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GradYear: From Ideation Through Product Delivery

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GRADYEAR:

FROM IDEATION THROUGH PRODUCT DELIVERY

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

LAURA ANN SALVADOR: GradYear: From Ideation Through Product Delivery

(Under the direction of Dr. Jack McClurg)

This thesis will serve to document the first year of GradYear, from ideation through product delivery. GradYear is a Center for Manufacturing Excellence (CME) Senior Capstone Project; the GradYear team is comprised of five students with academic disciplines ranging across business, accountancy, and engineering. The goal of the team was to design and manufacture a high-quality, classic wooden picture frame for college or university graduates that highlights their graduating class year. Under the direction of Dr. Jack McClurg, Dr. Matthew O'Keefe and factory floor technician Mr. James McPhail, the team designed the GradYear Classic using principles of DFMA and implementing principles of lean manufacturing during production. The author also created a supplementary GradYear Order Management System, applying what she learned from her Management Information Systems and Computer Science coursework.

This thesis will give an in-depth introduction to GradYear and will analyze how the GradYear Classic was designed and manufactured. It will provide a risk analysis, marketing plan, and financial report, each written under the assumption of full production. It will discuss how the GradYear Order Management System was built and include a brief software and technical specification overview of the system. Finally, the author will provide an analysis of the project and give recommendations for the future of GradYear.

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LIST OF ABBREVIATIONS

1NF	First Normal Form
2NF	Second Normal Form
3NF	Third Normal Form
B2B	Business to Business
B2C	Business to Consumer
CAD	Computer Aided Design
CDN	Content Delivery Network
CME	Haley Barbour Center for Manufacturing Excellence
CNC	Computer Numeric Control
CSS	Cascading Style Sheets
HTML	Hypertext Markup Language
JS	JavaScript
MDF	Medium-Density Fiberboard
MIS	Management Information Systems
OMS	Order Management System
PDO	PHP Data Object
PHP	Hypertext Preprocessor
SG&A	Selling, General, & Administrative Costs
SQL	Structured Query Language
UML	Unified Modeling Language
URL	Uniform Resource Locators
WIP	Work in Progress

Introduction

The Haley Barbour Center for Manufacturing Excellence (CME) is a competitive academic program at the University of Mississippi. If accepted, students will take courses in manufacturing processes, product realization, strategic planning, manufacturing accounting, continuous flow, standardized work, and practical problem solving. During their senior year, the students will form interdisciplinary teams to complete a Senior Capstone Project, directed by Dr. Matthew O'Keefe, before graduation. Each team is advised by a CME faculty member and a factory floor technician who provide aid in everything from conception to production. The Senior Capstone Project is an opportunity for students to apply all of the manufacturing-engineering knowledge they have acquired over the past four years towards a tangible product. Students will apply what they learned in class, on the factory floor, at different manufacturing facilities across the state, and from their own personal internships towards a product of their own conception and design. This is a year-long project, known for its intensity and difficulty.

The Team

1. Team Organization

The team was comprised of five CME students with different majors and minors; therefore, the roles and responsibilities varied based on the individual strengths each member brought to the team. These various perspectives and talents allowed for a high caliber group, effective at problem solving, to develop an innovative product.

Laura Ann Salvador, hereafter referred to as "the author," was a business student in the CME. She majored in Management Information Systems, with minors in Manufacturing Engineering, Computer Science, and French. After graduation, Salvador plans to pursue a career at the intersection of global manufacturing and information technology. Salvador was the point person for the project, in charge of liaising between the faculty and the team; she also designed and built the GradYear Order Management System.

Madeline Sellers was also a business student in the CME. She majored in Marketing & Corporate Relations, with a minor in Manufacturing Engineering. After graduation, Sellers plans to pursue a career in medical technology sales. Sellers was in charge of the marketing aspects of GradYear.

Mattie Huey was an accounting student in the CME. She majored in Accounting, with a minor in Manufacturing Engineering. After graduation, Huey plans to pursue a career in public accounting with PricewaterhouseCoopers in Dallas, Texas. Huey was in charge of the financial aspects of GradYear.

Drew Ramsey was another business student in the CME. He double-majored in Finance and Chinese, with a minor in Manufacturing Engineering. After graduation, Ramsey plans to pursue an art career in Shanghai, China. Ramsey assisted with the design of the GradYear Classic.

Claire Fanning was an engineering student in the CME. She majored in Mechanical Engineering, with an emphasis in Manufacturing and minors in Computer Science and Business. After graduation, Fanning will attend New York University in pursuit of a Masters of Business Administration. Fanning was in charge of the design and manufacturing of the GradYear Classic.

During the fall semester, the team organized into the organizational structure pictured below in **Figure 1** with each team member naturally settling into positions that suited his or her strengths. Huey, the team's accountant, was absent from January to March, due to an accounting internship. The author and Fanning maintained the finances while she was gone, and brought her up to speed when she returned.

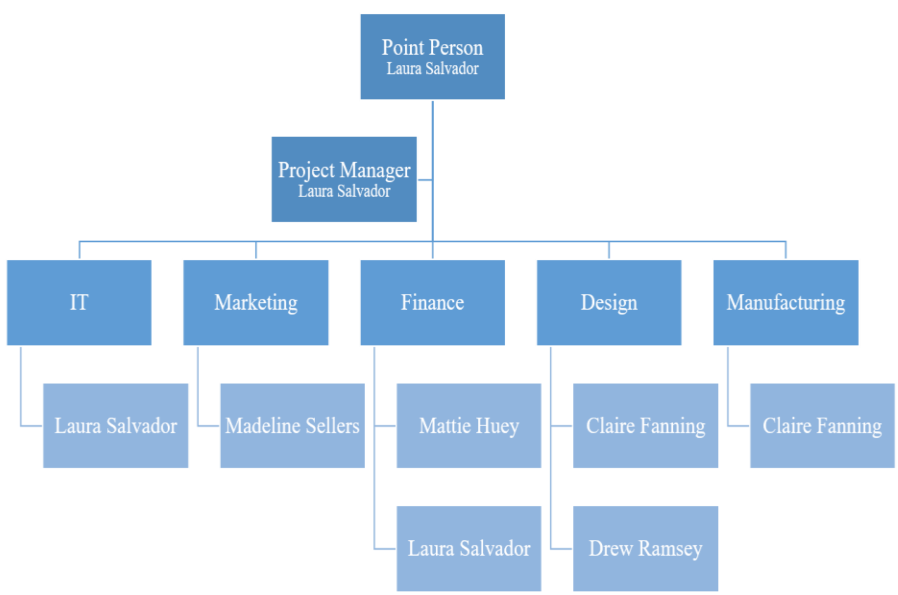

Figure 1 - Team Organizational Structure

2. Five Stages of Team Development

The trajectory and schedule of the project allowed the team to aptly follow the Five Stages of Team Development, as defined originally in 1965 by Bruce Tuckman [1], and revised in 1977 by Bruce Tuckman and Mary Ann Conover Jensen [2], shown below in **Figure 2**. The first four stages were defined in the original Tuckman model and include Forming, Storming, Norming, and Performing. According to [3], the fifth stage, Adjourning, was added during the revision to "[reflect] a group life cycle model in which separation is an important issue throughout the life of the group."

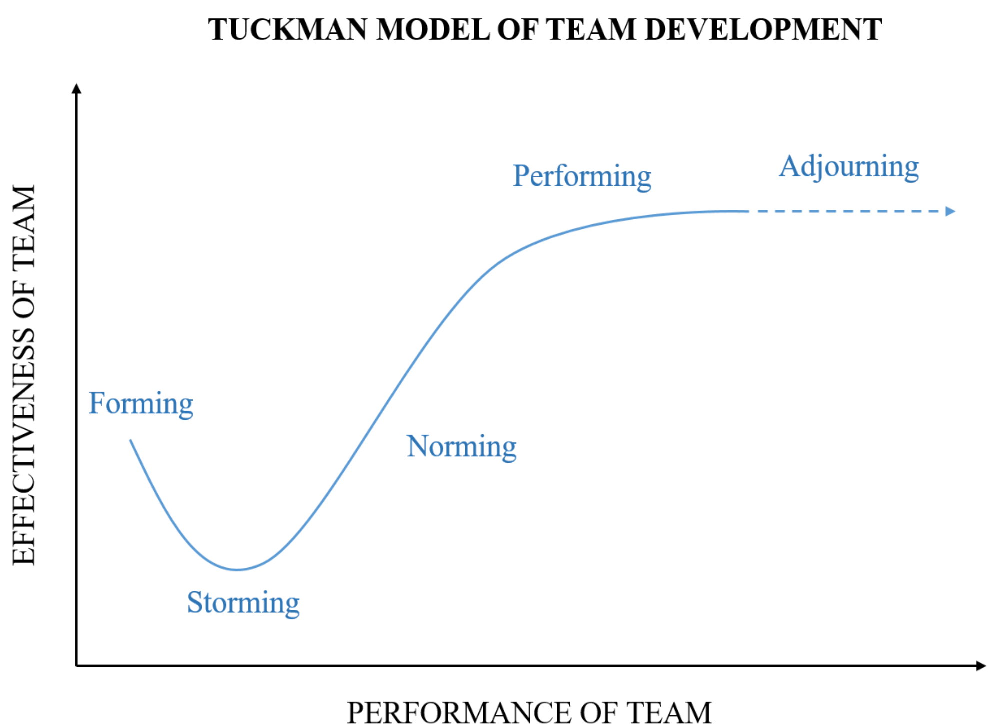

Figure 2 - Tuckman Model of Team Development

In a comprehensive review of the history of the Tuckman model, Denise Bonebright [3] attributed the immediate popularity of the Tuckman model when it was introduced in the 1960s to the way that it "proved useful for practice by describing the new ways that people were working together, helping group members understand what was happening in the development process." This attribution certainly held true during the case of this project. The Tuckman model was first introduced to CME students as freshmen, in Manufacturing 150: Introduction to Engineering / Manufacturing. It was the first time that CME students formed teams in a university setting, and without following the general structure of the Tuckman model, it is quite possible that students would have gotten stuck in the Storming phase indefinitely. Learning the Tuckman model allowed students to understand why their teammates acted and reacted the way that they did and move forward as a team.

Three years later, in Manf 451: Design-Product Realization, the first half of the CME Senior Capstone Course, students are again expected to follow the Tuckman model and form teams. It is crucial to reach the Performing stage quickly as to ensure completion of a successful project. Below is a summarization of the team's own journey through the Tuckman model.

Fall 2018:

1. **Forming:** The team formed in September, and did various team-building activities with the Manufacturing 451 class to get to know each other. The five team members had not previously worked together, so it was a completely fresh start.
2. **Storming:** The team certainly stormed in October as the first assignments were due, and team members learned firsthand the others' strengths and weaknesses. For example, it was realized that some team members always prefer to finish assignments at the last minute. As others did not understand this sentiment, it took some time to find a balance.
3. **Norming:** By the second report, the team had developed their norms and settled into a more-or-less consistent routine. Surprises did come up, but by this point, team members had learned how to deal with them.
4. **Performing:** By the presentation at the end of the semester, the team had started performing. The team satisfactorily completed all 3 reports, presented to the faculty, and finished a prototype. The author received an A in the Manufacturing 451 course.
5. **Adjourning:** Loose ends were wrapped up, assignments to be done over Winter Break were delegated, and the team adjourned for 6 weeks.

Spring 2019:

1. **Forming:** The team re-formed in January, without Huey. The author and Fanning had to take over her roles of purchasing and managing the budget. The team had been assigned the first Trial & Production periods and had to be completely prepared within 2 weeks.
2. **Storming:** There was storming in January as there had been a miscommunication with the team's wood supplier, and a new supplier had to be found within the week.
3. **Norming:** The team's norms shifted a bit in the spring, with the absence of Huey, but luckily, everything remained mostly the same.

   The first 3 stages were much shorter in the spring, as the team simply had to be prepared in 2 weeks for its scheduled Trial & Production periods in February.
4. **Performing:** The team performed well during the Trial & Production periods, receiving the sought-after approval of the technicians and the faculty. Fanning had to miss one of the Production periods, and the rest of the team faced a real-life scenario of performing without a crucial team member. The team continued to perform, again presenting to the faculty and compiling a final report.
5. **Adjourning:** The team gave recommendations to the CME faculty and staff for future iterations of the CME Senior Capstone Project, and attended one last luncheon with the CME Senior Class of 2019. April 2019 was a bittersweet month.

The Pitch

GradYear was pitched by the author, who realized the need and demand for this project almost two years ago when she was shopping for a graduation photo frame for her brother in April 2017, and there was not a frame that said "Class of 2017" to be found. There were plenty of frames that said "Ole Miss" or "Hotty Toddy" and were very decorative but none that were traditional and timeless with a simple "University of Mississippi" and "Class of 2017." After an extensive online search, the only customizable frames she found were pewter, vertical, and well over $50. **Figure 3**, pictured below, is a screenshot of some results from a detailed Google search.

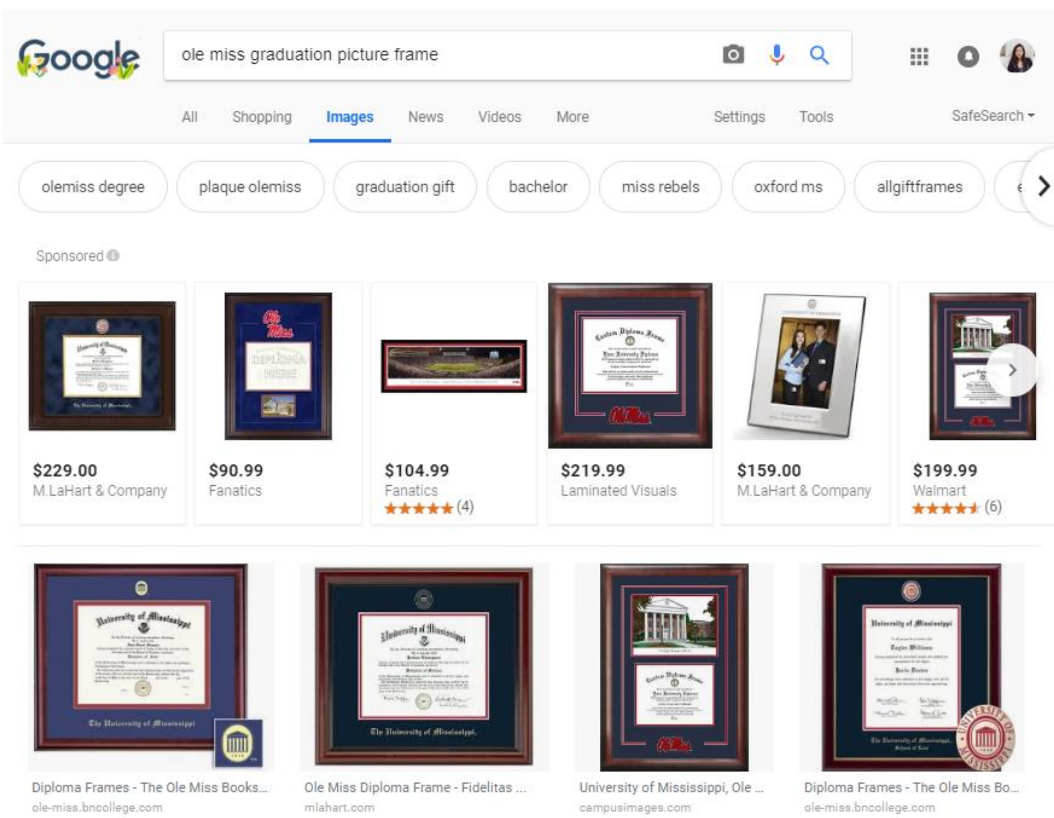

Figure 3 - Results from Google Search

The family members of the graduate were proud that he graduated in 2017 – proud that he finished in 4 years, even after changing his major. Despite not having the post-graduation plans he had always hoped for, it was a year of significance. They wanted a frame that highlighted his biggest accomplishment to date: graduating from the University of Mississippi in 2017.

The author ultimately decided that she would pitch making gradation photo frames for her CME Senior Capstone Project – although they may seem trivial to some, she knew they would be cherished by others. From the very beginning, she envisioned a classic, wooden horizontal frame, one that could hold a family photo taken in the Grove with the graduate in his or her full regalia. GradYear stayed true to that original design, keeping the horizontal orientation because it is better suited to family photos. It is the family who gets their students over the finish line – it is an accomplishment they share together.

Executive Summary

The objective of the GradYear team was to design, manufacture, and sell, at a reasonable price, high-quality wooden photo frames engraved with the alma mater and graduating class of the consumer. For the purposes of this project, a “reasonable” price was determined by both surveying the current picture frame price range online and in Oxford and by analyzing results from an initial survey. In **Phase 1: Planning**, the team determined that its feasible goal would be to create 39 GradYear frames for the 39 students in the CME Senior Capstone Class of 2019. In **Phase 2: Product Design**, the team further developed the budget, ordered the necessary materials for 5 prototypes, and began testing different materials and machines. In November 2018, the team presented the final prototype to the faculty. After a few minor modifications, the team finalized the design, named it the *GradYear Classic*, and launched **Phase 3: Trial & Production**. The team had 1 week of trial periods to test its process flow, make adjustments, and prepare for full production. The team had not factored handling time into their production estimates, so actual production was lower than projected production. Over the course of February and March, team members spent extra time on the factory floor to complete a total of 70 GradYear Classic frames. In **Phase 4: Strategic Planning**, the team analyzed the risk of the venture, created a marketing plan, and developed a series of financial reports for GradYear. As an additional component, in **Phase 5: GradYear Order Management System**, the author planned and developed a web-based system to track orders, customers, and inventory.

