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Using Manufacturing and Design Principles and Processes to Evaluate the Feasibility and Marketability of a Wooden Disc Golf Basket

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USING MANUFACTURING AND DESIGN PRINCIPLES AND PROCESSES TO EVALUATE THE FEASIBILITY AND MARKETABILITY OF A WOODEN DISC GOLF BASKET

By John Mark Huff and Yvonne Nguyen

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ABSTRACT

The purpose of this thesis is to analyze and discuss the product development process of a new product design of the commonly used disc golf basket as was executed through the Center for Manufacturing Excellence 2022 Senior Capstone Project. This project was executed over the course of the Fall 2021 and Spring 2022 University of Mississippi undergraduate semesters by a team of six, consisting of two mechanical engineering students, one finance student, and three accounting students. The end goal of the project was to develop a production plan to produce 1,000 units a month based on market demand and analyze the effectiveness and profitability to determine the feasibility of implementation. The project began with team formation and a project management plan to meet predetermined goals and deadlines while distributing tasks equally amongst team members. This was followed by process and design creation for a prototype which led to design and process changes and costs analysis, finally resulting in a production plan. Post production analysis included discussion of why and how the decisions were made along the product development process and the effects of those decisions. Hindsight analysis of the consumer market, cost implications, and additional design and process improvements led to data driven discussion of the effectiveness of a wooden disc golf basket. The authors of this thesis will discuss the ideal vs actual implementation of manufacturing and design principles in relation to this project.

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1 Introduction

Innovators have learned that while millions of products have been made, improving those products may be the key to a new product entirely. A starting point would be to ask oneself, "what problem is this product solving?" That realization opens the door for innovation, which poses the following questions:

Can the material be changed?

Can there be new design implementations?

Can new features be added to improve the product?

These questions leave room to explore options of sustainability, waste reduction, or modernizing. Once the problem needing to be solved is identified, the idea expands into something more: a business proposal. This is how the disc golf basket was chosen for the capstone project. From there, more questions start reeling in:

Who is the target audience?

How is this product going to be manufactured?

How much will this product cost?

The questions start broad, but they eventually narrow. Then, the business cycle develops, and the beginning stages of brainstorming seem like a lifetime ago. These questions lead to one thing: a team. The team is the key to a successful product and bringing that idea to life.

The goal of the disc golf basket capstone was to develop a design that would be cost efficient while meeting the expectations of the average consumer in today's market. Due to the majority of disc golf baskets in the market being made from metal, the team wanted to examine the result of a wooden disc golf basket in relation to costs and usage. This thesis analyzed the design attributes, manufacturing decisions, and team aspects that helped develop the creation of the wooden disc golf basket to meet the need of an inexpensive basket.

1.1 Center for Manufacturing Excellence

The Center for Manufacturing Excellence was founded in 2010 with the goal to incorporate real life manufacturing industry experiences into the classroom. The program admits students majoring in engineering, accountancy, and business. With a diverse group, the students benefit from the different courses that center around manufacturing sectors in engineering, accounting, and business. The classes focus on materials, manufacturing processes, accounting methodologies, and lean manufacturing. The courses sit at 60 students per student classification, so there is a specialized attention to each student's success. The program offers experiential classes that take place in a plant production site located in Mississippi such as Toyota, Nissan, and Viking Range. Students are led by the staff of the companies who guide the students through practical problem- solving techniques while combating a real-life problem the company is facing. The case studies can range from making a process more efficient to coming up with methods for a process the company is wanting to implement. The students are able to gain hands-on experience while applying classroom lessons to the projects.

Through the program, students accumulate the knowledge needed for their senior capstone. The capstone consists of elements of developing a product in areas of manufacturing, marketing, and finance. The capstone challenges students to use their knowledge of manufacturing principles and to go through the stages of team development.

1.2 Manufacturing Principles

Through the various classes the CME offers, students are continuously introduced to different manufacturing principles: LEAN, Six Sigma, and 5S, to name a few. The capstone centers around these principles in how they are used by companies across the board. Students are encouraged to use their knowledge of the principles to amplify their Capstone experience.

LEAN manufacturing focuses on waste reduction and continuous process improvements. Although the ideals of LEAN manufacturing have been around for ages, it was Toyota's Kiichiro Toyoda who conducted a study on the company's engineering practices. He recognized how their processes were accumulating waste and aimed to reduce it. Improvement teams were created to combat these issues, and it was Taiichi Ohno who developed the findings for what we now know as LEAN manufacturing, also known as Kaizen. Kaizen's philosophy is continuous improvement, which involves key objectives such as quality control, just-in-time delivery, standardized work, and waste elimination. It drives to improve sustainability and efficiency in regard to material usage, labor, and processes. Adopting LEAN manufacturing would reduce costs while improving quality. LEAN serves as an ideology for the principles to follow.

LEAN Six Sigma follows the methodology of data analytics and statistical analysis used by businesses to eliminate defects and improve processes to increase profits. The focus with this method is the customer. The goal is to improve the product for the customer's use and what the customer would value. Six Sigma serves as a benchmark on how assembly processes are operating. The benchmark rankings include white belt, yellow belt, green belt, and black belt, and each ranking comes with a special certification. The methods involve measuring the company's initial process. The company observes each step of the process, keeps an eye out for any root cause of a deficiency in the process, and works to find a solution in the system. They analyze what the initial measurement revealed to them to gain a better understanding of how to improve the process. The method is a work in progress. Because they use statistics such as time measurement, they also have to rely on the team to upkeep any changes. It is a gradual process to work towards the end goal.

The 5S's of LEAN manufacturing, sort, set in order, shine, standardize, and sustain, serve to provide an uncluttered workspace to improve performance. This method improves safety and increases standardized work. It lessens the potential of a misplaced item and waste accumulation. Sort is a term for general organization. For example, only tools being used should be in the workspace to avoid clutter. Set in order refers to items having a designated storage place. There should be an indication of where tools are being stored, and items not in use should go back to their rightful place. Shine, also known as cleanliness, revolves around equipment being free of any grease or dirt, and cleaning materials are easily accessible. Standardized work centers around the idea that if changes are made, everyone involved in the process is aware of the changes and actively works to upkeep them. Standardized work encourages employees to make the 5S ideology a habit and avoids potential confusion; for example, on where tools are. Sustain is self-discipline. The company needs to actively work to maintain the system set in place and inspect if 5S is truly being performed.

The eight discipline of problem solving (8D) is a technique used to identify the root cause of a problem and provide steps to find a solution. It prevents short term fixes and encourages long term solution-based thinking. It was founded by Ford Motor Company and has since made its way into other companies in the industry. The benefit of this technique is it uses team-based opinions, prevents recurring issues, allows more open conversation, and improves skills for problem solving. The steps for 8D are as follows. Step one is to form a team. Step two is to define the issue. Step three is to elect an interim containment action. In order to find a long-term solution, a preventive action needs to take place in the meantime. Step four is to identify a root cause to initiate the steps to form a permanent action plan. Step five is to develop a permanent corrective action plan based on risk assessments. Step six is to implement the plan. Step seven is to prevent reoccurrence. This is done by updating documents detailing the procedure and spreading the knowledge. The findings can aid other similar processes in identifying their root causes. Step eight is to allow feedback and compare before and after results of the change. Following these eight steps lead to a promising solution to an issue.

Through the use of these principles, the team was able to create the disc golf basket. The team implemented pieces of each philosophy into their planning and throughout the production run process. The principles served as a guideline for how to identify problems, find corrective actions, and maintain changes. It aided the team when problems arose and provided a mechanism to follow during the prototype.

1.3 Product Development Process

The team used Figure 1, which is shown below, to navigate through the product development process.

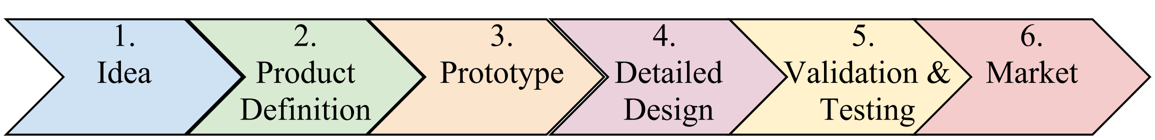

Figure 1. Product Development Process

The product development process is broken up into six stages: idea, product definition, prototype, detailed design, validation/testing, and marketing. To develop a product, the first stage has to be an idea. This stage is where brainstorming occurs for a new product and the needs it will fulfill. This stage encompasses whether the idea is feasible enough to move on to the next stage. The engineers and business team need to work as a partnership to determine if this idea will be profitable.

Product definition is the second stage. This stage is where refinements of the idea take place. The team needs to define how the core functionalities of the product would work and pinpoint who the target market is. This stage is where decision making needs to happen on what materials to use, what the budget for the product is, and how to cater to the target market. The goal of this stage is to articulate what exactly is the product the team is trying to sell to the consumers.

The third stage is a prototype. This stage is where the team makes a prototype to convert their ideas into real life. The prototype is used as a learning tool on if the product is viable and what changes will need to be made for the production run. The prototype needs to be where testing is done and calculations are made regarding time and labor costs. The prototype can also reveal to the team what materials may have had too much scrap and how to work on reducing waste. The prototype needs to be made as if this is the final production run and not perceived as a rough draft. In order to make a successful product, each stage in the building process needs to be given maximum effort.

The fourth stage is detailed design. This stage is taking what was learned from the prototype and fine-tuning it. This stage encompasses perfecting details from the prototype that did not work well and redesigning those processes. The redesign process can consist of material changes or equipment changes. The idea is to make a successful product while being efficient and cost-effective. The stage is crucial in terms of ensuring the product will have a successful production run. While this stage is for refining the prototype, the team needs to also be sure to stay within budget. The team needs to gather all of their ideas and be able to implement qualities that the prototype lacked.

The fifth stage is validation/testing. This stage is to ensure the product is working as planned. It is to test the changes that were made to the prototype and ensure the alterations worked accordingly. This stage is where the team needs to test whether the changes are viable or if more changes need to be made and how this will affect the product financially. This stage is where the team cannot afford for mistakes to happen since it is near the final stage of development.

The last stage is marketing. This stage is where the team needs to factor in how they are going to market this product to the consumer. This is the final step for profitability. The team needs to market the qualities the product possesses while focusing on the needs the product is fulfilling. The product will not be successful if the branding is not catered to the target market.

2. Team Management

With any project or work industry related tasks, team management has a large role in a successful outcome. It is important to establish a team dynamic early on to develop a unified front to tackle a common goal. In developing the disc golf basket, the team consisted of different majors and leadership styles which allowed them to explore different strengths and learn how to balance different communication styles.

2.1 Team Formation

Each CME senior was required to pitch a capstone idea to the CME faculty and senior class. Prior to creating the pitches, students had to take a questionnaire which would determine their actualized leader profile. The test showcased profiles to be either the asserter, affirmer, or achiever and gave students a self-actualization score. The product had to consist of four or more components that would be manufactured and assembled. Those who pitched the idea would serve as team captains. During the pitch development phase, team captains were encouraged to use what they had learned in prior years of the CME to create a successful pitch. Based on the pitches, the CME faculty members chose the products that best represented manufacturing qualities that could be done on the factory floor. The senior class had to rank the pitches on a scale of 1-5 by what team they would like to serve on as their capstone project. Teams were chosen by the faculty members based on ranks and majors ranging from engineering, accountancy, and general business.

2.2 Team Roles

After teams were chosen, team members congregated and established roles. Our team consisted of Will Wheatly (team captain and engineering), John Mark Huff (engineering), Yvonne Nguyen (accountancy), Coleman Miller (accountancy), Trent Cimina (accountancy), and Seth Nash (business). Will served as a project leader and was the liaison between the team and our instructor, Mike Gill. He was the point of contact for the team and was responsible for submitting the reports throughout the semester. He also made the appointments with the factory floor technician, Richard Hairston, as well as purchased the materials needed to make the product. He led the team meetings and created discussion points on what the team wanted to accomplish during each meeting. John Mark was responsible for ensuring the team stayed on schedule and aided Will in engineering aspects. John Mark created the Gantt chart and asked the team to update their portion when they completed a process. Throughout the execution of the prototype and production run, John Mark was able to help implement design changes the team had made through the processes using his background in engineering. They used their background knowledge to determine the materials the team would use for the product and how it could best be sustainable. They served as the constant voice of reason for if a process would not work or if there was a better method that could take place.

Yvonne and Coleman were responsible for the financial aspects of the project and ensured the team stayed within budget. Coleman was responsible for keeping track of the costs of materials associated with the product while Yvonne was responsible for keeping track of the cost of labor that would take place. They worked as a pair to maintain the lowest costs while ensuring the production run was efficient. They evaluated the equipment being used, materials purchased, and various labor options. They continuously updated the cost analysis to reflect the production run and any changes that took place.

Seth and Trent were responsible for the business and marketing aspects of the product. They communicated on the best methods to market the product to college students while planning the design features that would be added. Initial design features included painting the baskets and engraving logos.

2.3 Checks and Balances

With multiple different personalities and majors combined, it proved to be difficult to implement every idea that was offered. For example, there was controversy on whether the wood should be stained or left natural. To find a solution, the team proposed a vote which resulted in the wood to be left natural. The argument was there was not enough time to implement this process.

During the discussion of the production run assemblies, each member had a different take on what the best strategy was. To combat this, the team noted each variation on a white board and analyzed each proposed idea. They narrowed it down by reasons of why the run would work or why it fell short. The meeting did not conclude until every member was pleased with the chosen assembly run procedures. However, more checks and balances should have been put in place to hold the team accountable in regards to staying on schedule, which more effective communication and more meetings with the faculty advisor, Mike, should have occurred to ensure that.

