

# Developing a Manufacturing Process for Home-Based Business

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## Abstract

This study develops a manufacturing process for a home-based business initiated by the purchase of a laser engraver. Business financials are explained and expanded, the fundamentals of a manufacturing process are evaluated and some concepts in product design are explored at the aim of providing the business owner a foundation in which to launch his business. A basic model for reviewing the startup investment necessary to maintain the equipment investment made by the owner is used to explore cash flow, equipment risk and possible return on investment. A review of current workspace and recommended changes are explored. The 5S concept of workplace organization is applied to provide foundational structure to the owner's manufacturing process. Lastly, the three proposed concept products are reviewed with an aim to reduce wasted time and material. Basic recommendations are made to scale up from a prototyping workflow to production workflow.

## 1 Introduction

This study was initiated by Mr. Harvey S. Meyer of Meyer Enterprises. He purchased a mid-size laser engraver and air filtration system from the Epilog Laser Corporation for the purpose of manufacturing small wooden Alaska-themed products for the summer tourist season and winter holiday craft shows. He requested answers to the following questions as it pertains to his laser engraving & manufacturing business:

- “How do I make the best use of my Laser Engraver purchase?”
- “How do I decide which products to make?”
- “How much inventory should I keep?”
- “How do I manage costs of making the products?”
- “What's a good way to stage products for selling?”
- “What software do I use?”

He expressed his desire to grow his home business concept to a point of profitability within five years to provide part-time income for after he retired from his career with the Municipality of Anchorage.

### 1.1 Meyer Enterprises overview

Meyer Enterprises is a sole-proprietorship based out of his home in Eagle River, Alaska. He has approximately \$25,000 invested in his business and would like to position the company to begin returning on that investment by May 1st, 2023. Meyer Enterprises has no manufacturing processes established but does have several key product ideas in development and prototyping.

### 1.2 Meyer Enterprises' sample products

Mr. Meyer has developed several prototype products he wishes to move into a production process. The three prototypes that cover the general target product concept are: Drink Coasters, Engraved Maps, and Themed Plaques. Furthermore, as outlined in Table 1 in Mr. Meyer's business model, he envisioned that each product will have a standard version that determines base cost, manufacturing time, and post-manufacturing time, an economy version that's 15% lower in cost and manufacturing time, and a luxury version that costs no more than 15% over the standard model. He has requested an analysis of that model to determine the optimal values should plus or minus fifteen percent be insufficient.

**Table 1.** Meyer Enterprises' product concepts with estimated manufacturing constraints

Product	Version	Estimated Manufacturing Constraints
Drink Coaster	Economy	Material Cost * 0.85 (Base Manufacturing Time & Assembly Time) * 0.85
	Standard	Material Cost Base Manufacturing Time Assembly Time
	Luxury	Material Cost * 1.15 (Base Manufacturing Time & Assembly Time) * 1.15
Maps	Economy	Material Cost * 0.85 (Base Manufacturing Time & Assembly Time) * 0.85
	Standard	Material Cost Base Manufacturing Time Assembly Time
	Luxury	Material Cost * 1.15 (Base Manufacturing Time & Assembly Time) * 1.15
Themed Plaques	Economy	Material Cost * 0.85 (Base Manufacturing Time & Assembly Time) * 0.85
	Standard	Material Cost Base Manufacturing Time Assembly Time
	Luxury	Material Cost * 1.15 (Base Manufacturing Time & Assembly Time) * 1.15

**1.2.1 Product overview**

Mr. Meyer shared detailed information on three of his prototypical products: Drink Coasters, Engraved Maps, and Themed Plaques. Mr. Meyer explained he observed engraving time for each of his prototypes and provided a rough unit material cost derived from dividing the surface area of each prototype by the total surface area of his raw material (or blank), then dividing the Raw Material Cost per sheet by the number of units produced from a single sheet of raw material.

$$\# \text{ of Units} = (\text{Surface Area of Raw Material}) / (\text{Surface Area of Unit})$$

$$\text{Unit Cost} = (\text{Raw Material Cost}) / (\# \text{ of Units})$$

Additionally, Mr. Meyer provided his estimated sale price per prototype which was greater than the cost of the material and a rough estimation of the time involved in the post engraving clean up.

**1.2.2 Product: drink coaster**

Mr. Meyer shared that the Drink Coaster product line, as shown in Fig. 1, had the most diversity of any of his product concepts as shown in Table 2. He intends to sell these in packs of four, six, and eight.



Fig. 1 Drink coaster product example

Table 2. Product details for drink coaster prototype

Product Information	
Material	Baltic Birch
Dimension	4" diameter by 1/4" thickness
Engraving Time	2.5 minutes
Material Cost	\$1.86 / unit
Estimated Sale Price	\$4.50 / unit

**1.2.3 Product: Engraved Maps**

Mr. Meyer shared the second product line prototype he'd like to explore are engraved maps of Alaska. They could range from simple vector line cut to topographical maps of areas around Alaska.



Fig. 2 Engraved map product example

Table 3. Product details for the engraved map prototype

Product Information		
Material	Baltic Birch	Baltic Birch
Dimension	6" wide x 6" length by 1/4" thickness	8" wide x 12" length x 1/4" thickness
Engraving Time	3 minutes	8 minutes
Material Cost	\$0.23 / unit	\$0.62 / unit
Estimated Sale Price	\$10.00 / unit	\$20.00 / unit

**1.2.4 Product: Themed Plaques**

Lastly, Mr. Meyer shared his concepts for themed plaques. He had several ideas that were essentially large and small plaques that contained diagrams or lettering as shown in

Fig. 3.



Fig. 3 Themed plaques product example

Table 4. Product details for the themed plaque prototype

Product Information		
Material	Baltic Birch	Baltic Birch
Dimension	6" wide by 6" length by 1/4" thickness	12" wide by 12" length by 1/4" thickness
Engraving Time	18 minutes	120 minutes
Material Cost	\$0.23 / unit	\$0.33 / unit
Estimated Sale Price	\$20.00 / unit	\$50.00 / unit

### 1.3 Meyer Enterprises' Facilities

Meyer Enterprises' production space is approximately 100 sq. ft. area set aside in a relative's garage as shown in Fig. 4. Meyer Enterprises is renting this space at a rate of \$1.02/sq. ft. There is additional space that may be claimed, but Mr. Meyer wants to know the business benefit before increasing his monthly obligation.

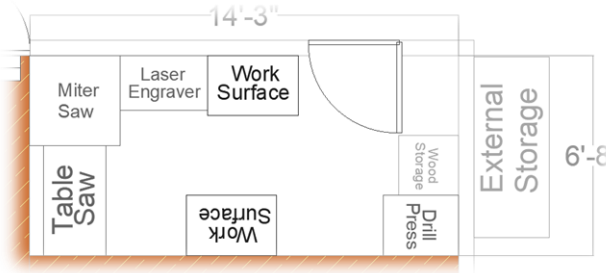


Fig. 4 The current floorplan of Meyer Enterprise shop

Mr. Meyer shared that the current workspace is sufficient for prototyping due to the low volume of work but would like a recommendation on a more efficient layout for larger production runs of products.