Phase 1: Planning

1. Background Research

To verify the initial findings from 2017, the team split up and visited most of the stores in Oxford that sold picture frames, and looked for a frame that displayed an official University of Mississippi logo and a graduating class year.

- Rebel Bookstore (on Jackson Ave.) did not have a frame that met the criteria.
- Rebel Rags (on Jackson Ave.) had quite a colorful collection of Ole Miss-themed picture frames, but did not have one that featured the graduating class year.
    - The majority of the frames were designed for photos size 4”x6” - which looked a bit small compared to the grandeur of the frames. Prices ranged from $24 - $56.
- The local Walmart (on Jackson Ave.) did not have a frame that met the criteria.
- The Ole Miss Bookstore (the Barnes & Noble on Jackson Ave.), did not have a frame that met the criteria.
    - When a team member asked an employee about picture frames and explained the product idea, he was told that if the team made the frames according to the criteria, they would buy them.

- The boutiques (on Courthouse Square) did not have a frame that met the criteria. Inquiries with some of the boutique owners and employees about the product idea were met with the same enthusiasm: if the team made them, they would buy them. One owner agreed, “That’s a great idea! I don’t know why we don’t already have something like that.”
    - Katherine Beck sold their basic photo frames for $38, and employees reported that they sold very quickly.
    - The Lily Pad employees said that they sold their frames for $32-46, and they had 4” x 6” and 5” x 7” frames with the 5” x 7” always selling faster. In the store, it was usually parents or grandparents buying these frames for their relatives as gifts.
    - Frame Up - Basement Gallery owners were excited about the product idea, and agreed that it was a great proposal. They also recommended to keep in mind that there is a spike in graduation type frames from May to July, and that wood tones with gold accents are the most popular frame style.

The survey of the current picture-frame landscape in Oxford confirmed that nowhere sold anything like what the team had in mind. The team also discovered that across the board, 5” x 7” was the most popular frame size. Determining what existing products looked like and how they were priced helped the team to design the GradYear Classic to be unlike anything on the market, at a price that people were willing to pay.

2. Market Research

Market research via an online survey was conducted to measure consumer preferences for the GradYear Classic. This gave the team numerical data to make decisions with, and proved invaluable throughout the course of the project.

Survey 1, created with Qualtrics, a survey software commonly used by students, was released in September 2018. Each question was carefully crafted as to not be leading and ordered for the most accurate results. The purpose of Survey 1 was to collect data on the target market of the product, and their specific preferences on engravings and price. **Figure 4** displays how a participant would view Survey 1 on a mobile phone.

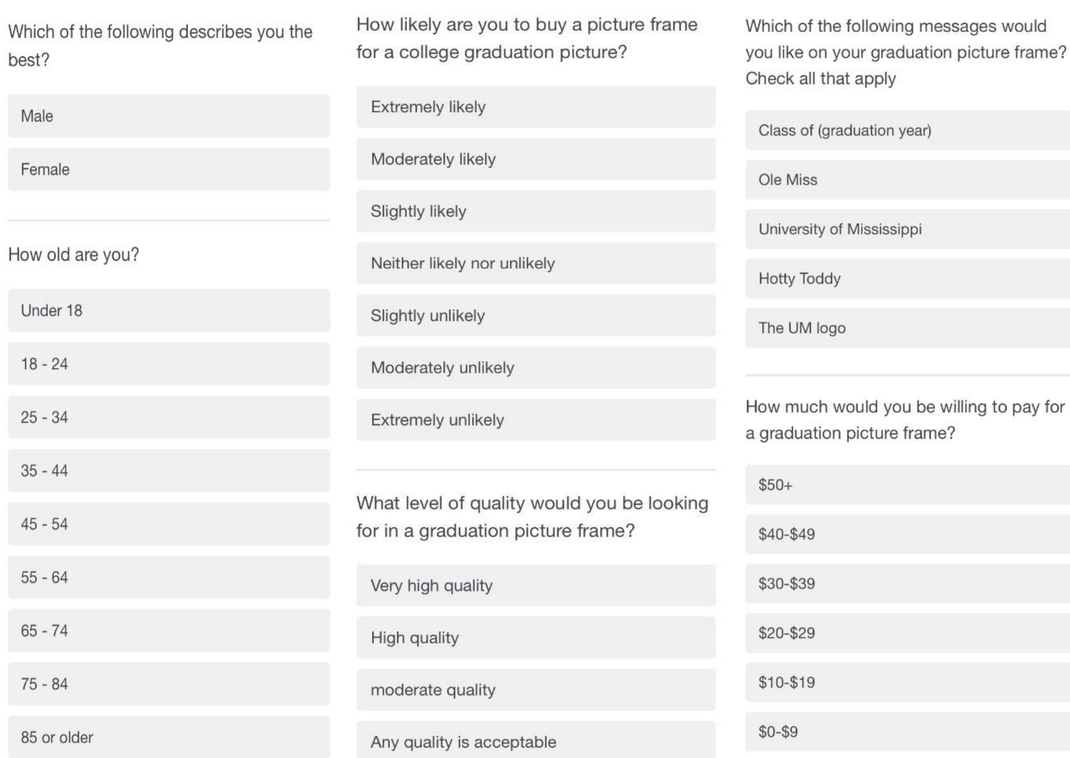

Figure 4 - Survey 1

Each team member asked friends and family members to take the survey, and posted links to the survey on their social media profiles. The team hoped to record responses from a wide variety of people.

After Survey 1 was closed, Qualtrics generated a report of the results, as seen below in **Figure 5**. There were a total of 167 responses.

Survey 1 Results

Q1	Which of the following describes you the best?		
	Male	26	16%
	Female	141	84%
	Total	**167**	**100%**

Q2	How old are you?		
	Under 18	0	0%
	18-24	152	91%
	25-34	0	0%
	35-44	1	1%
	45-54	10	6%
	55-64	3	2%
	65-74	1	1%
	75-84	0	0%
	85 or older	0	0%
	Total	**167**	**100%**

Q3	How likely are you to buy a picture frame for a college graduation picture?		
	Extremely likely	50	30%
	Moderately likely	45	27%
	Slightly likely	35	21%
	Neither likely or unlikely	11	7%
	Slightly unlikely	13	8%
	Moderately unlikely	7	4%
	Extremely unlikely	6	4%
	Total	**167**	**100%**

Q4	What level of quality would you be looking for in a graduation picture frame?		
	Very high quality	25	15%
	High quality	92	55%
	Moderate quality	35	21%
	Any quality is acceptable	15	9%
	Total	**167**	**100%**

Q5	Which of the following messages would you like on your graduation picture frame? Check all that apply.		
	Class of (graduation year)	106	36%
	Ole Miss	27	9%
	University of Mississippi	100	34%
	Hotty Toddy	12	4%
	The UM logo	48	16%
	Total	**293**	**100%**

Q6	How much would you be willing to pay for a graduation picture frame?		
	$50+	22	13%
	$40-$49	26	16%
	$30-$39	37	22%
	$20-$29	51	31%
	$10-$19	25	15%
	$0-$9	6	4%
	Total	**167**	**100%**

Figure 5 - Survey 1 Results

84% of responders reported to be female. This was likely due to the limited social nets of the team. Four of five team members were female, and their social media followings were largely constituted of other females.

Nearly everyone who took the survey was aged 18-24. Only 15 responses were by people who reported to be over the age of 25. The team had hoped to capture more responses from people outside of the college environment in order to determine if alumni would be interested in purchasing custom frames with older graduation years, but the data was too scant to make a definitive decision on this demographic.

57% of responders reported that they were *moderately likely* or *extremely likely* to buy a college graduation picture frame, which proved the viability of this product.

The fourth question was critiqued by the faculty as being too vague. What is quality in terms of picture frames? How do you quantify quality? The team defined quality on a scale ranging from a basic, acceptable picture frame made of mediocre materials that will serve its purpose, to a luxurious, high-end picture frame made of valuable materials that will be a statement piece in a room. This redefinition was not added to the survey, as the critique was not given until after it was closed, and so the data from this question was not considered in the designing of the product.

The messages with the most interest to be on the frame were *Class of (graduation year)* with 106 selections and *University of Mississippi* with 100 selections. It was helpful to see that in comparison, *Ole Miss* only received 27 selections from the responders.

The most popular price range with responders was $20 - $29, with 31%. However, it was important to note that a cumulative 51% of responders selected an option over $30.

3. Problem Definition

After gathering the data and analyzing the results, the team defined the problem: *Graduation is a milestone in the lives of many young adults. It is an event that is celebrated and commemorated with a great deal of photographs. However, it has been realized that at the moment, there are no picture frames available for purchase that are tailored specifically to graduation, highlighting both the alma mater and class of the new graduates.*

4. Project Scope

Although the initial project proposal intended to sell the frames to local businesses, after discussing the idea with several staff and faculty members, the team decided to limit the scope of the project to set a more achievable goal. The main concern with selling the frames to local businesses was the transfer of licensing. The CME has an agreement with the University for unlimited usage of current University of Mississippi logos, but that right is not transferred to other organizations who wish to resell the product. A similar concern the team faced was whether or not student organizations had the right to "sell" products made with University money. The CME operates on a "donation" system, wherein upon receiving a donation from a benefactor, the CME can give them a gift as a thank-you. Other concerns ranged from contracts to product packaging to shipping. Unsure of the actual demand from local businesses and the production capacity that the team could achieve in the spring, the team decided to curtail all of these issues by changing the goal of the project: the new goal was to gift a GradYear frame to every member of the CME Senior Capstone Class of 2019. This change gave the team an exact demand of 39 frames, and as an added bonus, completely circumvented any legal ramifications of selling University licensed products without University approval.

5. Project Management

Previous courses in the CME had taught students about the Project Management Triangle, pictured below in **Figure 6**. Also known as the Iron Triangle, for its sometimes severe rigidity, the Project Management Triangle strives to "balance cost, schedule, and quality constraints to meet the owner's needs, which define the scope of the project" [4]. As the project manager, the author was responsible for attaining this coveted balance. Cost was not a real issue for the team, as the team had been given a flexible $1,000 budget for the project. After the scope was limited to 39 frames, the workload of the project was brought to an acceptable, achievable level. Time proved to be the most difficult constraint of the project, as each team member was also entrenched in major-specific coursework and stressed about interviews throughout the duration of the project.

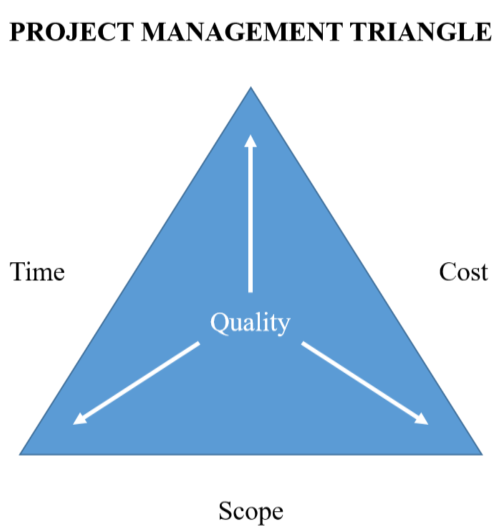

Figure 6 - Project Management Triangle

To alleviate some of the pressure from the time constraint, the author used Microsoft Project to create tracking Gantt charts for each semester to set a schedule for the team. The Gantt charts were to help keep team members on track, and to keep track of all of the tasks, milestones, and overall progress of the project. **Figure 7** displays the Gantt chart from the fall semester, which was split into 3 phases, and **Figure 8** displays the Gantt chart from the spring semester, which was also split into three phases.

The team stayed on track throughout the year, usually cutting it a little close to deadlines, but always completing the necessary tasks. Unfortunately, each team member had very specific, differentiated skill sets and subsequently, each team member was usually not able to help another when help was needed – team members had to reach out to students on other teams and the faculty to solve their niche problems. This inevitably caused build-up in workload, but the team managed to meet all of its goals and complete its deliverables on time.

The author learned something new about project management and people management almost every day because of this project. From confronting scheduling issues to navigating difficult topics concerning team members, it was a truly eye-opening experience to manage a group of peers for an 8-month project.

		Task Mode	Task Name	Duration
0			UM_Graduation_Photo_Frames_Fall_Semester	64 days
1			Phase 1	14 days
2	✓		Introduction to product and establish roles	1 day
3	✓		Conduct Market Research	6 days
4	✓		Survey 1	0 days
5	✓		Complete Report 1	7 days
6			Report 1	0 days
7	✓		Phase 2	24 days
8	✓		Order materials for prototypes	5 days
9	✓		Meet with Factory Floor advisor	3 days
10	✓		Create CAD file of design	6 days
11	✓		Develop manf. & assembly processes	6 days
12	✓		Complete Report 2	4 days
13	✓		Report 2	0 days
14	✓		Phase 3	25 days
15	✓		Testing of design and processes	7 days
16	✓		Complete prototype	3 days
17	✓		Final Presentation	0 days
18	✓		Complete Report 3	9 days
19	✓		Report 3	0 days

TRACKING GANTT

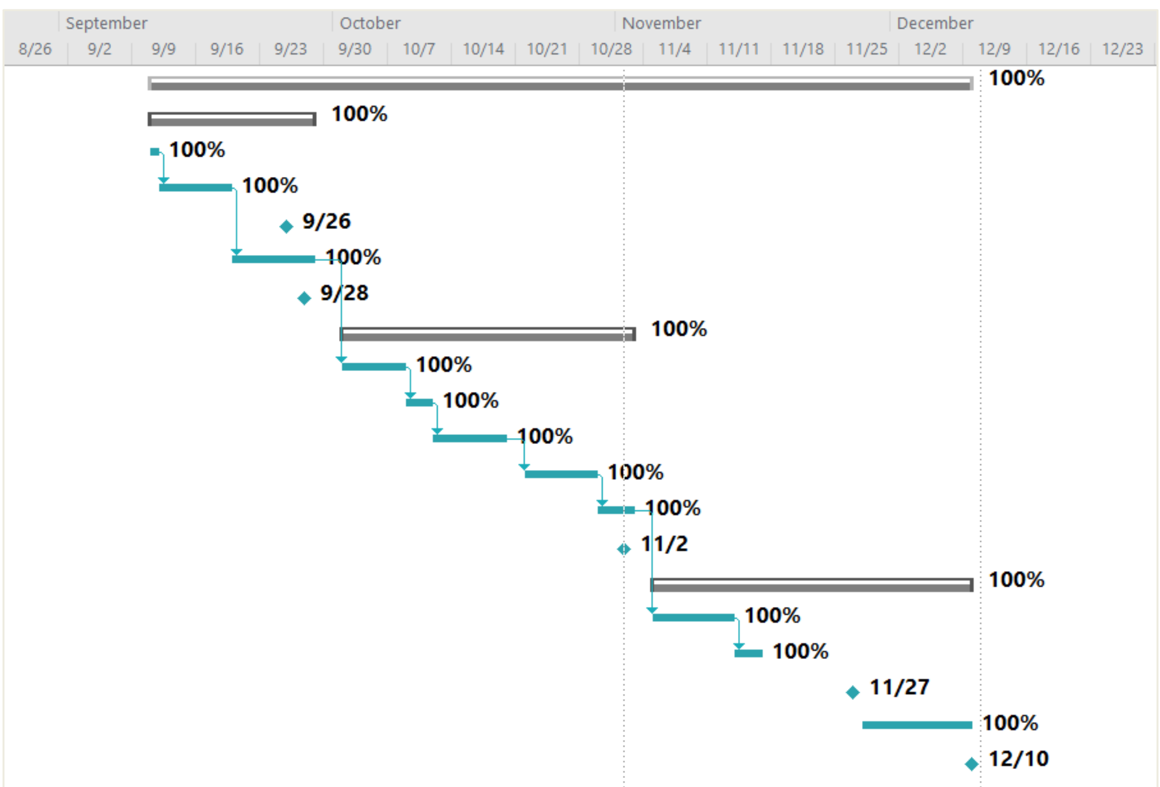

Figure 7 - Tracking Gantt Chart for Fall Semester

TRACKING GANTT

		Task Mode	Task Name	Duration
0	✓		**UM_Graduation_Photo_Frames_Spring_Semester**	**59 days**
1	✓		**Preparation**	**9 days**
2	✓		Order materials for Trial & Production	1 day
3	✓		Make last changes to design	6 days
4	✓		Be ready for Trial & Production	0 days
5	✓		**Trial & Production**	**40 days**
6	✓		Learn each process	1 day
7	✓		Create WIP for Production	1 day
8	✓		Full Production Day 1	1 day
9	✓		Full Production Day 2	1 day
10	✓		Finish the rest of the frames	32 days
11	✓		**Post_Production**	**14 days**
12	✓		Final Presentation	1 day
13	✓		Complete Report 3	6 days
14	✓		Report 3	0 days

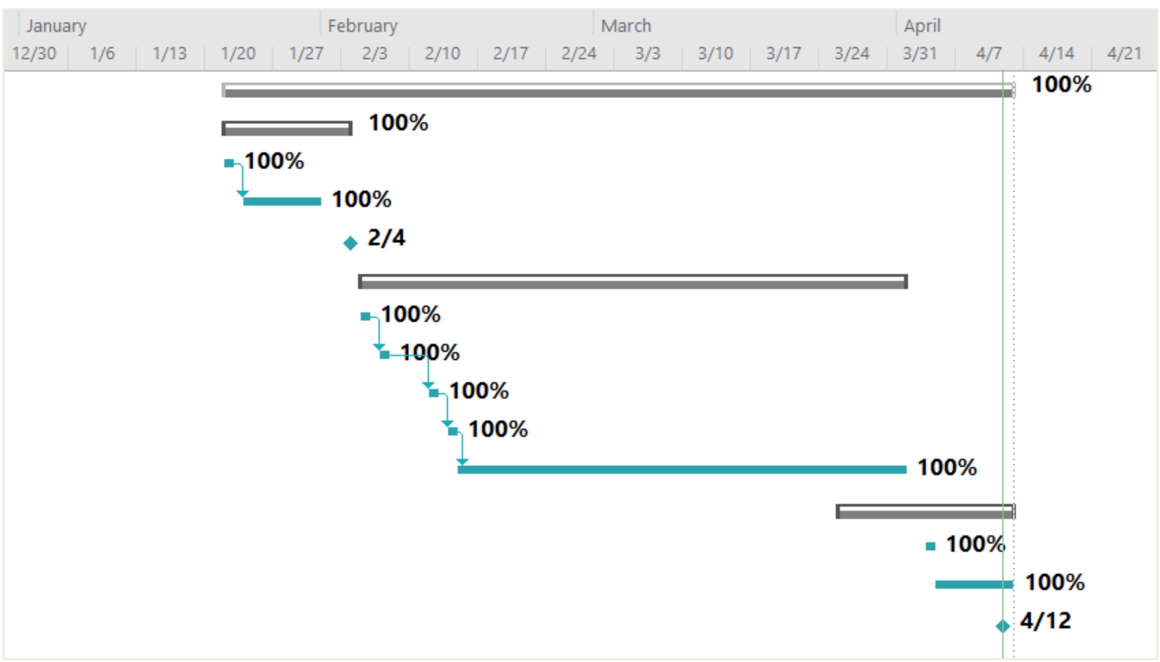

Figure 8 - Tracking Gantt Chart for Spring Semester

Phase 2: Product Design

The GradYear Classic was designed in CREO Parametric 4.0 by Claire Fanning. Materials were sourced by the author or recommended by Mr. McPhail. The original operations were defined by Fanning.