2.4 Production Roles

The production roles were separated into five categories: cutting operation, L bracket installation, chain installation, stand assembly operation, and final assembly operation.

The cutting operation consisted of cutting 2x4's for the four-piece stand and center pole, cutting chains for the basket, water jetting the octagon middle piece and circle base piece, and cutting eight plywood basket walls. L bracket installation required fastening two L brackets into each of the eight walls and then fastening them into the octagon piece. The chain installation consisted of attaching chains to the pre-marked holes on top of the circle piece and attaching the L bracket to the pre-marked holes for the circle to attach to the center piece. Stand assembly operation consisted of drilling the four 2x4 stand pieces into the center pole and attaching the stand to the octagon pieces. The final assembly operation consisted of attaching the octagon piece to the stand, attaching the circle piece to the stop of the stand, and assembling the chains together using the metal circle. This is shown in Figure 2 below.

Figure 2. Stand Assembly

After the creation of the five processes, the team needed to determine how the processes would be divided up between three team members due to the other three members leaving for winter internships. The team analyzed each process to determine the time that should be allotted for that process, and that would determine the division.

While this is further discussed in section 5.3, the operations were roughly timed to be between 20 and 40 minutes during the prototype creation and led to the following decisions:

1. Operation one, the cutting operation, would take the most amount of time and deemed it to be a one-person job.
2. The second operation, L bracket installation, and third operation, chain installation, would be the second operator's job based on the similarities of the tasks.
3. The last operator would be responsible for operation four, stand assembly, and operation five, final assembly.

The team felt the assignment of these roles created the most efficient assembly process.

2.5 Management Changes

As the team dynamic kept shifting with the progress of the project, the team should have referred back to methods taught by the CME such as steps of the forming, storming, norming, and performing model when making decisions. This model was created in 1965 by psychologist Bruce Tuckman who created this model for a guide of team development as the team changes and relationships are built. The team had set a project schedule in the beginning and tried to ensure milestones were being met, but more accountability needed to be incorporated into the team dynamic. Changes that needed to take place were to keep track of the project schedule and update it accordingly. A schedule only works if it is accurate in real time. Section 3.3 discusses the Gantt chart in further detail on how the team used it to manage milestones. In addition, more time needed to be dedicated to the product. During the prototype, the process was flawed and time-consuming which section 5.2 expands on. Changes to the processes were necessary in order to have a successful production run. That required more involvement and time commitment from the team members. In order to have a successful product, the team dynamic needed to be enhanced and synergized. More meetings should have been made to discuss benchmarks, team involvement, and improvements to the product.

3. Problem Definition

"Before we delve into the design process, it is always important to ask yourself WHY you and your team are building the product. Having a vision gives you purpose and helps to define what you are trying to build. Too often teams jump into development without having a clearly defined goal. This can lead to disastrous results if the end product does not meet the needs of users or stakeholder expectations." (Lo). The team captain Will created the disc golf basket design based on a lack of inexpensive disc golf baskets on the market. The need was founded due to the lack of inexpensive disc golf baskets on the market. The basket created for the project needed to be as similar to the average disc golf basket as possible while being made from wood. The basket was made from wood because of the aesthetic appeal, and it would create a differentiating factor from the other baskets on the market. The team aimed to use these ideals to create a cost efficient and effective basket.

3.1 Solution

The team initially wanted to solve this issue by creating a design that was cost efficient and met the needs of the disc golf consumers. The proposed design would be made out of wood under the assumption that the material would cost less due to the elimination of capital investment in metal fabrication equipment. However, this later proved to be a lack of professional judgment as more research should have been done on the type of wood. The team ran into issues during the production run such as the wood splitting. A different type of wood would have prevented such issues.

3.2 Supporting Information

The team did not initially establish a market survey which hindered the marketing strategies that were set. The use of the prototype was based on ideas during the brainstorming phase of the capstone. The team did compare costs of disc golf baskets through the use of retailers such as Amazon and Wal-Mart. The goal was to test how long it would take to make the prototype and the costs associated with the build. The goal was to keep it under the average costs the team had seen on websites which were roughly around $200. The use of equipment had a large role on the cost factor which the prototype revealed. Meetings with the factory floor advisor, Richard, consisted of discussion of how to lessen labor costs, which are calculated in section 4.3, to make the product more cost-efficient.

3.3 Stage Planning

The instructor, Mike Gill, also applied deadlines throughout the semesters. The mid-semester report had a due date of October 1st with the expectation that the prototype would be halfway done. The final fall semester report was due December 1 which consisted of a reflection of the prototype and future improvements. The production run was scheduled for February and a final report due April 6th. The team-based milestones on due dates set by the instructor and team-based goals. Milestones were monitored using a Gantt Chart shown in Figure 3.

PROJECT TITLE	Wooden Disc Golf Basket
PROJECT MANAGER	Will Wheatley
COMPANY NAME	Manf 451
DATE	9/10/2021

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Project Conception and Initiation**					
1.1	Initial Design	Will W	9/10/21	9/20/21	10	100%
1.1.1	Gathering of Materials	Will W and John H	9/20/21	9/24/21	4	100%
1.2	Prototype Creation Scheduling on Floor	Will W	9/20/21	9/24/21	4	100%
1.3	Prototype Creation	Team	9/24/21	10/1/21	7	100%
1.4	Initial Cost Analysis	Coleman M, Yvonne N	9/24/21	10/1/21	7	100%
1.5	Initial Market Analysis	Yvonne N	9/24/21	10/1/21	7	100%
1.6	Initial Report	Team	9/27/21	10/1/21	4	100%
1.7	Initial Project Explanation and Risk Assessment	Seth N	9/27/21	10/1/21	4	100%
1.8	Initial Project Schedule	John H	9/24/21	10/1/21	7	100%
2	**75% Prototype Completion**					
2.1	Review of Progress and Future Goals	Team	10/4/21	10/15/21	11	100%
2.2	Wood Cutting	Team	10/4/21	10/15/21	11	100%
2.3	Base Creation	Team	10/4/21	10/25/21	21	100%
2.4	Basket Goal	Team	10/4/21	10/25/21	21	100%
3	**Final 25% Prototype Completion and Review**					
3.1	Basket Goal	Team	10/25/21	10/29/21	4	100%
3.2	Basket Top	Team	10/25/21	10/29/21	4	100%
3.3	Review of Progress and Future Goals	Team	10/22/21	11/5/21	13	100%
3.4	Process Adjustment	Trent C	11/5/21	12/2/21	27	100%
3.5	Cost Adjustment	Coleman M	11/5/21	12/2/21	27	100%
3.6	Risk Assessment Adjustment	Seth N/Yvonne N	11/5/21	12/2/21	27	100%
3.7	Final Report Review and Completion	Team	11/29/21	12/3/21	4	100%

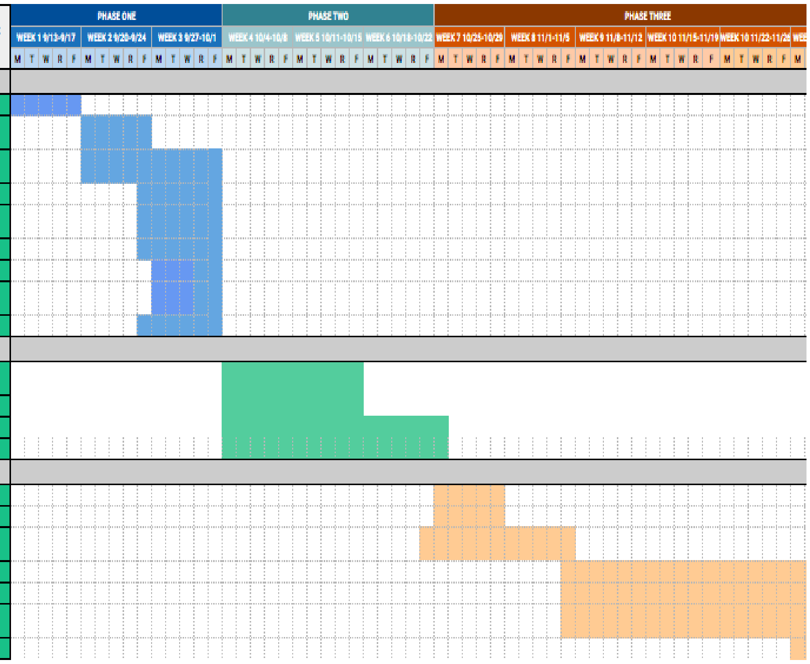

Figure 3. Gantt Chart

The chart was made by team member John Mark and was updated after each session on the factory floor. The chart is separated into three phases and was used for the team to understand the progress of the prototype. The chart allowed the team to view when drawbacks were present and held the team accountable for staying on schedule. It aided the team in reflecting what components of the process were the most time consuming or consisted of issues that needed to be viewed. It allotted room for risk adjustments and changes that needed to be made to the process as time went on. However, there were points when the team noticed the chart was not being updated accordingly, which the team should have been checking properly to ensure the team was maintaining group pace and deadlines.

4 Product Design

The initial product design was inspired by a YouTube video Will found. In the video, the operator was building a disc golf basket in his backyard with minimal equipment in comparison to what the CME offers. The team noticed that the factory floor had more equipment options and could enhance the design to increase sustainability. For example, the wood chosen was not stained which would cause an issue because disc golf is an outdoor sport. The designs went through stages of changes as the team experienced manufacturing flaws. The manufacturing flaws ranged from time consuming processes to lack of built-in quality structure which caused weaknesses within the basket walls, chain assembly, base levelness, weight, size, and overall lack of a clean finish. These flaws are discussed in further detail in sections 5.2 and 5.3. Few of these flaws were resolved, and reasons are discussed in sections 7.1 through 7.4.

However, regardless of the defects, the disc golf basket would need a base, a stand, and a basket. The base was made out of 2x4 pine wood boards and attached to the pole to form the stand. The 2x4 boards were used due to their stability, symmetry, ease of acquisition, and widely accepted use. The basket consisted of 8 precut plywood pieces secured together by gorilla glue to form the basket walls. The top of the basket consisted of 24 eye hooks equally distanced apart. The chains were designed to attach to the eye hooks, so they could hang in the basket to form the goal. The figure below served as a design guide in the prototype, but it does not show the attached hooks. The YouTube video was used as a substitute for a CAD drawing since the goal was to make the basket in the video while improving on the design. A CAD drawing was deemed unnecessary as the team thought a prototype would be more helpful in visualizing design changes. Figures 3 and 4 show surface level drawings of design.

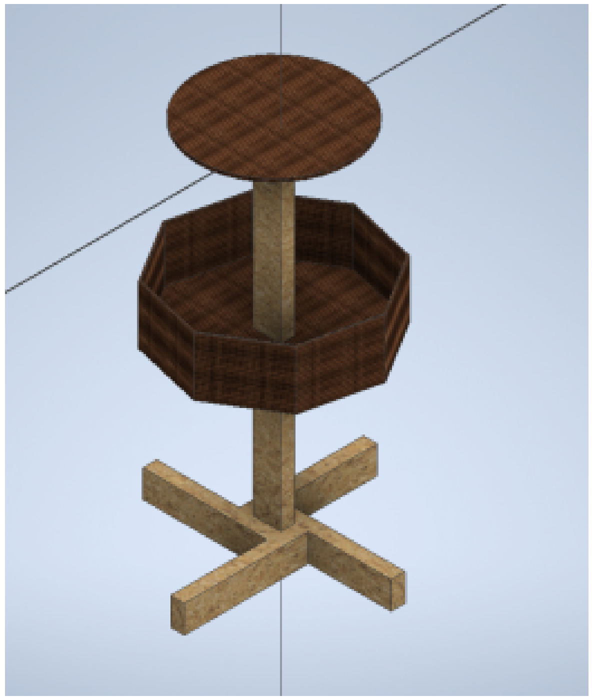

Figure 4. Whole Basket Drawing

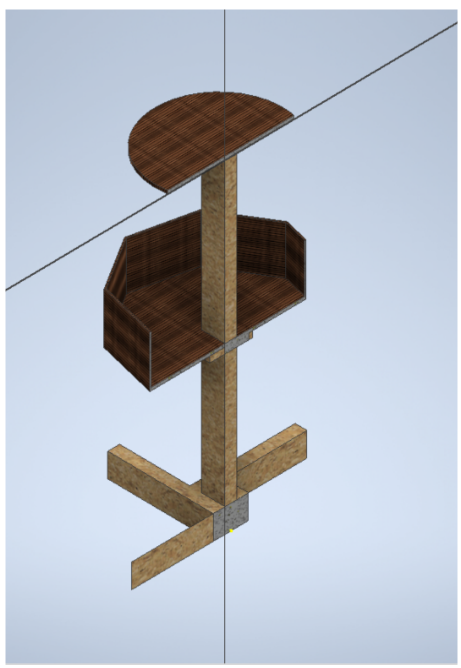

Figure 5. Half Basket Drawing

4.2 Materials

The materials purchased for the prototype are tabulated in Table 1 below.

