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A Study of the Design and Manufacturing of an Elevated Dog Feeder

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A STUDY OF THE DESIGN AND MANUFACTURING OF AN ELEVATED DOG FEEDER

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 senior capstone which students in the Center for Manufacturing Excellence program partake in was the basis for project. The Dog Box is an elevated dog feeder with an internal food storage compartment. It was designed for medium to large dogs, and can hold over 40 lbs of dog food. The internal storage compartment has drawer access and contains a plastic tote that will hold the food. The purpose of the design was to create an aesthetically pleasing elevated dog feeder that would double as a storage device, and elevated feeding can help prevent health issues in large dog breeds. There were four different design iterations before the fourth and final design was confirmed. The final design featured a wooden exterior with a polyurethane finish, two bowls, a laser engraving, two satin nickel knobs, and a soft close drawer which contained the plastic tote. The manufacturing process utilized a panel saw, radial arm saw, table saw, table saw with a dado blade, finish nailer, brad nailer, impact driver, laser engraver, waterjet cutter, hand sander, and a vacuum. Multiple fixtures and poka yokes were used throughout the process to improve manufacturability, efficiency, and quality. A quality product was created within the scope, cost, and time of the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS

CAD……………………………………………………………Computer Aided Design

CME………………………………………………Center for Manufacturing Excellence

LBS………………………………………………………………………………Pounds

INTRODUCTION

OVERVIEW OF THE CENTER FOR MANUFACTURING EXCELLENCE

The Center for Manufacturing Excellence (CME) is a program at the University of Mississippi that offers a minor or emphasis in Manufacturing. As part of the four year program, students complete a capstone project that spans their last two semesters. The CME consists of engineering, business, and accountancy students who work together in interdisciplinary teams of about five students to complete their capstone projects. A capstone project can be either an industry project or a factory floor project, and consists of two main phases: design and production.

LEAN MANUFACTURING

The CME curriculum puts an emphasis on lean manufacturing principles which focus on eliminating waste and maximizing value added work. Lean manufacturing starts with the customer and ensures that they receive a quality product. There are eight deadly wastes which include defects, transportation, excessive motion, waiting, inventory, over production, over processing, and underutilizing people [1]. One of the project goals was to eliminate as many of these wastes as possible. A tool that is used to decrease defects is called a poka yoke which is Japanese for mistake proofing. A poka yoke can include anything in the process that makes it difficult or even impossible to make an error [2]. A poke yoke can be built into the design or function as a quality check within the process to reduce rework down the line. Another lean manufacturing tool is called 5S which consists of five steps: sort, set in order, shine, standardize, and sustain. The five steps should be completed in the order they are listed. 5S helps in eliminating waste from the process and works to ensure that everything in the workplace is value added [3]. One fundamental aspect of lean manufacturing is Kaizen, which is Japanese for continuous improvement [4]. The theory behind continuously improving a process is that small, constant change leads to significant results.

PROBLEM DEFINITION

The inspiration for the Elevated Dog Feeder came from project team member, Will Broome, who has two Labrador retrievers. The project goal was to create an elevated dog feeder that was aesthetically pleasing and can hold up to 40 lbs of dog food in a sealed, internal storage compartment. The feeder has two bowls, for food and water, as well as a custom engraving.

SCOPE OF WORK

The objective of the elevated dog feeder was to provide a niche product for medium to large dogs. The product was designed to be functional and aesthetically pleasing. The elevated dog feeder included two removable, well-sealed bowls; an easily accessible, refillable, and cleanable storage compartment. The beta prototype and report were scheduled to be completed by December 5, 2019, and the budget was not to exceed $1,000. In order to complete the prototype, the team coordinated with the CME manufacturing technician to procure machine time on the shop floor. For full production in spring 2020, the team developed the process flow for production and manufactured products for an hour. In the hour of full scale production, the team was scheduled to manufacture three to five units.

ROLES AND RESPONSIBILITIES

In order to successfully complete all of the required tasks for the project, roles and responsibilities were decided by the team members.

Will was in charge of research and development. This involved detailed work towards innovation, introduction, and improvement of the product. This included, but was not limited to, material selection, sourcing, and transportation.

Tyler was assigned to supply chain management and market research. This role challenged him to source high quality materials that allowed the product to be built to customer specifications at the lowest possible cost. This was all contingent upon market research being conducted thoughtfully so as to understand which features were most desired and which materials must be selected to meet those expectations.

Miller was tasked with tracking the budget and keeping up with the spending for the project. She researched material and production costs and maintained a detailed log of any and all financial data.

Preston was in charge of coordinating with the CME manufacturing technician for production, helping with CAD development, and assisting with material sourcing.

Lena was the point of contact (POC) and was therefore in charge of communicating the needs and progress of the group to the CME capstone instructor. Lena also served as the project manager and therefore oversaw the scope, budget, and schedule, and kept the project on track for completion.

PLAN FOR GATHERING INFORMATION, MATERIALS, AND DATA

In order to position this capstone project for enduring success throughout the stages of product development the team established a plan to gather information, secure raw materials and collect data throughout the process that supported benchmarking of progress throughout the product development, prototyping and launch. The supply chain of this product connected the operational team to the suppliers of raw materials, to the distributors of the finished goods, and eventually to the customers either directly from operations or through retail locations.

In order to collect valuable information, it was important to understand the stakeholders involved in the product life cycle. There are two main users of the product: the dog and the dog's owner. Both have unique desires for what this product offers them in terms of features. The dogs must be able to eat their food and drink their water comfortably. The dog owner must be able to store the food in a clean and dry environment. The product should also enhance the aesthetic of the pet owner's home with the installation of the feeder unit. Market research was conducted in order to understand how to cater to the needs of animals and their owners. The project team conducted research on large dog heights to get a reasonable average for our prototypes. The hope was that the model would be the best fit for the majority of dogs that may use it. We also surveyed dog owners to find out how much dog food they typically purchase, how much they normally spend on this type of purchase for their animals, and what types of features they find essential.

In order to obtain the necessary materials, the team's project manager developed a vendor information spreadsheet that contained material costs. Many decisions were made and adapted to the budget, but other decisions were budgeted and then a decision was made on a cost basis. In terms of delivery, a team member's vehicle was available or in unique scenarios the seller was paid to ship the materials to the CME facility. Once raw materials were received, inventory was stored until it was queued for prototyping or production runs.

In order to determine the target selling price per unit, financial data which included overall costs, per unit costs, and overhead costs were collected and common sized. The target price was the driving force for production decisions because this is a premium product. Once the theoretical "maximum" that users will pay for this type of product was understood, the team was able to design a process and benchmark during that process to ensure that the threshold was not exceeded.

SCHEDULE FOR INTERACTING WITH SHOP FLOOR ADVISOR

To produce a prototype and plan for production, the team collaborated with the designated manufacturing technician. The team consulted with the technician regarding the machine planning, overall dimensions, materials, CAD models, and physical prototype. The group was required to give notice at least 24 hours in advance to use the CME factory floor or to schedule an advisor meeting.

ANTICIPATED CHALLENGES AND RISK ANALYSIS

The team conducted a SWOT analysis to determine what could have an impact on the success of the project. Strengths and weaknesses are internal while opportunities and threats are external.

Table 1: SWOT Analysis

Strengths	**Weaknesses**
• Multipurpose product that combines feeding, watering, and storage • Aesthetically pleasing • Easy access to food • Optimized scoop for ergonomic and efficient food refilling	• Potential issues maintaining dog food freshness • Must build around existing plastic containers • Limited funds limit testing materials and designs • Limited time with manufacturing floor
Opportunities	**Threats**
• Niche market to medium to large size dog owners • 60.2 million pet owners in the US • Pet industry expenditures show rapid growth • Applies to all demographics • Room for personalization	• Cost competitive to the alternative of a separate feeder and storage bin • Relatively high competition

ASSUMPTIONS

It was assumed that the customer would plan to store 40 lbs of dog food within the elevated feeder which is about a month's supply [5]. Another assumption was that the customer's dog would measure between 17 and 25 inches tall which includes medium to large dog breeds. For these heights, an elevated dog feeder should be between 15 and 20 inches [6].

