to production output. Some examples of items that would be included in variable overhead are utilities, maintenance and repair materials, maintenance technicians' wages, cleaning materials, and machine lubricants. Netting all of these variable costs with sales revenue provides a total annual contribution margin of $1,154,163.00 or a per unit contribution margin of $57.71. This represents the total and per unit amounts available to cover fixed costs and generate a profit.

The fixed costs consist of fixed manufacturing overhead and fixed selling and administrative expenses. The fixed manufacturing overhead was calculated to be $563,143.00 by taking 70% of the direct material and direct labor costs. Fixed overhead items are those that do not vary in relation to production output. Examples include factory rent and taxes, insurance on equipment, inventory, and factory, and machine depreciation.

One of these overhead items, machine depreciation, we were actually able to calculate. It is important to note that we considered renting equipment versus purchasing equipment. As seen in Table 7 the annual cost for renting equipment would be

$80,000.00 per year. In Table 8, the cost of purchasing equipment is shown to be $9,074.00. Therefore, if the equipment is depreciated via straight line depreciation over 7 years, the depreciation expense would be $1,296.29 per year. As such we choose to purchase equipment instead of renting it, and capture this expense in the manufacturing overhead estimate. $90,000 of the $100,000 fixed selling and administrative expenses cover the salaries of one or two managers in charge of both managing the factory workers and handling all selling and administrative activities. The other $10,000 is allocated to marketing the product to potential customers. All together, when these fixed costs are netted with the contribution margin, an operating income of $491,020.00 or a per stool income of $24.55 is created.

The break-even point in units can now be calculated by dividing the annual fixed costs ($663,143.00) by the contribution margin per unit ($57.71). This results in a break even unit of 11,491 stools. The break even point in dollars can be found by dividing the annual fixed costs by the contribution margin ratio (52.46%). The break even point in dollars is therefore $1,264,092.64 A graphical representation of this break even analysis can be seen in Figure 14.

Table 6: Direct Labor Calculation

Hourly wage		$20.00
*Working hours per year	x	2000
Yearly wage per worker		$40,000.00
Workers	x	5
Direct Labor Costs Before Tax		$200,000.00
Social Security (6.2%)		$12,400.00
Medicare (1.45%)		$2,090.00
Direct Labor Costs After Tax		**$214,490.00**
*Assumes a 40 hour work week, 5 days of unpaid vacation, and 5 Holidays.		

Table 7: Equipment Rental Costs

Equipment		**Hourly Cost**
Miter Saw		$10.00
Dado Table Saw		$10.00
Sandblaster		$10.00
Panel Saw		$10.00
Total Hourly Cost		$40.00
Working Hours/Yr	x	2000
Total Annual Rental Cost		**$80,000.00**

Table 8: Equipment Purchase Costs

Equipment	Quantity	Unit Cost	Total Cost
Belt Sander	1	$880.00	$880.00
Miter Saw	1	$839.00	$839.00
Table Saw	1	$4,349.00	$4,349.00
Panel Saw	1	$1,399.00	$1,399.00
Clamps	6	$1.50	$9.00
Uline Table	4	$294.00	$1,176.00
Paint Roller	3	$6.98	$20.94
Rolling Pads	1	$11.93	$11.93
Dado Blade	1	$50.00	$50.00
Scissors	1	$20.00	$20.00
Cutting Mat	1	$60.00	$60.00
Nail Gun	1	$260.00	$260.00
Total Cost			**$9,074.87**

Table 9: Income Statement

				Total	Per Unit
Sales				$2,200,000.00	$110.00
Variable Costs					
	Direct Material		$590,200.00		
	Direct Labor		$214,290.00		
	Variable Manf. Overhead		$241,347.00		
		Total		$1,045,837.00	$52.29
Contribution Margin				$1,154,163.00	$57.71
Fixed Costs					
	Fixed Manf. Overhead		$563,143.00		
	Fixed SG&A Expenses		$100,000.00		
		Total		$663,143.00	$33.16
Operating Income				$491,020.00	$24.55