Table 1. Total Cost of Materials for Prototype

Material	**Amount Used**	**Cost (Assume Scrap)**
Plywood	(48in x 26in + 22in x 22in + 26in x 26in) = 2408 in^2, ½" diameter	$20.15
Wood Screws	½ box	$5.25
2x4	2 units of 96" length- 192"	$6.96
Chains	36'	$90.00
Metal Ring	1	$2.77
I Hooks	18	$5.07
L Brackets	20	$4.00
	Total	**$134.20**

4.3 Equipment

The equipment selection was based on the assumption that the product would be produced at 1,000 units per month on the factory floor. Table 2 shows these costs below.

Table 2. Equipment Costs

Machine	Source of Acquisition	Total Cost
Bevel Saw	https://www.homedepot.com/p/DEWALT-15-Amp-Corded-12-in-Compound-Single-Bevel-Miter-Saw-with-Bonus-Heavy-Duty-Miter-Saw-	$412.75
Table Saw	https://www.grizzly.com/products/grizzly-10-3-hp-240v-cabinet-table-saw/g1023rl	$2,274.00
2 Pack Drills	RYOBI ONE+ HP 18V Brushless Cordless 1/2 in. Drill/Driver and Impact Driver Kit w/(2) 2.0 Ah Batteries, Charger, and Bag-PBLCK01K	$199.00
WaterJet Cutter	https://www.aliexpress.com/item/32717864626.html?src=google&aff_fcid=4081e3bc472144ac9ca016bd9c58cbcc-1638484215825-00768-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=4081e3bc472144ac9ca016bd9c58cbcc-1638484215825-00768-UneMJZVf&terminal_id=422456e50f2e40ae82686749cb11d9d5	$25,000
Misc items: PPE, Clamps, Squares, Tape Measures, Pencils, etc.	N/A	$1,000.00
Total Costs		**$28,885.75**

To pay for the equipment, the team will ask the bank for a $29,000 loan and plans to repay the loan in 7 years with a 5% interest. To calculate the monthly payment, the following was inputted into excel to arrive at the monthly payment of **$409.88,** which will be used in the cost analysis.

Excel formula = PMT (5%/12,84,29000)

Equipment costs per unit = $409.88 / 1,000 units = $0.41

Table 3 is an amortization schedule for the first year.

Table 3. Amortization Schedule

Start Date

04/18/2022

Estimated Payoff Date

April 18, 2029

Amortization Schedule

Payment Date	Payment	Principal	Interest	Total Interest	Balance
May 2022	$409.88	$289.05	$120.83	$120.83	$28,710.95
Jun 2022	$409.88	$290.25	$119.63	$240.46	$28,420.70
Jul 2022	$409.88	$291.46	$118.42	$358.88	$28,129.23
Aug 2022	$409.88	$292.68	$117.21	$476.09	$27,836.55
Sep 2022	$409.88	$293.90	$115.99	$592.07	$27,542.66
Oct 2022	$409.88	$295.12	$114.76	$706.83	$27,247.53
Nov 2022	$409.88	$296.35	$113.53	$820.37	$26,951.18
Dec 2022	$409.88	$297.59	$112.30	$932.66	$26,653.59
Jan 2023	$409.88	$298.83	$111.06	$1,043.72	$26,354.77
Feb 2023	$409.88	$300.07	$109.81	$1,153.53	$26,054.70
Mar 2023	$409.88	$301.32	$108.56	$1,262.09	$25,753.37
Apr 2023	$409.88	$302.58	$107.31	$1,369.40	$25,450.80
May 2023	$409.88	$303.84	$106.04	$1,475.44	$25,146.96

4.4 Labor

In order to meet the demand of 1,000 units a month, the paid work time was calculated as follows:

Demand: 1,000 units /month

Total Labor Time Per Unit: 90 minutes

Total Labor per Month: 1,000 units * 90 minutes = 90,000 minutes/month

Assume 85% Efficiency: 90,000 minutes * 1.15 = 103,500 minutes

Available Working Hours per Month: 20 days * 8 working hours per day = 160 hours/month, 160 hours * 60 minutes = 9,600 available working minutes/month

Full Time Equivalent (FTE Employees): 103,500 minutes / 9,600 available working minutes = 10.8 = 11 FTE Employees

Based on the calculation above, the company would need 11 FTE employees to achieve 1,000 units per month.

11 FTE employees * 160 hours * $15.00 = $26,400.00 per 1,000 units per month

Required Labor Cost per unit: $26,400/1,000 units = **$26.40/unit**

The current process has three FTE employees. Therefore, the current process would only be able to produce 273 units per month. The team realized the number of operators and cycle time did not allow for demand to be meant accordingly. Therefore, the process needed to be modified which is later described in section 5.2.

1,000 units / 11 FTE employees = 90.91 = 91 units per employee

91 units x 3 FTE employees = 273 units per month

4.5 Cost Analysis

Materials cost, equipment cost, labor cost, overhead cost

The calculation below is to determine how much it would cost to produce one unit based on material, equipment, overhead, and labor costs. “Overhead costs consist of the rental and utilities of your shop, tools, glue, nails, sandpaper and finishing materials. An industry average is 15%. Multiply your total of materials and labor by 15%. For the table, multiply $136.50 by 0.15. ($20.50) and add this amount to $136.50. The total cost for materials, labor, and overhead for the table is now $157.00.” (Rockler)

11 Employees for 1,000 units/month:

$134.20 material + $0.41 equipment + $26.40 labor cost = $161.01 costs/unit

Add overhead: $161.01 * (15% overhead) = $24.15 overhead cost/unit

Total cost/unit: $161.01+ $24.15 = **$185.16**

Based on the cost analysis for 1,000 units per month, the cost to produce one unit would be $185.16. In order to gain profit through selling the disc golf basket through a wholesaler, the selling price would have to be double the cost. Therefore, the team decided the selling price would be $370.32/unit. In comparison to metal disc golf baskets on the market, this price is above average. The typical disc golf basket at Amazon and Wal-Mart ranges from $80.00 to $150.000. With this price, the team realized it would be difficult to compete with the market and proposed process and design changes described in sections 5.2 and 5.3.

After analyzing the cost factors associated with the prototype and the ideal product run, the team saw that the product price point was higher than the ones on the market. This analysis revealed to the team that the product was not financially practical.

5 Testing and Production

During the product development process, production runs are completed as tests to analyze the effectiveness of the design. The initial runs should only be initiated after the ideation phase (phase three) has reached a point of readiness after factoring costs, material, processes, ethics, environment, and multiple effective prototypes. Oftentimes, a design that works well on paper does not necessarily transfer to the manufacturing floor. Most quality issues can be identified during the test production runs to be changed for future runs. Production runs are also used to refine the actual process itself in terms of people, machinery, and material flow. Before the initial production run occurs however, an effective prototype is of chief concern. Prototype runs are to ensure that the product is functional and that it operates safely and as designed. It's not necessarily in its final form. It doesn't have to be. Instead, product prototyping may be utilized in several phases, throughout the iterations of development to thoroughly test and perfect the product. Without testing multiple prototypes, in the long run, it may cost a company in revenue, but also in production runs, by settling on sub-optimal product design." (Hleob@tizinc.com) Despite professionals noting that most companies require a "working prototype" before production begins, the disc golf basket underwent one prototype run before production under the expectation that design and process changes made as a result of the prototype would be implemented smoothly during the production run. Due to this lack of testing, smooth implementation did not occur. Quality and efficiency issues from a material and process perspective were noticeable and the design proved not ready for full scale production.

5.1 Process Implementation

The first step in beginning process improvement is to establish the process flow. This flow comes from laying out each task needed to transform raw material into a finished product in a consecutive and organized manner from start to finish as a "downstream flow". During this flow, labor, time, equipment, and other inputs and outputs are included. The prototype production process for the basket had five main process stages.

Proper assembly instructions are crucial for success. Work instructions are effectively the "How to Do" in industry as they answer the question of how the product or service will be provided in a manner expected by the customer, which is integral to customer satisfaction. Additionally, this challenges the manufacturer to structure tasks to be as productive and profitable as possible while also maintaining quality. Work instructions play a part in maintaining quality as they allow the operator to: accomplish his or her task effectively, identify the relevance of each step defined in the work instructions, propose improvements, and document improvements. (Picomto) Work instructions for all three builders were printed and given to the team members before final production.

The first process was cutting. The wood for the stand consisted of two units of 96" length 2"x4" pine wood pieces. One pine board was cut to 54" length and the other was cut to 4 units of 18" length each. All of the 2"x4" wood was cut using a table saw as seen in Figure 6.

Figure 6. Pole and Leg Cutting

The next stage of cutting was the water jet cutting which took a programmed cad file and a 2408in^2, 0.5" thick plywood board and cut the basket goal bottom and basket top along with a square hole in the center of the basket bottom that fit the 2"x4" frame. The waterjet requires two operators in order to load and unload the large plywood board. It is important to have well trained operators for jet cutting to ensure the program is running correctly and that the material is properly loaded and unloaded without affecting the jet diode causing inaccurate cutting. The SOLIDWORKS drawing that was sent to the waterjet is shown in Figure 7. Figures 8 and 9 show the waterjet cutting in action.

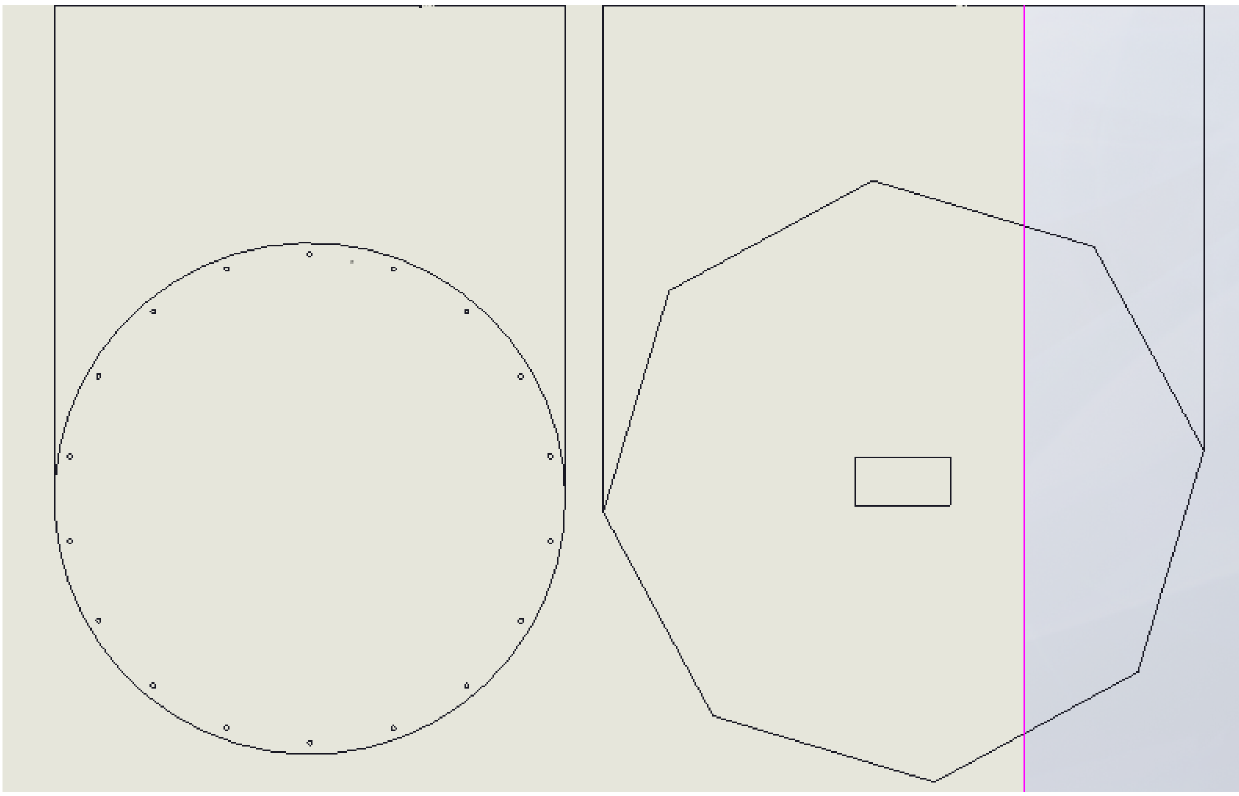

Figure 7. Waterjet Cutting Drawing

Figure 8. Waterjet Cutting

Figure 9. Cut Basket Bottom and Top

Following this, a vertical saw was used to cut the plywood board 4’ long and 8” wide, as seen in Figure 10.

Figure 10. Vertical Band Saw for Wall Slab Cutting

After this, a table saw was used to cut the board into four 8” wide segments 9 in long and four segments 9 in long. This was to allow the walls to fit to each other more ideally. The process is shown in Figure 11.

Figure 11. Table Saw for Continued Wall Cutting

Following the cutting of all the wood, one 50ft chain was held using a clamp and cut using a band saw on every 23rd chain link into 18 different segments. Figure 12 shows the band saw and Figure 13 shows the cut chains.