1. Materials

The direct materials for each frame included a promotional photo, a 9.49” x 11.89” piece of medium-density fiberboard (MDF) plywood, a frame backing, a 5” x 7” piece of glass, six ½” x 12mm staples, a piece of gold plastic plating, and a clear spray finish. Each material was carefully sourced for quality and price.

The promotional photo was designed by the author and included in the frame as a visual marketing tool. As seen in **Figure 9**, it displays the GradYear logo, indicates its status as a student project, and explains the meaning behind the project name.

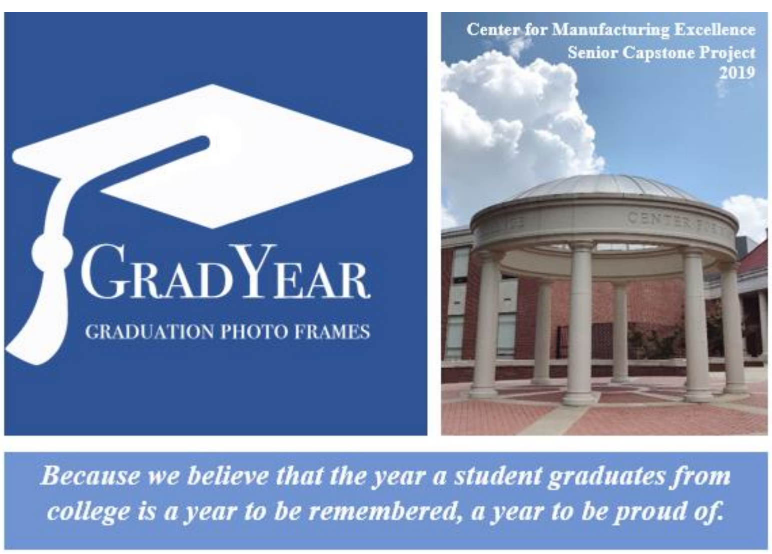

Figure 9 - GradYear Promotional Photo

After some discussion, it was decided that the frames would be built with ¾” MDF plywood with a birch veneer, shown below in **Figure 10** and **Figure 11.** MDF plywood was chosen because of the nice wood finish it has on its exterior and because it does not have the obvious layering on the edges that regular plywood does, so when the edging was routed with the Toyoda Computer Numeric Control (CNC) Mill, it produced a smooth and consistent surface, as opposed to a layered surface with the various levels showing.

Figure 10 - MDF Plywood Front View

Figure 11 - Regular Plywood Side View vs MDF Plywood Side View

A full 4’ x 8’ sheet of MDF plywood was used to make the frames. The dimensions of the frame were designed to get the most frames (40) out of one sheet of MDF plywood (also referred to as “wood”). The dimensions of the frame were set to be 9.5” x 12” in the original drawings. However, the dimensions of the frame were changed to be 9.49” x 11.89” after a few trials, in order to optimize the wood and reduce scrap.

According to [6], design for manufacturing and assembly (DFMA) is "a well-established technique in product design for minimizing production costs and development time by designing products into utilizing the simplest components." DFMA is the combination of design for manufacturing (DFM), which focuses on manufacturing cost reduction, and design for assembly (DFA), which focuses on part consolidation [7]. In DFMA, the entire production line, from manufacturing processes to assembly, is considered when designing the product and choosing the materials. DFMA helps engineers select processes and components that allow for the easiest manufacturing and assembly, to ultimately reduce waste and errors during actual production, and increase profit for the company.

The most obvious instance of DFMA can be seen in the choice of frame backings, as they were chosen for their unique design that drastically reduced manufacturing time, and therefore manufacturing cost, and for their ease of assembly, as they are simply slid into the proper groove and stapled into place.

The frame backings that were chosen were intended for a standard 5" x 7" picture with an 8" x 10" frame. **Figure 12** displays the frame backing from National Artcraft, an online craft supplier. Unfortunately, the frame's dimensions were larger than 8" x 10" so the frame backing had to be positioned carefully and strategically. The frame backing was intentionally positioned off-center, at the bottom of the frame, to allow the easel to reach the ground and support the frame, as seen in **Figure 13** and **Figure 14**. This frame backing had a unique design that proved to be extremely useful, and ultimately led to its selection over another frame backing the team had ordered online. As demonstrated in **Figure 15,** the opening of this frame backing was connected on one edge; when opened, it opened like a door (unlike traditional frame backings where the entire back is removed). This connected edge allowed for easy application – a staple gun was used to fasten the frame backing to the wooden frame. It also completely eliminated the need for turn buttons, which in turn eliminated multiple excess steps, decreased cost, and increased quality assurance, as turn buttons are likely to fall out, difficult to use and assemble, and will rust over time.

Figure 12 - Frame Backing

Figure 13 - GradYear Classic (Standing)

Figure 14 - Prototype with Frame Backing

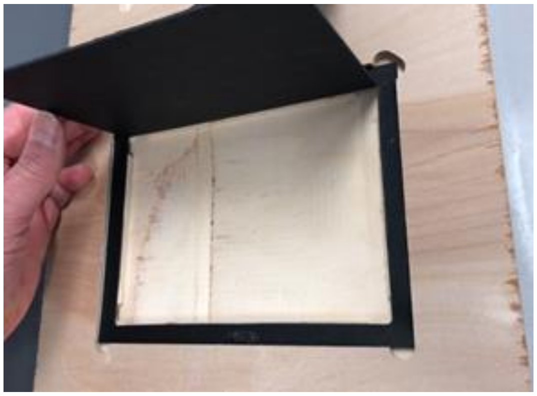

Figure 15 - Prototype with Frame Backing (Open)

It had been heavily debated whether or not to outsource the frame backings and the glass pieces. The frame backings were by far the most expensive piece required for the product, but it was realized that the labor cost to make them in-house would greatly exceed the cost of outsourcing, not to mention the additional materials that would have to be purchased or the time it would take to design something of equitable value. The decision to outsource the glass pieces was much simpler; the CME factory floor did not have the machinery to process glass. Luckily, the team found a solution in buying glass replacement sets, intended for consumers who had broken the glass in pre-existing frames, but wished to continue using the frame. Each set came carefully packaged and included a piece of corrugated backboard, another product that the team would have had to manufacture in-house. The decision to outsource the frame backings and the glass pieces saved the team time and money, and allowed the team to focus on other design aspects.

The staples were purchased at Home Depot. Mr. McPhail had recommended purchasing smaller staples, but they were not available. This is an area of possible improvement; the future owners of GradYear should try and find the next-size down of staples and try using the smaller size in the GradYear Classic.

The gold plastic plate was a creative solution in and of itself; it was essentially a shiny engravable sticker. **Figure 16** displays one of the first iterations of an engraved piece of gold plastic plating; the final design has rounded corners and says “Class of 2019.” After being etched by the laser engraver, the sticker backing could be peeled off and the gold plastic plating could be adhered in the groove on the front of the finished frame. However, its ease of application makes reworking a frame with an incorrect gold plastic plating nearly impossible. It is below the surface level of the frame and attached with an adhesive. Since this is the last step in the process, it is the most expensive point to make an error; every other cost-adding activity such as machining or material usage has already been completed. If a mistake is made at this moment, there is no way to rework it, so the entire frame must be scrapped. This is also an area of possible improvement; the future owners of GradYear should devise a way to remove the gold plastic plating once it has been adhered to the frame.

Figure 16 - Engraved Gold Plastic Plate (Example)

The clear spray finish was selected because it was easy to apply, and it did not detract from the beauty of the birch veneer or of the engraved logo. It acted as both a stain and a sealant for the finished frames. The spray slightly darkened the color of the wood, just enough to enhance the effect of the engraving. This spray finish was chosen over traditional stain because it is more cost effective and time efficient, and it provides a uniform finish on all frames. Another avenue of improvement or growth would be to explore using other spray finishes, for different looks to suit consumer preferences.

2. Operations

Although heavily contested by the faculty, the team decided to use a series of machines rather unorthodox for woodworking to manufacture the frames. By using these machines, frames are cut out of a 4’x8’ sheet of wood which altogether eliminates the tedious, difficult process of aligning the edges of the frame and affixing them, as in traditional picture frame manufacturing. Mr. McPhail, having worked in the picture frame industry for a number of years, suggested that the team follow this simplified ideology to allow for more standardization, to increase the design possibilities on the frames’ edges, and to decrease production time, production cost, and personnel**. Table 1** displays the number of operations, the machine or the location of the operation, and the activity of the operation.

Table 1 - Operations

Operation	Machine / Location	Activity
0	Epilog Laser	Engraving
1	Panel Saw	Cutting
2	Laguna Sheet Router	Routing
3	Radial Arm Saw	Cutting
4	Toyoda Computer Numeric Control (CNC) Mill	Milling
5	Epilog Laser	Engraving
6	Paint Station	Finishing
7	Assembly Station	Assembling
8	Assembly Station	Adhering
9	Assembly Station	Packaging

In addition to the regular preparation required for a manufacturing process (i.e., turning on all of the machines, setting up the dust collectors, readying materials, etc.), this process included an operation 0 wherein all of the gold plastic plating required for a production period was engraved. Mr. McPhail recommended that instead of producing each gold plastic plate during the production period, to produce all of the gold plastic plates prior to the production period. This entire operation could be done in the time that it took to warm up all of the other machines. Operations similar to this are routinely done during breaks at manufacturing facilities; all that is required is placing the material in the Epilog laser, selecting the right program, and pressing the start button. By preparing the gold plastic plating ahead of time, more time and attention is afforded to the other operations during the production period.

In operation 1, the panel saw was used to cut one 4' x 8' sheet of wood into eight 4' x 11.89" pieces. **Figure 17** displays the Computer Aided Design (CAD) drawing for operation 1, detailing these cuts.

In operation 2, one 4' x 11.89" piece was taken to the Laguna Sheet Router to rout out the grooves on the backside of the frame. Three grooves are routed: the groove for the piece of glass, the groove for the frame backing, and the groove for the keyhole on the back of the frame. **Figure 18** displays the CAD drawing for operation 2, detailing these cuts. Operation 2 routs the backsides of 5 frames, as shown in **Figure 19.** The team programmed the Laguna Sheet Router to rout all 5 of the grooves for the frame backing, then all 5 of the grooves for the glass pieces, and finally all 5 of the grooves for the keyholes because each process used a different end mill cutter and switching between each frame would have been highly inefficient. The frames were not fully cut out in operation 2 because each 4' x 11.89" piece was held in its place in the machine with a vacuum seal; fully cutting the front opening would have disrupted the vacuum seal and the rest of the cuts would have been misaligned.

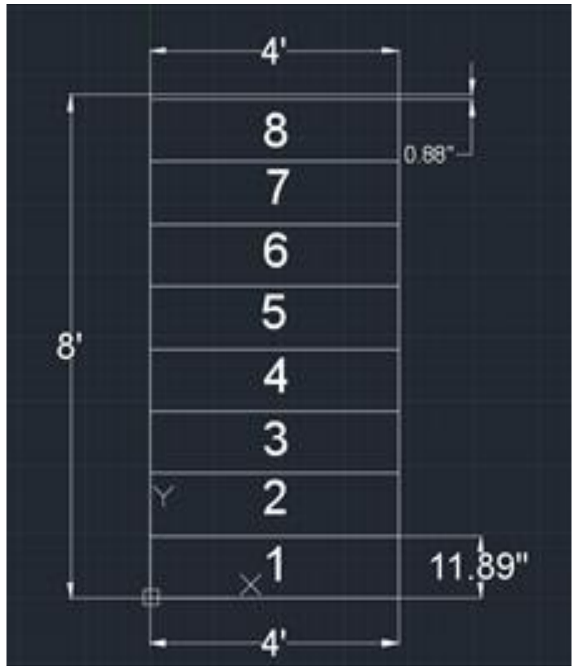

Figure 17 - CAD Drawing for Operation 1

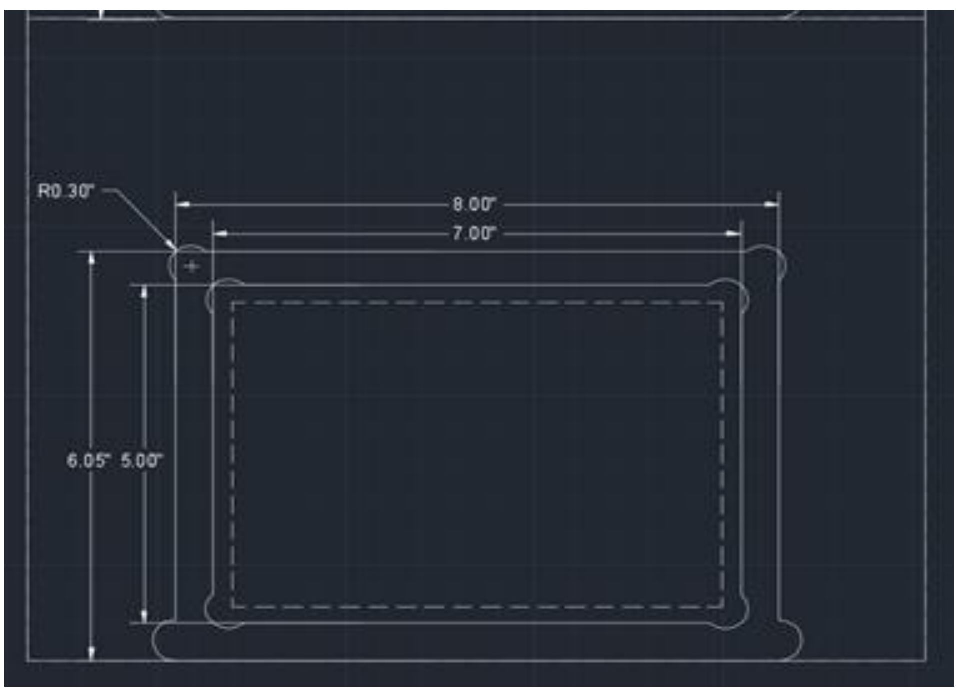

Figure 18 - CAD Drawing for Operation 2

Figure 19 - Operation 2: Prototype (4 of 5 Frames)

In operation 3, one 4’ x 11.89” piece was taken to the radial arm saw to be cut into five individual 9.49” x 11.89” pieces. **Figure 20** displays the CAD drawing for operation 3, detailing these cuts.