Meyer Enterprises primary tool is a Desktop-sized Epilog Laser Mini 24 laser engraver that has an engraving surface capacity of 24" width by 12" length by 5" thickness containing a 60-watt CO2 Laser (Epilog Corporation, 2018). The Mini 24 laser unit is driven by a Microsoft Windows/Intel Laptop running various graphics packages and a specialty driver from Epilog Corporation.

Supporting this primary tool is a small array of traditional wood-working power tools, such as: Portable Table Saw, Miter Saw, a Drill Press and small hand-held power tools such as drills, screw drivers and saws.

### 1.4 Meyer Enterprise's Manufacturing Process

Meyer Enterprises currently works on singular piece manufacturing. The process takes place within the aforementioned 100 ft<sup>2</sup> workspace. A primary work surface to the right of the Laser Engraver serves as the material preparation space as well as the post-cutting clean up area, and a second work surface opposite of the Laser Engraver often serves as a drying rack and storage. As new work comes into the shop, old work must be moved out of the way to make room.

### 1.5 Problem Statement

This body of work seeks to provide actionable analysis of Mr. Meyer's business concepts by focusing primarily on product development process, manufacturing process, cost analysis of manufacturing expenses and cost analysis on future tool investment that may compliment his core business concepts.

The following guiding research and analysis questions were developed from the interview with Mr. Meyer and were submitted to him for his approval:

#### Business Financials

- a. Outline the company financial statements, cash flow, and projected cash flow for the next 5 years.
- b. Calculate overhead and equipment depreciation.

- c. Calculate the break-even point for initial business investment, calculate a Return On Investment (ROI) for the equipment purchase.
- b. What is the most cost-effective method of managing business software, subscription or purchase?

#### Process Development & Review

- a. What would be an optimal manufacturing process given 3 categories of common product types?
- b. How can an optimal manufacturing process be expanded to increase manufacturing volume?

#### Product Cost Analysis

- a. Examine a simple Inventory Management process and cost analysis of inventory.
- b. What tools could be added to the business to provide a shorter return on investment?

Having received his approval on February 17<sup>th</sup>, 2018, principal work began on this project.

### 1.6 Methodology

In response to the questions asked in our initial interview, the following methods and approaches will be used for analysis to convergence towards a solution.

Since the business is little more than a concept, some assumptions will be made to bound the problems of analysis. These assumptions will be documented at the start of each analysis section to help provide continuity and flow to the analysis.

This body of work covers three primary areas of analysis that focus on the three categorizations of the Problem Statement outlined in section 0. The first analysis will be on the business costs, overhead, and depreciation of equipment which will drive the cost constraints of the manufacturing process. The second analysis will review the facilities available for the manufacturing process, an analysis will help provide guidance on the needed space and structure of the manufacturing process. The third analysis will review the product concepts and the price differences between the quality categorizations to evaluation production time and cost changes as different raw materials are chosen for products. Lastly, a conclusion will provide steps and recommendations for how to proceed between now and business launch.

The first analysis will be covered in 2 where a financial overview of Mr. Meyer's expenses will be examined. In order to maintain his investment, expenses during the pre-business years and the risks he's accepting during this timeframe will be documented. A review of business startup expenses will be estimated and projected with future value dollars with the goal of providing Mr. Meyer some projected startup expenses for his financial planning.

The second analysis is covered in **Error! Reference source not found.** and reviews Mr. Meyer's facilities for running the operation of his business. It covers space requirements and possible changes in rent and equipment to help execute his business vision.

The third analysis is covered in **Error! Reference source not found.** and this chapter reviews utilizing the findings from **Error! Reference source not found.** to evaluate the cost associated with manufacturing three different prototypes. Manufacturing costs is analyzed to compare raw materials being used for the various prototypes with the goal of providing an estimated manufacturing schedule, and cost analysis of the various products.

**Error! Reference source not found.** reviews the conclusions from this body of work and presents an outlined summary of the solutions of the

analysis and interpretation to provide specific recommendations on Mr. Meyer’s business venture.

Lastly, **Error! Reference source not found.** covers future work that could be performed to provide additional answers to Mr. Meyer prior to his business launch.

## 2 Business Financials Overview

Mr. Meyer plans on engaging with his business in May 1st, 2023 when he retires from his professional career with the Municipality of Anchorage. However, before that time he intends to invest time in refining product concepts, experimenting with materials, and gaining experience with the Laser Engraver as a tool.

Five years has a lot of potential for a change in priority, direction and interest, so the analysis will focus on the investment between January 2017 and December 31, 2025. By casting the timeline between these ranges the analysis will review the investment period where the core business and product concepts are defined and allow a projected return as the business becomes Mr. Meyer’s primary focus in 2023 and its growth through December 2025.

Additionally, to minimize the financial risk of Mr. Meyer’s retirement lifestyle the analysis will take a risk adverse approach to growth meaning that after the initial investment in equipment and materials, growth will be primarily built from the sales of produced products with additional out-of-pocket invests being a last resort for business continuance.

Focus will also be to have an established inventory at May 1st, 2023 to launch the business with on-hand inventory which the production analysis will provide lead time and inventory sizing for an estimated sales season.

### 2.1 Business Financials Analysis

Due to the conceptual nature of the business there are not a lot of assets or expenses to analyze, but the following sections will outline the starting point for Meyer Enterprises and will provide context for the subsequent projections. Additionally, the time period prior to Mr. Meyer’s taking the business live in 2023 was analyzed to explore any inherit risks that should be taken into account.

### 2.2 Business Assets

The primary asset owned by Meyer Enterprises is the Epilog Mini 24 Engraving Laser which retailed for a grand total of \$23,000 and included a large air filtration system and a small air compressor. The Laser Engraver contains a 60W laser and has a cutting bed of 12 inches by 24 inches (288 square inches) by 6 inches in thickness. It can cut plastic, cloth, acrylic, and some wooden materials below 1/4 inch in thickness, and can engrave on most metals and woods.

Additionally, Mr. Meyer has an array of small power hand tools that are periodically used in the manufacturing process that are estimated to be worth \$2,000. He also purchased a Dell Precision M7720 Laptop for \$2,500.

#### 2.2.1 Business Assets Valuation and Depreciation

Mr. Meyer intends to start Meyer Enterprises in May of 2023, and at that point, all previous assets will be assigned to the business. The Internal Revenue Service Tax Code Section 179 allows for the total purchase price

of an asset to be applied to the business for depreciation purposes regardless current appraised value (Legal Information Institute, 2018).

However, it’s recommended that Mr. Meyer start his business the previous year so he can capitalize on a full year of depreciation in the 2023 tax year on his business equipment.

#### 2.2.2 Principal Asset Value and Depreciation

The principal asset for Meyer Enterprises is the Epilog Mini 24 Laser Engraver which was purchased for \$23,000.00. Since it will be used as a core component of a manufacturing business the analysis will use a “Unit of Production” depreciation model calculated around the hours of use per year with a lifetime hourly usage of 3,850 hours<sup>1</sup> and no salvage price. The Internal Revenue Service defines the asset class of 24.4 and allows for a ten-year recovery period for this class of equipment (Internal Revenue Service, 2018).