Figure 12. Band Saw for Chain Cutting

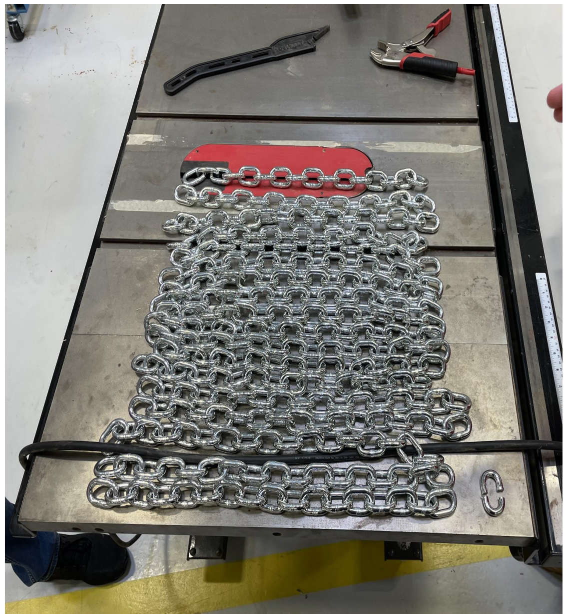

Figure 13. Cut Chains

A majority of the cutting process is simple and straightforward. The table saw process requires one operator and has minimal safety hazards. As discussed later in 5.2, it was decided that the cutting operation would be considered out of production scope. Because of this, standard work instructions were not written for cutting operations.

The next four processes discussed are assembly processes. Instructions for the execution of each process is written below and is accompanied by an assigned builder. With three available workers for assembly of the basket, the worker names for each process are Builder 1, Builder 2, and Builder 3.

The second process was the L bracket installation completed by Builder 1. This was comprised of taking 16 L brackets and using screws to attach one side to the precut walls and the other side to the bottom of the basket base to form an eight-sided wall. The materials, equipment needed, and standard work procedures are seen below.

L Bracket Assembly Station Equipment and Materials

- 1 Octagon Piece
- 8 wall pieces (four 9 inch) (four 9 inch)
- 16 Corner Braces
- 64 screws (½ inch)
- 1 Power Drill
- 1 Phillips Head Drill bit

Step 1: Using the drill, assemble two corner braces for each of the eight octagon wall pieces at the pre-marked drilling location with two ½ inch screws per corner brace while ensuring that the corner brace is flat and flush with the bottom of the wall and will make a 90-degree angle when assembled to the octagon.

Step 2: After each corner brace is installed, drill each corner brace of the wall piece into the octagon piece at the pre-marked drilling points using two ½ inch screws per corner brace. Make sure that each wall piece is installed flush and straight to the octagon piece at a 90-degree angle. Install each wall piece into the octagon piece in order, alternating between the 9 inch wall piece and the 9 inch wall piece, so the walls will all fit flush. Figure 14 shows the L Bracket assembly of the walls.

Figure 14. L Bracket Assembly

The third process included the installation of the chains for the goal itself, completed by Builder 2. Each chain was attached to an S hook which was then attached to an I hook. The I hooks were screwed into pre-drilled holes through the bottom side of the basket top. The pre-dilled holes were measured 0.5” from the edge and 20 degrees apart. The materials, equipment needed, and standard work procedures are seen below.

Chain Assembly Station

- 18 chains (precut)
- 18 S-Hooks
- 18 Screw Eyes
- 1 Circle Piece (precut)
- 1 Pliers

Step 1: Assemble the S-Hooks to each of 18 Screw Eyes using pliers

Step 2: Attach the S-Hook & Screw Eye assembly to each of the 18 chains using the other side of the S-Hook

Step 3: Attach the chain, S-Hook, Screw Eye assembly to the circle top piece of wood by hand screwing in the Screw Eyes into the precut holes.

The fourth process included the stand assembly completed by Builder 3. Using a table and clamps, each 18”, previously-cut board was drilled into the main frame board of 54”, following a diagram. Once this was completed, the stand was laid upright and the remaining two pieces of the basket joined together for the fifth process. The materials, equipment needed, and standard work procedures are seen below.

Stand Assembly Station

- 4 (18in) legs
- 1 (54 in) center pole
- 3 clamps (2 for mounting center pole, 1 for mounting leg while drilling)
- 20 screws (four for each leg totaling to 16 screws and two for each basket support 2x4 totaling to four screws)
- 1 power drill (with battery)
- 1 Philips head drill bit
- 2 2x4 support pieces

Step 1: Place the 2x4 center pole (54in) flat on the table and clamp it down with two clamps at the top and bottom of the pole so it cannot move, with enough of the pole hanging off the table to drill the leg piece to the pole.

Step 2: Using figure 15 below, place the first 2x4 leg (18in) on the mounted center pole and clamp it down making sure it is flush on both top and bottom of the center pole so the stand will be flat on the ground. Drill four screws into the 2x4 leg inches from the corners (on marked location).

Step 3: Repeat step two by flipping the center pole over to the other flat side and remounting the center pole using clamps and drill the second leg into the center pole.

Step 4: Repeat step two, clamping the center pole now on the 2-inch-wide (thin side of the board) side and drill the third leg into the center pole, using leg one and two to line the leg up, still using clamps to secure the leg before drilling and making sure it is flush to the bottom and will be flat.

Step 5: Repeat step four, for the fourth leg.

Step 6: Attach two 2x4 support pieces to the center pole at marked locations on both sides of the flat side of the center pole for the octagon to rest on.

Figures 15, 16, and 17 show the assembly of the stand.

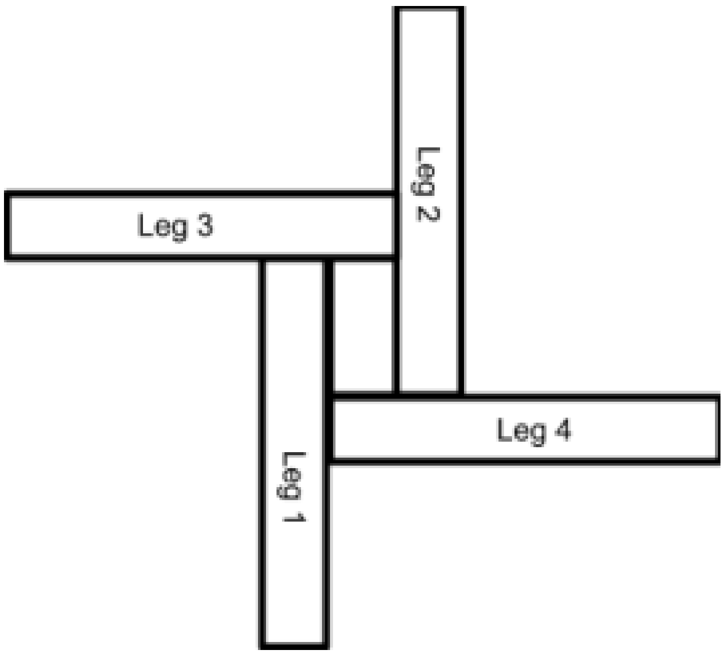

Figure 15. Stand Assembly Schematic

Figure 16. Stand Mid-Assembly

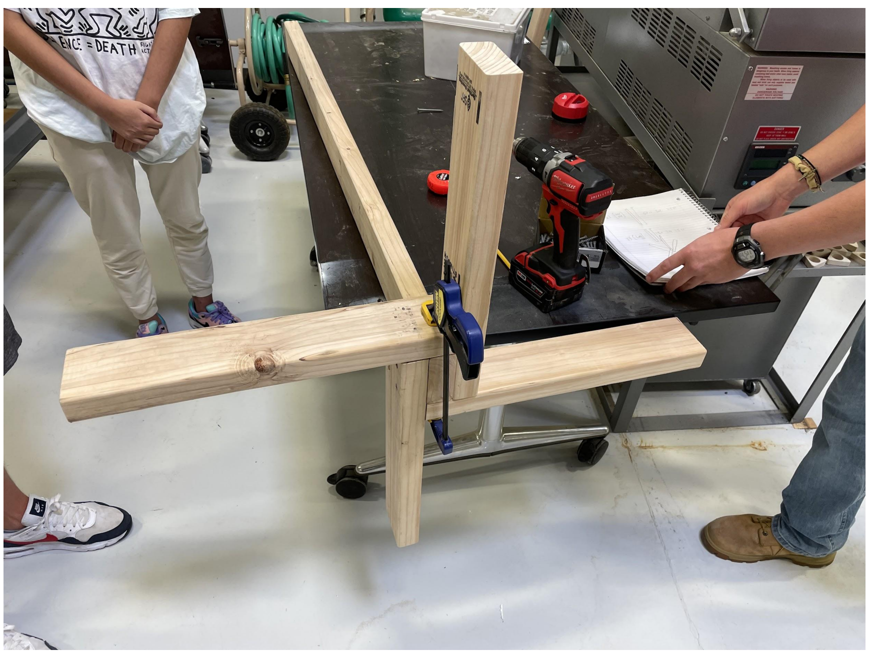

Figure 17. Assembled Stand

The fifth process took the basket, the basket top, and the stand sub-assemblies and combined them together into one finished product. The basket was laid on the stand while the stand center ran through the basket center. Wooden blocks were then screwed to the basket bottom and the stand center to hold it in place. Following this, the top was laid on the top of the stand and screwed in. The chains dropped down and were gathered using a metal ring at the bottom of the basket. The materials, equipment needed, and standard work procedures are seen below.

Final Assembly Station (Stand Assembly Table)

- 1 Circle piece with chain assembly
- 1 Octagon piece with will assembly
- 2 2x4 support pieces
- 8 screws (2 each for support pieces (4)) (4 for attaching the circle piece to the center pole)
- 1 metal ring for attaching the chains at the bottom of the basket together.

Step 1: After the three builders have completed their steps, Builders 1 and 2 will bring their assemblies together to the stand assembly table where Builder 3 is located. Builder 1 will bring the basket assembly and Builder 2 will bring the top & chain assembly.

Step 2: Builder 1 will place the octagon piece onto the 2x4 center pole through the pre-cut hole on the octagon piece, and screw it into the 2x4 support blocks from the inside of the basket, two screws on each side.

Step 3: Builder 3 will install circle piece support (2x4s) on the top of the center pole, one on each flat side, using two long screws on each support piece, making sure that the support piece is flat and flush with the top of the center pole so the circle will sit flat on top of the center pole.

Step 4: Builder 1 will attach the circle piece with chains to the top of the basket, using four screws on top while ensuring that the circle piece is centered to the center of the pole.

Step 5: Using the metal ring, loop through all of the chains at the bottom of the basket. Figure 18 shows the three subassemblies of the basket. Figure 19 shows the disc golf basket post production.

Figure 18. Basket Post Production Run

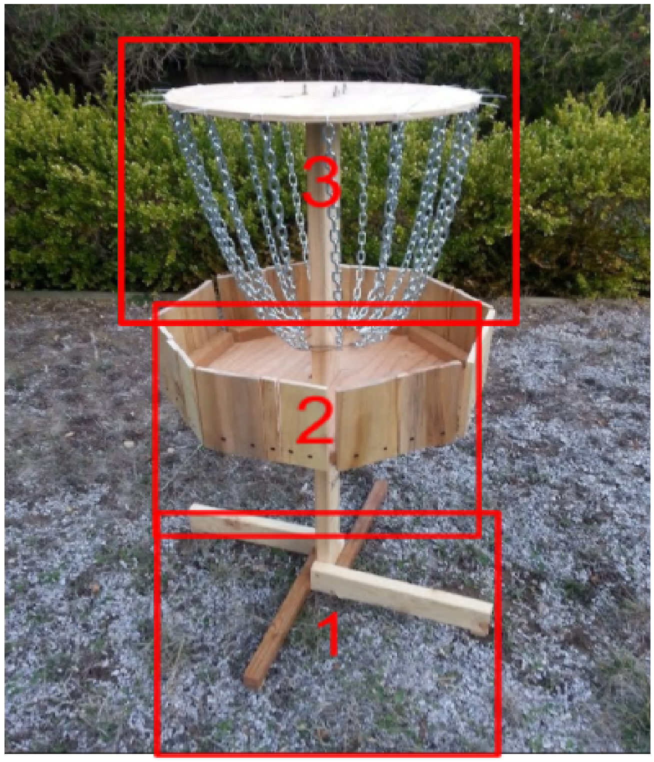

Figure 19. Basket Subassemblies

5.2 Process Improvement

Due to three of the six team members being unavailable for the production run, the challenge for the team was to reduce the assembly process from five processes to three. Real world assembly process decisions should be based on line balancing to meet takt time. Splitting up or combining processes based on their takt time in order to achieve overall production takt time is deciding factor on headcount. The processes were initially: cutting, L bracket installation, chain installation, stand assembly, final assembly. The cutting portion was set apart as part of pre-cut pieces that would be outsourced or pre-cut from a fabrication area. Outsourcing pre-fabricated parts would certainly drive up procurement costs; however, it would effectively negate the need for capital expenditures in terms of equipment purchasing, installation, and operation. This left three workers with an effectively four-assembly process. When looking at process improvement, the goal is to meet a set takt time to resultantly meet production demand while maintaining quality. Several factors such as how the equipment is used, what equipment is used, the instructions for executing the process, the amount of something needed (manpower, material, time, energy), and the location of the process should be taken into consideration. All of these factors affect the production takt time.

Most of the time, every process needs improvement of some form, but locating what needs the most improvement is harder. The lean manufacturing philosophy helps identify where to start improvement. The Toyota Production system coined the term “Gemba” meaning “go and see yourself” as part of the lean methodology to identify bottlenecks and opportunity for kaizen (improvement). Bottlenecks occur from one process maintaining a slower speed than the other processes, causing a buildup of inventory and wait time for the faster processes. Figure 20 visualizes this.