Table 2: Average Common Breed Heights [7,8]

Breed	**Height**
Labrador Retriever	21-24 in
Boxer	21-25 in
Border Collie	17-24 in
Chow Chow	17-20 in
English Shepherd	18-23 in
Brittany	18-21 in
Golden Retriever	21-24 in
Bearded Collie	20-22 in
Dalmatian	21-24 in

CHAPTER 1: BACKGROUND RESEARCH

CHAPTER 1.1: SURVEY RESULTS

Before moving forward, background research was conducted. A survey was distributed through GroupMe and Facebook by all five team members, and 81 people responded. 93.8% of responders owned a dog, and the other 6.2% took the survey hypothetically. The height of the respondents' dogs ranged from short to extra tall with 27.2% in the tall category. Our original intent was to cater to customers who either have one dog or two dogs of the same height. The results of the survey indicated that 65.4% fell into those two categories and only 14.8% of owners had two dogs that eat different food. Only 6.2% of owners purchased dog food in quantities over 50 lbs, therefore, the 40 lbs capacity of the elevated dog feeder fits the needs of the majority of potential customers. The majority of respondents indicated interest in an elevated dog feeder with a food storage compartment with only 16% expressing a lack of interest. The survey results can be seen in Appendix A. Good survey results are difficult to achieve with a sample as small as 81 people, so market research is often more valuable. According to a 2019-2020 survey conducted by the American Pet Products Association (APPA), a dog is owned by 63.4 U.S. households, and 89.7 million dogs are owned in the United States. Since 2010, pet expenditures have increased from $48.35 billion to $75.38 billion [9].

CHAPTER 1.2: OPTIMAL ELEVATION

The best way to choose the proper elevated dog feeder height is to measure your dog while it is standing, from the floor to his or her lower chest. An alternative way to measure is from the floor to their withers and subtract six inches [10] According to Deanna deBara, for larger breeds, the optimal height is between 15 and 20 inches [11]. The Dog Box is 17 inches tall which allows it to service most large dogs.

CHAPTER 1.3: MATERIAL CONSIDERATIONS

Aesthetics, functionality, and durability were important aspects of material selection. Ultimately, wood was chosen as the material for the feeder based on aesthetics and manufacturability. In order to increase the durability, waterproof, scratch-resistant polyurethane was used to coat the completed Dog Box. Another aesthetics concern was the holes created by the nails. To remedy this problem, wood putty was used to fill any holes on the front or top of the dog box. Furthermore, satin nickel knobs were chosen to coordinate with the stainless steel bowls. For functionality, the specified drawer slides were rated for 50 lbs, and the tote at full capacity holds less than 47 lbs. An important element of the drawer slides is their soft close feature which adds quality to the Dog Box.

CHAPTER 2: CONCEPT TO REALITY

CHAPTER 2.1: CONCEPTUAL DESIGN

The original conceptual design was created by team member Will Broome and it featured two side steps, a headboard with a custom engraving, a hinged lid, and a sealed box. The size was determined by the volume that 80 lbs of dog food would occupy. The dog food would fill the internal compartment that could be accessed by the hinged top. The conceptual design can be seen in Figure 1.

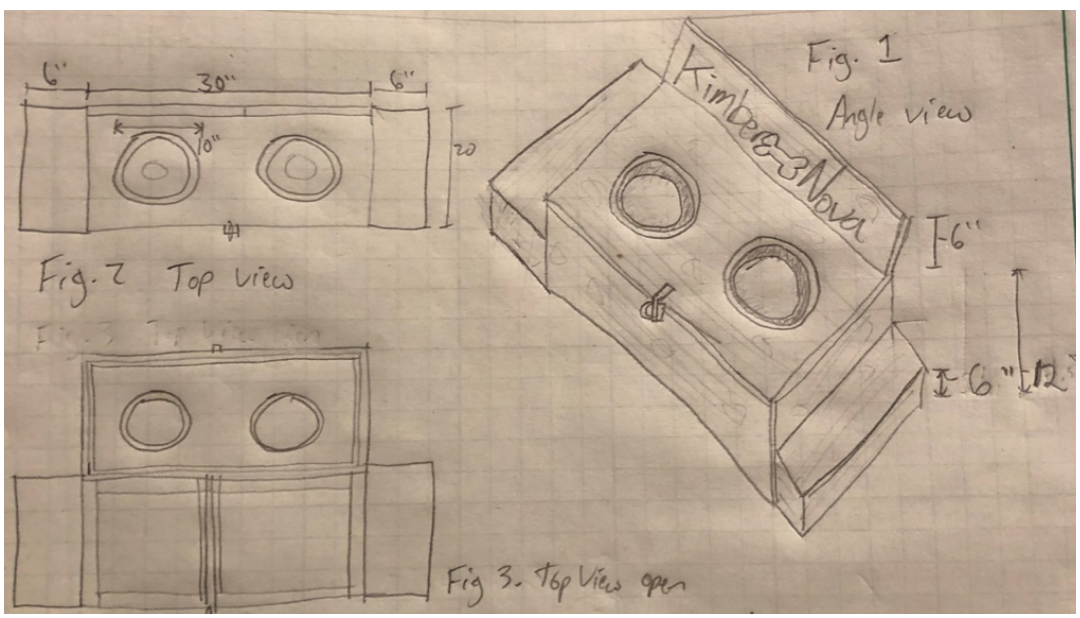

Figure 1: Conceptual Design

CHAPTER 2.2: ORIGINAL CAD DESIGN

After discussing the original concept with the team, several changes were made to the design. One change was a smaller footprint in order to give customers greater placement flexibility. The headboard was also eliminated so that the design was more streamlined, and to increase manufacturability. Instead of a hinged lid, the internal storage compartment is accessed by a drawer that opens from the front. Also, instead of the dog food being poured in, for the new design the food is placed in a sealed container that is stored within the drawer. The CAD design can be seen in Figure 2.

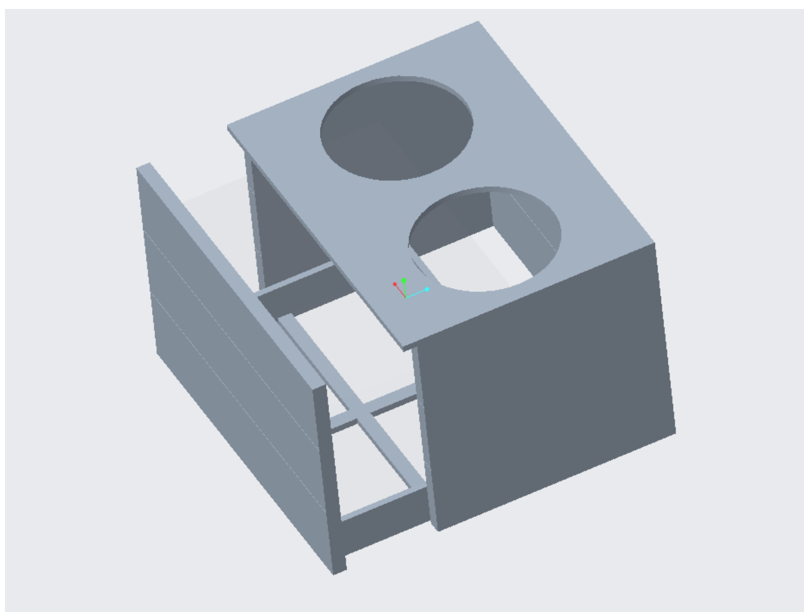

Figure 2: Original CAD Design

CHAPTER 2.3: PROTOTYPE I

The material used for Prototype I can be seen in Table 3. Pressure treated pine decking board was used for the four sides and construction grade plywood sheathing was used for the top. These materials were chosen because they were inexpensive. The decking board was used to create a paneled look for the sides. The 12 gallon tote was the optimal size to fit within the dimensions of the Dog Box and it holds slightly more than 40 lbs of dog food.

Table 3: Prototype I Materials

Material	**Cost**	**Quantity**	**Location**
14 in. Soft-Close Full Extension Side Mount Ball Bearing Drawer Slide Set	$15.48	1	Home Depot
12 gal. flip top tote	$6.98	1	Home Depot
15/32 in. x 4 ft. x 8 ft. 3-ply RTD Sheathing	$17.45	1	Home Depot
5/4 in. x 6 in. x 12 ft. Pressure Treated Pine Decking Board	$9.57	3	Discount Lumber

Prototype I is shown in Figure 3. Due to the low quality of the decking board, it had to be ripped to its proper six inch height using the table saw. To rip wood means to make a cut parallel to the grain along the length of the wood [12]. The ripping also helped in ensuring that the boards lay flat when stacking them to create the sides. A radial arm saw was used to cut the decking board to length. The panel saw was used to cut the top piece to size, and a jigsaw was used to cut the holes. A nail gun was used to affix all of the pieces together. The Dog Box is 25 inches long, 20 inches wide, and 17 inches tall.

Figure 3: Prototype I

The drawer assembly is shown in Figure 4. In order to attach the front three pieces, two vertical pieces of plywood were used. Triangular structural supports were added to the drawer to increase its integrity. The tote fit within the drawer assembly with very little wiggle room which was desirable. This confirmed that the dimensions were correct. When the drawer assembly was ready to be attached to the outer box, there was about a ¾” gap on each side. To fix this issue, two pieces of plywood were added to the inside of the outer box sides.