Table 5 outlines the 10-year recovery period with estimated hours of use on the equipment. The recovery period will be concluded in 2031. The estimated hours were based on projections necessary to build sufficient inventory to justify the rental of a booth at a local craft fair which is covered in more detail in **Error! Reference source not found.**

**Table 5.** Unit of production depreciation chart for Epilog Mini 24 Laser Engraver

Year	Starting Value	Hours of Use	Depreciation Expense	Year End Value	Net Depreciation
2022	\$23,000	0	0	\$23,000	0
2023	\$23,000	600	\$3,584	\$19,416	\$3,584
2024	\$19,416	350	\$2,091	\$17,325	\$5,675
2025	\$17,325	300	\$1,792	\$15,532	\$7,468
2026	\$15,532	400	\$2,390	\$13,143	\$9,857
2027	\$13,143	400	\$2,390	\$10,753	\$12,247
2028	\$10,753	450	\$2,688	\$8,065	\$14,935
2029	\$8,065	450	\$2,688	\$5,377	\$17,623
2030	\$5,377	450	\$2,688	\$2,688	\$20,312
2031	\$2,688	450	\$2,688	0	\$23,000

The Unit of Production depreciation value is \$5.97/manufacturing hour is based on 3,850 hours of use over 10 years of useful life of the laser engraver. Fig. 5 depicts the depreciation over time.

<sup>1</sup> 3,850 hours was calculated at 400-600 hours per year for approximately 10 years, where the first few years will see increased machine use and normalize as Mr.

Meyer transitions to primarily focusing on the business full time. It is estimated there will be a need for a new laser engraver by 2031.

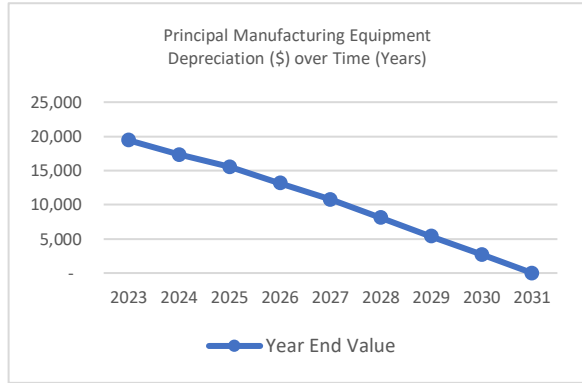


Fig. 5. Chart depicting the unit of production depreciation values

**2.2.3 Secondary Manufacturing Equipment**

Mr. Meyer owns approximately \$2,000 of power tools that will be bundled with Meyer Enterprises’ assets at business launch. Due to the low cost, they are expensed in the year they are purchased. (Internal Revenue Service, 2018).

**2.2.4 Office Business Equipment**

Mr. Meyer purchased a Dell Precision M7720 Laptop for \$2,500 to run the graphics software required by the Epilog Laser Engraver. The Internal Revenue Service classifies computers as a 00.12 asset class and allows them to be depreciated over 5 years as shown in Table 6.

Table 6. Straight-line depreciation chart for business equipment

Year	Starting Value	Depreciation Expense	Year End Value	Net Depreciation
2023	\$2,500	\$500	\$2,000	\$500
2024	\$2,000	\$500	\$1,500	\$1,000
2025	\$1,500	\$500	\$1,000	\$1,500
2026	\$1,000	\$500	\$500	\$2,000
2027	\$500	\$500	-	\$2,500

The yearly depreciation rate is \$500.00 / year as illustrated in Fig. 6.

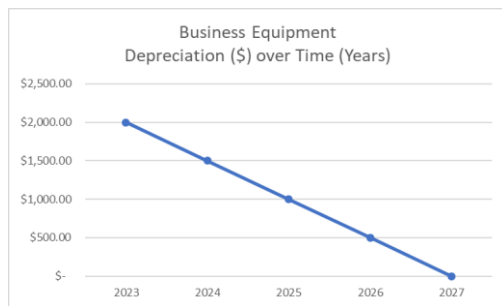


Fig. 6. Chart depicting the straight-line depreciation values

**2.2.5 Summarized Depreciation**

The depreciation for the various categories of equipment will be summed for each year and be applied to the cost projections for that year. Depreciation for the Principal Equipment, the Laser Engraver, will be depreciated over 10 years, the business equipment will be depreciated over 5 years, and the secondary equipment will be expensed in the first year of business with replacement being made every 3 years. Table 7 shows the year-by-year projected breakdown of depreciation for the first 10-years of business. Since this is an amortized data, it is not adjusted for inflation.

Table 7. Summarized depreciation for each asset class

Year	Principal Equipment	Business Equipment	Total
2022		\$0	
2023	\$3,584.42	\$500.00	\$4,084.42
2024	\$2,090.91	\$500.00	\$2,590.91
2025	\$1,792.21	\$500.00	\$2,292.21
2026	\$2,389.61	\$500.00	\$2,889.61
2027	\$2,389.61	\$500.00	\$2,889.61
2028	\$2,688.31		\$2,688.31
2029	\$2,688.31	\$500.00	\$3,188.31
2030	\$2,688.31	\$500.00	\$3,188.31
2031	\$2,688.31	\$500.00	\$3,188.31

This data will be incorporated later in this analysis to capture the projected depreciation for the equipment over the life of the business.

**2.2.6 Asset Conclusion**

Meyer Enterprises will start business with approximately \$29,500 worth of equipment with most assets having some period of recovery in depreciation. Secondary Equipment such as power and hand tools, will be expensed in the year they are purchased.

Other assets that are more difficult to predict will be the Raw Material inventory needed to make the products, and how many products will be placed in inventory for the purpose of selling. This depends on the frequency and consistency of product manufacturing prior to the start of business in May 2023.

**2.3 Business Liabilities**

Mr. Meyer will have a large operating constrain during the time prior to the Meyer Enterprises officially starting in May 2023 due to the lack of business income to cover any expenditures. As a result, all material costs or equipment maintenance will need to be covered out-of-pocket from present day through the first year of business operations.

Mr. Meyer purchased the Epilog Mini 24 Laser Engraver in spring of 2017. He entered into a deferred rental agreement with a relative for shop space and purchased approximately \$200 dollars of Baltic Birch lumber to use as product development stock.

**2.3.1 Equipment Expense**

The Epilog Mini 24 Laser Engraver, like any machinery, has maintenance expenses and ownership costs. This section will explain those expenses and parameterize them as an hourly expense.

According to the Epilog Mini 24 Owner’s manual the following are recommended maintenance processes that should be observed. In Table 8, the maintenance tasks for the outlined showing the frequency of occurrence and the expenses associated with each occurrence.

Table 8. Maintenance operations and expense

Task	Frequency	Expense
Cleaning	Every 8 hours of Operation	15 minutes of Labor

Laser Assembly Maintenance	Every 100 hours of Operation	3 Hour of Labor
Replace Filters	Every 400 hours of Operation	1 Hour of Labor \$250.00 Replacement Filters

Additionally, research has shown that the Epilog Laser Engravers have a critical component, the Laser Tube, that has an erratic Mean Time Between Failures (MTBF) of 1,500 hours and can cost \$2,500 to replace. Some reports this laser tube failing after as few as 200 hours, others have reported years without issue (Sawmill Creek, 2009). The more erratic reports were from before 2007, when Epilog outsourced laser tube manufacturing. This function has since been brought in-house (Epilog Laser, 2018), but there is a lack of data to prove quantifiably an improvement in quality, as such, this analysis will budget in a replacement cost of \$2,500 every 1,500 hours. Table 9 shows the problem discussed, the frequency and the associated expense.