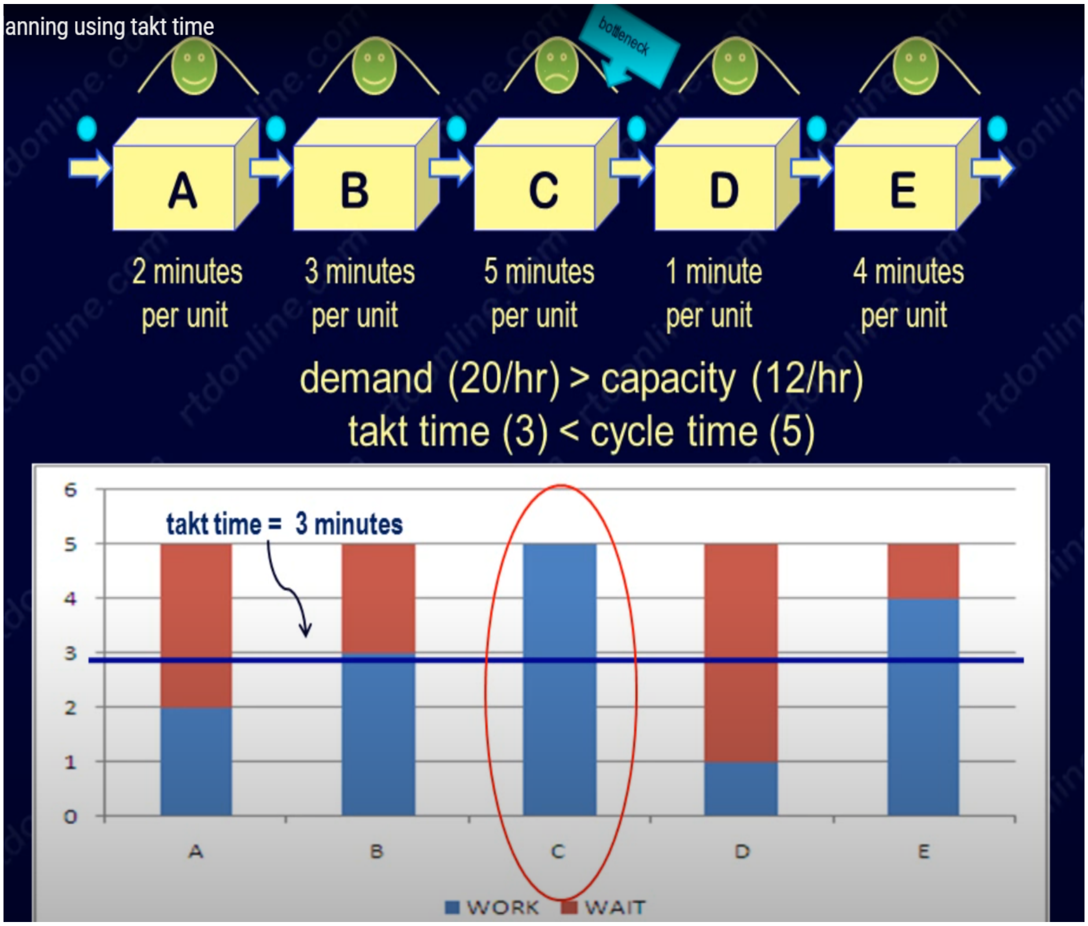

Figure 20. Line Balancing to Meet Takt Time

When analyzing the processes for the basket, takt time should have been recorded but was not. This decision was made with the assumption that the operation would be completed at low production levels and that workload and line balancing could be completed without takt time consideration. Post project analysis showed the team that the ability to meet a production demand was crucial to determining profitability and process takt time plays a pivotal role making process changes. Despite the lack of takt time, each process, except for cutting, was gauged to take roughly 10 to 20 minutes. The cutting operation proved to have the longest bottleneck. The various cutting processes took up to an hour for one worker to complete for one basket, required movement to and from machinery, and considerably larger uptime to make up for machine cost.

Because of this issue, the cutting was selected as a separate portion to be outsourced or isolated from the assembly labeled “not in scope” for the project. The remaining processes as a whole were kept the same; however, the order in which they were positioned and completed was changed. When designing an assembly, there are multiple ways to setup a line as defined by workflow characteristics and classifications. Research Gate provides an article that summarizes this as seen in Figure 21.

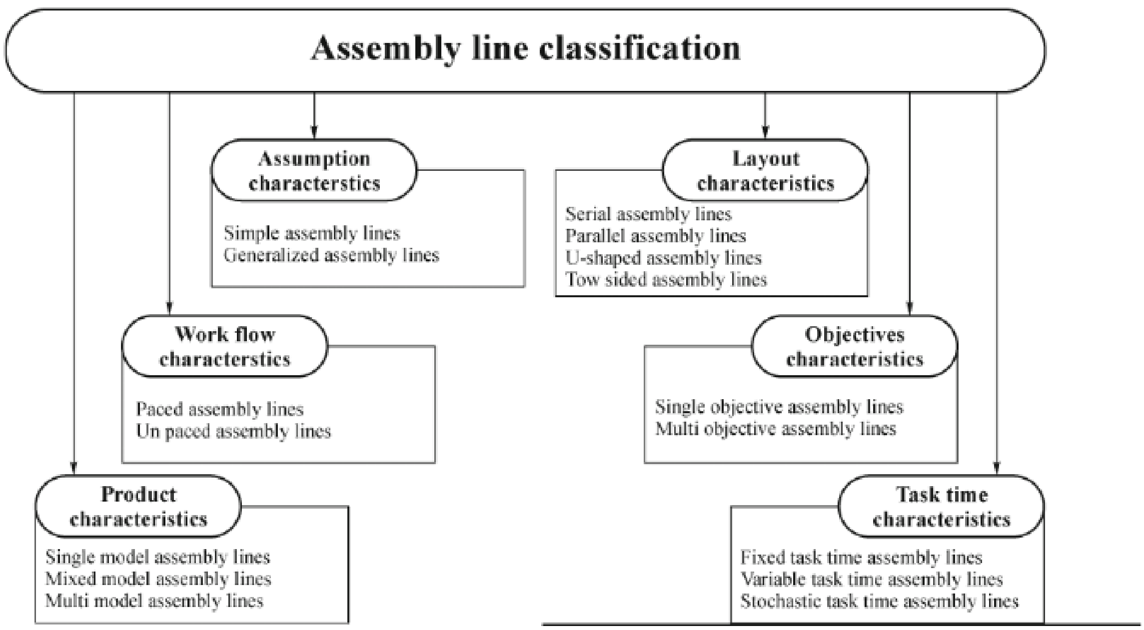

Figure 21. Assembly Line Classifications

The workflow goal for the disc golf basket assembly line was to have a single model, paced, simple, single objective, fixed task time assembly line. The ultimate decision to be made regarding the basket was the layout characteristics. For the initial production run, a parallel or “traditional straight line” assembly line was used. Pre-cut material was fed perpendicularly to each independent work station. After one cycle, the assembly from the previous three work stations were brought to station four for final assembly. Figure 22 shows the layout.

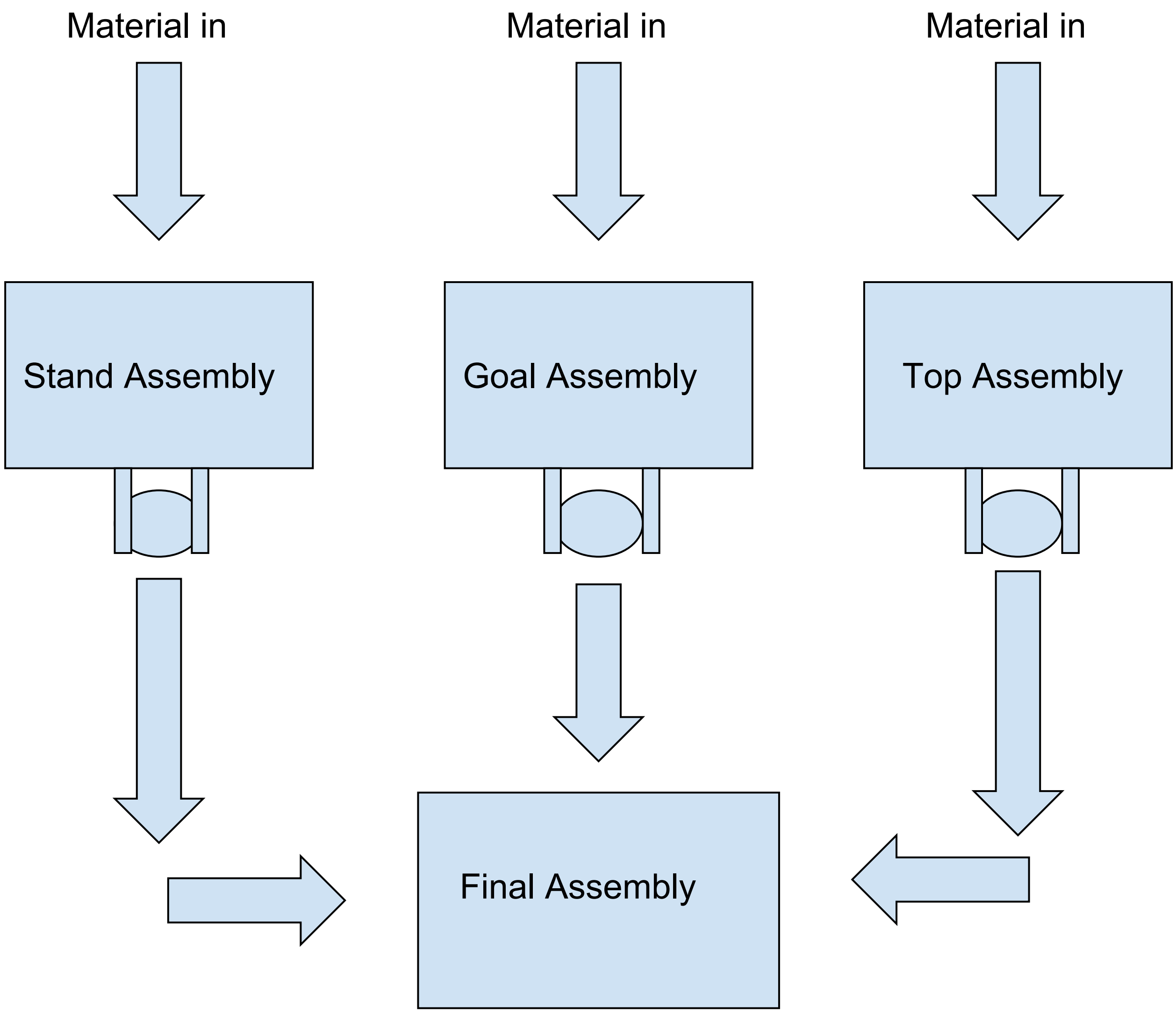

Figure 22. Assembly Layout

This assembly layout was made with the constraints requiring a three-man process in mind. While processes were categorized by their general time from the prototype run and the amount of manpower need to complete the process without factoring time, it is important to look at production from a real-world manufacturing perspective. Table 4 below takes an assumed demand of 1,000 units per month which is justified by the 500,000+ golfers in the US and

80,000+ registered Professional Disc Golf Association members discussed in section 6.2 and determines the required takt time for production and number of personnel to meet that takt time.

Table 4. Layout Based off of Demand

Item	Count	Unit				
Assumed demand per month	1000	units				
Available working days (5-day weeks) per month	20	days				
Available working minutes per month (8-hour days * available days)	9600	min				
Takt time in minutes:	9.6	min/unit				
Required Labor						
	cycle time	unit				
Stand assembly	20	mins				
Goal assembly	20	mins				
Top assembly	20	mins				
Final assembly	30	mins				
Paid Time Per Unit (1 worker)	90	mins				
Labor Per Month (Assume 85% efficiency)	103500	mins				
FTE Employees	11	workers				
Future Setup (Achieve takt time)						
Line 1			Current cycle time		Required time	
Stand assembly	1	workers	20	mins	19.2	mins
Goal assembly	1	workers	20	mins	19.2	mins
Top assembly	1	workers	20	mins	19.2	mins
Final assembly	2	workers	15	mins	19.2	mins
Total paid time per unit			90	mins	96	
Cycle time			20	mins	19.2	
Line 2					Required time	
Stand assembly	1	workers	20	mins	19.2	mins
Goal assembly	1	workers	20	mins	19.2	mins

Top assembly	1	workers	20	mins	19.2	mins
Final assembly	2	workers	15	mins	38.4	mins
Total paid time per unit			90	mins	96	mins
Cycle time			20	mins	19.2	mins
Total headcount	10					
New cycle time per unit: 20 minutes/2 lines	10	mins				
Required Headcount	11					
Required cycle time per line: 9.6min*2lines	19.2					

The table shows that in order to meet expected demand, the current layout would not work as 10.7 ~ 11 workers are required. In order to achieve a 10-minute takt time (not factoring the use of jig use, design changes, and various other process improvement techniques), two lines would be required with six workers each. Figure 23 shows a new proposed layout for production following U-shaped assembly layout.