Figure 4: Drawer Assembly

Many lessons were learned from Prototype I. The pressure treated wood can actually be harmful to dogs and the paneling made assembly difficult. Therefore, the design moved towards solid non-pressure treated sides. The low quality lumber added steps to the process to adjust for incorrect dimensions of the wood. The biggest challenge with the assembly was getting the drawer and sides square, so that was an aspect that was kept in mind moving forward. The plywood top sagged in the middle which caused a problem with the drawer closing. One success was sufficient clearance between the top of the tote and the bottom of the bowls when the tote was in the drawer within the Dog Box. The 2” nails worked for every attachment except for the triangular bracing, so smaller nails were used for that component moving forward. During the construction of the drawer, it was decided that a slot would be cut into the middle two braces so that they would nest in each other which was not in the original plan. The slot was created using a table saw with a dado blade. The first drawer slides that were purchased attached to the bottom of a drawer, but those were returned and exchanged for drawer slides that attach to the sides which are shown in Figure 4. Also, the holes in the top piece were centered in the middle in the CAD drawing, but during construction, it was decided that they should be moved forward for ease of use. Another benefit of moving them forward was that more room was available for the laser engraving that will go above the bowls.

CHAPTER 3: REDESIGN

CHAPTER 3.1: CAD REDESIGN

Based on lessons learned with Prototype I, several changes were made to the CAD design. There was an abundance of extra space in between the back of the drawer and the back side of the outer box. There was also extra space between the drawer sides and sides of the box. From the beginning of the design, the height and volume controlled the other dimensions. The volume determined the size of the tote which fit perfectly within the drawer, so the redesign stemmed from the drawer dimensions. The design features solid sides and the front of the drawer extends the full length of the box and is flush with the top of the box. The redesigned Dog Box measures 24-7/8 inches long, 18-1/4 inches wide, and 17 inches tall.

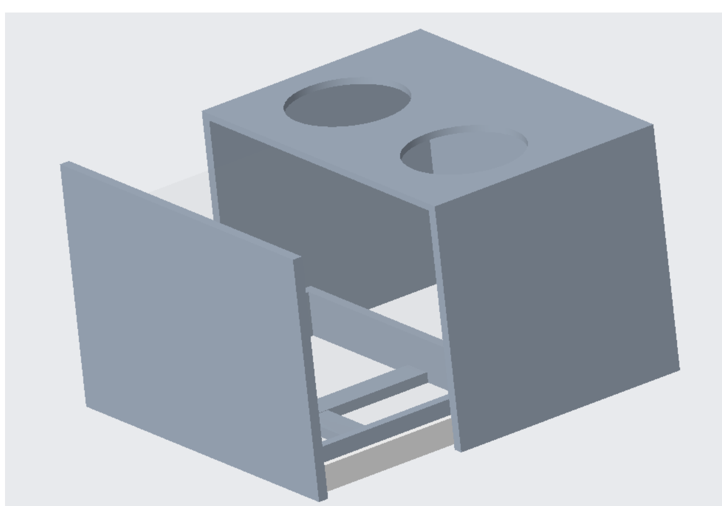

Figure 5: Redesigned Dog Box

CHAPTER 3.2: PROTOTYPE II

Table 4 shows the materials that were used in Prototype II. Sande plywood, which is a hardwood, was used for the sides and the top. For the sides, ¾" was used, and for the top, ½" was used. Knobs that coordinated with the stainless steel bowls were chosen. The original plan was to have a handle in the middle, but knobs were chosen instead because it is easier to pull the drawer open with two hands than with one from the middle. Also, it makes it more difficult for a dog to pull open the drawer from the knobs as opposed to the handle.

Table 4: Prototype II Materials

Material	**Cost**	**Quantity**	**Location**
14 in. Soft-Close Full Extension Side Mount Ball Bearing Drawer Slide Set	$15.48	1	Home Depot
18 mm – Sande Plywood (¾ in. x 4 ft. x 8 ft.)	$45.98	1	Home Depot
12 mm – Sande Plywood (1/2 in. x 4 ft. x 8 ft.)	$35.95	1	Home Depot
Classic Round 1-1/4 in. Satin Nickel Hollow Cabinet Knob	$1.00	2	Home Depot

Figure 6 shows a comparison between Prototype I and Prototype II. The side by side comparison allows a visualization of the change in size. The panel saw was used for the initial cuts on the sides, front, and back. Secondary and tertiary cuts for the front, back, and longest drawer components were made on the table saw. Secondary and tertiary cuts for the sides, shorter drawer components, and drawer bracing were made on the radial arm saw. A 15 gauge finish nailer with 2” nails and a 18 gauge brad nailer with ¾” nails was used to assemble the Dog Box, and an impact driver was used to screw the drawer slides and knobs on. The waterjet cutter with garnet abrasive was used to cut the holes in the top piece, and a laser engraver was used to engrave the CME logo onto the top piece. A hand sander with 180 grit sand paper was used to round sharp corners and create a smooth finish on the assembled Dog Box. The reduced size and solid sides made Prototype II easier and quicker to build. Figure 7 shows Prototype II with the drawer open and the tote inside the drawer and the bowls in place.

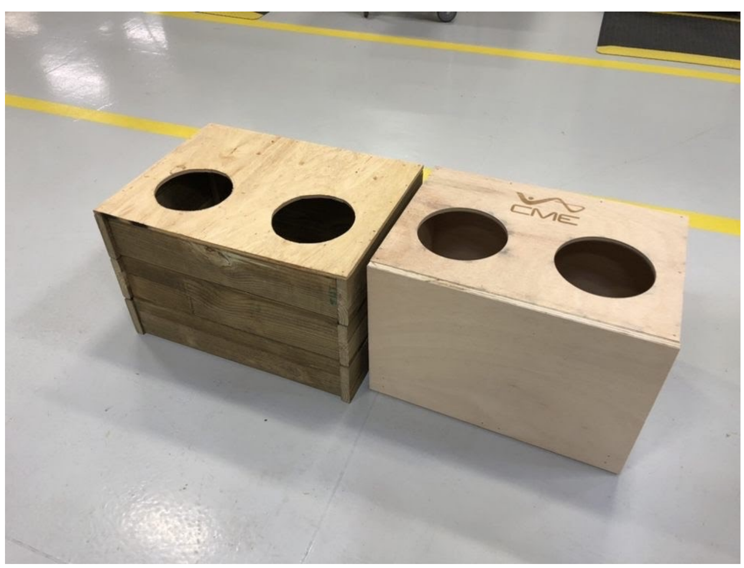

Figure 6: Prototype I versus Prototype II

Figure 7: Prototype II Drawer

There were several lessons learned during the second round of prototyping. First, the cutouts on the top piece were too large for the bowls. The goal was to have the bowls fit snug within the cutout, so the dimension had to be reduced. The corners of the Dog Box were sanded in order to reduce a safety concern with sharp edges, and 180 grit sand paper was used. For the polyurethane coat, spray and brush on were both experimented with and it was determined that brush on was easier to apply and went on more evenly than the spray. Furthermore, instead of having the front piece flush with the top, the team decided to extend the top over the front. It was confirmed that ¾” nails would be used for the drawer bracing and triangular supports and 2” nails worked everywhere else.

Table 5 shows the material cost per unit for each material that goes into the Dog Box. Based on the values shown in the table, the material cost of each Dog Box is $45.47.

Table 5: Material Cost

Material	½ ply	¾ ply	¾" nails	2" nails	Bowls	Knobs	Polyurethane	Tote	Drawer rails
Cost per unit	$3.38	$13.73	$0.14	$0.62	$1.94	$1.98	$0.72	$6.98	$15.98

CHAPTER 4: FINAL DESIGN AND PRODUCTION

CHAPTER 4.1: FINAL DESIGN

The main changes made between the final design and prototype II were that the front drawer was lowered, and the top was extended to change the way the drawer nested within the box. This change was made to improve the aesthetics and to improve functionality. Another benefit of the new design is that it is harder for food and water to get into the drawer compartment when the top extends over the front of the drawer. The final design is shown below in Figures 8 and 9.

Figure 8: Final Design

Figure 9: Final Design with Extended Drawer

CHAPTER 4.2: PRODUCTION OVERVIEW

Chapter 4.2.1: Trial with the Waterjet Cutter

When developing the manufacturing process, the team considered the idea of using the waterjet cutter to make all of the cuts previously made with the panel saw, table saw, and radial arm saw. If the waterjet cutter was used in this way, cycle time could have been reduced and the cuts would be accurate and precise. Another potential benefit was the reduction in floor space from eliminating three machines. Part of the plan for cutting every component with the waterjet cutter was the inclusion of pilot holes for the knobs as well as for the drawer slides that attached to the drawer itself. Although it was a good idea, when the concept became a reality there were several issues. When an entire sheet of plywood was used for each run which produced the components for two feeders, the run time was close to 10 minutes. The quality of the wood was diminished after it had been covered with water for the length of the process. The garnet aggregate used in the waterjet cutter stains wood gray which presented another quality issue despite the wood being constantly sprayed off throughout the process. A trial run with this process can be seen in Figure 10, and Figure 11 shows the wood after it had been cut and dried. The machine costs of the waterjet cutter was another limiting factor, and although it decreased cycle time initially, there is very little room for reducing the time further. Whereas, with operators running saws, there will be a learning curve and over time the cycle time will decrease.