**Table 9.** Known repair issues and expense

Task	Frequency	Expense
Laser Tube Replacement	Estimated Every 1,500 hours	2 Hours of Labor \$2,500 Laser Tube

Lastly, the Laser Engraver is an electrical device powered by electricity, and a sample of hour multi-hour batches<sup>2</sup> shows that it pulls approximately 1.4 Kilowatts of electricity, or 1.4 kilowatt-hours (kWhr<sup>3</sup>). The cost of electricity at the current location is \$0.22/kWhr. Table 10 outlines how the cost of ownership for the Epilog Laser was developed.

By collating this data and bringing forward the expected lifetime hourly use from section 0 of 3,850 hours, and applying a labor rate of \$30.83, the total cost of ownership can be calculated and parameterized:

**Table 10.** Cost of operation expenses for Epilog Mini 24 Laser Engraver

Laser Usage Overhead						
Average Electrical Use	1.4	kWhr	Labor Rate	\$30.83	/Hour	
Electricity Cost	\$0.22	/kWhr				
Total Machine Usage (hrs)	3,850	Hours				
Total Electrical Cost	\$ 847					
Task	Occurrence Rate	Labor Time / Occurrence (hrs)	Number of Occurrence	Material Cost/ Occurrence	Labor Cost/ Occurrence	Total Cost
Clean	8	0.25	481	\$0	\$7.71	\$3,707
Replace Filters	400	1	9	\$250.00	\$30.83	\$2,527
Laser Assembly Maintenance	100	3	38	\$0	\$92.49	\$3,515
Laser Tube Replacement	1500	2	2	\$2,500.00	\$61.66	\$5,123
<b>Hourly Rate</b>	<b>\$3.86</b>		<b>Total Operational Costs</b>			<b>\$14,873</b>

This data allows for the calculation of a parametric value based on hours of usage, as follows:

$$\begin{aligned} \text{Number of Occurrences} \\ &= (\text{Total Machine Usage}) \\ &\quad / (\text{Occurrence Rate}) \end{aligned}$$

The Number of Occurrences is simply the number of times a particular maintenance task will occur given the total lifetime of usage. For example, the table shows that the maintenance task of Cleaning should occur every 8 hours, and that given a lifetime usage of 3,850 hours, the cleaning task will need to be completed 481 times over the life of the Laser Engraver.

$$\begin{aligned} \text{Labor Costs} &= \text{Labor Time per Occurrence} \times \text{Labor Rate} \\ &\quad \times \text{Number of Occurrences} \end{aligned}$$

The Labor Costs is derived by taking a maintenance activity labor time and multiplying it by the cost of the labor multiplied by the number of occurrences. To continue the previous example, the labor rate is \$30.83/hour and there will be 481 occurrences of the cleaning maintenance task with each cleaning task taking approximately 15 minutes (or 0.25 hours). By multiplying the labor time, 0.25 hours, by the labor rate, \$30.83/hour, by the number of occurrences over the life of the machine, 481, will produce a total cost of \$926.83.

$$\begin{aligned} \text{Material Costs} \\ &= \text{Material Costs per Occurrence} \times \text{Number of Occurrences} \end{aligned}$$

Material Costs is derived by taking the material costs per occurrence of a maintenance task and multiplying it by the number of overall occurrences. For example, replacing a filter should happen once every 400 hours of use and is estimated to occur 9 times over the life of the product. Each new filter will be cost \$250. So, by multiplying \$250 by 9 we get the total material costs of \$2,250.00 for this maintenance task over the life of the unit.

$$\begin{aligned} \text{Total Electrical Costs} \\ &= \text{Electricity Cost per KWhr} \\ &\quad \times \text{Total Machine Usage} \end{aligned}$$

Total Electrical Costs is the electrical rate multiplied by the estimated total machine usage in hours.

$$\begin{aligned} \text{Hourly Cost} &= (\sum(\text{Labor Costs} + \text{Material Costs} \\ &\quad + \text{Total Electrical Costs})) \\ &\quad / (\text{Total Machine Usage}) \end{aligned}$$

At the defined total machine usage hours of 3,850 hours and the summation of the maintenance rates and expenses an hourly operating rate of \$3.86/operating hour has been calculated.

### 2.3.2 Shop Rental Expense

Mr. Meyer's contracted with a family member to rent part of their large garage to place his engraving machine and house his business. The agreement was to cover a portion of the house's expenses proportional to the space being occupied by his business.

$$\begin{aligned} \text{Business Percentage} \\ &= (\text{Business Space Usage}) \\ &\quad / (\text{Total House Space}) \end{aligned}$$

$$\text{Business Rent} = (\sum \text{House Expenses}) * \text{Business Percentage}$$

<sup>2</sup> See Appendix for power usage data gathering and calculation.

<sup>3</sup> A Kilowatt-hour is a measure of energy usage, specifically the amount of energy used to power a 1,000-Watt device for 1 hour (Richardson, 2018).

After totally the relative's house mortgage, and average utility expenses such as, electrical, natural gas, Internet and water, and dividing by the square footage of the house, a rental rate of \$1.02/square foot. Initially, Mr. Meyer is taking up 100 square feet of space which is costing him \$102/month or \$1,228.00/year. It's conceivable that Mr. Meyer's business space needs could triple by the start of his business (see Section 0).

As part of the agreement, the relative agreed to carry the expense until such time as the business began generating income. This expense will be included in the break-even analysis to determine profitability.

**2.3.3 Software Subscription Expenses**

Mr. Meyer utilizes several software titles to help design the products he sends to the Laser Engraver. Table 11 outlines a shift in software expenses when Mr. Meyer transitions from to business entity.

To help manage costs and to lower the initial cost of entry, he signed up for monthly subscription services to allow access to the desired software. Other options are available, such as pay annually, or commit annually and pay monthly. Both offer cost savings at the risk of over commitment.

**Table 11.** Comparison of personal subscription costs vs business subscription costs

Software Title	Personal Month-to-Month Subscription Annual Costs	Personal Yearly Subscription Cost <sup>4</sup>	Business Yearly Subscription Cost
Adobe Photoshop CC	\$119.99	\$119.88	\$815.76
Adobe Lightroom CC			
Adobe Illustrator CC	\$377.88	\$239.88	\$407.88
Autodesk AutoCAD LT	\$600.00	\$292.50	\$292.50
<b>Total</b>	<b>\$1,097.87</b>	<b>\$652.26</b>	<b>\$1,516.14</b>

During the pre-business time, a yearly subscription for a personal subscription is the most economical choice. A prepaid yearly subscription for all the software comes to \$652.26, where opting for the month-to-month is \$1,097.98 or 71% more expensive. A take away here is for Mr. Meyer to consider the cost savings in the pre-business timeframe to commit to a yearly subscription to save himself the \$445.62/year (or \$2,614.32 prior to business launch).