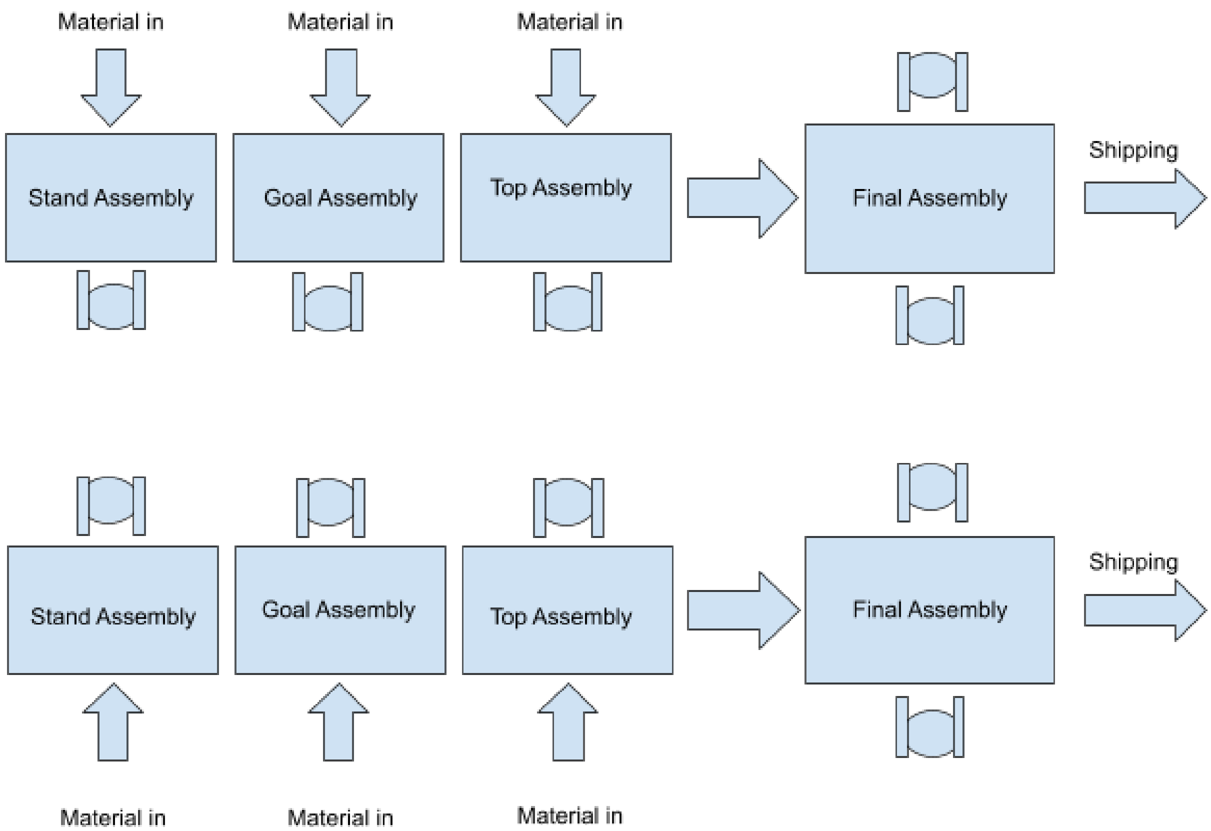

Figure 23. Production Layout

Figure 23 shows a balanced line to achieve a takt time of 10 minutes per unit with 10 workers with a 5 minute down time for the two final assembly workers at the end of each line as shown in Figure 24 by the lower bar. Because of this, the line is still not perfectly balanced and waste of waiting is still generated by four employees. Furthermore, the figure does not achieve the exact takt time of 9.6 minutes per unit requiring 11 workers. Figure 24 shows that an ideal cycle time of each process should be 19.2 minutes. In order to achieve the cycle time of 9.6 minutes per unit, there are two options:

1. Use 11 not 10 workers and utilize the 11th worker as floater to make up for process inefficiencies
2. Require overtime from the 10 workers to achieve the 1,000 units per month demand

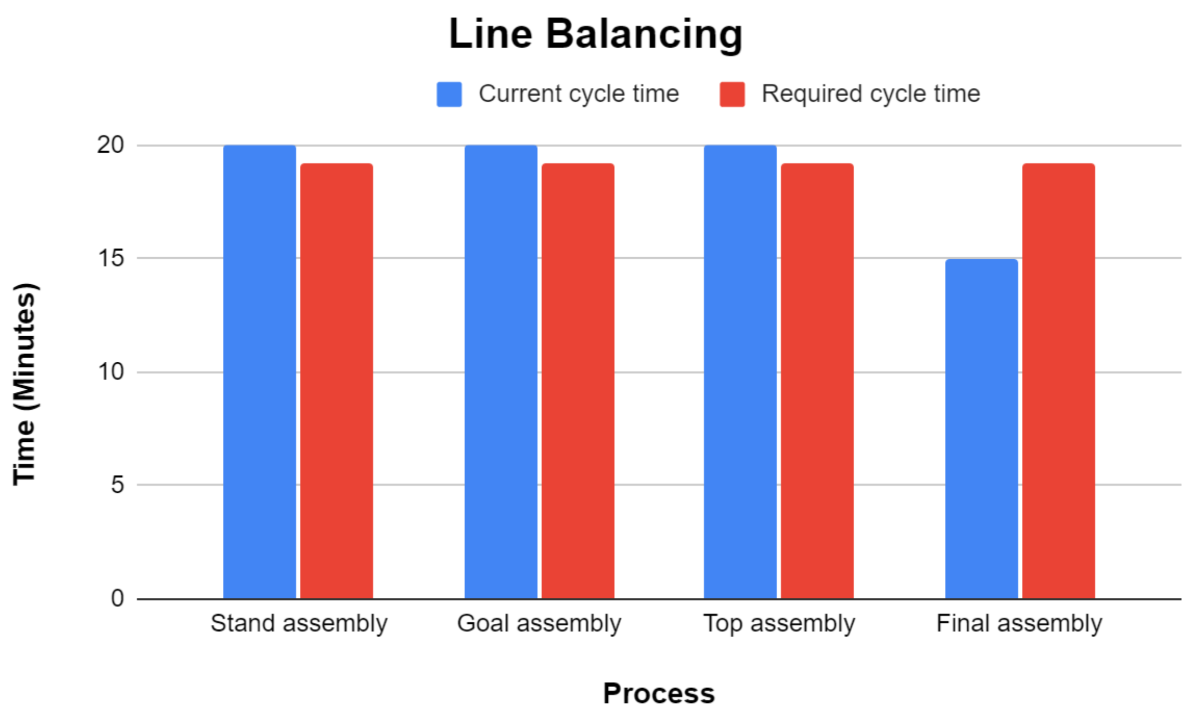

Figure 24. Line Balancing

The workers for final assembly will have 5 minutes wasted time per unit as shown in the above figure. While this is a close to ideal state, further use of Plan, Do, Check, Act is required to achieve a perfectly balanced line with no wasted waiting time.

5.3 Design Changes

After the initial prototype run, there were multiple design flaws that were addressed and changed. The prototype incorporated the temporary use of zip ties during assembly to secure the chains together; however, this could not be a final measure. The use of I-hooks combined with S-hooks to attach then screw in the chain proved to be an effective solution to this issue; however, the end of the screw could potentially protrude out the top-hole requiring grinding or cutting to produce a smooth top. An additional design change put into effect after the first prototype was the use of smaller and lighter chains. The original chain link diameter was 5/16" which proved too heavy and cumbersome. A better choice was 3/16" diameter chains.

During the prototype and production run, precut wood blocks were attached around the stand for the basket and for the top to rest on and attach to as supports. Issues occurred during the process and were found during quality inspection. The blocks had to be pre-cut and screwed into the wood. Due to the screws and the use of pine wood, the small supports had splitting issues when being drilled. Shorter screws of 2" or dissolving the need for the wood supports would resolve this. The use of L Brackets fixes the time wasted on wood cutting and splitting due to screws. L Brackets also provide a cleaner aesthetic appeal with a more practical and long-lasting functionality.

The walls were initially glued to the basket base to form the basket frame. This proved to be a considerably messy and time-consuming process. The walls had to be clamped to the basket base and the process stopped for the glue to dry. Furthermore, only half of the walls could be glued at a time, due to the clamps interfering with each other. After gluing, residue that spilled over cracks had to be cleaned off or risk contributing to the poor aesthetic quality. A simple fix for this was the further use of L Brackets implemented in the first production run. The L brackets provided the same functionality as the glue; however, they were significantly simpler to attach and less time consuming**.**

The use of S hooks was implemented in the first production run to attach the chains to the I-hooks in the basket top. After attaching the S hook to the I hook, the hook had to be clamped closed using pliers to ensure it wouldn't come off the I hook. This had to be repeated when the chain was attached to the other side of the S hook for a total of 36 clamping actions per basket. While it serves all practical purposes required for the basket functionality and quality, the time required to complete this and the room for operator error was significant. This error and time can be reduced by the use of quick links to connect both the chain and hook by easily unscrewing the link and putting both the chain and hook inside, then securing the link. The last major design change consists of the use of an openable metal ring to gather all the chains at the bottom of the basket to form the goal. A 5" metal ring with a screw lock effectively resolves this issue. Figures 25 and 26 show the prototype and production result for comparison.

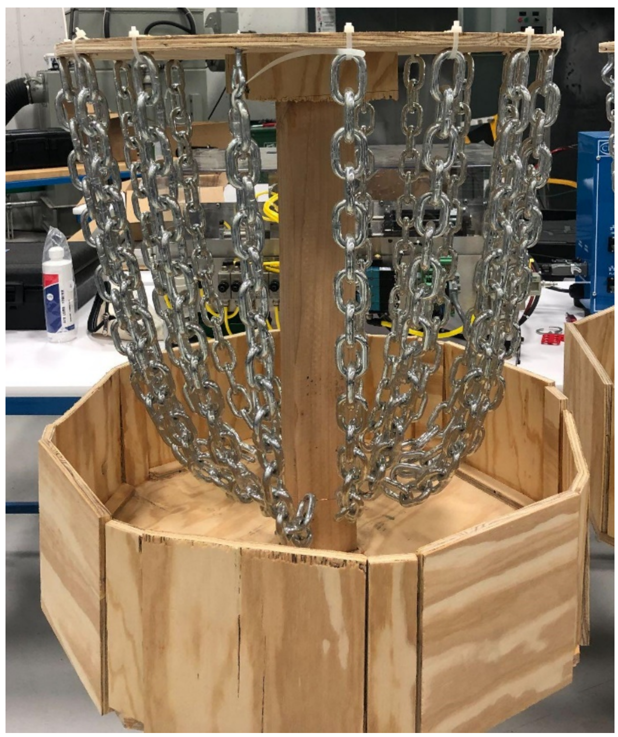

Figure 25. Prototype

Figure 26. Production

6 Effectiveness Analysis

6.1 Quality Analysis

During this project, quality proved to be one of the two major roadblocks for the team, with the other being the marketability of the product. Quality determines a product's value—what the customers are willing to pay for. In manufacturing, quality can be simply defined as a product that satisfies the stated or implied needs and is free from deficiencies. (Klaess) In more detailed terms, quality is fitness for use. This prompts the question is the product fit for its intended use? This is decided by five factors as seen in Figure 27 below.

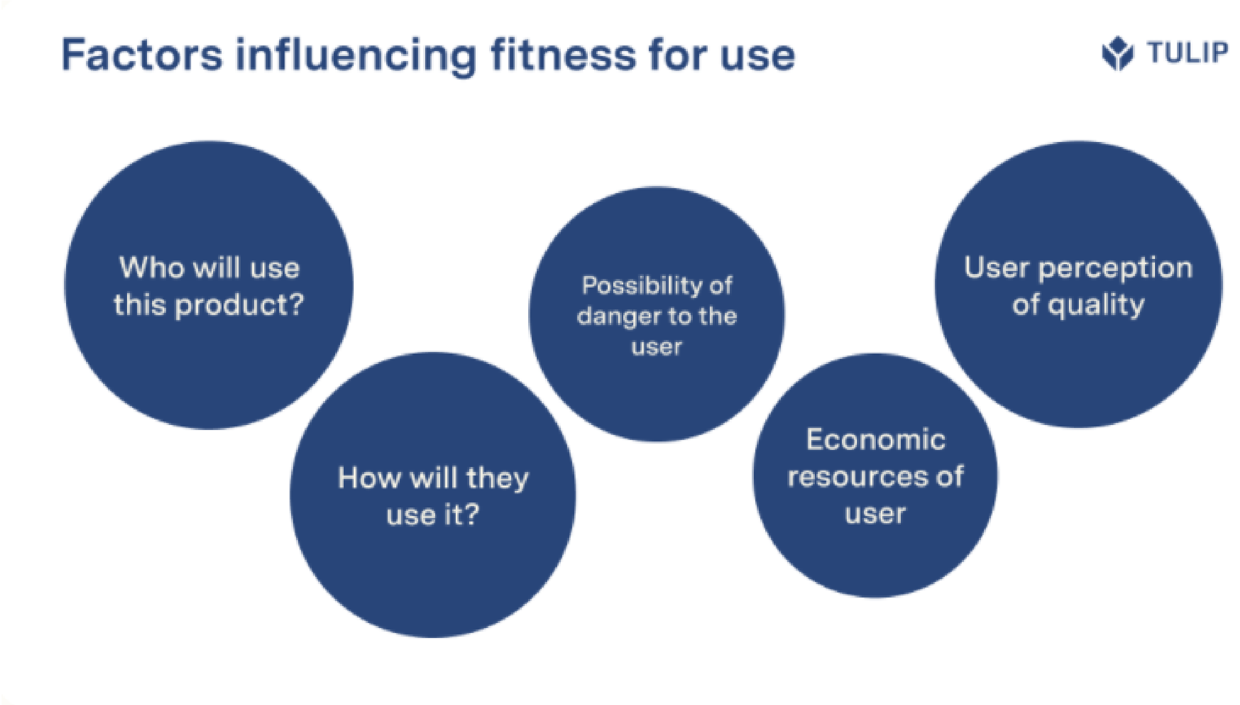

Figure 27. Factors Influencing Fitness for Use

A different approach to the definition of quality is conforming to requirements. These requirements are established for the product and by the customer. These requirements form the inherent characteristics of a product. Such characteristics are defined as weight, shape, speed, capacity, reliability, portability, taste, etc. (Transition Support) "When they design a product, manufacturers will establish its technical specs. These serve as a guideline for 'requirements' on the product side." (Klaess) Because of this, a product's quality directly points back to the effectiveness of the design and processes.