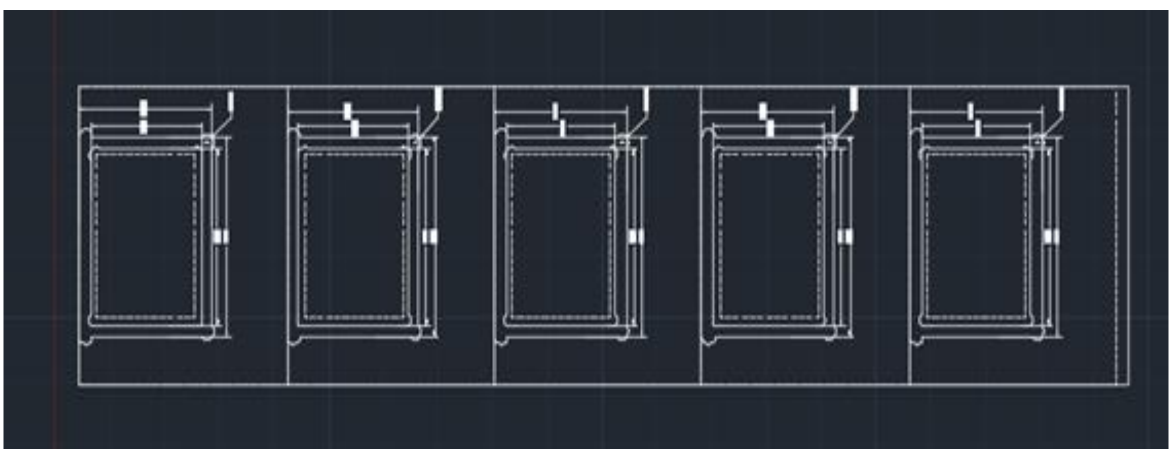

Figure 20 - CAD Drawing for Operation 3

In operation 4, two of the individual 9.49” x 11.89” pieces are taken to the Toyoda CNC Mill and secured into a specially designed clamp. During operation 4, the reverse bevel, front opening, and groove for the gold plastic plating are milled. **Figure 21** displays the CAD Drawing for operation 4, detailing these cuts. Although a Toyoda CNC Mill is extremely expensive to rent or to buy, the cost savings of the current process outweighed the cost of the special equipment, materials and labor time that would have been necessary to make frames the traditional way by cutting 4 individual sides and having to ensure that all 4 corners aligned perfectly. With the Toyoda CNC Mill, every operation produced frames with perfectly aligned corners.

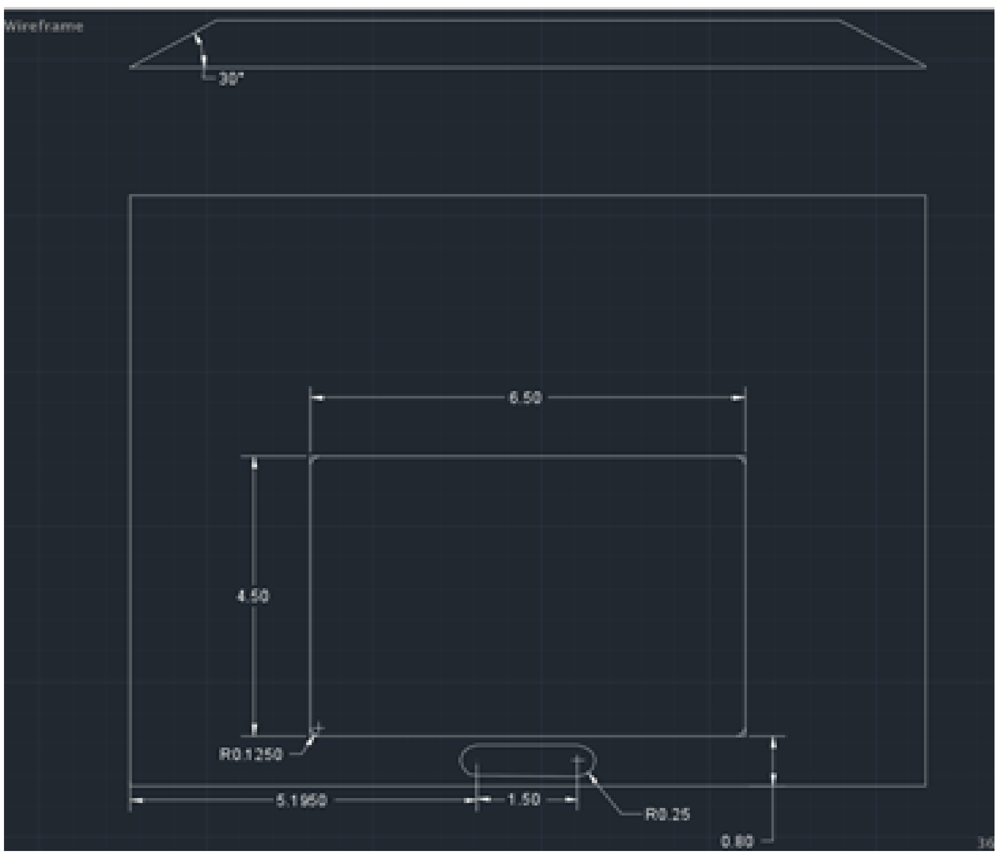

Figure 21 - CAD Drawing for Operation 4

In operation 5, the two frames were taken to the Epilog Laser to be engraved with the University of Mississippi logo. The logo was chosen from the Creative Toolbox of the University of Mississippi [5]; it is officially recognized as the Crest-UM Vertical. **Figure 22** displays the logo used for engraving. The engraving was centered above the front opening of the frame, as seen in **Figure 23**. Different speeds of the Epilog Laser were tested to determine what settings burned the darkest and created the most prominent engraving.

Figure 22 - Logo Used for Engraving

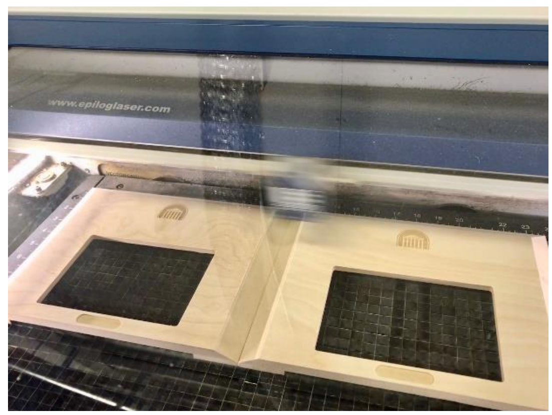

Figure 23 - Operation 5: Logo Placement

In operation 6, the two engraved frames were taken to the paint station to be finished. As the MDF plywood used in making the frame was a wood composite, machining produced dust on the edges of the frame. The clear spray finish was applied in two coats to seal the edges and provide a smooth glossy finish on the front and the back of the frame. The time required in between coats and before moving to the next operation was minimal, as the clear spray finish was very quick drying.

In operation 7, the two engraved and finished frames were taken to the assembly station to be assembled. Assembling consisted of placing the glass piece and promotional photo in the deeper groove, placing the frame backing in the shallower groove, and stapling the frame backing in place. Each frame backing was secured with 6 staples. One frame is assembled at a time.

In operation 8, the two engraved, finished, and assembled frames were adorned with the appropriately engraved gold plastic plating. As mentioned earlier, extreme precaution was necessary in adhering the gold plastic plating, as reworking this operation is not possible at this time.

In operation 9, a sheet of wax paper was cut from a roll using a box cutter. This piece of wax paper was placed above finished frame in the finished frame box, to protect the surface of the front of the frame from being scratched by the frame placed on top of it. Wax paper was a temporary solution for packaging. If GradYear continues to operate on a smaller scale, wax paper is satisfactory; pre-cut wax paper would be an easy optimization. However, if GradYear expands, as is detailed in later sections, a new solution for packaging would have to be developed, which would subsequently increase the cost per frame.

3. Prototype

Figure 24 displays the final prototype for the fall semester. Each material and operation was chosen with careful consideration. The final prototype satisfied the two objectives of GradYear – it was a classic, wooden frame emblazoned with the alma mater *and* graduating class of the consumer. As the first product of GradYear, and as a tribute to its timeless style, the frame was named the GradYear Classic. The team and the faculty were pleased with the design and appearance of the GradYear Classic; major changes to the materials or to the operations were not anticipated.

Figure 24 - Final Prototype (Fall 2018)

Phase 3: Trial & Production

In January, the team was notified that GradYear had been scheduled for four trial and production periods. The goals of the two trial periods were to give each team member an opportunity to try all of the operations and to give the team an opportunity to make any last-minute changes that were needed before production. During the trial periods, the team also prepared work in progress (WIP) for the following production periods. WIP is recommended for an optimized process, as it allows the cycle to flow continuously because there is a constant supply of material ready for the next operation. The goals of the two production periods were to see how the team performed and to see if the production estimates from the fall semester could be met. Below is a record of the original process flow from the trial period, the corrected process flow from the production period, and an optimized process flow to be implemented in the future, and the defects that were discovered and the improvements that were made during the trial and production periods.

1. Trial & Original Process Flow

The original process flow from the trial periods was organized in a linear fashion along the natural boundaries of the CME factory floor. It consisted of two operators and nine operations. **Figure 25** displays the original process flow used during the two trial periods, not drawn to scale. Operator 1 was tasked with operations 1-4. Operator 2 was tasked with operations 5-9.

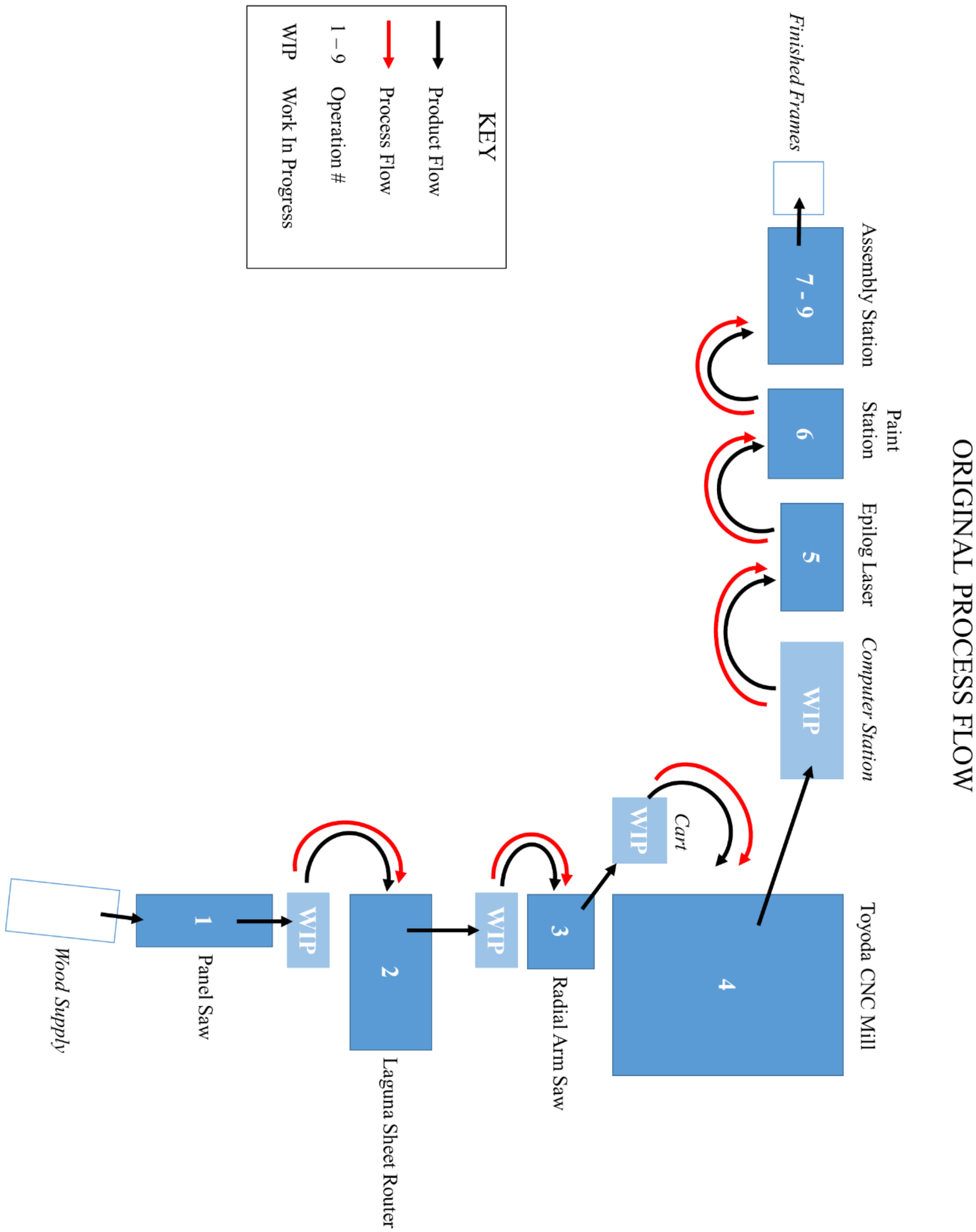

Figure 25 - Original Process Flow

The original process flow was very balanced, as the time it took to complete operations 1-4 was comparable to the time it took to complete operations 5-9. However, there is always room for improvement, and the team closely examined the process and products from the trial periods to try and identify potential areas of the production line where lean manufacturing principles could be applied. The goal of lean manufacturing and production is defined in the scientific article, “Integrating ergonomics and lean manufacturing principles in a hybrid assembly line,” as “reduc[ing] costs and increas[ing] productivity by eliminating waste” [8].

Upon close inspection, the frames produced from the original process flow had far too many “fuzzies” or rough edges. While satisfactory for the majority of the purposes of this process, MDF plywood is essentially just glued sawdust. During machining, as the layers are routed and beveled away, the edges become rough and need to be sanded down. Another problem was that some of the sawdust had stuck to the frame – and had subsequently been sealed to the surface during operation 6. Against the wishes of the team’s engineer, the author (acting as operator 1) decided to add two operations to the process for sanding and vacuuming. Although adding operations seemingly goes against the mindset of lean manufacturing, it actually helped to standardize quality and reduce scrap parts. A frame with frayed edges and sealed-over sawdust simply did not meet the level of quality that the team wished to maintain. **Table 2** displays the updated sequence of operations.

Table 2 – Updated Operations

Operation	Machine / Location	Activity
0	Epilog Laser	Engraving
1	Panel Saw	Cutting
2	Laguna Sheet Router	Routing
3	Radial Arm Saw	Cutting
4	Toyoda CNC	Milling
5	Sanding Station	Sanding
6	Shop Vacuum	Vacuuming
7	Epilog Laser	Engraving
8	Paint Station	Finishing
9	Assembly Station	Assembling
10	Assembly Station	Adhering
11	Assembly Station	Packaging

Sellers (acting as operator 2) also detected an area of improvement; she realized the need for another WIP station between the Epilog laser and the paint station. Before the two production periods began, the team was able to acquire a wire shelf to serve as a new WIP station, as seen below in **Figure 26**.

Figure 26 - New WIP Station

2. Production & Corrected Process Flow

Figure 27 displays the corrected process flow that was used during the two production periods, not drawn to scale.

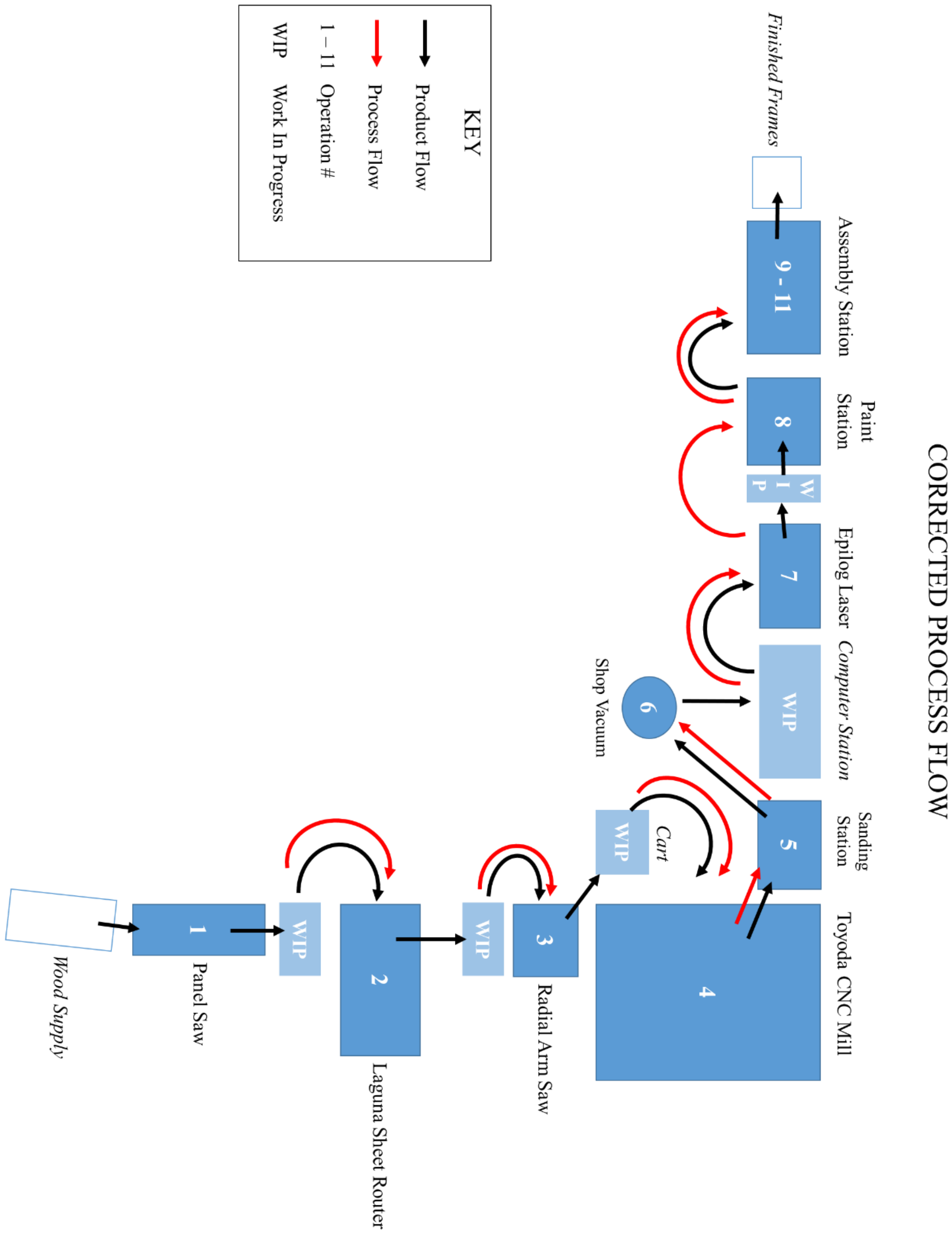

Figure 27 - Corrected Process Flow

Table 3 contains a breakdown of time in seconds per operation, noting the product and the quantity of the product that was produced at the end of the operation.