Additional analysis reveals that if Mr. Meyer is comfortable he'll utilize the software for more than 7 months in a given year without unsubscribing, then it's cost effective for him to go with the yearly discounted rate. At 7 months, the month-by-month subscription surpasses the yearly discounted rate and he could enjoy the use of the products for the remaining 5 months at essentially no-charge.

However, once the business is launched the proper licensing costs of the software will grow 236% from the personal annual plan to the business annual plan for a new annual cost of \$1,516.14.

**2.4 Projected Expenses**

To aid in quantifying the investment requirements from current day through December 2025 it is necessary to project some long-term expenses over the next several years. Due to the subjective nature of forecasting, the following assumptions are assumed to aid in calculation:

**Assumptions:**

1. A 1.75%/year inflation is assumed, based off a calculated average from 2010-2017 (Statista, 2016). All values are represented in future value dollars.
2. For income in years 2023-2025, 80% of produced products will sell at the set markup price<sup>5</sup>. This is simply a placeholder for income and represents an oversimplified projection.

**2.4.1 Pre-Launch Expenses**

In the pre-business years, the primary expense to Mr. Meyer is the replenishment of the Raw Materials to make his prototype products and maintaining his software subscriptions.

The software subscriptions can be maintained with a personal license for an annual cost of \$722/year, and the raw material will vary depending on the material but can be purchased in low volumes. Since volume is low it's reasonable to assume that raw material expenses could be kept below \$250/year. This will be further elaborated on in Section 0.

However, Mr. Meyer will be accepting a large equipment maintenance risk during this time, since the required maintenance for Laser Engraver and the Laser Tube risk will still need to be covered should it break.

**2.4.2 Meyer Enterprise Expenses (2023-2025)**

Upon starting his business in 2023 the lifecycle replacement costs of his equipment take effect, the deferred rent debt repayment will start, software licensure will need to be transferred to business class licenses, business licensure will need to be covered, and booth rental for craft shows will need to be covered as shown in Table 12.

**Table 12.** Projected overhead business expenses for the years 2023 - 2025

Expense	2023	2024	2025
Rent	\$4,420.79	\$4,420.79	\$4,420.79
Deferred Rent Repayment	\$2,148.00	\$2,148.00	\$2,148.00
Equipment Lifecycle Replacement	\$6,379.32	\$6,379.32	\$6,379.32
Business Licensure	\$100.00		\$100.00
Saturday Market Booth Rental	\$343.54	\$466.07	\$474.23
Christmas Village	\$1,330.55	\$1,353.84	\$1,377.53
Raw Materials	\$1,635.92	\$1,664.55	\$1,693.68
<b>Total</b>	<b>\$14,722.21</b>	<b>\$14,768.02</b>	<b>\$14,899.87</b>

The expenses listed above helps calculate an overhead that needs to be budgeted for in the planning process. By calculating this, a projected budget can be estimated. Table 13 is a review of the projected Expenses for Mr. Meyer during the years leading up to Meyer Enterprise's launch through the first 2 years of operating. Some of these expenses will not occur without an accompanying revenue stream, so this table doesn't tell a complete story.

**Table 13.** Projected expenses for Mr. Meyer and Meyer Enterprises

Year	Cumulative Cash Flow	Deferred Debt
2017	-\$26,222.26	\$ 1,228.00
2018	-\$722.26	\$ 2,456.00
2019	-\$1,040.15	\$ 3,684.00
2020	-\$747.76	\$ 4,912.00
2021	-\$4,483.04	\$ 6,140.00
2022	-\$12,177.78	\$ 10,560.79
2023	-\$21,385.95	\$ 14,981.58
2024	-\$23,737.37	\$ 19,402.37
2025	-\$21,737.51	\$ 23,823.16

<sup>4</sup> Software prices were pulled from Adobe Creative Cloud website (Adobe Creative Cloud, 2018), and Autodesk's AutoCAD LT websites (Autodesk, 2018).

<sup>5</sup> In the Product Section, details of the markup percentage are covered.

The cash flow reflects Mr. Meyer’s initial purchase of the Laser Engraver and Dell Laptop and the start of his deferred rent debt of \$1,228.00. In Fig. 7 shows that for years 2018-2022 minimal expenses occur, primarily to cover raw materials, in 2021 a new laptop will be purchased, and starting in 2022 the investment in material, equipment usage and increase manufacturing space needed to start building an inventory is reflected.

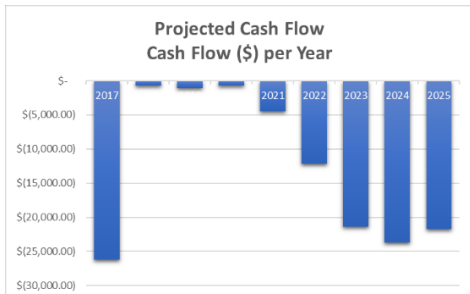


Fig. 7 Cash flow for Mr. Meyer and Meyer Enterprises

Fig. 7 is not an accurate representation since an estimated revenue is missing. The next section will review how a projected revenue was constructed.

### 2.5 Projected Revenue

In the absence of a market analysis for the various products being offered by Meyer Enterprises, there is no way to project the market reception of Mr. Meyer’s offerings or a suitable price point. So, the following simplified model will be used to project the business revenue and growth.

Utilizing a model for the manufacturing of the products, a total per unit cost is calculated, and a gross markup is applied depending on the product’s quality categorization. For this model, a fundamental unit of production is a batch and it’s defined as a single 12” x 24” board, which is the largest capacity wood the Epilog Mini 24 Laser Engraver can hold.

$$Unit\ Cost = (\sum(Material\ Costs) + Labor\ Costs + Equipment\ Costs) / Units$$

$$Unit\ Price = Unit\ Cost \times Markup$$

This formula is applied on a per Batch-basis, and allows for the changing of different woods, stains, and equipment time that vary based on wood. For example, the wood Baltic Birch is a soft wood that can be marked with the laser more easily and thus allowing for either faster laser movement or less power to be used. On a harder wood, like Red Oak, the laser power must be more intense or the laser move at a slower speed to accomplish the same look as the Baltic Birch.

Each quality categorization will be an additional 10% markup over the product’s manufacturing costs (see Table 14. This markup may have no bearing on how the actual products will perform in the market. It’s simply a starting point.

Table 14. Definition of markup per quality category

Quality Category	Markup
Economy	10%
Standard	20%
Luxury	30%

Using an Excel model that itemized and summed all the costs for each product, labor and equipment usage for each batch a multi-batch order can be created and quantified. The model calculated 9 batches of coasters (3 / quality category) for a total of 162 units, and since the coaster product is sold in sets of 6, there are 27 sets. There are 6 batches of Engraved Maps creating 33 units, and 6 batches of Themed Plaques making 30 units. These represent a good guess at what could potentially be sold per market event (i.e. Saturday Market Booth, Holiday Bizarre, etc.) or craft show.

Table 15 shows the cost breakdown for each category of product and the projected revenue based on the described model.