When analyzing the quality after the first production run, there were many issues that were evident, as mentioned during the discussion of design changes and process improvement. Because a market analysis was not initially done for the product, customer requirements were not set and a product was made for needs that were not defined. When needs are not defined, requirements cannot be properly set to achieve ideal quality. Customer needs will be discussed later in more detail; however, initial market research after the creation of the product showed that wood was not even a remotely required feature. Because of this, the basket failed the first quality test. When comparing the basket to the requirements set in the initial scope, the chief requirements were that the basket be the same in functionality as a common metal basket, that it be relatively cheap, aesthetically pleasing, and symmetrical. If market research had been conducted beforehand, additional requirements would be set. When analyzing the quality of the basket after the initial production run, the requirement of functionality was met except for the endurance of the basket. Made from untreated wood, the basket wood soon change color when subjected to outside weather and would eventually rot. The basket was not aesthetically pleasing in multiple ways. The basket wood was not stained, painted or changed in form from its original processed form. Markings from the supplier were still on the stand 2"x4" pieces. The wood was course to the feel and gave the disc golf basket a rough and unfinished look. The symmetry of the basket was also not fully met. The walls of the basket were not cut on the sides at angles so they could join one another flush, which caused the need for every other wall to be smaller than the previous in order to fit as the wall perimeter. The stand base was not assembled properly to allow for a level stand so a slight rock occurred when touching the basket. Finally, the cost of the materials, initial cost for equipment, labor, and overhead totaling to $185.16 per unit requires the basket to be sold at a minimum of $370.32 wholesale to gain profit. This price does not compete with most metal alternatives that meet all other quality criteria and also provide their product at prices ranging from $60.00 to $400.00.

6.2 Market Analysis

A product will be only as successful as the demand for it. To understand the demand and need of a product and resultantly its potential for success amongst consumers, a post production market analysis was completed to determine the marketability of the basket. Josh Woods from Parked! Disc Golf showed in an in-depth Facebook survey that the U.S. disc golfer population was at approximately 530,000 with a mean average age of 33 years old. This can be projected to upwards of 600,000 disc golfers for 2022. Further research showed that "the Midwest has the largest per capita disc golfer population. It exceeds the populations in the Northeast, South and West by 50 to 100 percent." (Woods) The U.S. Professional Disc Golf Association provides a yearly demographic report of its members. As of 2020, the PDGA had 71,016 active members. Further analysis shows 80% of disc golfers being between the ages of 20-50 years old. Disc golfer average income was shown be between $50k-$75k. With this in mind, the target group for the basket should be centered towards to middle aged consumers of the middle class in central U.S.

The disc golf industry is a multimillion-dollar industry of more than $170 million in USD as provided by Ajay More through Market Watch. Park! Disc Golf's survey in 2017 showed that the average disc golf player spends an annual average of $400-$500. This encompasses beginner, amateur, and professional golfers along with their expenses concerning discs, bags, baskets, apparel, tournament fees, and other expenses. From these findings, in order to compete in such a niche market and to convince golfers to increase their annual spending by as little as $200.00 for a basket, an extremely well-designed product from low cost production would be required. When making equipment purchases for the sport, disc golfers focus first on the bag that carries their discs. Secondly, golfers focus on the discs themselves, and following that, apparel, and for some advanced golfers, a basket to practice while off of the course. It must be considered that most beginner and many amateur golfers would have no need for a personal disc golf basket as their investment into the sport would not require the additional expense. Furthermore, if they were interested in the investment, a basket would be the last amenity to add to their equipment inventory. With this in mind, it is crucial that a high quality, low cost, but high profit product with a clear differentiator that meets the true needs of the disc golfer is designed and manufactured or else there is little to no possibility of product success.

To achieve this product goal, an understanding of disc golfer's needs must be obtained. To understand what features disc golfers desire to have for their basket, a survey was created and shared via email, text, and word of mouth to 259 students at Ole Miss. An ideal survey would consist of participants of varying ages, financial status and demographic location; however, that was not completed due to time constraints. The survey to these students showed unsurprisingly that few would actually be interested in purchasing a disc golf basket for the price it could be manufactured at and only 6% liked the wooden appeal of the basket. With the background research and analysis not being completed at the beginning of the product development stage, a proper project scope wasn't created and the team effectively began product development under a false and non-data backed hypothesis.

6.3 Market Strategy and Profitability

"The ultimate goal of a marketing strategy is to achieve and communicate a sustainable competitive advantage over rival companies by understanding the needs and wants of its consumers" (Barone). After completing initial market research to understand the age, location, size, and income range of the disc golf consumer base, an effective marketing strategy follows up with a method on how to answer the consumer wants and needs. In order to operate in a niche market like the disc golf industry, product sales to generate enough revenue for profit require continuous consumption and/or brand dedication, unless a generic product that can fit all the industry consumers' needs is produced. Many metal disc golf baskets are already on the market, varying in size, weight, color, and portability. "Small, crowded markets are just as competitive – if not more so – than their larger counterparts. For this reason, it's essential that you genuinely think of the customer first, and make this commitment to excellence a cornerstone of your niche marketing strategy." (Shewan) The survey sent to the 259 college students at Ole Miss included a question asking what features they would like on their disc golf basket. The results are seen in Figure 28.

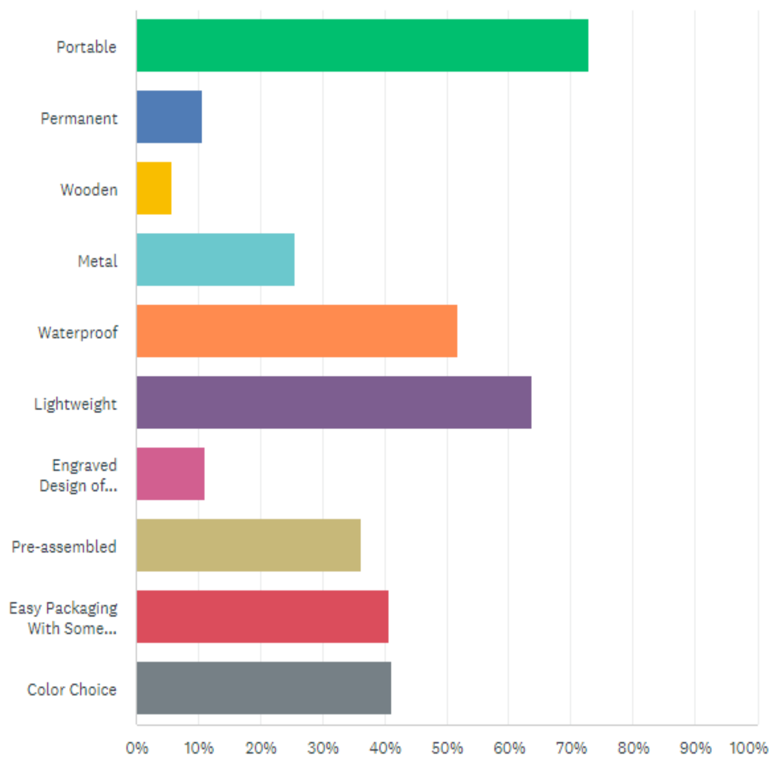

Figure 28. Desired Features Survey Results

From the survey, potential customers want a portable, lightweight and waterproof (rustproof for metal and rotproof for wood) basket. Choice of color to allow for basket customization was chosen by slightly less than half of the participants and almost half of the participants split between wanting a pre-assembled basket or an easily packed basket requiring some assembly. A permanent, wooden, or engraved basket would for all practical purposes be useless in the eyes of most potential customers. From this survey, it can be deduced that the customer wants a long-term basket that is easy to move around. These features dictate future design changes to make a basket that can succeed in today's market.

When looking at competitors, multiple products of the exact same features are already in the market and have differentiated themselves to be successful in other aspects such as allowing for color choice, free shipping, low cost, high visibility, free returns with money back guarantee, easy assembly, lightweight, and the ability for security on rough or angled terrain. From this analysis, the largest barriers to entry are economies of scale, product differentiation and capital requirements. With the discussed product features well established in the current market, it would be useless and unprofitable to mirror a product that possesses those same features. For this reason, a metal basket it out of the question. In order to get the competitive edge, appealing to the classic wooden aesthetic and genuine feel, the lack of rust, the healthy, safe, and recyclable aspects of wood, the lack of tooling and material cost are the largest contributing factors to success.

A brand-new facility dedicated to making wooden frisbee golf baskets would not prove profitable due to the overarching overhead costs and economies of scale barriers. For this reason, it would be more profitable to introduce a wooden basket line in an already established facility within a company making similar products and targeting a similar consumer base in order to synergize machinery, material, personnel, suppliers, and distributors. Currently established companies that specialize in wooden sports products such as baseball bats, hockey sticks, cricket bats, pool cues, archery bows, surf boards, canoes, and toys would be more readily equipped to handle a line dedicated to wooden disc golf baskets. (Aged Woods) Due to the limited need for functionality variation, differentiators that would be commonly seen in wide variety markets such as the automotive industry in terms of performance in various conditions and terrain, aesthetic look and feel, size, and comfort level cannot be introduced into the currently saturated market.

The profitability of the basket hinges on the ability to provide either a functional basket at low cost or provide a high tier basket differentiated by the color, textures, and visible appeal of a different material basket such as wood. The combination of manufacturing the product under a company in similar markets to provide synergy along with ease of transportation and assembly of the basket would allow discussion to be continued on whether a wooden disc golf basket could be a profitable product.

When asked at what price range they would be willing to pay for their basket from their list of chosen features, survey participants followed an expected trend of wanting the cheapest product. Figure 29 shows this.

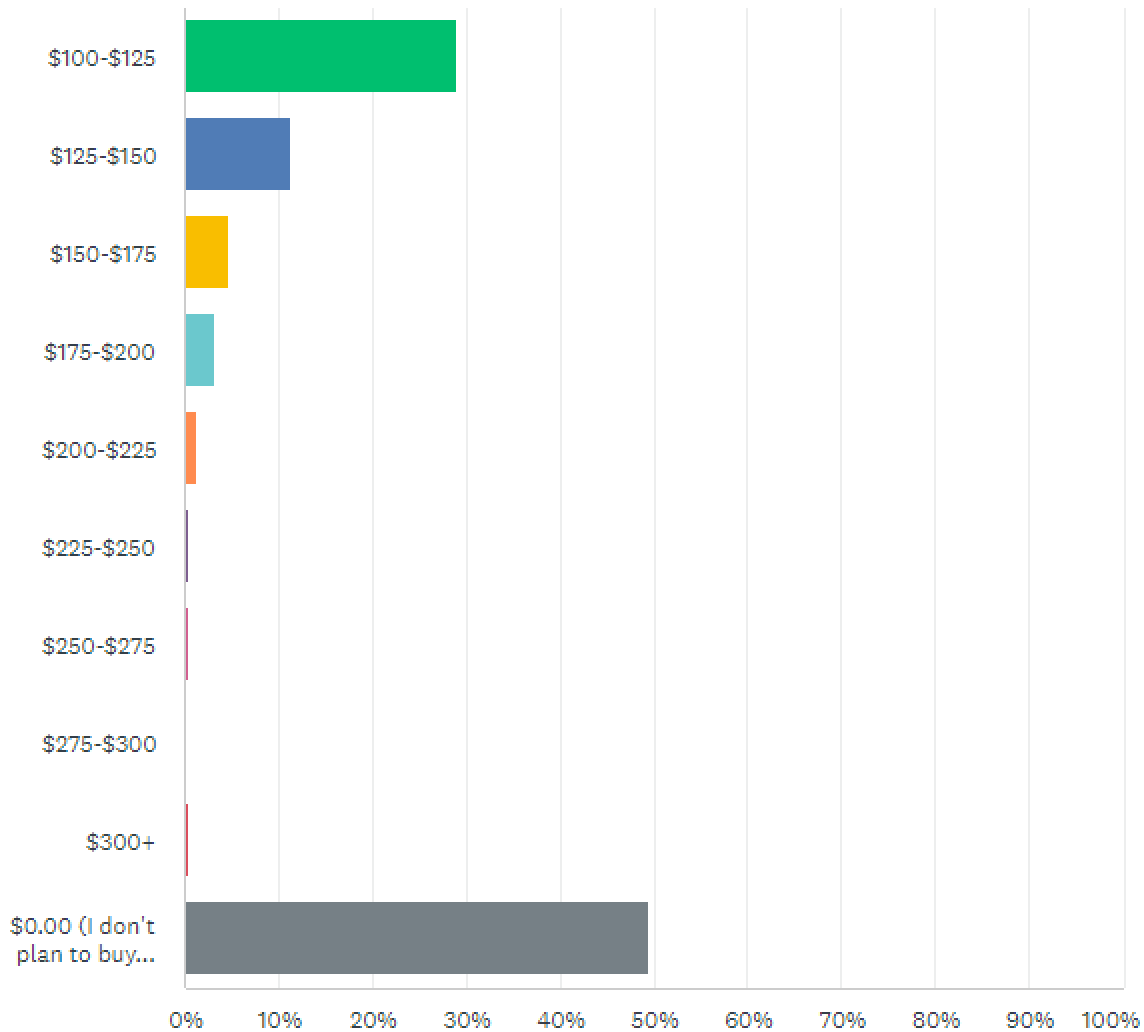

Figure 29. Product Value

Competitors of metal baskets with similar additional features have obtained wholesale and retail prices ranging between $120.00 to $200.00. This aligns with expected consumer price with a majority (30%) of participants desiring a basket for $100.00-$125.00. In order to achieve this, production costs would need to be at $50.00 or less to sell retail due to retail markup. Wholesale has the potential for a larger revenue as the expense of marketing their product's existence. Since retail allows for more product publicity, such as more positive customer interaction and experience, it may be a viable option. Wholesale allows for a much higher price of goods sold at the expense of selling in bulk and decreased customer interaction. With the knowledge of the consumer base in size being legitimately less than a couple hundred thousand, the wholesale approach while using a company's existing marketing platform and consumer base would theoretically prove to be the more viable option. This cannot be completed with the current unit cost at $185.16 not factoring in assumed startup costs. Major cost reduction discussed in 7.4 would be necessary for a successful product.