Figure10: Trial with Waterjet Cutouts Figure 11: Pieces cut with Waterjet

After the trial, it was decided that the saws would continue to be used, and the waterjet would only be used for cutting the holes in the top piece. After seeing the effect that the water and garnet had on the wood, it was decided that the top would be cut to size and laser engraved before moving onto the waterjet cutter. This minimized the time that the wood was in contact with the garnet and water.

Chapter 4.2.2: Production Layout

The figures below show the production layout for the manufacturing process. Some challenges were involved with creating a layout with minimal conveyance and balancing the work with operators who worked multiple stations. The pieces that were cut using the panel saw had to go to two different saws, the radial arm saw and the table saw. Seeing that those pieces were the largest and most cumbersome, it was a priority to set up the three saws in a way that would be ergonomic and lean. To aid in the flow of materials from the saws to the assembly area, a shadow board was put into place. The designated placement of each component was based on where it was coming from as well as where it was going. The process required four operators. Operator #1 operated the panel saw and table saw, and assembled the outer box, front, and top. Operator #2 ran the radial arm saw and table saw with the dado blade, and assembled the drawer. Operator #3 operated the laser engraver and waterjet cutter. Furthermore, the third operator placed the finished top at its point of use and was in charge of disassembling the drawer slides from the packaging and distributing the components to their point of use. Operator #4 completed the sanding, polyurethane, and final assembly.

Figure 12 shows the first production layout and Figure 13 shows the second and final production layout. The main difference is that initially there was no shadow board and the table saw was perpendicular to the panel saw. When the shadow board was added, Operator #1 could not easily place the cut pieces from the table saw onto the shadow board. When the table saw was turned parallel to the panel saw, the placement of cut pieces from the table saw to the shadow board was much easier. Also, Operator #1 had to be able to move easily from the panel saw to the table saw and then to the outer box assembly. With the new arrangement, movement between the table saw and the main assembly area was much easier. One potential problem created with rotating the table saw was that a walkway was created in between the table saw and the roller conveyer leading to the radial arm saw. However, power cords and the dust collection hose that connected to the table saw ran across the new walkway. So, to prevent people from walking through the space, a trash can was used to block the path. Two other trash cans were used throughout the production area.

One was placed in between the table saw and the shadow board for scrap that was produced from the table saw. The other was positioned to the left of the radial arm saw for the remaining scrap. A larger view of the final layout can be seen in Figure 14.

Figure 12: Production Layout 1

Figure 13: Production Layout 2

Figure 14: Production Layout 2 – Alternative View

Chapter 4.2.3: Material Flow

The flow of materials to and from each station is illustrated in the Figure 15. Raw material in the form of Sande plywood (¾" x 4 ft. x 8 ft) got cut by the panel saw into a 17-½" x 4 ft. piece and a 24-⅞" x 4 ft. piece. The two pieces then traveled to the radial arm saw and the table saw, respectively. The table saw produced the front and back panels of the outer box as well as two of the drawer components. The radial arm saw produced the left and right panels of the outer box, three drawer components, and the triangular drawer bracings. All of the components cut with the saws were placed on the shadow board. The two pieces that form the bottom of the drawer travel from the shadow to the table saw that uses a dado blade and then get returned to their new position on the shadow board. The drawer assembly and outer box assembly both use components that are on the shadow board, and the drawer slides are at their point of use. The top piece gets cut to size with the panel saw and then travels to the laser engraver and then to the waterjet cutter. From there, it goes to the outer box assembly. The Dog Box gets sanded and vacuumed and then moves to polyurethane and final assembly where the bowls, knobs, and tote are installed.

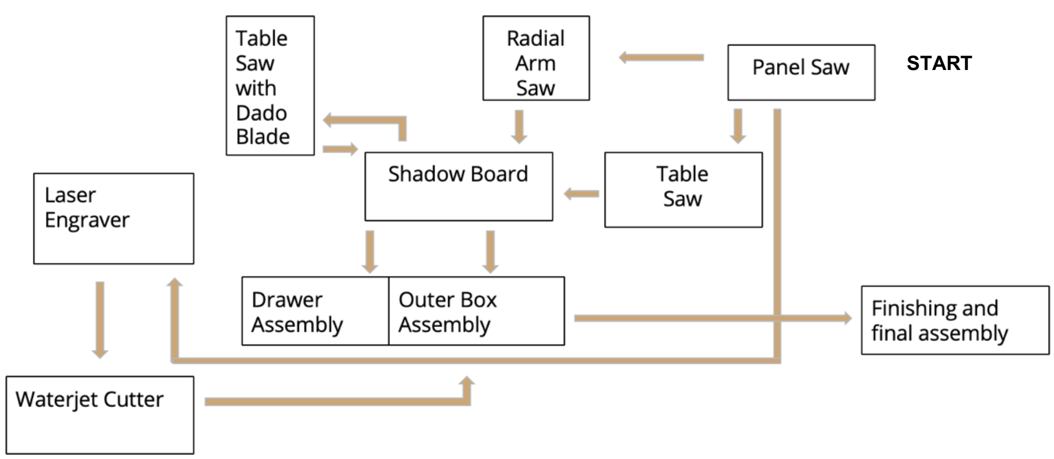

Figure 15: Material Flow

CHAPTER 4.3: POKA YOKES FOR SAWS

Chapter 4.3.1: Indicated Cutting Positions

The first step in the process was to load the plywood onto the panel saw. Before the panel cart was used to store raw material, loading the sheet of plywood required two operators. However, the positioning of the cart shown in Figure 16 allows an easy transition from cart to saw that can be performed by one operator. One of the first improvements made by the team was to add cutting positions to the panel, table, and radial arm saws as indicated with arrows in Figures 17, 18, and 19, respectively. The cutting positions eliminated the need to measure each cut throughout the process. It also increased accuracy because there was no longer the opportunity for mismeasurement. Additionally, the cuts were numbered in order of the process. For the cuts made on the table saw, the operator had to rotate certain pieces after each cut. However, the order of the cuts was poke yoked so that the cut could not be made if the piece was not rotated. As a queue to the operator, "flip" was written on each mark that needed to be rotated. Adding the cutting positions significantly decreased the production time and the number of defects.

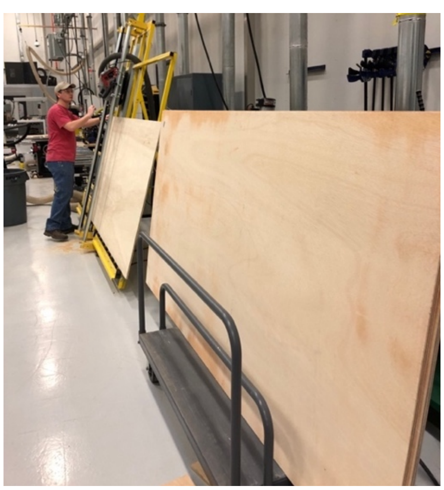

Figure 16: Plywood Loading and Cutting

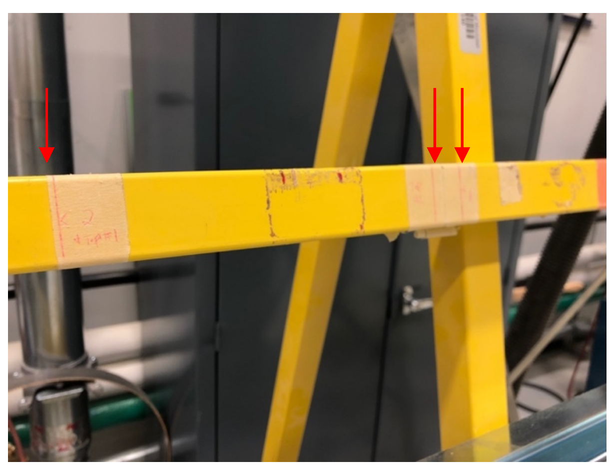

Figure 17: Cutting Positions – Panel Saw

The cutting positions shown on the radial arm saw in Figure 19 include the number of times that specific cut should be made. The hard stop created by the clamps makes the two cuts made at that position even quicker.