Table 15. Projected pricing model per market event

	Products Per Show	Material Cost	Equipment Cost	Total Expense	Projected Revenue	Projected Net Revenue
Coasters	27	\$296.15	\$65.68	\$1,690.96	\$2,113.90	\$1,752.07
Engraved Maps	33	\$241.55	\$17.69	\$742.97	\$928.39	\$669.15
Themed Plaques	30	\$368.35	\$24.39	\$756.45	\$925.37	\$532.63

The Total Projected Net Revenue per Market Event is \$ 2,953.85.

Next, the total expenses and revenues for each show was multiplied by a number of showings/events per year to reflect a yearly cost and revenue. From this data, a projected cash flow was constructed as seen in Table 16. Starting in the year 2023, it’s projected that Meyer Enterprises will rent space at four Market Events, like the Anchorage Saturday Market, and we make the assumption that all inventory sells. The following year, 8 market events are attended, and 12 market events will be attended in 2025. All values are in future dollars based on their projected year.

Table 16. Projected model cash flow for Meyer Enterprises

	Income	Expense	Cash Flow
2017		\$0	-\$25,800.00
2018		\$0	\$0
2019		\$305.25	-\$305.25
2020		\$0	\$0
2021		\$316.03	-\$316.03
2022		\$964.67	-\$964.67
2023	\$17,308.78	\$15,394.07	\$1,914.71
2024	\$35,223.37	\$16,723.41	\$18,499.97
2025	\$53,759.67	\$18,302.05	\$35,457.62

With this model of behavior, a cash flow diagram can be constructed as shown in Fig. 8. The deferred rental debt would be paid back by December 2027.



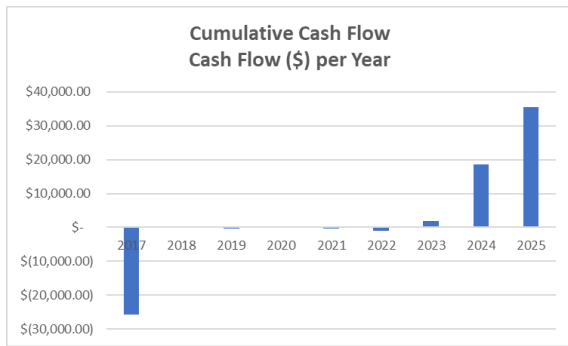


Fig. 8. Projected cash flow for Meyer Enterprises

**2.5.1 Projected Break-Even Analysis**

A Break-Even Analysis is a calculation that is performed that sums the net profits over one or more intervals to demonstrate when an outstanding debt will be paid off. The interval can be a number of years, or some number events that bring revenue. In this analysis, since the revenue model has a static performance per Market Event, the Break-Even Analysis reports the number of shows until Mr. Meyer breaks-even with his investment in this Laser Engrave and Laptop.

In Table 15, it was reported that according to the revenue model a net profit of \$2,953.85 for each show. If we apply the net profit against the \$25,500 investment of the Laser Engraver and Laptop.

$$\begin{aligned}
 \text{Break - Even Interval} &= (\text{Investment Total}) / (\text{Unit Contribution per Interval}) \\
 \text{Break - Even Interval} &= (\$25,500 \text{ Investment Total}) / (\$2,953.85 \text{ Per Show}) \\
 \text{Break - Even Interval} &= 9 \text{ Shows}
 \end{aligned}$$

So, 9 Shows with the static performance revenue model will give Mr. Meyer his break-even point. According to the revenue model, 9 shows would take approximately 2 years if maintaining the Market Event engagement schedule of the revenue model.

**2.5.2 Projected Return On Investment (ROI)**

A Return On Investment is the financial surplus that is generated by an investment, and is calculated as follows (Fisher, 2012):

$$ROI = (\text{Return} - \text{Investment}) / \text{Investment}$$

By summing the projected cash flow for 2023 – 2025, a total value of \$55,872.30, coupled with the initial investment of \$23,000, we can calculate the ROI as:

$$\begin{aligned}
 ROI &= ((\$55,872.30 - \$23,000)) / \$23,000 \\
 ROI &= 143\%
 \end{aligned}$$

In an oversimplified theoretical model with little variation in performance the laser engraver has a great return on investment.

**2.6 Business Financials Conclusions**

While it’s doubtful the financial performance will be anything near the theoretical model done in Section 0, it does show that it is mathematically possible to make a profit with the laser engraver tool.

After reviewing the financials and model, a couple of observations:

- 1) If Mr. Meyer is comfortable with the idea of continuously using his software for longer than 7 months / year, he should switch to the annual plan for the \$455/year savings.
- 2) Usage of the Laser Engraver during the pre-business timeframe runs a risk of incurring the Laser Tube replacement cost. The software cost savings mentioned above could be applied to this in the event of an outage.

**3 Manufacturing Processes**

This chapter will cover details of the manufacturing facilities and processes for Meyer Enterprises and investigate the questions of required space for an optimal manufacturing process and process efficiencies in product creation.

As was stated in Section 0, Mr. Meyer has a 100 sq. ft. workspace in a relative’s garage that is his primary work space. As was cover in section 0, Mr. Meyer has a deferred rental agreement for this space that runs \$1.02/sq. ft.

The fundamental challenge with this arrangement is the limited space to handle the steps of the manufacturing process. This section will review the space to quantify the benefits and expenses of the current space usage, and potential growth. Additionally, an inspection of the process of manufacturing a sample product and how it will be impacted by suggested space changes.

**3.1 Manufacturing Basics**

It’s necessary to cover some basic concepts of manufacturing to provide context to the following sections.

The definition of Manufacture is “the making of goods or wares by manual labor or by machinery, especially on a large scale.” (Dictionary.com, 2018) At its essence it’s a repeated pattern of motions that take in an input, like raw material, execute a series of prescribed steps either by machine or person that produces an expected outcome. For example, a 1 ft. x 2 ft. board enters a machine, the machine executes a pre-determined program, and 18 wooden coasters are created.

Because of this repeating nature, one focus of optimization is to reduce the time for individual steps thus increasing the process efficiency or, alternatively, reducing the cost of the materials entering the process, or to reduce the waste generated by the process could be considered as well. By focusing on optimizing individual steps the multiplicative nature of manufacturing cascades those savings over the batch of the process (Halevi, 2014).

For example, if a single step of a process takes an average of 45 seconds, and an improvement is made to that reduces the average to 38 seconds, a 7 second decrease in process time is obtained each time that step is executed. If the particular step is executed 2,000 times over the course of a product batch a time saving of almost 4 hours can be gained.

For the purpose of this work, the analysis will focus on steps that could potentially have a high time variance and materials that may bring a high product cost. The fundamental unit of production for this analysis is a blank which is a 12” x 24” board, which is the largest size the Epilog Mini 24 can accept.

### 3.2 Current Workspace Review

The current space has been configured for prototype creation and works well for singular creations. Outlined in Fig. 9 are the work stations used for creating prototypes.

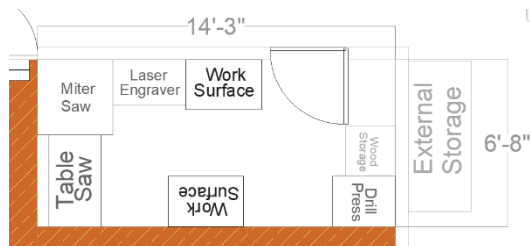


Fig. 9. Mr. Meuyer's current approximately 100 sq. ft. workspace

Here is an overview of each workstation and how it's currently used:  
**Computer (Not Shown)** – The laptop is the driver of the laser engraving process and is generally placed on one of the work surfaces to start the engraving process.