7 Project Analysis

7.1 Project Changes

Significant changes should be made to this product before entering the market. Discussion and implementation of an improved design, assembly time reduction, and material cost reduction are crucial. Material costs were factored from retail suppliers in small quantities and provided a significant amount of waste from cutting. Costs can be reduced from changing wood suppliers to partnering with wholesale suppliers to obtain quantities and sizes more tailored to the needed parts to reduce scrap and purchasing costs.

A clearly defined scope of work with scheduled goals and timelines that are followed due to project management checks should be included. Designated roles and responsibilities of each team member involved, along with required milestones and deadlines, would ensure goal completion. Mandatory meetings and collaboration followed by performance checks would ensure continued progress.

7.2 Design

There are many potential design changes despite the simplicity of the functionality of the basket. An initial design change included the switch from wood to metal due to barriers discussed in the market analysis and strategy. While this may prove to fit the customer needs, an additional disc golf basket made of metal would be very difficult to differentiate from other baskets. Even though metal parts, such as chains, pole stands, hooks, and wires can be prefabricated by the supplier, and is cheaper than wood, the cost of tool, dye, and welding operations costs would likely increase the cost of goods sold.

The implementation of sanding and staining the wood would prove to be a crucial change in increasing the aesthetic appeal of the basket and appeal to the customer looking for the fresh and outdoors look. Staining with waterproof stain would effectively solve the concern of rot and prolong product life to allow for weathering. This should have been a basic design feature.

Incorporating the ability to assemble the basket simply and effectively would allow for ease of shipping and customer transportation to various locations. The use of precut holes to allow for a hex key screw or insertable peg would allow the stand and top to be easily assembled to one another. A clampable square ring for the basket to rest upon would allow the basket to come on and off the base pole. The use of unglued biscuit joints would allow the walls on the basket to join to the basket floor while also allowing them to detach. This would theoretically cause an unsteady basket wall during use due to the unglued or shallow joints but could be negated by the additional use of insertable pegs or hex screws from the bottom of the basket floor up into the walls themselves whilst avoiding the biscuit joints. For this to be effective, the basket walls would need to be slightly wider to allow for screws or pegs to be inserted, thus increasing the basket diameter to ensure the added wall width does not affect the goal size. Additional work in cutting via drilling 8-16 holes through the basket floor and walls while obtaining geometric accuracy and low tolerance would add to the cost of production; however, a cost comparison would prove helpful in making data-driven decisions to achieve customer satisfaction.

A change in material use from 2”x4” wood to a circular wood base and pole would reduce weight and increase a smoother blend without the crisp corners from the 2”x4” while reducing size and weight. Additionally, the walls should be cut at 22.5-degree angles and the same size to allow for the walls to join one another with no uneven gaps or jagged edges.

With these changes, additional prototypes and testing would be required, along with process changes. While it cannot be confidently stated that these changes would lead to an effective design to be bought by the consumer, they are impactful changes to achieve an ideal wooden disc golf basket.

7.3 Process

When evaluating the process planning steps during the prototype and initial production run, several crucial aspects were left out. Processes are the steps taken to move something from point A to point B. Processes in manufacturing, particularly in high volume manufacturing, require clearly defined steps and flow to provide the smoothest and most effective transition of an item to its next phase in assembly, while maintaining quality. Process methodologies are in place to guide the manufacturer to achieve this goal. Sarah Laoyan from Asana discusses six major methodologies commonly used in manufacturing and are shown in Table 5.

Table 5. Process Improvement Methodologies

Six Sigma Methodology	Total Quality Management	Lean Manufacturing
Define improvement opportunity	Customer-focus	Identify value
Measure performance	Full-team involvement	Value steam mapping
Analyze for defects and root causes	Continuous improvement	Create flow
Improve root causes	Data-driven decision making	Establish pull
Control deviation		Continuous improvement
Continuous Improvement (kaizen)	Plan Do Check Act	5 Whys Analysis
Remove-	Plan: Define problem and plan how to solve	Ask why the problem occured approximately times until the root cause is defined
Wastefulness	Do: Test and implement plan at small scale	
Unevenness	Check: Review how actions in Do stage performed	
Overburdening	Act: Implement change at large scale	

The nature of the wooden disc golf basket requires absolute customer satisfaction with product quality. For this reason, Total Quality Management in conjunction with Lean Manufacturing are the two methodologies that would have proven vital in managing an effective assembly of the disc golf basket. Retrospective analysis showed that the prototyping and production run were both executed without customer-focus in mind. In fact, customer focus was not closely monitored or included in the scope as it should have been. Clearly defined requirements for quality and customer satisfaction would have dictated the need for improved design changes. Team involvement was not widely encouraged by any participating members resulting in the lack of completed tasks, lack of design, process, and marketing roadblocks and resulting solutions, and collaboration to encourage contribution to and ownership of the product. Continuous improvement can be slightly seen in the changes from prototype to production; however, the dedication to kaizen and cutting waste from processes was not implemented. While the team most closely followed the methodology of Plan Do Check Act, equipment costs per product, time wasted, and labor costs could have effectively been reduced through the use of takt time analytics to create line balancing and meet demand. Through both the prototyping and production, the value-added processes were not identified, resulting in an inability to decide where to improve the quality of the product and what processes should be cut or whose times should be reduced. A continuous flow was not established with an effective pull system to allow for the reduction of waste or the ability to make accurate data-driven decisions.

While the cost of each frisbee basket made is high due to the length of production and equipment used, the lack of implementation of the methodologies shows that there is significant room for improvement to reduce that cost. Before changes can be made to improve the takt time of the process, changes to ensure the quality and effectiveness of assembly must come first. This begins with a detailed design drawing and clear, safe instructions that result in the desired quality.

The operator leveling the bottom of the wooden frame had a difficult time ensuring that the wood was properly clamped onto the stand pole and flush. This caused an uneven base that rocked. The previously discussed design change to use a flat, circular base that could drill into the bottom of the frame poll or utilize a securely attached sleeve in its center for the poll to slide into would allow for a level base. The level of balance and stability would depend on the thickness of the pole and if supports would be needed, however this change would additionally decrease a significant amount of time and variation when clamping the poll to the table, and the legs to the frame. It would erase the need for screwing the wood legs in place and reduce cumbersome weight and size of the 2”x4” boards, allowing for easier operator handling.

While the cutting time of the walls would be increased due to cutting the corners at the proper angle, the time required to position them equidistant from one another would be erased. The change in cutting length of the walls in order to ensure they would fit against each other would also be erased as the angled edges would allow all walls to be one size and thereby decreasing process variation and the potential for operator error. When assembling the walls to the basket floor via the L brackets, the operator had to lay the L bracket flat on the table, drill one bracket side into the wall whilst ensuring it was flush with the wall bottom, then turn the wall upright and hold it with one hand while using the other hand to position the screw in the hole and hope that it wouldn't lose its hold before the drill could be grabbed and the screw could be secured. Another method of doing this was to attach the bracket first to the basket floor whilst ensuring it was the proper distance. The screws were small and easy to handle with two fingers, but were easily misplaced and when attempting to assemble two standalone pieces while using a drill, the process proved to be cumbersome. A solution to this would incorporate the use of a jig to temporarily secure the wall in place while the screw is drilled in. Another use of the jig would be to line up the L bracket on the basket floor to ensure it is at the correct location for a flush wall. The L bracket would then be attached to the basket floor followed by the wall itself.

As discussed in 5.3, the assembly of clamping the chains to S hook and the S hook to I hook using pliers 36 times proved to be both time consuming, strenuous on operator joints, and open to variance. The quick links would effectively reduce this time and strain while also decreasing the potential for quality error. It furthermore allows for the disassembly of the top for easy packaging.

While wood blocks screwed into the frame pole to secure the basket and top proved effective in functionality, they did not serve to improve aesthetic quality and were time consuming to use. At a set height above the frame base, four pre-cut wood blocks from the 2”x4” scrap were screwed into the 2”x4” pole. Two of these blocks were used to support and secure the basket as it slid over the pole and onto the frame. The other two blocks were attached to the top of the pole to secure the basket top onto the pole. The builder had to use a level and pencil marking to ensure the levelness and security of the blocks. With the combined use of eight specifically cut blocks and 16 drilled screws, the potential for operator error was increased, an increase in wood splitting probability occurred, and the time taken to complete this process showed the need for significant improvement. The use of L brackets to attach the basket and top to the pole could be implemented to erase this issue, however other roadblocks arise. The L brackets would need to be pre-attached to the top and basket floor before sliding over the pole and due to the basket and top bulky sizes from walls and chains, securing the brackets to the pole would be difficult and may even require two operators. A drilled hole in the basket top that aligns with a drilled hole in the pole would allow a peg to slide smoothly into the two pieces, joining them loosely while the L brackets for the top are secured. In all aspects of L bracket installation, the use of pre-drilled holes for hex screws or pegs would be necessary for disassembly.

Multiple process changes to reduce production time, build in quality, and reduce the chance of operator error and workplace accidents should be tested and measured in additional production testing before a customer-ready product can be manufactured.

7.4 Cost Reduction

Cost reduction is one the most important aspects of manufacturing. Companies across the globe challenge their managers and engineers to achieve cost reduction and eliminate waste. The equipment, material, and operating costs for the disc golf basket can be effectively reduced in several areas.

The water jet was used to precisely and efficiently cut out the basket floor and top. While these two assembly pieces require precision cutting, there are alternatives. A wood router is a commonly used, low cost ($60.00-$500.00) equipment piece that allows for the creation of rounded or angled edges which is the intended use of the waterjet. Outsourcing to wood fabricators would effectively reduce the large capital investment, setup, and operating costs of the water jet while also receiving parts made to order. The necessity for the octagon shaped basket floor was to allow for the wooden walls to join to one another. However, if suppliers are not equipped to provide an octagon floor, discussion for design change to a circular floor could be opened. This would allow for the incorporation of a wire basket wall to be formed smoothly around the circular basket. This would reduce the material costs for L brackets and hex screws, as well as assembly time by requiring a pre-formed wire basket to be inserted smoothly. The cost of wood for walls and their cutting could be replaced by cheaper metal material. Outsourcing or using jigs to weld the wires together could add to this reduced cost.

Materials for this project were bought at retail price in small quantities. Instead of paying a marked-up price to the middle man, going directly to fabricators and manufacturers of these materials and buying their product in bulk or at a contracted rate would significantly reduce the cost of materials. At the same time, it would open the door to synergizing the purchase of these materials with outsourcing their cutting such as ordering a box of chain with links precut to a certain length as opposed to one singular chain.

Suggestions presented for process improvement and design changes as well as the presented market and strategy all discuss potential positives of outsourcing various operations and materials. With high startup costs for a low demand product, operating as a design firm and working with established companies that operate in similar industries could increase profitability and would certainly reduce operating costs. Companies such as Step Park who specialize in various playgrounds and park fitness equipment made from wood, metal, and plastic, have facilities well equipped for the production of a disc golf basket. A disc golf basket would work well as an additional amenity to offer along with their wide array of services and would most certainly target their consumer market. As a design firm contracting the wooden disc golf basket to Step Park, manufacturing costs would be primarily their responsibility. This takes quality out of direct control and puts it in the trust of a partner. These partnerships can create communication roadblocks and product goal disagreements. The tradeoff of outsourcing and/or contracting internationally is that while workforce and material costs may be cheaper, quality is not often assured. Outsourcing and/or contracting nationally may not reduce costs as effectively, however is does reduce the communication barrier and increase the probability of maintained quality.

Conclusion

A wooden disc golf basket does not fit the stated needs or wants of the current consumer market. Due to a saturated market of metal baskets that meet currently consumer desired features, a metal basket is not a viable option. In regards to a successful disc golf basket made primarily from wood, excessive marketing would be required to inform customers of the product and convince them of their necessity to purchase one. With the cost of production requiring large economies of scale, the niche market of frisbee golf does not allow for a startup facility dedicated to wooden frisbee golf baskets. Potential solutions to this include the use of outsourcing manufacturing and operating as a design firm. Pending the successful implementation of design changes, the frisbee golf basket has the potential for success as a product in a currently established company with complementary products in similar industries and consumer bases.

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