Figure 18: Cut Positions – Table Saw

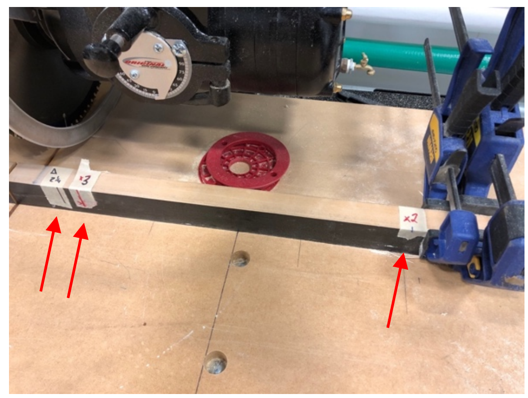

Figure 19: Cut Positions – Radial Arm Saw

Chapter 4.3.2: Triangular Bracings

The last cuts made by Operator #2 on the radial arm saw were the triangular braces. After cutting the outer box sides, drawer sides, and one of the drawer bracings, the remaining wood was used to cut the triangular bracings. First, a 2-1/4" wide strip was cut and then rotated 90˚ so that the longest side rested against the backstop on the saw. Then, the right angle shown in Figure 20 was used to cut four triangular braces. To make the cuts, the edge of the right angle was placed on the table so that the corner was lined up to the slit for the saw as shown in Figure 20. The left edge of the wood was then placed against the right angle so that the top left corner of the wood nested in the slit for the saw blade. At that point the blade was pulled through the wood and one brace was created. For the second brace, the remaining wood was flipped so that the angle created by the cut rested against the right angle before the saw was pulled through. For the third brace, the now straight edge of the wood was placed flush with the right angle so that the top left corner of the wood rested in the slit for the saw blade before the cut was made. The remaining wood was then used to create a fourth in the same way that the second brace was created. The orientation for the first and third brace were the same, and the orientation for the second and fourth brace were the same. Finally, the four triangular braces were placed at their designated location on the shadow board.

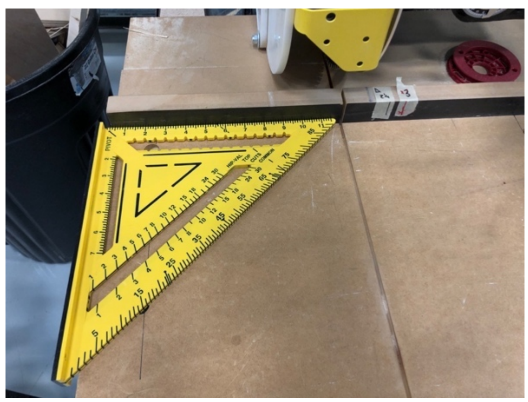

Figure 20: Triangular Bracing Fixture

Chapter 4.3.3: Table Saw with Dado Blade

Once Operator #2 was finished with the radial arm saw, the two inner bracing pieces were picked up from the shadow board and brought to the table saw with the dado blade. The smaller of the braces used the smaller distance fixture and the larger brace used the larger fixture which can be seen in Figure 21. The fixtures were used to mark the braces so that the operator could see where to run the brace over the dado blade. Two lines were marked with a red pencil on each brace. The masking tape on each side of the dado blade shown in Figure 21 has lines that aid in the process. For each brace, the left mark on the brace was lined up with left masking tape line, and then the brace was pushed over the dado blade. This process was repeated for the right side. This set the edges of what the dado blade will clear away for each brace. Next, the brace was pushed over the dado blade several more times to clear away the middle section. Once this had been done for each brace, the braces were fitted together to nest in one another at their cross section. If they easily fit together, then they were placed on their respective locations on the shadow board. If they did not marry easily, then the brace with the narrower opening was passed over the dado blade to widen the slot until they fit together easily.

Figure 21: Dado Blade and Fixtures

Chapter 4.3.4: Assembly Shadow Board

All of the components that came from the saws would be placed on the shadow board shown in Figure 22 so that they could be easily accessed by the main assembly stations. The placement of the pieces was determined by where they were coming from as well as where they would be used next.

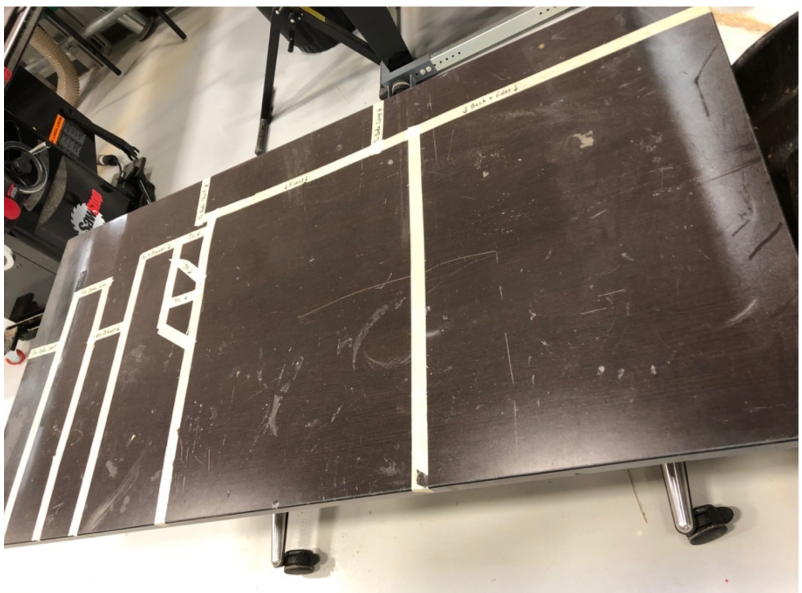

Figure 22: Assembly Shadow Board

CHAPTER 4.4: MAIN ASSEMBLY

The main assembly is the heart of the process. It takes the most time and is where the potential for errors is the highest. Due to the high potential for errors, several poka yokes, or fixtures were designed, built, and put into place. All of the cut pieces used in the main assembly are retrieved from the assembly shadow board. Each piece could be easily reached by the main assembly workers. For the final production run, Operator #1 and Operator #2 transitioned from their respective saws to the main assembly area. The large pieces that were cut with the table saw and placed on the assembly shadow board were used in the outer box assembly which is in the foreground of Figure 23. The smaller pieces flowed from the radial arm saw to the assembly shadow board, and then to the drawer assembly shown in the background of Figure 24. Additional apparatuses that can be seen in Figures 23 and 24 include backstops and tool holsters. The backstops ensure pieces do not fall to the floor and provided a static force to make sure the wood would "suck up" once nailed. The holsters held the nail guns and hardware for the operators. The use of holsters created a clean, organized workspace and was an implementation of 5S.

Figure 23: Main Assembly

Figure 24: Main Assembly – Angled View

Chapter 4.4.1: Drawer Assembly

The drawer assembly was completed by Operator #2 immediately after the two bottom drawer components had been slotted with the dado blade. The first step was to grab the inner braces created by the dado blade from the shadow board and move to the end of the main assembly shown in Figure 25. Then, the two pieces were fitted together and the framing square shown in Figure 25 was used to ensure that they were square. Once the pieces were square, they were nailed together with the brad nailer which was holstered to the right of where the operator stood. Five, ¾" nails were shot into the spot where the two components overlap; therefore permanently fixing the bottom brace. The brad nailer was positioned to the right for a right-handed operator, but it could be easily moved to the left for a left-handed operator.

Operator #2 then moved to the left to the station shown in Figure 26. During the transition between stations, the operator picked up the outer drawer components and the triangular braces from the shadow board. The outer drawer components were placed in the three sided square fixture shown in Figure 26 so that the sides of the drawer ran along the two inside edges of the fixture and the back drawer component was opposite the back side of the fixture. After the three sides were in, the drawer bracing was put into place for extra stabilization. When all of the components were in the fixture, the back drawer component was within the sides of the fixture. The finish nailer to the right of the fixture was used to attach each drawer side to the back of the drawer with three nails each. Then, the L-shaped fixture in Figure 26 to the left of the three sided square was placed over where the drawer bracing meets the back and sides of the drawer, and the red pencil was used to make a mark under the bottom of the L-shaped fixture. This line indicated where the top of the bracing was in order to give the operator parameters for the nail locations when the bracing was nailed to the outer drawer. Three nails were used to connect the drawer bracing to the outer drawer on the left side, right side, and back of the outer drawer.

Figure 25: Drawer Bracing Assembly

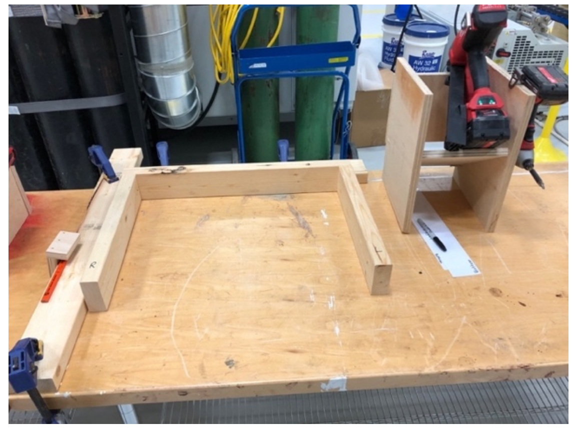

Figure 26: Outer Drawer Assembly

Chapter 4.4.2: Outer Box Assembly

The main box assembly started at the drawer slide assembly. This included a milled out fixture that fits the side of the box in a specific poka yoke position. The depth of the milled out section was the offset that the drawer slide needed to be. The production on the milled out portion can be seen in Figure 27. The fixture also included marked lines for the screws that attach the slide to the side, and an elevated back stop for upright, ergonomic use. Attaching the slides to the sides was once the hardest, most time consuming parts of the entire assembly due to the need for precise measurements within 1/32”. The drawer slides poka yoke eliminated the need for taking measurements. The drawer slides poka yoke can be seen in Figure 28. The operator only had to remember which side was left and which was right. The screw locations for each side were color coded; the left side was marked with red, and the right side was marked with blue. If more fixtures were made, the color coding would be switched so that the alliteration of right and red would make it easy to remember.