Table 3 – Operation Time Breakdown

Operation	Time (seconds)	Product	Quantity Produced
0	420	Engraved Gold Plastic Plates	50
1	80	4' x 11.89" piece of MDF	8
2	1000	4' x 11.89" piece of MDF, routed	1
3	50	9.49" x 11.89" pieces of MDF, routed	5
4	130	Frame	2
5	60	Sanded Frame	2
6	60	Sanded, Vacuumed Frame	2
7	200	Sanded, Vacuumed, Engraved Frame	2
8-11	300	Completed Frame	2
Total (1-11)	1880		

Note that while the time for operation 0 is listed, it is not included in the total time as it is done prior to the production period beginning.

With no WIP, a straight run-through of operations 1-11 should last 1880 seconds, or 31 minutes. From **Table 3**, it appears that only 2 frames were produced in 31 minutes. This is misleading, as although only 2 frames were fully finished, there were many unfinished frames in WIP throughout the 11 operations. A straight run-through was never done, as cycle times of each operation vary greatly. Operators were to use their judgment to balance cycle times and WIP. Operation 2 was by far the longest process; it took roughly 1000 seconds, or 16 minutes to complete. As the main potential bottleneck, the rest of the operations were completed around operation 2. To be as effective as possible, the Laguna Sheet Router always had to be running. Operator 1 had to vary the production rates of operation 1 and operation 3 to balance all of the WIP and keep operation 2 supplied at all times.

Before the trial and production periods, it had been difficult to determine the cycle time of the process. Cycle time is defined by Kashyap Trivedi in an article for minterapp, an online time tracking tool, as “the time taken to produce one unit from the start to the end” [9]. This difficulty was attributed to the fact that the number of frames that could potentially be made per piece of MDF decreased from 40 to 5 to 2 to 1 throughout the 11 operations. One frame was not cut from the original 4’ x 8’ piece of MDF, routed, milled, and engraved at a time. However, after tracking one frame all the way through completion, it was ascertained that the total time to create 1 frame was roughly 1560 seconds, or 26 minutes, plus or minus some time depending on the operators’ skill levels and familiarity with the operations. A traditional benefit of calculating cycle time is that it can give an idea of the production rate; however, in this process, cycle time was not at all indicative of production rate [9]. Again, it is crucial to remember that while only 1 frame was fully finished in 26 minutes, there were many unfinished frames in WIP throughout the 11 operations. **Table 4** contains a breakdown of time in seconds per operation for 1 frame.

Cycle time is usually discussed along with takt time and lead time. Takt time is equal to the total productive minutes divided by the total required units [9]. Lead time is “the total time taken for a unit from getting an order to receiving payment” [9]. However, for the purposes of this product, takt time could not be calculated because there was not an official demand or requirement beyond the scope of 39 frames for the 39 members of the CME Senior Capstone Class of 2019. Lead time was similarly not able to be calculated because it was out of the scope of the project.

Table 4 - Operation Time Breakdown for 1 Frame

Operation	Time (seconds)
0	-
1	10
2	1000
3	10
4	130
5	30
6	30
7	200
8-11	150
Total	1560

- If only 1 cut was made in operation 1, and only one 4’ x 11.89” piece was made, it would only take 10 seconds.
- If this 4’ x 11.89” piece was routed by the Laguna Sheet Router in operation 2, it would still take 1000 seconds because the program was designed to route 5 frames at once; the program would have to be rewritten if only 1 frame was to be produced.
- If only 1 cut was made in operation 3, and only one 9.49” x 11.89” piece was made, it would only take 10 seconds.

- If this 9.49” x 11.89” piece was milled by the Toyoda CNC Mill in operation 4, it would still take 130 seconds because the program was designed to mill 2 frames at once; the program would have to be rewritten if only 1 frame was to be produced.
- If only 1 frame was to be sanded in operation 5, it would only take 30 seconds.
- If only 1 frame was to be vacuumed in operation 6, it would only take 30 seconds.
- If only 1 frame was to be engraved in operation 7, it would still take 200 seconds because the program was designed to engrave 2 frames at once; the program would have to be rewritten if only 1 frame was to be produced.
- If only 1 frame was to be completed in operations 8-11, it would only take 150 seconds.

Each production period was 1 hour in duration. The original goal for the production periods was to produce 20 frames per production period. This production rate was set by Fanning and was based purely off of the machine cycle times and did not account for handling time. It also assumed a level of WIP that could compensate for the bottleneck of operation 2 (taking approximately 16 minutes and only producing 5 frames). Without established WIP, it would be impossible to meet the original goal of 20 frames per hour. During the first production period, the team produced 13 frames. During the second production period, the team produced 17 frames. This increase was due to the operators’ increase in experience and familiarity with the machines and operations which reduced handling time. The author, who operated as operator 1, agrees that with more practice, the production rate will increase slightly. However, she believes that 20 frames per hour will only be attainable with the optimized process flow described below.

3. Optimized Process Flow

Figure 28 presents a proposed optimized process flow, not drawn to scale. Note that while the operations have remained the same, the machines and WIP stations and activity stations have been rearranged to suit a circular flow of products and processes.

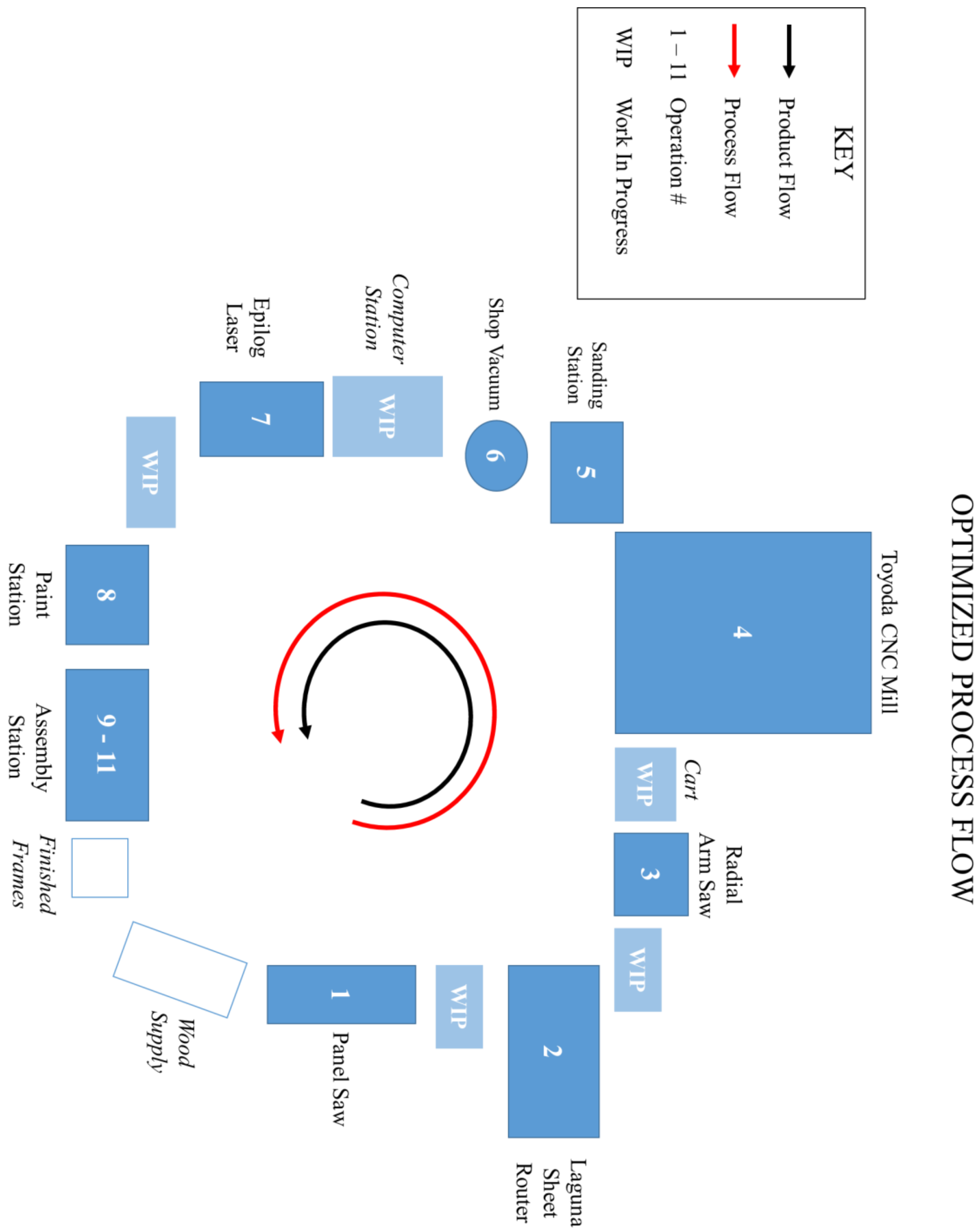

Figure 28 - Optimized Process Flow

Working around the CME factory floor layout to create the most optimal floor layout of this process was a bigger challenger than the team expected. While the team was able to create a linear flow during its trial and production periods, a circular flow, as seen previously in **Figure 27**, with all of the machines closer together, would have been more favorable. Motion and material movement are two forms of waste that negatively affect productivity [8]. If GradYear were to become its own company and rent its own facility, a new floor layout would greatly increase efficiency, as time spent walking and moving materials would be reduced. More optimal WIP stations could also be introduced to further reduce movement. If the machines were also optimized for the specifications of the GradYear Classic, the time spent calibrating and reconfiguring could be reduced. If the operators worked on the production line 8 hours a day, 5 days a week, proficiency would increase and handling time would be reduced. All of these small changes could cause the cycle time to reduce, and the production rate to increase to 20 frames per hour.

4. Defects & Solutions

Defect #1

Some of the MDF plywood pieces used during prototyping and during the trial periods were from older pieces of MDF plywood that had been left from other projects on the CME factory floor. The increased exposure on the factory floor (months, possible years) caused understandable wear and tear on the wood. **Figure 29** shows one of the completed frames from a Trial period that had a black dirt / dust smudge that wasn't noticed and was sealed with the clear spray finish. The team attempted to use a sanding power tool to sand over the birch veneer to remove any dirty smudges before the spraying operation, but this proved to be too powerful and actually stripped some of the surface completely off, as seen in **Figure 30**. The solution to the smudging was to use fine-grit sanding blocks, lighting brushing them over the surface of the birch veneer.

Figure 29 - Defect #1: Trial Frame (Smudge)

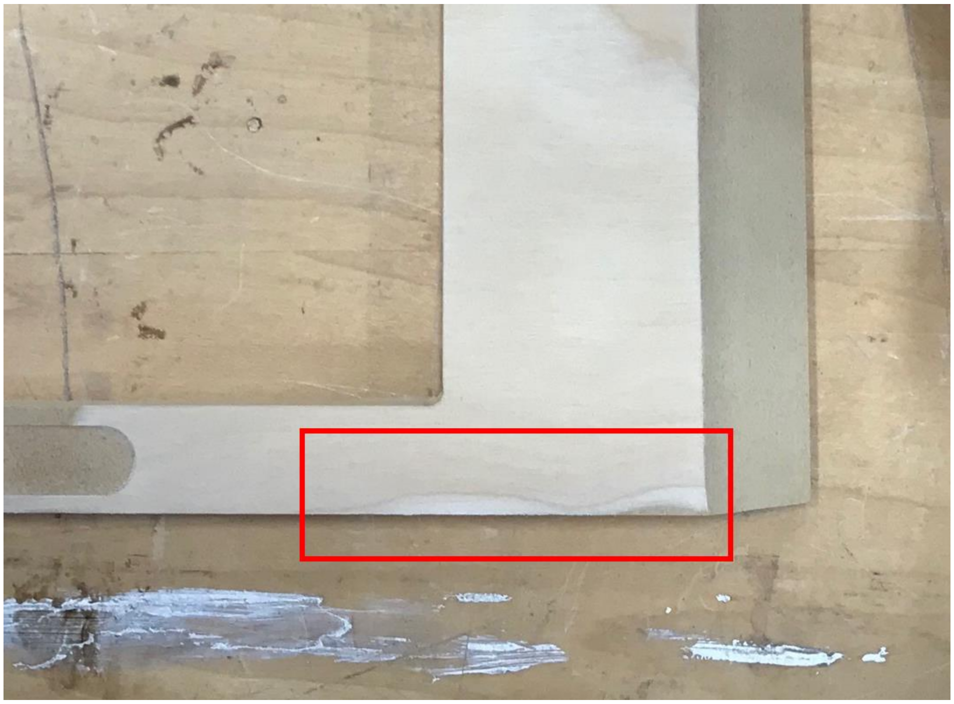

Figure 30 - Defect #1: Trial Frame (Power Sander)

Defect #2

During one of the Trial periods, a frame came out of the Toyoda CNC Mill with a large miscut, as seen in **Figure 31**. The team determined that this defect came from slippage while inside the Toyoda CNC Mill. The frame had slipped in the vice grips, becoming misaligned. The machine had operated as normal, but the misplacement of the frame caused the miscut on the front opening. Fortunately, this defect had an easy solution. The vice grips were removed from the machine and sandblasted, as seen in **Figure 32**. Sandblasting the vice grips created a rough surface for the frame to sit on when in the machine, which allowed for a better hold and eliminated slippage. This solution proved to be completely effective, as this defect was not seen again in the rest of the trial and production periods.

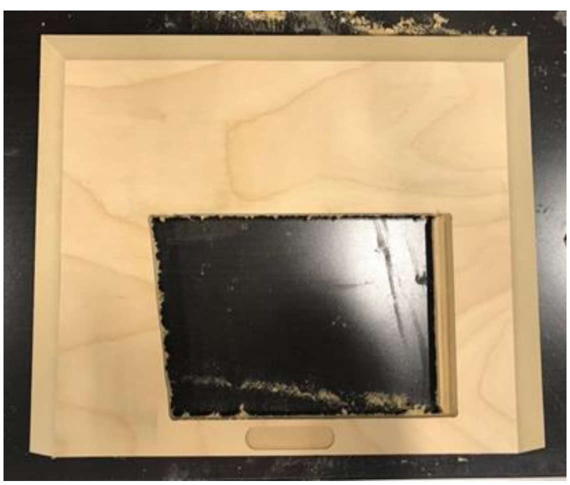

Figure 31 – Defect #2: Miscut

Figure 32 – Defect #2: Solution (Sandblasting Vice Grips)

Defect #3

As this process included a lot of human handling, human errors were bound to occur. One notable defect caused by human error occurred in operation 4. When placing the frame in the grips of the Toyoda CNC Mill, the frame was not placed all the way against the stop. This caused the bevel to cut unevenly, as seen in **Figure 33**, and for the front opening to be slightly off-center, as seen in **Figure 34**. This defect was only seen once during the four days of trial and production. The operator was reminded to be careful when placing the frame in the grips, and to be sure that the frame was butted against the stop.

Figure 33 - Defect #3: Uneven Beveling

Figure 34 - Defect #3: Off-Center Front Opening

5. Kaizen Improvements

Kaizen is a revered Japanese business philosophy, also founded by Taiichi Ohno, that focuses on continuous improvement. According to Ohno [10], the most important aspect of kaizen to remember is “to do kaizen when times are good, the economy is strong, and the company is profitable.” Luckily, the team did not face the typical cost limitations or pressures of a real company, and were able to apply principles of kaizen to the production line during the four trial and production periods.

One principle of kaizen is poka-yoke, or error-proofing. In his book, “Kaizen Assembly: Designing, Constructing, and Managing a Lean Assembly Line,” Chris Ortiz [11] defines a poka-yoke device as something that “prevents incorrect parts from being assembled, or [that] easily identifies a mistake.” After careful analysis of the process flow during the trial periods, the team identified two potential areas for poka-yoke. The team was able to devise and implement two poka-yoke devices on the production line during the production periods. Over time, these mechanisms greatly reduced the number and value of scrap parts, as errors were caught earlier in the production line.

In operation 1, the 4’ x 8’ sheets of MDF plywood are slid from the wood supply cart onto the panel saw, as seen in **Figure 35**. This movement was difficult, as the sheets were large and heavy and sliding back and forth fractions of an inch to hit the right measurement was tedious.