**External Storage** – This is where the wood for products is placed when purchased from the vendor. It's approximately 5ft high, 5 ft wide, and 2 ft deep, for a total volume of 50 cubic feet.

**Wood Storage** – by the entrance is a small storage box for wood that has been cut down to the size that can be used by the laser engraver. Also, referred to as internal storage.

**Work Surface** – There are two work surfaces in this area and both are 3 ft wide, 2 ft deep and sit 3ft off the floor. The work surface by the door is generally where materials are prepared prior to being placed into the Laser Engraver. The second work surface is on the opposite side of the work space and is where units that have been engraved or cut are finished.

**Laser Engraver** – The laser engraver machine is a desktop unit that sits upon a 3ft x 3ft x 3ft air filtration system, and itself is 2ft tall, 1.5 ft deep and 3 ft wide. It has a top load protective lid that can be raised for adding or removing material.

**Miter Saw** – The work-horse mounted miter saw is generally low usage and sits next to the laser engraver unless its needed, and then units are reconfigured to provide access.

**Table Saw** – The table saw is used to create the blanks by cutting the raw materials wood from the external storage into usable blank sizes (12in. x 24in. surface area). It stands 3 ft. tall, with a width of up 5 ft. and a depth of 3 ft.

**Drill Press** – The drill press is for drilling holes into the wood and has an adjustable table for precise work. It's rarely used in the current scope of work. It stands 6ft. tall, with a width of 2 ft., and a depth of 3ft.

**Scrap Bin (not show)** – The scrap bin is a large plastic container under the work surface by the door. It contains the wooden remains or scraps of the creation process. It's 2.5 ft. wide, 2 ft. tall and 1.5ft deep for a volume of 7.5 cubic ft.

One quickly apparent short-coming of this arrangement is post-creation storage. There is no designated place to store completed works. Often items that have been stained take much longer than advertised to dry, creating space issues that must be addressed at each step of the process.

### 3.3 Current Process Review

Upon observation, a work session was executed with Mr. Meyer to observe his current process. His steps were observed and plotted within a spaghetti diagram to look for inefficiencies in the equipment layout.

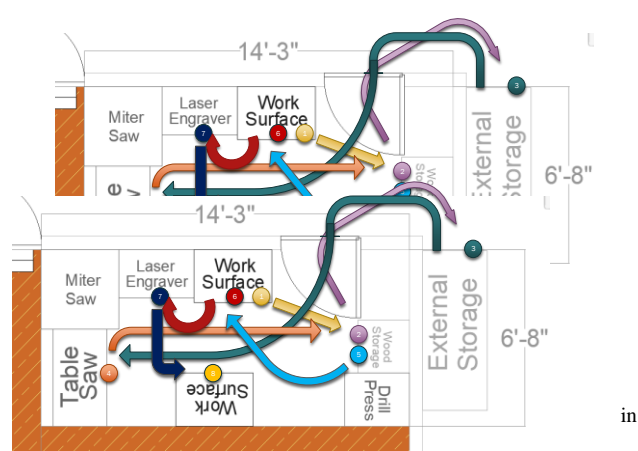


Fig. 10, the workflow begins from a laptop on the work surface (1), moves to the Internal Wood Storage to grab a blank (2), there isn't the correct type. A short trip outside to the external storage to grab a 6 ft. by 1 ft. board (3) and carry it over to the table saw (4). The board is cut into three 1ft. x 2 ft. blanks. The two extra boards are carried to the Internal Wood Storage (5). The one, freshly cut blank, is carried to the work surface where it is taped with masking tape (6) then placed in the Laser Engraver and positioned (7). The Laser Engraver job is started and the machine cuts the board into several units. Once the Laser Engraving is completed, the units are then taken to the second work surface where the tape is removed and the units are cleaned up (8).

A total of 63 feet is travelled in the course of his workflow, not including tool or material misplacement and retrieval. A distance of 14 feet is travelled if the wood is available in the internal wood storage.

Several inefficiencies presented themselves, namely the long path from External Storage (3) to Table Saw (4) while carrying a large board for cutting, and then carrying the cut pieces back to the internal storage area (5). Notes were taken for future recommendations covered in the next section.

Given that this is a one-person operation with limited space, there is no formal process to creating products. The general focus has been on creation of prototype creations that could be used as product concepts and for the low volume prototyping work that is being done, this space sufficiently meets Mr. Meyer's needs.

### 3.4 Process Analysis

After reviewing the methods used in the prototyping process and observing the disarray of the materials in use (as mentioned in Section 0) it was clear some type of methodology would be beneficial. The 5S's with its emphasis on workspace allocation and cleanliness seemed appropriate.

The 5S's are a continuous improvement methodology that focuses on work place organization and cleanliness (García-Alcaraz & Maldonado-Macias, 2014). It prescribes to organizing a work space for both efficiency and effectiveness by creating an organizational system that's clearly outlines work areas by functionality, and work spaces labeled with tools have specific placements that are easy to retrieve. Each step in the methodology

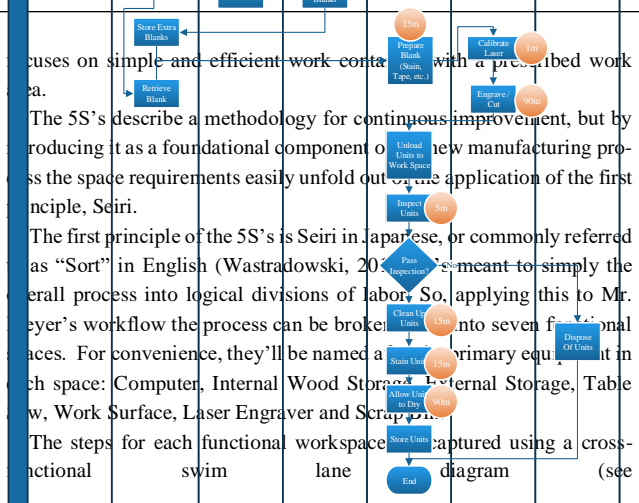
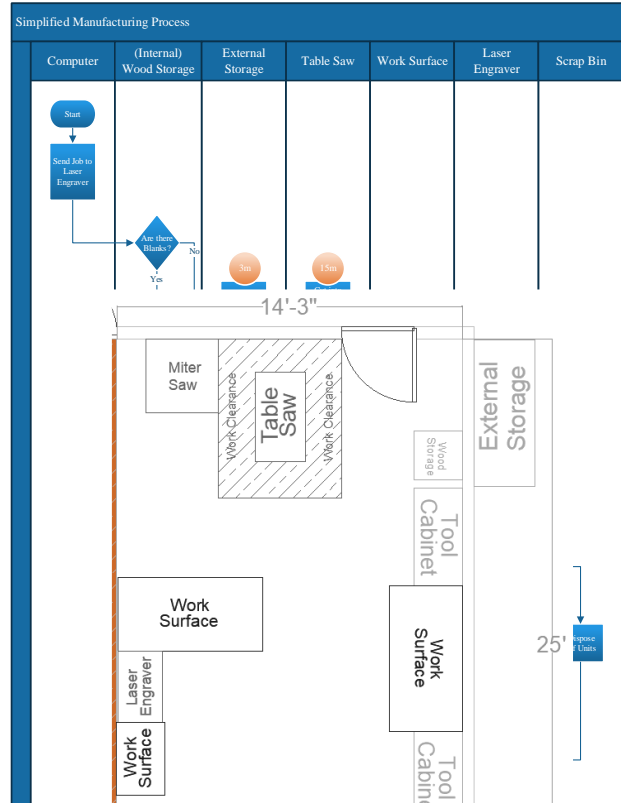