Figure 27: Production of Poka Yoke

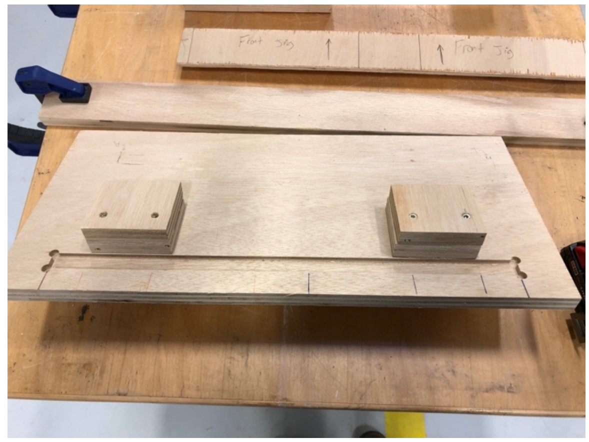

Figure 28: Drawer Slides Poka Yoke

Once the slides were attached to the sides, the pieces were moved to the main outer box assembly where the back was attached to the sides. For this, a three sided rectangle fixture, shown in Figure 29, was used to ensure the sides were square. Ensuring that the outer box was square was vital to the drawer function. If the outer box and drawer itself were not square, then the drawer would not open and close properly. Once the sides were attached to the back, the fixture could be flipped up against the backstop out of the way for the front assembly which is shown in Figure 30.

Figure 29: Outer Box Assembly Position 1

Figure 30: Outer Box Assembly Position 2

Chapter 4.4.3: Front Assembly

Before the front could be attached, the drawer was installed in the outer box. At this point in the assembly, Operator #1 and Operator #2 had finished the outer box assembly and the drawer assembly, respectively. The drawer instillation was a difficult part of the process, so Operator #1 and #2 work together to make it a more efficient process. For the front assembly, two jigs were used. One to lift the front to ensure there was enough ground clearance and another to drill pilot holes for the knobs which can be seen in Figure 31. A 5/32” drill bit was used for the pilot holes and allowed the knobs to be installed by hand.

The main challenges encountered with the outer box assembly included hard to reach gun locations when connecting the sides to back, two men needed to combine the slides, and front lifting jig not producing level front pieces. The final jig used to lift the front piece was the third iteration. The previous iterations did not produce the correct height, and they did not result the front being level. The assembled front is shown in Figure 32.

Figure 31: Pilot Holes for Drawer Knobs

Figure 32: Assembled Front

CHAPTER 4.5: MANUFACTURING THE TOP PIECE

The pieces for the top assembly were cut to size with the panel saw from a ¾ in. x 4 ft. x 8 ft. sheet of Sande plywood. One sheet produced seven tops. From the panel saw, the tops got laser engraved. After the engraving, they went to the waterjet cutter, and then to the main assembly area. In the main assembly area, the completed top got placed on the bottom shelf of the table where it was then installed. Operator #1 cut the pieces to size with the panel saw, and Operator #3 had ownership over the laser engraving, waterjet cutting, and transportation of the top piece between processes.

Chapter 4.5.1: Laser Engraving

Before the top was laser engraved, the concavity was checked with a level. To minimize drawer inference with the top, the engraved side had to be concave down. First, the top was placed in the laser engraver, then the level was placed on the top as shown in Figure 33. If the level touched only the middle and not the sides, then it was concave down, and in the correct position. If the level touched the sides, but not the middle, then it was concave up and needed to be flipped over. After the correct orientation was determined, the left and top edges were aligned for squareness. From that point, the lid was closed and the laser engraving could commence. The laser engraver was already set up to engrave the CME logo, so the process could begin with a push of the start button. The laser engraving in process is shown in Figure 34. In the future, the intensity of the engraving could be decreased to reduce the cycle time and better balance the manufacturing process.

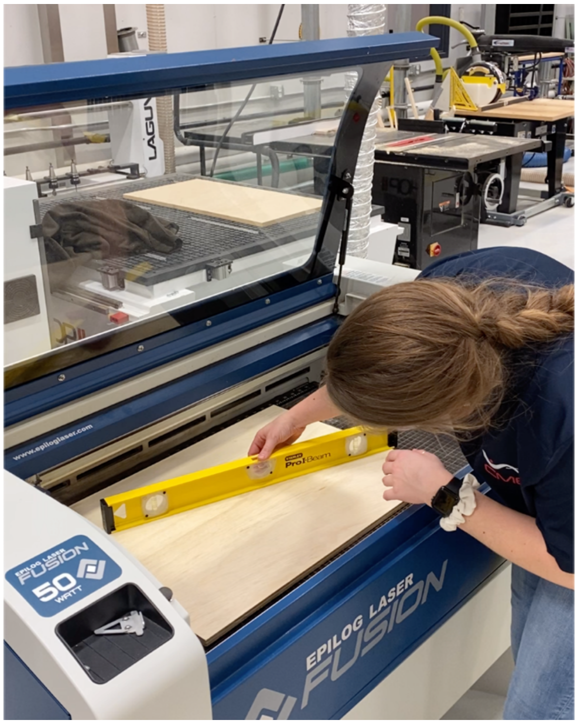

Figure 33: Testing for Concavity

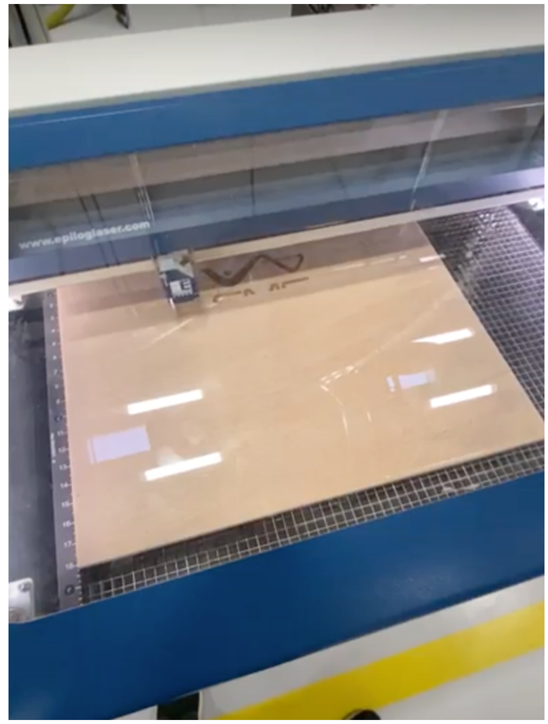

Figure 34: Laser Engraving in Progress

Chapter 4.5.2: Waterjet Cutter

When the laser engraving was completed, the top was taken to the waterjet cutter. Metal pieces were fastened into place on the grid of the waterjet cutter and act as a positioning fixture and can be seen in Figure 35. This allowed the operator to know where to place the top piece. After the piece was placed, the guards were lifted into place and the cutting began. The program for the cutouts was already set up, so just like the laser engraver, the cutting started with the push of a button. Ordinarily, the head of the waterjet cutter had to run along the edges of the component with a laser so that it was oriented properly. However, the positioning fixture eliminated the need for reorienting with every run. When the finished top was removed from the waterjet cutter, any excess water remaining on the surface was wiped off with a shop towel. Then, the operator delivered the top to the main assembly area and placed it on the shelf below the top assembly station.

Figure 35: Top Piece Loaded onto the Waterjet Cutter

Chapter 4.5.3: Top Assembly

The top assembly was completed by Operator #1 and took place directly after the front assembly. Seven nails were used to attach the top to the outer box assembly which included three across the back and two more on each side. Sometimes, the nail would not go into the sides or back correctly which resulted in nails sticking out of the surfaces. This problem lessened over time with experience.