Figure 35 - Wood Supply to Panel Saw

To eliminate the continuous measuring, duct tape was used to create the first poka-yoke device, a visual stop. Instead of a physical stop that would slowly move as the sheet is repeatedly slid against it, a visual stop was an application of visual management, another principle of kaizen, and was used to help align the sheet before cutting, thereby eliminating measurement error and reducing handling time. Duct tape was also used to create the second poka-yoke device, a “go or no-go” gauge. Once the 4’ x 11.89” piece was cut from the original sheet, it was slid over to the “go or no-go” gauge. If the piece did not fit perfectly within the four duct tape markings, it was either reworked for being too large (recut the piece to make it smaller) or scrapped for being too small. These two poka-yoke devices are seen in **Figure 36**. By error-proofing the first operation, parts were either reworked or scrapped at the cheapest point in the process.

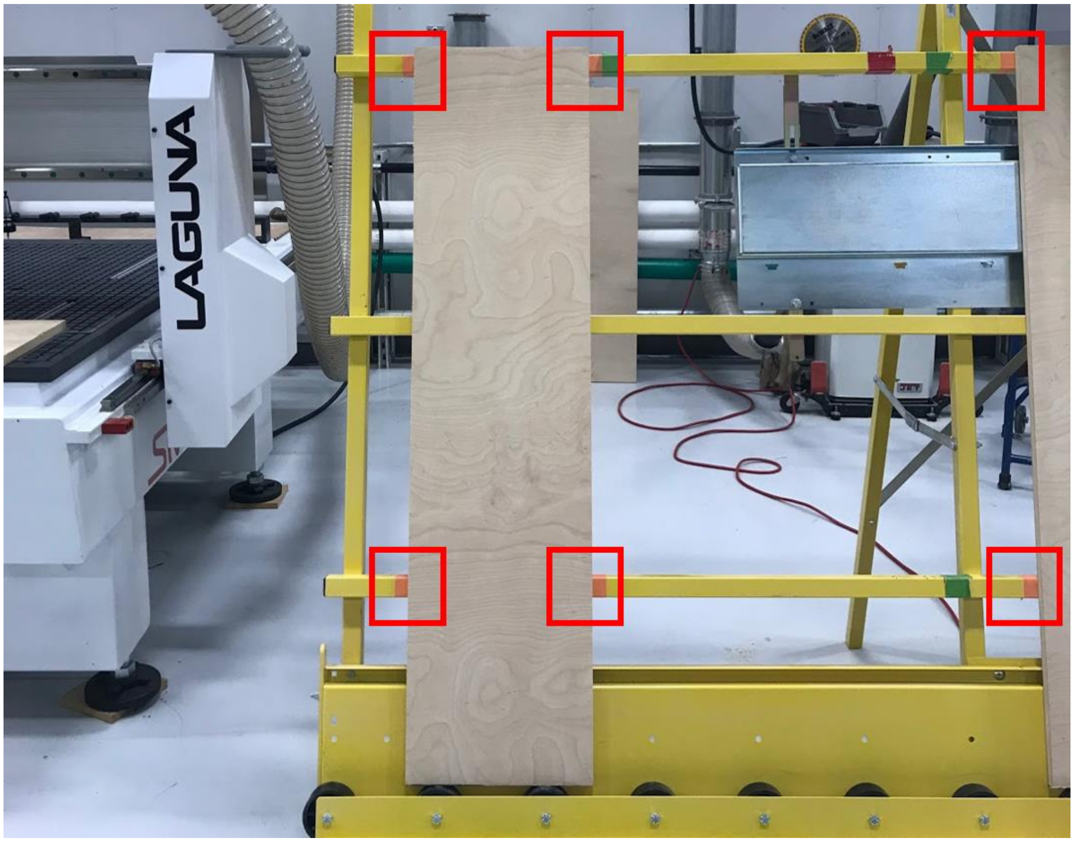

Figure 36 – Poka-Yoke Devices

After the successful implementation of the first and second poka-yoke devices, the team identified another measurement that could be poka-yoked. In operation 3, after the first 9.49” x 11.89” piece of wood was cut with the radial arm saw, it needed to be measured, as demonstrated in **Figure 37**. If the first 9.49” x 11.89” piece of wood was not the correct length of 3” from the top of the frame and the top of the back cut, all of the following frames from that 4’ x 11.89” piece would have incorrect dimensions as well. If the error was not caught on the first frame, it was possible that the following 4 frames would all be wrong, and all 5 frames would have to be scrapped. If the error *was* caught on the first frame, it was possible to rework some of the following 4 frames. Incorrect dimensions after operation 3 could lead to warping in the Toyoda CNC Mill, misalignment in engraving in the Epilog laser, or simply being incompatible with the frame backing. Although measuring the top of the frame to the top of the back cut was simple enough, another duct tape "go or no-go" gauge could have been used in this situation to more easily check the frame's dimensions. The team would recommend implementing this third poka-yoke device in the future.

Figure 37 - Measuring Distance after Operation 3

Several other kaizen principles were implemented between the first and second production periods at the assembly station (where operations 8-10 occur). **Figure 38** displays the assembly station on the first day of production and **Figure 39** displays the assembly station on the second day of production.

Figure 38 – Assembly Station on Production Day 1

Figure 39 – Assembly Station on Production Day 2

The first kaizen principle to be implemented was a *motion study* of the operator at this work station. From the initial layout of the assembly station, the operator had to bend down to throw away trash while assembling the frame, and had to bend down to place the finished frames in the box that was on the floor. By simply moving the box of finished frames up onto the table, the operator's bending was reduced by 50%. Each extra bend had ultimately been a waste of time, so this was an example of *waste reduction* as well. It was also a crossover with *ergonomics,* the "scientific approach to analyzing the interaction between the human body and its environment," as moving the box greatly alleviated the operator's back pain [11].

The second kaizen principle to be implemented was another visual management technique called *shadow boarding,* where "an outline or image of a tool [is used] to represent where it should be stored" [1]. The operator had previously had difficulty remembering where tools were and frequently had to rummage around the assembly station to find what she needed. Duct tape was used to create boxes around where tools belonged, to help the operator remember where to put things when she had finished with them. The operator described this process as "giving all of the tools a home" at the assembly station. Moving the location of the finished frames box and shadow boarding the assembly station were two simple things that were done in approximately 10 minutes that greatly reduced the time required to complete operations 8-11.

From the first day of production to the second day of production, the time required to complete operations 8-11 was reduced by over 50%, and the total production rate increased from 13 frames to 17 frames.

Phase 4: Strategic Planning

The following phase, comprised of a brief risk analysis, marketing plan, and financial report was written under the assumption of full production, unless specified otherwise. In this scenario, GradYear is its own company with its own production facility that operates with the optimized process flow (seen earlier in **Figure 28**) and has a production rate of 20 frames per hour. Madeline Sellers created the original marketing plan, and Mattie Huey both compiled and analyzed the original financial report.

1. Risk Analysis

As a startup company, there were many potential challenges to overcome. The main risk for GradYear was the potential that the product would not take off as projected and that the company would "go under." There are endless other scenarios of risk ending in the failure of GradYear; for example, the product could have a great starting point but sales could plummet after a few months, resulting in the company going under. There are too many scenarios of risk ending in failure to define or even attempt to negate - the overall risk in launching a startup company is well known by all, and impossible to mitigate. Instead, this risk analysis will discuss a recent industry report, internal risk factors and external risk factors.

According to IBISWorld Industry Report OD4270 [12], the picture frame industry is at significant risk. Overall, the picture framing store industry is on a multi-decade decline, as major corporations are starting to offer additional framing services and e-commerce continues to “steal” business from brick-and-mortar stores. However, the overarching consensus of the report is that, as disposable income in the U.S. continues to rise, it will slow the industry’s decline. As GradYear will not have a physical storefront and will actually capitalize on e-commerce, the odds seem favorable. GradYear also has an advantage in its integrated cost leadership-differentiation strategy – its product is highly unique and sold at a highly affordable price. The GradYear Classic is unlike anything on the market – and as such, it’s difficult to compare it to the rises and falls of today’s market.

Internal risk factors include material and labor going over budget, time and machine cost going over budget, manufacturing of product being more difficult or costly than originally projected, and technological issues. Thankfully, the team’s engineer took a conservative design approach, refusing to start on a prototype until she was almost 100% certain it was the perfect design. The team has spent very little of its budget prototyping, and from the team’s projections, everything that is needed for production is well within the team’s means. Mr. McPhail has been an enormous help in developing the manufacturing processes, and has worked with the team’s engineer to make everything as smooth as possible. The original internal risk factors have been assuaged at this point in time.

External risk factors include competitors entering the market with similar products, the target market being eliminated as the industry shifts, and potential macroeconomic changes whose ripple effects create risk. After speaking with the patent lawyers who came to the Manf 451 Design-Product Realization class, the team was ultimately told that because of its simplicity, there was no way to patent or otherwise protect the design of the GradYear Classic. The team can only hope that its first-mover advantage will be enough to offset the risk of competition. If the target market of Ole Miss graduates is completely eliminated, GradYear's design and manufacturing processes are flexible enough to incorporate other school's insignias and try other demographics before completely collapsing. As for macroeconomic shifts, GradYear does not have the budget to pay for lobbyists to counteract those changes - the team can only do their parts as individual citizens to keep the macroeconomy stable.

2. Marketing Plan

Figure 40 and **Figure 41** display the GradYear logos, overlaid on gray backgrounds. These logos can be used interchangeably to best suit the needs of the particular memo.

Figure 40 - GradYear Logo in Black

Figure 41 - GradYear Logo in White

Target Market

Unlike most schools, the University of Mississippi does not hold a graduation ceremony in the fall for its fall graduates; instead, they request that fall graduates return to their alma mater in the spring if they wish to walk across the stage. Therefore, GradYear’s primary target market are the male and female Ole Miss seniors who are graduating in the month of May. An extension of this target market are the students graduating in the month of December, but as many do not participate in the traditional graduation festivities, they are a much harder market to reach. Another extension of this target market are the older family members of the graduates, and as they usually have a higher disposable income, they are an easier market to reach.

Unique Selling Proposition

Graduating from a 4-year university with a Bachelor's degree is a huge milestone in life, and it is the team’s strong belief that students should celebrate their GradYear.

The GradYear Classic is the only readily available frame in Oxford that boasts official University of Mississippi logo and the message “Class of ____” on a classic, 5” x 7” wooden picture frame. It is a traditional and professional styled frame that can be used in the home or office to honor the hard work and the long hours that students put in to graduate from the University of Mississippi.

Pricing and Position Strategy

As seen earlier in **Figure 5**, the Survey 1 results suggested that consumers would be most likely to pay for a graduation photo frame of this genre if it were priced between

$20-$39. The team meets this parameter, as the price point for the GradYear Classic has been set to $35. These frames may be sold to various stores around Oxford that are likely to reach our target market. The GradYear Classic was presented to the LilyPad (on Courthouse Square), and Rebel Rags (on Jackson Ave.). Both stores expressed great interest in the product, and provided the contact information for their buyers. From the initial market research done in September, to the positive feedback received in April, it is clear that the GradYear Classic is a product that people and businesses would love to purchase, if available.

Distribution Plan

At this time, there is not a defined distribution plan for GradYear, as it would depend on the production volumes, the layout of the facility, and the consumers.

If GradYear begins selling business to consumer (B2C), frames would likely be ordered in small quantities and would either have to be picked up at the facility or shipped to the consumer. In testing, a frame was shipped via a standard bubble mailer labeled "FRAGILE" by the United States Postal Services (USPS) to a team member's home in Texas. It cost $13 to mail, and the frame arrived undamaged in 2 days. Shipping costs would obviously vary depending on final destination, but without a contract with a delivery service, would be around $13 per frame. Shipping cost would need to be covered by the consumer.

If GradYear begins selling business to business (B2B), frames would likely be ordered in large quantities and would either have to be picked up at the facility or shipped to the consumer. In the contract with the buying business, it will need to be specified that the buying business is responsible for shipping and transportation. Another contract with a delivery service would need to be initiated when shipping large quantities.

Promotion Strategy

If GradYear were to sell B2C, it would need to launch a full-scale promotion strategy to reach the target market. As specified later in the financial report, in the full production scenario, GradYear will need to sell 412 frames to break-even. Assuming a 1:1 ratio, that each consumer will only buy 1 frame, GradYear will need to reach 412 consumers, or graduates. To do so, GradYear will need to create various social media accounts and engage with local organizations to promote awareness. Flyers can be posted around campus and around the Oxford Square. Chalking sidewalks is another popular way to promote startups or products on campus; however, GradYear would need to get approval from the university before doing so.

From the positive responses from Survey 1 and from personal interactions, if people know about the GradYear Classic, they want one, either for themselves or for a friend or family member. The GradYear Classic sells itself. The GradYear team just needs to let people know about it.

3. Financial Report

Startup Costs

Startup costs, also known as prototype costs, include direct materials, direct labor, machine rental, and various other costs associated with starting up the project, prototyping, and product design. For the purposes of this project, both the fall and spring semester spending was attributed to startup costs. The CME did not charge the team for machine costs during the fall or spring semester and the team was not compensated for their hours on the factory floor during Phase 2 and Phase 3; therefore, the GradYear startup costs only include direct materials.

Table 5 identifies all materials purchased during the fall semester, totaling $169.46. Many of the purchased items were not used in actual production but ultimately aided in the selection of more effective materials. The costs incurred to acquire both the used and unused material are considered startup costs.

Table 5 - Fall Semester Spending (Startup Costs)

Vendor	Item(s)	Quantity	Price ($)
-	Leftover MDF Sheets	1/2	$17.67
Amazon	Turn Buttons - Not Used	N/A	$5.99
National Aircraft	Frame Backings	5	$27.20
Walmart	Glass Pieces	5	$39.10
Carinapicture	Frame Backings - Not Used	N/A	$41.10
Home Depot	Spray	6	$38.40
			$169.46

Note that the first record is for “Leftover MDF Sheets.” This wood was left over from previous projects on the CME Factory Floor. Appropriate costs were allocated as if the team purchased these MDF sheets from the CME, but these costs were not officially incurred.

Table 6 identifies all materials purchased during in the spring semester, totaling $612.21. The portion of these costs that were necessary in the initiation of frame production were also considered startup costs. For example, this included materials such as wood sheets, glass pieces, and frame backings. These materials were used in the production of 70 frames.

Table 6 - Spring Semester Spending (Startup Costs)

Vendor	Item(s)	Quantity	Price ($)
Walmart	Glass Pieces	60	$120.95
National Aircraft	Frame Backings	60	$182.50
Home Depot	Sand Block	1	$3.18
Home Depot	Wood Sheets	2	$70.66
Home Depot	Blades	4	$11.93
Amazon	Wax Paper	2	$9.97
Home Depot	Sand Block	2	$6.36
Home Depot	Staples	1250	$23.61
BF Plastics	Gold Plastic Sheet	1	$33.60
Walmart	Glass Pieces	20	$56.20
National Aircraft	Frame Backings	20	$82.05
Home Depot	Spray Handle	1	$11.20
			$612.21

The original budget estimation for this project was $650.00, however, actual spending from the fall semester and the spring semester totaled $781.67. The additional costs were attributed to unanticipated purchases such as sand blocks, wax paper, and a spray handle. Furthermore, a last-minute change in wood supplier also caused an increase in spending.

Machine Costs

Table 7 identifies the machine costs of the entire process, from operation 0 to operation 11. The costs to rent and the costs to buy for each machine / tool were given to the team from the CME.

Table 7 - Machine Costs

Machines / Tools	Cost to Rent ($) / 1 Hour	Cost to Buy ($)
Panel Saw	$10.00	$4,099.00
Laguna Sheet Router	$50.00	$43,895.00
Radial Arm Saw	$10.00	$10,000.00
Toyoda CNC Mill	$100.00	$354,185.42
Epilog Laser	$50.00	$26,001.85
Paint Station	$10.00	$7,852.72
File	-	$20.00
Staple Gun	-	$70.00
	$230.00	**$446,123.99**

Not that the costs to rent the file and the staple gun were not listed, and therefore considered negligible.

Projected Operating Income

The projected operating income statement is based on a number of assumptions. If operations continue through future periods, certain elements of the statement, such as material and labor costs, will become more closely aligned to actual costs. In this scenario, machine costs are allocated as if the machines were rented on an hourly basis. Furthermore, the peripheral costs that have not actually been incurred in any sense during the course of the project, such as selling, general and administrative costs (SG&A), will become more accurate. As operations continue, the projection would rely less on assumptions and more on actual spending.

With that being said, projected calculations rely on the following assumptions:

1. The team decided that an appropriate target volume of production would be 20% of the graduating class (around 1,070 students), selling 1 frame per 1 student. Survey 1 revealed that students would be willing to spend $35 on the product; this provided the basis for projected selling price. The projected operating income statement will assume that GradYear produced 1,070 frames and sold each one for $35, generating sales of $37,450.