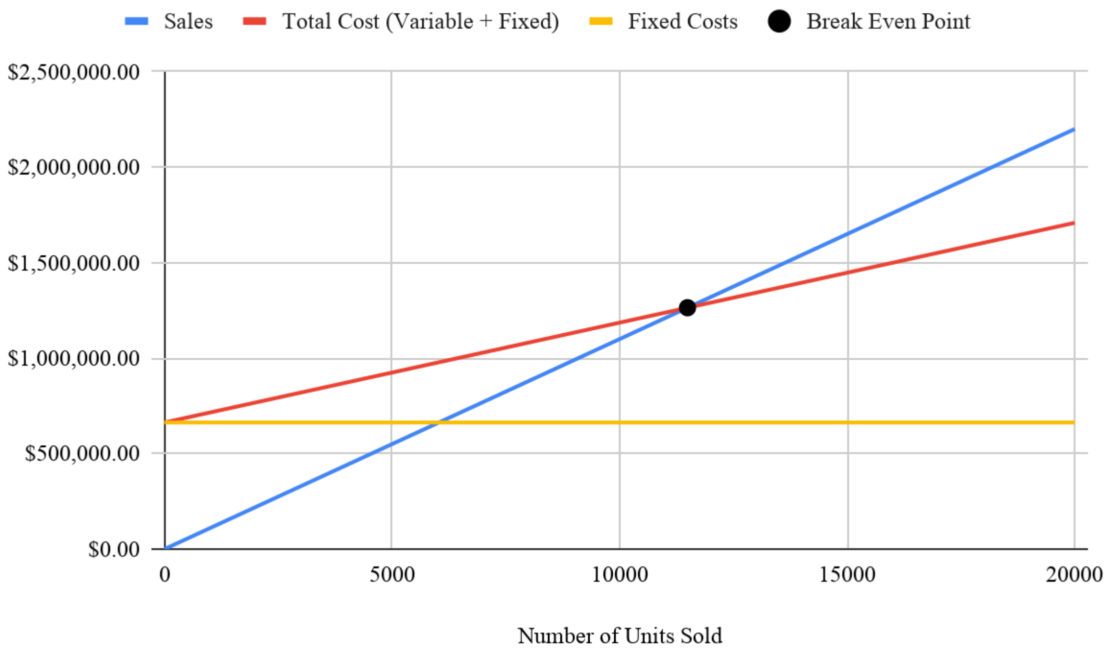

Figure 14: Break Even Analysis

VI. CONCLUSION

Needless to say, our capstone took a unique turn, changing our plans with only weeks left in the project. With the help of the CME faculty, we were able to get the information we needed to draft standardized work instructions and a production plan so that the incoming freshman class can complete production of the 22 steps for Willie Price in their Manf 251 course. However, due to lack of resources and access to the CME, estimates were made to complete this project as well as creative ways to complete our drawings.

We lacked official cycle times, making it hard to calculate the exact time needed to complete the project. Additionally, due to lack of access to CAD on our computers, hand drawings were completed for many parts and processes. Once things return to normal, we hope that better drawings can be made. Additionally, we were unable to create a jig ourselves, but we hope the younger cohort can also design and 3D print a jig to help the legs stand on their own in the assembly process.

We hope that after the completion of the steps, this project will be utilized year after year as a service project. Not only will this production run teach the freshman about manufacturing, it will also give them teamworking skills as well as an opportunity to give back to others. These steps could also be utilized in places such as other preschools, children's hospitals, Boys and Girls Clubs, and underfunded elementary schools.

We were grateful to at least start this process and we look forward to seeing it be completed, even if we will not be on campus. Willie Price and the CME will hold a special place in our hearts, and we were grateful to be the team that brought the pair together again.

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