CHAPTER 4.6: FINISHING AND FINAL ASSEMBLY

Chapter 4.6.1: Sanding Station

After the top assembly, the Dog Box moved to the sanding station which can be seen in Figure 36, and a close up of the vacuuming and sanding units can be seen in Figure 37. Before sanding, the box was inspected to ensure that all nails were flush with the outer surface. If not, they were nailed flush with a hammer and any holes on the top or front were filled with wood putty. If there were any issues with the drawer not having enough clearance, the sander with a coarser grit of 80 was used to correct the issue. Otherwise, the sander with a lighter grit of 180 was used over the outer surfaces of the Dog Box. The two different hand sanders can be seen Figure 38. After it was sanded, a vacuum with a bristle brush, shown in Figure 39, was used to clean the surface of the feeder to prepare for polyurethane.

Figure 36: Sanding Station

Figure 37: Sanding and Vacuuming Units

Figure 38: Two Different Sanders

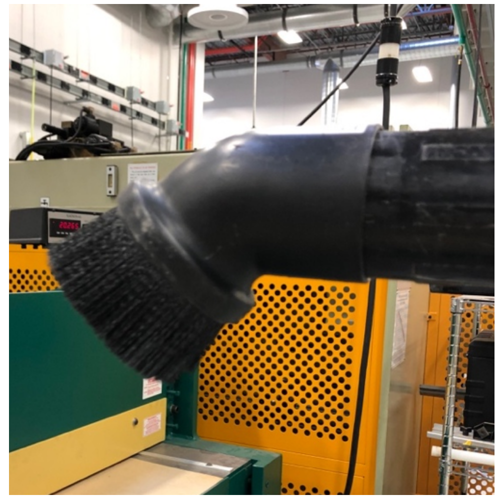

Figure 39: Vacuum Head

Chapter 4.6.2: Polyurethane and Final Assembly

The cart seen in the bottom right of Figure 40 is used to transport the Dog Box from the sanding station to the polyurethane station shown in Figure 41. The cart height is adjustable which makes the transition between the two stations more ergonomic. A handheld pale with a plastic liner is used to hold the polyurethane to make the application easier for the operator. During production only one coat of polyurethane was applied, but the finishing process was improved after the final production run. The improved process included one coat of a mineral spirits polyurethane mixture in a 1:2 ratio, respectively. That coat created a seal, and was followed by two coats of pure polyurethane. To implement the improved finishing process into production, a drying area and queue would have to be set up for the works in progress to facilitate the three different coats. After the Dog Box was dry, the tote was placed in the drawer, the bowls were put in place, and the knobs were screwed in. The cart seen in the figure below would be used to transport the finished Dog Box to a designated finished goods location.

Figure 40: Final Station with Carts

Figure 41: Polyurethane and Final Assembly

CHAPTER 4.7: FIELD TESTING

Field testing the finished product was a success as well as a learning opportunity. The box itself is durable enough to handle two Labrador retrievers, and they have not been able to get into it. Furthermore, the tote holds 40 pounds of food perfectly, and the drawer has not shown any sign of sagging or weakening. The box and tote combination allow for sufficient sealing of food. No smell can be found around the box and it has not attracted any bugs. However, there is also room for continuous improvement which could include an additional polyurethane coat and a gasket around the bowl holes for a more secure seal. It is important to note that the specific Dog Box being tested only had one coat of polyurethane. Also, a human bowl can be placed upside down in the dog bowl to slow down fast eaters as shown in Figure 42.

Figure 42: Field Testing with Kimber and Nova

CHAPTER 5: FINANCIALS

CHAPTER 5.1: COMPARABLE MODELS

The opportunity to see a product from idea to realization has been an essential practice in developing an accounting system from the ground up. The main three objectives were cost control, waste minimization, and preparation for scaling. After the original conceptualization of the product, the team determined an acceptable asking price. During our deliberation, several factors were taken into account such as the price of comparable models. Comparable models fell into the $80 to $150 price range, and the models shown in Figures 43-45 are examples of similar products. The Dog Box's ability to hold 40 pounds of dog food and addition of a custom laser engraving differentiate it from most comparable products.

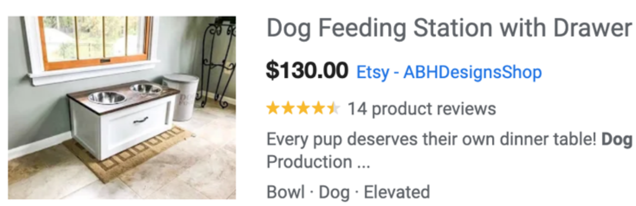

Figure 43: Comparable Model with Drawer [13]

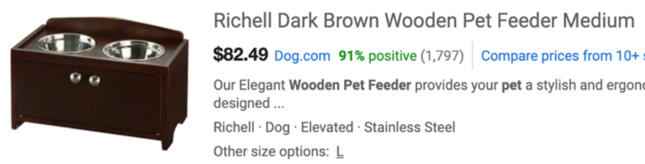

Figure 44: Comparable Model with Cabinet [14]

Figure 45: Comparable Model for Large Dogs [15]

CHAPTER 5.2: FIXED AND VARIABLE COSTS

Based on these factors, it was decided that the asking price for the Dog Box would be $100 which set a benchmark for cost controls. As a new business, the target profit margin was 20% which meant that costs could not exceed $80 [16]. The fixed costs were the starting point for consumption, starting with facility costs. The production floor space was 825 square feet, and in 2019 the average rent for industrial space in Mississippi was $5.80 per square foot based on a quote from Statistica.com [17]. Based on these numbers, the facility rent would be $57,420 per year and production was estimated to be 6,000 units yearly. Therefore, factory floor space only accounted for $9.57 of the total unit cost.

Chapter 5.2.1: Labor Costs

The manufacturing process used four employees, but looking forward the top pieces would be outsourced to save money on floor space, CNC costs of the waterjet cutter, and labor cost. Therefore, the financial analysis was completed with this in mind. The goal was to compensate above the average Mississippi rate of $11.00/hour [18]. An hourly rate of $15.00/hour was decided on in order to attract quality craftsmanship to the emerging company. The production run yielded three units in an hour meaning that the labor cost would account for $15.00 per unit.

Chapter 5.2.2: Capital Investments

Capital investments were the third cost consideration. In order to manufacture the elevated dog feeders, six pieces of machinery were needed. Based on a rent versus buy analysis, four of the machines would have been purchased outright. Those machines include two table saws and one radial arm saw for a total cost of: $18,100. In an effort to capitalize all costs in the first year of production that equates to $3.02 per unit. Some equipment was simply too expensive and too underutilized that an outright purchase of the equipment would not be economically feasible. The first piece of equipment was the laser engraver to personalize the dog feeders. The engraver costs $26,001.85; based on a ten year life cycle and a utilization rate of one thousand usage hours per year the hourly rental rate is $32.60 per hour for the outsourced process. Since the capacity is ten units per hour, the laser engraver accounts for $3.26 per unit. The second piece of equipment that was deemed necessary for rental was the water jet cutter used to cut the top holes for the dog bowls. The cutter costs $254,403.86 based on an eight year life cycle and a utilization rate of one thousand hours per year, so the rental rate is $136 per hour. The waterjet's capacity is fifty units per hour; and to match the output of the laser engraver, it would need to be outsourced for 120 hours per year. Therefore, the waterjet cutter equates to $2.72 per unit. Consequently, the total rental cost is $5.98 per unit.

Chapter 5.2.3: Material Costs

Once the facility costs, labor costs, and capital investments were determined, the remaining money could be put towards material costs. The material allocation could be $46.43 per unit and still maintain the goal of a 20% profit margin. A few of the material costs could not be adjusted. Those included the drawer slides ($15.48), the dog bowls ($6.20), and the plastic totes ($6.98). The nonadjustable cost totaled to $28.66 which left $17.77 for the remaining raw materials. Each top piece was constructed from ½" thick Sande plywood that was $35.95 per sheet, and each sheet made seven tops for a unit cost of $5.14 per top. The remainder of the Dog Box was constructed from 3/4" thick Sande plywood that cost $45.98 per sheet. Two units were made from each sheet for a unit cost of $22.99 per unit which caused the $80 goal to be exceeded. Knobs, nails, polyurethane, and putty for filling holes added $4.66 of materials per unit. Therefore, the total material cost was $61.44 per unit making the total cost per unit $95.01. This total estimate was based on buying the material for the tops and renting the waterjet cutter, but only using three operators. The material cost and rental cost of the tops was used as an estimate because that part of the process would be outsourced. Due to this, the actual cost would be lower than estimated. Nevertheless, because the original goal was exceeded, in order to reach a profit margin of 20% the feeder would have to be sold at $114.