   Sales = 1,070 frames x $35 = $37,450

2. Many direct materials used in production are purchased in batches, making them variable costs. The remaining direct materials are considered variable, meaning they vary directly with units produced. **Table 8** classifies each direct material cost

as either step or variable and projects them out to show total cost of direct materials necessary to meet production of 1,070 frames.

a. Upon attempt to reduce direct material costs, the team noticed that the frame backings were the most expensive direct material when considered on a per unit basis. The team considered alternative methods of acquiring such material, including in-house production of the frame back. However, production of such an item would cost five times as much as purchase, based on labor fees alone. Therefore, the team agreed that purchasing frame backings was necessary.

Table 8 - Preliminary Budget

Item	Cost ($)	Cost per unit produced ($)	Type	How many frames can be made with it?	Cost projected out to produce 1,070 frames
Frame Backing	$3.04	$3.04	Variable Cost	1	$3,252.80
Wood	$35.33	$0.88	Step Cost	40	$953.91
Glass Pieces	$2.02	$2.02	Variable Cost	1	$2,161.80
Gold Plating	$33.60	$0.21	Step Cost	160	$235.20
Staples	$23.61	$0.11	Step Cost	208	$23.61
Stock Photo	$0.05	$0.05	Variable Cost	1	$53.50
Clear Spray	$6.40	$0.32	Step Cost	20	$345.60
					$7,026.42

Direct Material =$7,026.42

3. If the production rate is 20 frames per hour, then 54 production hours will be required to produce 1,070 frames.

Production Rate = 20 frames / 1 hour

Production Hours = 1,070 x Production Rate = 53.5 hours (rounded to 54 hours)

4. Direct labor includes two operators with compensation of $20 per 1 hour. This compensation was set on the recommendation of Dr. Jeremy Griffin, as it is comparable to the average compensation for manufacturing positions in northern Mississippi.

Compensation = $20 / 1 hour

Direct Labor = 2 Operators x Compensation x Production Hours = $2,160

5. Machines are assumed to be rented. Rent is stated separately from the allocation for overhead.

*Total Cost to Rent = $230 / 1 hour (as seen in **Table 7**)*

Machine Cost = Total Cost to Rent x Production Hours = $12,420

6. Overhead is allocated at 80% of direct material and direct labor costs, the standard for overhead allocation. Overhead costs include plant manager salary, indirect material, utilities, rent, security, property insurance, factory supervisors, etc.

Overhead = 80% of Direct Material + Direct Labor

Overhead = .8 (7,026.42 + 2,160) = $7,349.14

7. SG&A is allocated at 50% of direct material and direct labor costs. These costs would include packaging, marketing, sales, and other facility cost associated with operating the business. 50% is the standard for SG&A allocation.

SG&A = 50% of Direct Material + Direct Labor

SG&A = .5 (7,026.42 + 2,160) = $4,593.21

Figure 42 illustrates the projected income statement, featuring a calculation of cost of goods sold, gross margin, and the final operating income.

GradYear
Projected Income Statement
For the year ended December 31, 20XX

Sales			$37,450	
Cost of Goods Sold				
Direct Material				
	Glass	2,161.80		
	Wood	953.91		
	Frame Backs	3,252.80		
	Staples	23.61		
	Gold Plaque	235.20		
	Spray	345.60		
	Stock Photo	53.50	7,026.42	
Direct Labor			2,160.00	
Machine Cost			12,420.00	
Overhead			7,349.14	
Gross Margin				8,494.44
Sales, General, & Administrative Costs				4,593.21
Operating Income				$3,901.23

Figure 42 - Projected Income Statement (Version 1)

Figure 43 illustrates the projected income statement, featuring a calculation of variable costs, fixed costs, contribution margin, and the final operating income.

GradYear
Projected Income Statement
For the year ended December 31, 20XX

Sales			37,450.00	
Variable Costs				
	Glass	2,161.80		
	Wood	953.91		
	Frame Backs	3,252.80		
	Staples	23.61		
	Gold Plaque	235.20		
	Spray	345.60		
	Stock Photo	53.50		
	Machine Cost	12,420.00		
	Direct Labor	2,160.00	21,606.42	
Contribution Margin				15,843.58
Fixed Costs				
	Overhead			7,349.14
	Sales, General, & Adminsistrative Costs			4,593.21
Operating Income				3,901.23

Figure 43 - Projected Income Statement (Version 2)

Note that although overhead and SG&A costs are allocated based on percentages of variable costs, they are classified as fixed costs in **Figure 43**. In this financial report, overhead and SG&A were allocated by percentage in order to approximate costs that are unknown at this time. However, traditionally these two costs would be fixed costs, so they are designated as fixed costs.

Profit Margin

The profit margin is important in determining how much profit GradYear is actually making from a seemingly large amount of sales. The profit margin will be useful in the future when it can be compared to past and future performance, other products, and other companies similar in size and industry.

Profit Margin = Gross Margin / Sales

Profit Margin = $8,494.44 / $37,450 = 23%

Break Even Point (BEP) Analysis

The BEP in Units was calculated to determine how many frames needed to be manufactured and sold to cover the cost of production.

BEP in Units = Fixed Costs / Contribution Margin per Unit

Fixed Costs = $7,349.14 + $4,593.21 = $11,942.35

Contribution Margin per Unit = $15,843.58 / 1,070 frames = $14.81 / 1 frame

BEP in Units = 806.5 frames (rounded to 807 frames)

This analysis shows that production and sale of 807 frames at $35, below the goal production of 1,070 frames, will create enough revenue to cover the cost of production.

Rent vs Buy Analysis

As seen in **Table 7**, the cost to buy all of the necessary machines and tools for this process is $446,123.99. **Table 9** highlights the cost to rent all of the necessary machines and tools by yearly quarters (increments of 3 months). It would take 5 quarters, or 15 months, for the cost to rent to outweigh the cost to buy.

Table 9 - Rental Costs by Quarter

Hours / Week	Weeks / Month	Months	Production Hours	Cost to Rent ($) / 1 Hour	Cost to Rent ($)	Cost to Buy ($)	Rental Adv / Disadv.
40	4	3	480	$230.00	$110,400.00	$446,123.99	Advantage
40	4	6	960	$230.00	$220,800.00	$446,123.99	Advantage
40	4	9	1440	$230.00	$331,200.00	$446,123.99	Advantage
40	4	12	1920	$230.00	$441,600.00	$446,123.99	Advantage
40	**4**	**15**	**2400**	**$230.00**	**$552,000.00**	**$446,123.99**	**Disadvantage**

Note that the column “Production Hours” assumed the following calculation.

Production Hours = 40 hours / 1 week x 4 weeks / 1 month x Number of Months

- If GradYear was to only produce frames during the 3 months of the year leading up to graduation in May, purchase of the equipment would be preferable after four years in business.
- If GradYear increased the production period to 6 months a year, either in the 6 months of the year leading up to graduation in May, or split 3 months before graduation in May and 3 months before graduation in December, purchase of the equipment would be preferable after two years in business.
- If GradYear had a year-round production period, over 12 months the cost to rent is still below the cost to buy, so purchase of the equipment would likely be preferable

after two years in business. However, the owners of GradYear might decide that the roughly $5,000 difference from cost to rent to cost to buy was negligible, and consider the purchase of equipment preferable after just one year in business.

- If GradYear had a 15 month production period, the cost to rent outweighs the cost to buy by $105,876.01. It would be extremely preferable to purchase the equipment in the case of a 15 month production period, as to not waste $105,876.01 on rent.

In 15 months, GradYear will be able to produce 48,000 frames.

Production Rate = 20 frames / 1 hour

Production Hours = 2,400 hours x Production Rate = 48,000 frames

From these calculations, purchase of equipment seems to be the most economic choice. However, assuming production of twenty frames an hour for three, six, twelve and fifteen full months would result in the production of 9,600 frames, 19,200 frames, 38,400 frames, and 48,000 frames, respectively. Current goals only provide for the sale of 1,070 frames, requiring only fifty-four total hours, or around 10% of a quarter, of production. Therefore, for purchase of the equipment to be feasible or beneficial, the projected demand for the product would have to increase significantly.

Phase 5: GradYear Order Management System

The GradYear Order Management System (OMS) was an extension of the GradYear project designed to challenge the author and fully utilize her MIS knowledge. The author knew that she would have to build a software system useful for GradYear, and devised her semester projects for MIS 408: Database and Csci 390: Introduction to Scripting Languages to be compatible with the end product. With a normalized Structured Query Language (SQL) database, a website built with Hypertext Markup Language (HTML) and Hypertext Preprocessor (PHP), and a web hosting account with GoDaddy, an American Internet domain registrar and web hosting company, the author built the GradYear OMS, a web-accessible system that allows employees to manage orders, customers, and inventory.

The GradYear OMS was designed for the hypothetical future scenario wherein the CME Student Advisory Board (SAB) leverages GradYear as their annual fundraiser. In return for a $35 donation to the CME, which would then be allocated to the SAB's budget, the donor would receive a thank-you note and a GradYear Classic, customized to the recipient's graduation year of choice. Without a contract with one of the big shipping firms, shipping could be up to $13 per frame; the GradYear OMS was designed for pick-up only at this time.

1. Initial Design

The author initially designed the GradYear OMS as a series of sketches in a notebook. This technique is called wireframing; it is a way to visually represent the framework of the future website. It is especially useful for recognizing data containers. Below in **Figure 44** is a sketch of the login screen.

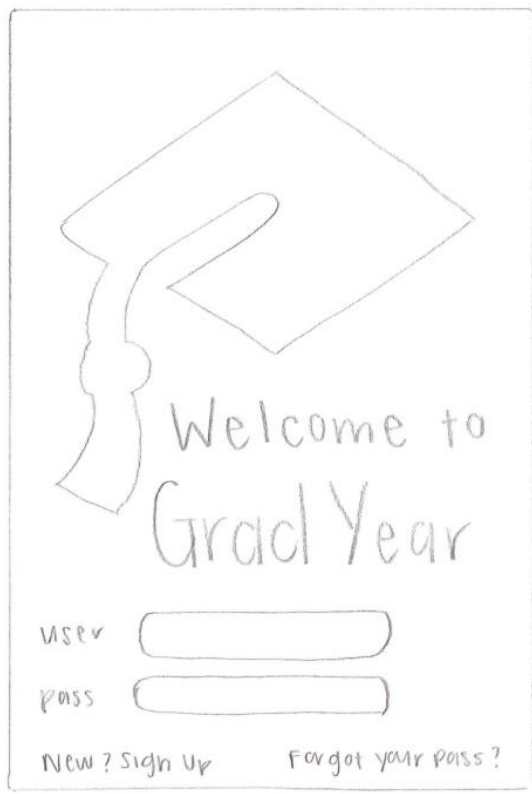

Figure 44 - Initial Design of Login Screen

2. Database Organization

After wireframing the page schematics, the author determined the database tables necessary to incorporate functionality into the GradYear OMS. **Figure 45** displays the database tables that were built. To database administrators, tables are also known as "relations" and each row of a table is known as a "record." The author used phpMyAdmin, a feature available on GoDaddy, to manage a MySQL database. MySQL is an open-source relational database management system that is centered on Structured Query Language (SQL).

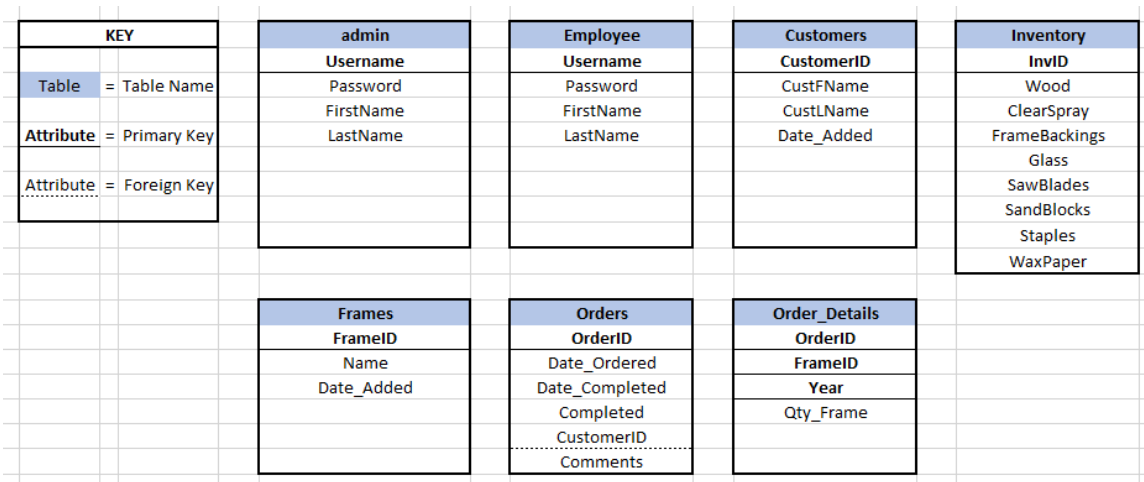

Figure 45 - Database Tables

The database has been normalized to third normal form (3NF). Normalization is an essential part of database design. It is the process of decomposing complex data structures into smaller tables to reduce redundancy and minimize anomalies in inserting, updating, and deleting data. Databases that are constantly updating should be normalized, because its specificity can allow only 1 table to be modified at a time, which saves time and money in computing power. However, inversely, retrieving data is more costly in a highly normalized database, as all of the smaller tables now have to be joined. As the

GradYear OMS was built for a small-scale, local hypothetical situation, the assumption was made that hundreds of thousands of records would not be retrieved or modified each day, and that the cost of normalization was acceptable.

To be in third normal form, a database must meet a certain set of criteria.

1. It must satisfy the requirements of first normal form (1NF): it must have a key and all attributes must be atomic (non-divisible).
2. It must satisfy the requirements of second normal form (2NF): it must be in 1NF, and there cannot be any partial dependencies.
3. It must satisfy the requirements of third normal form (3NF): it must be in 2NF, and there cannot be any transitive dependencies. Transitive dependencies occur when attributes are indirectly related to the primary key and they exist in the same database table as the primary key.

Following 3NF in the levels of normalization is Boyce-Codd normal form. The author chose to normalize the database to 3NF to reduce data duplication and ensure referential integrity. By having a Customers tables and an Order table, if a customer's phone number needs to be changed, it only needs to be changed once, in the customer table. If there was only an Order table, the customer's phone number would need to be updated for every order that the customer had ever placed. With separate tables, it is easier to keep data distinct and ensure that it is uniform across the database.

3. Software Specifications

The GradYear OMS was designed to be used by employees to track orders, keep in touch with customers, and easily order inventory. A Unified Modeling Language (UML) diagram is displayed in **Figure 46**, to visually represent how the system works.

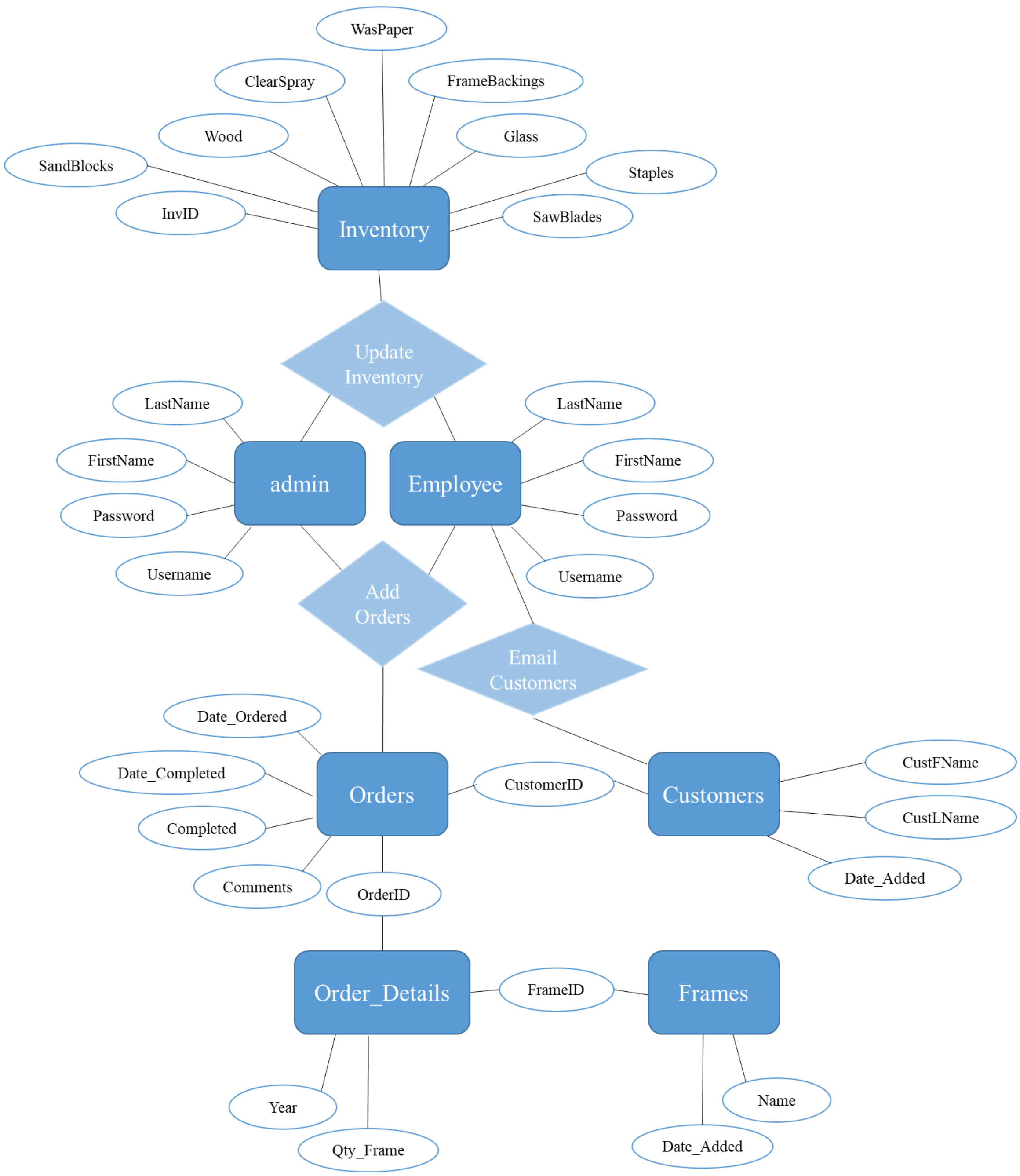

Figure 46 - GradYear OMS: UML Diagram

The GradYear OMS was built with many tooltips, modals, and alerts to give the user help when needed. A Use-Case document, detailing how to add orders under the Orders tab, is included in the Appendix (1). If further assistance is needed, the author is available for help. The author is responsible for the foreseeable software maintenance on the GradYear OMS.