CONCLUSION

Throughout the design and manufacturing process many valuable lessons were learned. The fourth and final design was the culmination of the lessons learned from the design process. Material selection, dimensions, bowl location, and method of food containment were aspects of the project that changed before reaching a final design and began designing the production layout. The team designed fixtures and poka yokes, developed best practices, and added steps to the original process. Every fixture that was designed was made to reduce errors, increase efficiency, and improve manufacturability. Once the fixtures were created, their method of use was continuously improved to move towards establishing a best practice. All of the fixtures were constructed from scrap wood from the plywood sheets and scrap from the CME in order to be environmentally and fiscally conscious. Originally, only one coat of polyurethane was applied, but aesthetically and functionally it was decided that one sealant coat of mineral spirits and polyurethane and two coats of polyurethane were a better option. Extending the top and lowering the front was a success that did its intended job of improving the aesthetics and preventing food and water leaks. The new design also improved the security of the drawer access. Overall, the team was pleased with the final design as well as the manufacturing process that was established. Three Dog Boxes were made during the production run. Nine were made total which included prototype I, prototype II, and seven units of the final design.

If production of the Dog Box were to continue and grow in the following years there are some improvements and considerations in the categories of design, production, and financials. On the basis of design, future models could include a scoop if market research supported that decision. Furthermore, there was an issue with the front piece bowing out so that it was no longer flush with the rest of the Dog Box. This occurred because the front piece is only connected to the drawer at the bottom, over time the nails become looser which creates a gap between the front of the drawer and the rest of the Dog Box. This happens because the nails act as a fulcrum and the front acts as a lever. Opening the drawer creates an applied force at the knobs which over time loosens the nails similar to the way the claw of a hammer removes nails. By lowering the front, the gap decreased the distance between the applied force and the nails. Also, the gap was not as noticeable with the new design. However, if an angled piece of metal was added to attach the sides of the drawer to the front piece, the gap could be eliminated in the future. Another plan was to distribute the seven models and receive feedback in order to discover any problems that might occur over long term usage. During production, the bowls and knobs were installed; however, if the Dog Boxes were shipped, the tote would be installed and the bowls, knobs, and screws would be placed inside the tote. The knobs and bowls would be protected inside the tote, and without the knobs on the front the feeders would be easier to pack together. Another addition that could be added is a dog-proof latch. This would be added if the field testing feedback indicated that dogs could get into the drawer. Lastly, another addition to the final design could be a rubber gasket around the bowl cutouts to create a more secure seal. On a production basis, some improvements that could have been made were adding standardized work instructions and visual aids to the process to act as a poka yoke. The dado blade fixtures could have been adjusted so that the braces always fit together because there was a problem with the fit being consistent. The CNC router could have been used for making the bowl cutouts, and eliminating the waterjet cutter would prevent the top from getting wet. However, for the CNC router to be used, a spoilboard would have to be purchased and added to the routing table. A spoilboard is a surface that is disposable and it sits on the routers worktable to prevent it from getting damaged [19]. Currently, the CNC router could not be used to cut completely through material. The fixtures could be further refined, especially the dado blade fixtures and the front assembly fixture which did not produce consistent results.

Looking forward financially would include waste minimization and preparation for scaling. The team would source plywood sheets that are even larger to optimize material utilization which would even further reduce unit costs and increase our margin. Furthermore, as production continued and the operators became more familiar and efficient with the work the units per hour could increase. The minimization of time and scrap could drastically increase profits for the company. The equipment would be capitalized the first year, so the profit margin would increase 4% in years to come. Procuring preferable contracts for dog bowls, drawer slides and plywood by purchasing in larger quantities would work to increase the profit margin and potentially lower the cost of the Dog Box. Furthermore, it would be important to source warehousing and delivery contracts which will eat into profits by some amount, but since we have factored in a very healthy margin these costs should be insulated from damaging the profitability of the project. Overall, the team created a design that was within the scope, cost, and time of the project and successfully produced a product with quality built into the manufacturing process.

Figure 46: Team Picture Post Production

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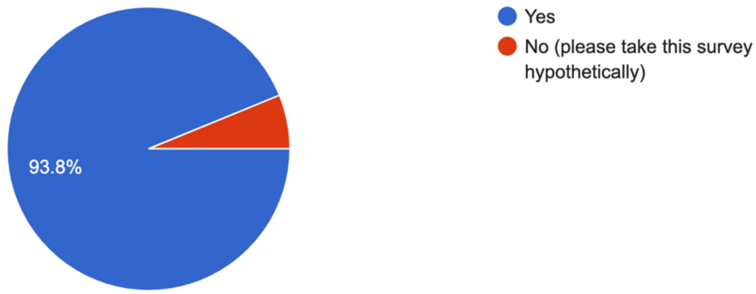
APPENDIX

APPENDIX A: SURVEY INFORMATION

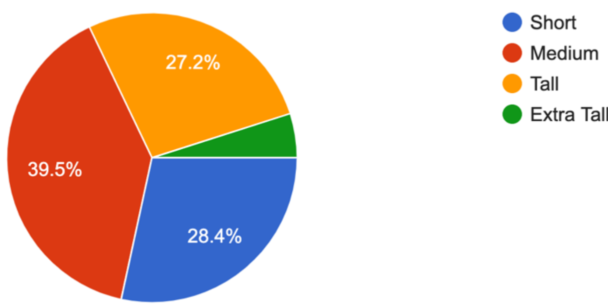
Do you have a dog?

81 responses



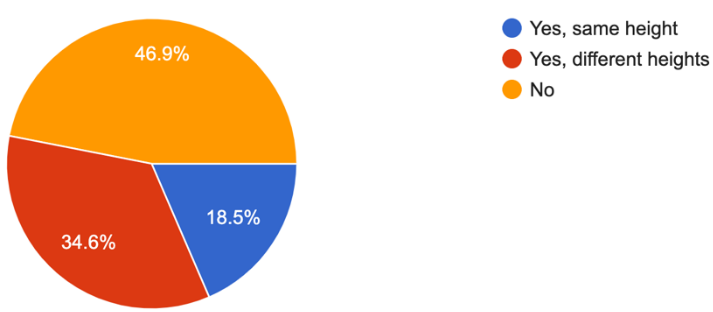
What height is your dog?

81 responses



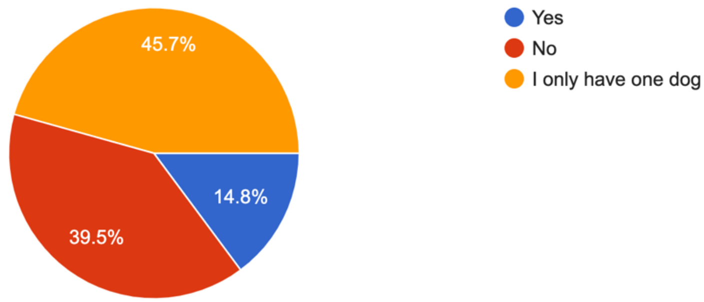
Do you have more than one dog? If yes, are they different heights?

81 responses



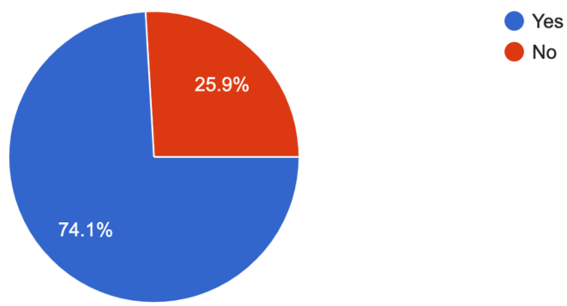
If you have more than one dog, do they each eat different dog food?

81 responses



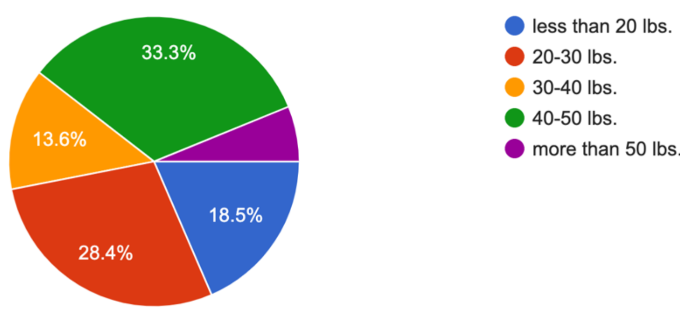
Are you satisfied with your dog's current feeder/ food bowls?

81 responses



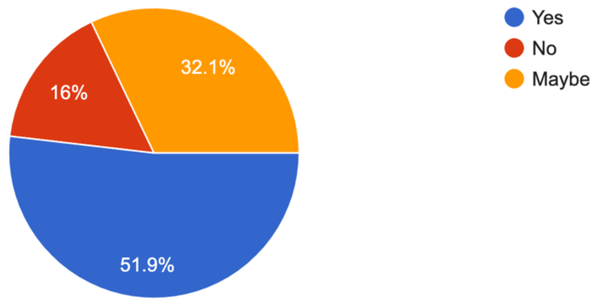
What size bag of dog food do you typically buy?

81 responses



Would you be interested in an elevated dog feeder (featuring a food storage compartment) to promote your dog's neck and back health?

81 responses



How much would you pay for an aesthetically pleasing, elevated feeder that includes a storage compartment?

81 responses