4. Technical Specifications

The GradYear OMS is hosted on GoDaddy, under the domain helloworldfromlas.com/GradYear. It was built using Twitter Bootstrap, a free software comprised of predesigned Cascading Style Sheet (CSS) files and JavaScript (JS) files, Hypertext Markup Language (HTML), and Hypertext Preprocessor (PHP).

Twitter Bootstrap is an incredible compilation of hundreds of thousands of hours of testing and de-bugging by millions of people around the world to create the perfect aesthetic. It has powerful built-in classes and functions that make web development almost effortless; perhaps the most useful feature of Twitter Bootstrap is its internal layout responsiveness: Twitter Bootstrap websites will automatically respond to the viewport (screen size) of the client browser. The author chose to make a copy of Twitter Bootstrap on a local server instead of relying on the software through its Content Delivery Network (CDN), a network hosted by servers all over the world. Although using CDN's drastically reduces storage space for applications, it is exponentially more volatile, as the program owner could choose to remove their code from the server at any moment, and cause all programs reliant on these vital code sections to crash.

HTML is the backbone of web development, and provides a stable structure to be embedded with JavaScript, which adds interactivity to web pages; CSS, which adds customization to web pages; and PHP, which adds functionality to web pages. The author chose to use HTML for creating the basic layouts of the GradYear OMS.

PHP is an open source, general purpose, server-side, back-end, interpreted scripting language. One of the most important features of PHP is that it is a preprocessor, meaning that PHP code is processed server-side before being outputted by the client’s browser. When viewing the source code of a page, PHP code will not be displayed; therefore, PHP is a good language to use for applications of higher security. There is an ongoing debate on the usefulness of PHP. When compared to newer scripting languages, it is certainly more basic. However, PHP and MySQL is still a formidable combination for web development. Wordpress, the world’s largest content management system (CMS) is built on a PHP/MySQL platform, and they subsequently host over a third of all websites on the Internet. The author used PHP Data Objects (PDOs) to interact with the MySQL database (available through GoDaddy). PDOs exclusively use Prepared Statements, which protect applications from SQL injection attacks, where hackers try to inject the database with harmful or disruptive data.

5. Usage

The author wrote over 4,000 lines of code in building the GradYear OMS. A complete list of the GradYear OMS files is provided in the Appendix (2). From the login screen, a user is able to login, reset their password, or create a new account (with an administrator's permission). After logging in, a user is able to view a descriptive home page made of card columns under the Home tab; view/edit their information under the MyAccount tab; view/add/update orders under the Orders tab; view/update/email customers under the Customers tab; and easily view/update inventory and order new materials under the Inventory tab. **Figure 47** displays the home page from a small viewport (i.e., a mobile phone).

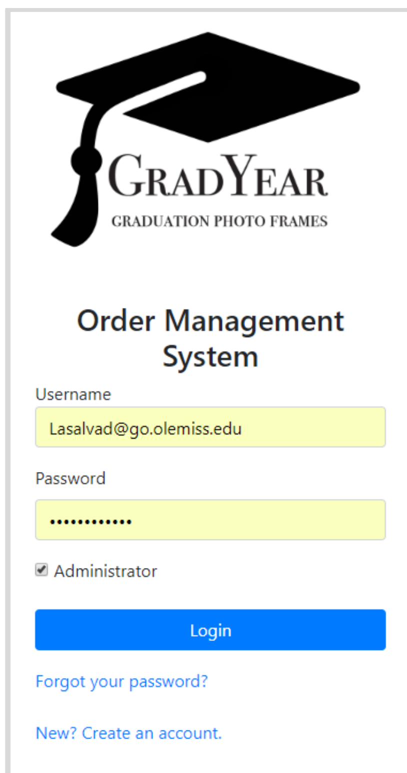

Figure 47 - GradYear OMS: Login Screen

Under the Orders tab, a user is able to add orders, mark orders as completed, or void orders if they no longer need to be completed. The author chose to not give the user the power to delete orders entirely. **Figure 48** displays the Order tab is the “All” view is chosen.

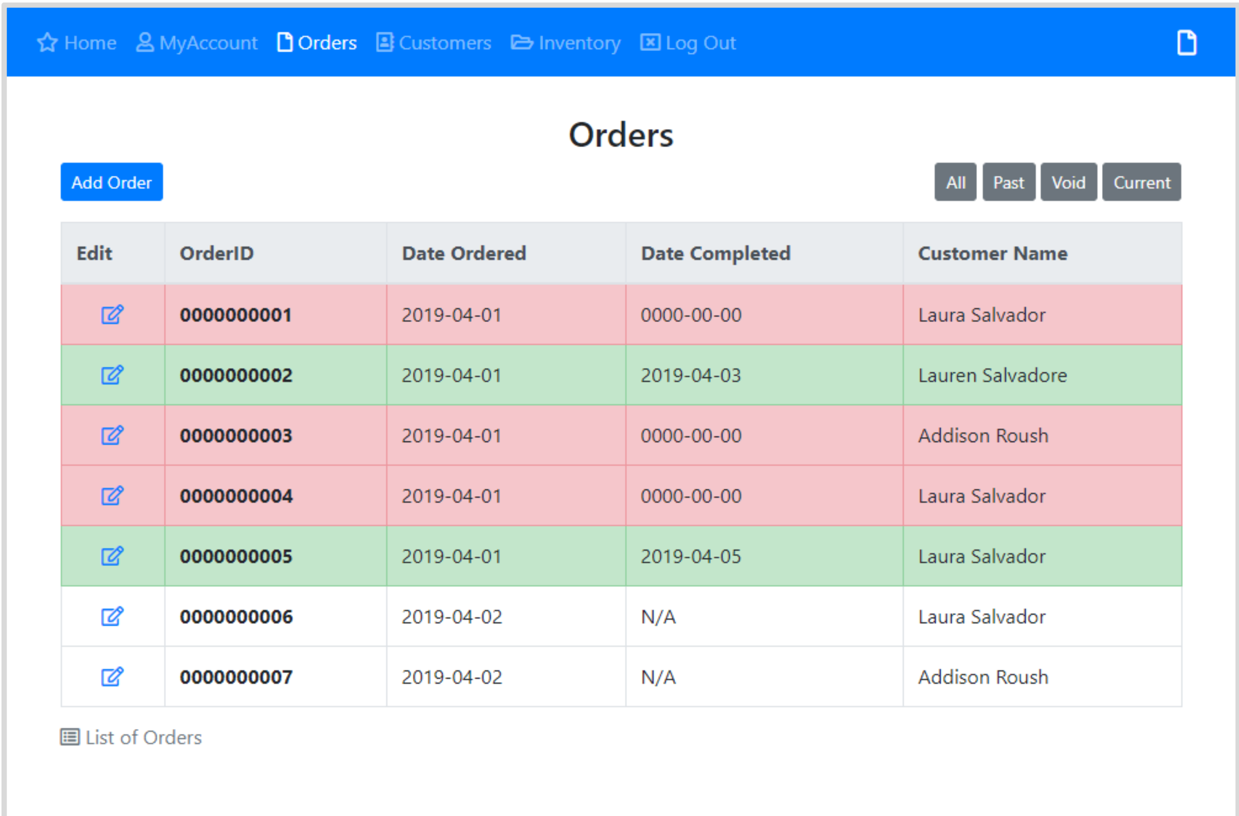

Figure 48 - GradYear OMS: Orders (View: All)

Throughout the GradYear OMS, the author built in success, warning, and failure alerts to notify the user if their action had been successful or not. This notification system was built using Uniform Resource Locator (URL) variables to pass data. **Figure 49** displays a success alert when an order has been added to the system. **Figure 50** displays a failure alert when a user has entered an order using a pre-existing customer’s email, but not their correct name.

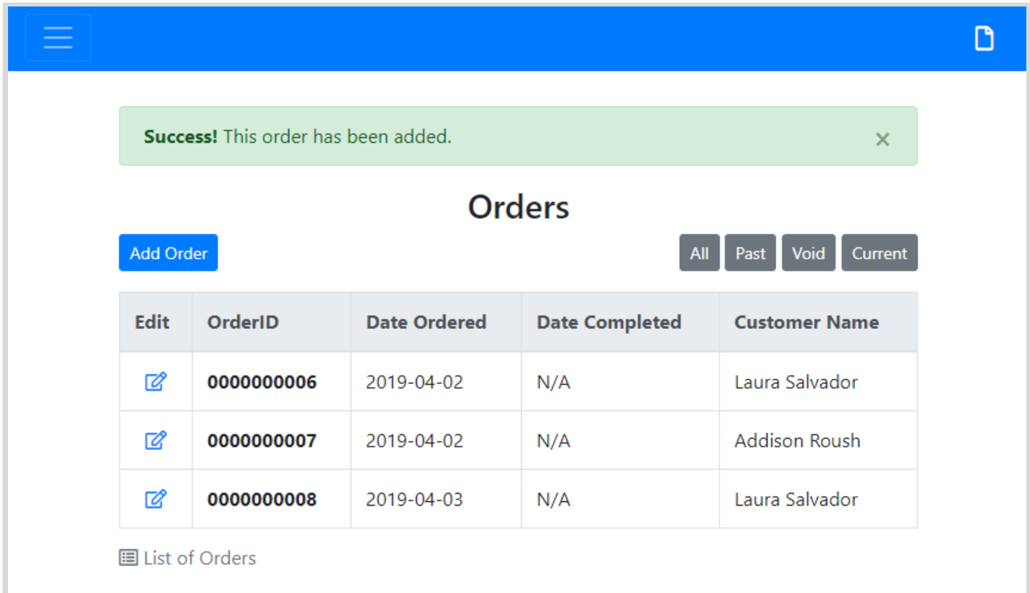

Figure 49 – GradYear OMS: Orders (Success Alert)

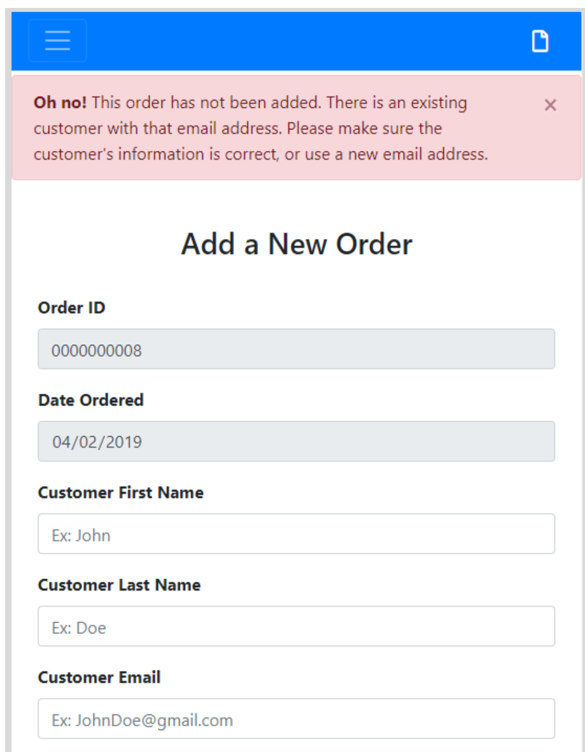

Figure 50 - GradYear OMS: Orders (Failure Alert)

An example set of login credentials will be provided in the Appendix (3).

Conclusion

During the GradYear project, team members had the opportunity to take a $1,000 budget and a crazy idea, and run with it.

The GradYear project was a huge success, in terms of both design popularity and application of lean principles. The design of the GradYear Classic stayed true to the author's original ideation. The design of the frame is quite appealing – although the dimensions are a bit strange and the frame is not symmetrical, there is something about the logo above the front opening and the gold plastic plating at the bottom that's really pleasing to the eye. During the trial and production periods, the team was able to implement principles of lean manufacturing and kaizen to the frame-making process. Whereas the team had previously had the experience to apply lean thinking towards processes at various manufacturing facilities across northern Mississippi, getting to analyze and improve a process of the team's own design was an altogether new, and far more challenging experience. It was a true testament to the manufacturing skills and problem solving abilities the team acquired throughout its time with the CME.

The GradYear OMS was also an enormous success for the author, in terms of designing an efficient and capable system and building said system. The author had the opportunity to be the customer, the business process analyst, and the software developer, which afforded her a new perspective on building information technology systems. She was able to apply what she had learned over eight semesters in the MIS department towards the GradYear OMS, and the experience was invaluable.

The future of GradYear is still uncertain at this point. While the product still has a high potential for success in the local picture frame market, it has not been determined who the future owners of GradYear will be. The author hopes that this thesis will serve as a manual for the future owners, outlining the design and the manufacturing operations for the GradYear Classic, while also providing the logic behind the team's decisions, and the team's recommendations for the future. The GradYear OMS will freely be given to the future owners of GradYear, and reconfigured as needed.

In conclusion, the team fully achieved its objective, designing and manufacturing a graduation photo frame that celebrates both the alma mater and the graduating class of the consumer, and ultimately exceeded the original goal of the project of 39 frames by 79%. The GradYear OMS was above and beyond the original scope of the project in its entirety. The original 39 frames will be given to the graduating CME Senior Capstone Class of 2019 at the graduation ceremony in May 2019. The excess frames were given to the faculty and staff as a thank-you for all of the years of advice, guidance, and encouragement that they poured into the team in challenging them to be the best manufacturing professionals they could be. The author will always be grateful for the experiential learning cycle of the CME; from learning how to form a team in Manf 150, to leading a team from ideation through product delivery in Manf 452.

Appendix

1. **Phase 5: Section 3** – Use Case Document for entering an order

Use Case

Use Case Title: Enter an order
Primary Actor: Employee
Level: Kite (summary)
Stakeholders: Employee, Customer
Precondition: The employee logs in and accesses the Orders tab
Minimal Guarantee: The employee returns to the Orders tab without having altered any of the preexisting orders
Success Guarantees: The employee adds the new order and receives a success alert
Trigger: The employee clicks the "Add Order" Button
Main Success Scenario:

1. The employee access the "Add a New Order" page
2. The employee is able to fill in the required fields
3. After clicking "Add Order," the employee is returned to the Orders page and receives a success alert that the order was added
4. The employee logs out of the GradYear OMS

Extensions:

1. The employee cannot login to the system
    1. The employee quits the site
    2. The employee requests new login credentials
2. The employee cannot access the Orders tab
    1. The employee quits the site
    2. The employee calls technical support
3. The employee cannot access the "Add a New Order" page
    1. The employee quits the site
    2. The employee calls technical support
4. The employee cannot submit the new order
    1. The employee returns to the Orders tab and ensures that a new, invalid order was not mistakenly made
    2. The employee quits the site
    3. The employee calls technical support
5. The employee does not log out of the GradYear OMS
    1. The Orders information is left unsafe
    2. The employee, customer, and inventory information is left unsafe

2. **Phase 5: Section 4** – Listing of GradYear OMS Files

Name	Size
css	4 KB
images	4 KB
js	4 KB
create_account.php	4.99 KB
create_account_handler.php	2.22 KB
create_account_verify.php	3.76 KB
create_account_verify_handler.php	3.2 KB
customers.php	11.96 KB
customers_edit.php	8.38 KB
customers_edit_handler.php	2.02 KB
customers_email.php	7.07 KB
customers_email_handler.php	2.24 KB
customers_handler.php	295 bytes
dbcreds.php	152 bytes
error_log	447.19 KB
index.php	7.64 KB
inventory.php	29.8 KB
inventory_handler.php	311 bytes
inventory_update.php	2.56 KB
login.php	4.56 KB
login_handler.php	5.24 KB
logout.php	502 bytes
my_account_edit.php	7.43 KB
my_account_edit_handler.php	3.58 KB
my_account_handler.php	5.74 KB
orders.php	20.93 KB
orders_add.php	11.67 KB
orders_add_handler.php	5.61 KB
orders_edit.php	16.31 KB
orders_edit_handler.php	3.95 KB
orders_handler.php	442 bytes
password_reset.php	4.63 KB
password_reset_handler.php	5.92 KB
verifyuser.php	244 bytes

3. **Phase 5: Section 5** – Example set of login credentials with Employee permissions

   Username: example@go.olemiss.edu

   Password: example!1234

   Please use responsibly!

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