Fig. 11) that outlines the steps for the high-level manufacturing process. Each machine in the process is a functional swim lane, and the tasks and times are documented to provide a start-to-finish view of the process of creating a sample product. This process will be covered in more depth in **Error! Reference source not found.**

With a better understanding of what takes place at each station, an appropriate amount of space can be estimated.

The next step in the process is Seiton, or “Set In Order”. This step is to organize the individual work spaces with appropriate space and tools to perform the assigned function efficiently and effectively.

To accomplish this reorganization, the work space was reevaluated at a larger size sufficient for the work stations needed. From personal conversations with Mr. Meyer, he revealed he suspected he’d have to grow as manufacturing ramped up and was open to seeing the concepts of a larger workspace. (This larger work space was accounted for in the cost analysis in Section 0).



**Fig. 11**  
The redesigned area now extends 25 feet, as shown in

Fig. 12. The new area is 356 square feet. It contains space to safely operate the table saw and has five times the work surface areas as the previous layout (60 sq. ft. to the original layout’s 12 sq. ft.). Additionally, the open space beneath the four work tables can be used for product storage by placing the products in boxes that are then stacked under the tables.

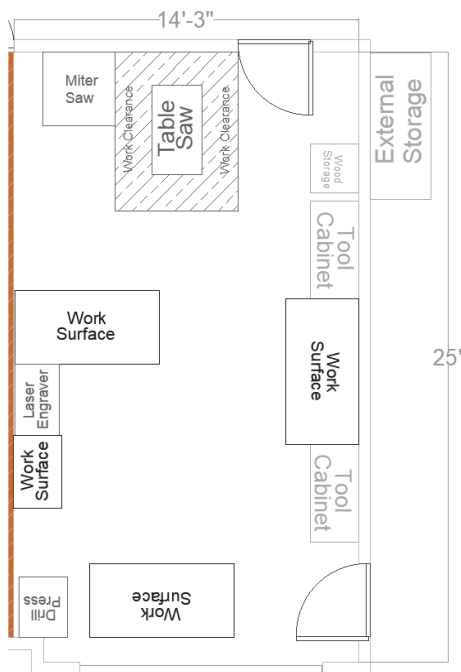


Fig. 12. Proposed layout for Meyer Enterprises

A projected spaghetti diagram was assembled to review the impact of these changes.

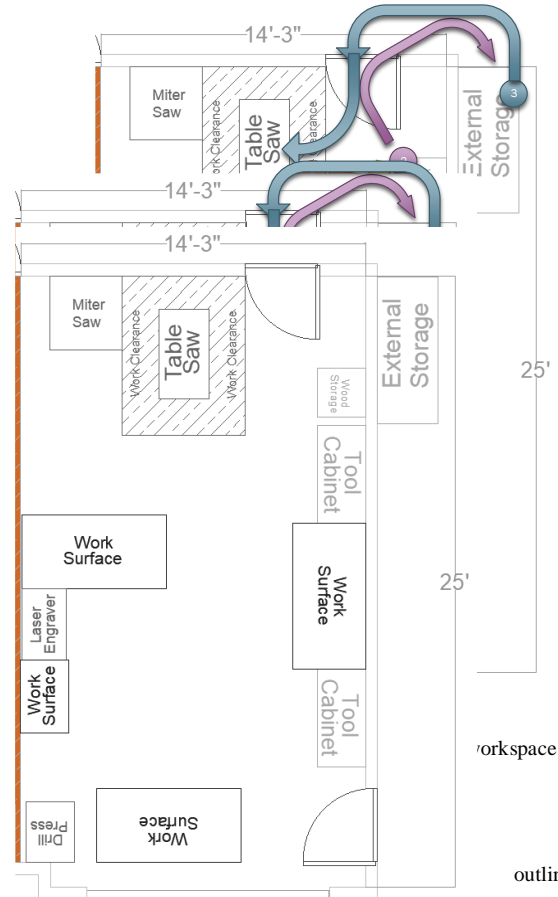


Fig. 12 with new travel distances and locations, with the exceptions of step (9) and (10). The station in step 9 is now the new staining station and station in step 10 is the new drying station. The drawback to this layout is the process now causes Mr. Meyer to travel 84 feet while manufacturing a batch of products, but each workstation has sufficient space to complete its task with minimal moving tools or materials. Additionally, the larger space allows for additional laborers to be added to the process for increased efficiency.

The last three S's, seiso (or shine), seiketsu (or standardize) and shitsuke (or sustain) are focused on the actions of the manufacturing (Wastradowski, 2018) and will be addressed in **Error! Reference source not found..**

### 3.4.1 Storage

If it's assumed that the space under each of the four tables is usable as a space for boxes, then a storage capacity for the new layout can be calculated. There's 5 feet between the legs of each of the large tables, a depth of 3 feet and a height of 3 feet, that's a cubic volume of 45 cubic feet. There are three spaces available, so the new layout has 135 cubic feet of storage space.

Pulling product dimensions from the example in Section 0, where there were 162 individual coasters divided into 27 sets, 33 Engraved Maps, and 30 Themed Plaques per show, for a total volume of 2,630 cubic inches. A cubic foot is 1728 in<sup>3</sup>, so one showings worth of material could be stored in 1.5 cubic feet of storage, so the new layout could store approximately

90 shows worth of product not including other shop items that may require storage.

### 3.5 Manufacturing Processes Conclusions

In this section, a review was done on the existing workspace and processed used by Mr. Meyer for his prototyping. From the review a need for an organizing methodology was discovered and the 5S's were applied to a new layout to better serve the needs for Meyer Enterprises in the future. This increased size and rent obligation was factored into the projected expense theoretical model in Section 0.

## 4 Product Analysis

The primary materials that are being used by Mr. Meyer for his products are wood and acrylic. Both materials, if under 3/8" in thickness, can be cut by the Epilog Mini 24 laser (Epilog Corporation, 2018). A change in thickness or material alters the speed or power settings at which the laser engraver can perform which directly impact production throughput. This chapter will review the product concepts provided by Mr. Meyer to look for risks and optimizations that may help save time and money.

### 4.1 Product Review

In the initial interview with Mr. Meyer he outlined three concept products that he wanted reviewed. They were: Drink Coasters, Engraved Maps, and Themed Plaques. Since they are conceptual products, not a lot is defined about them. To aid in analysis, some assumptions and definitions had to be made.

### 4.2 Raw Materials

In the world of woodworking there are hundreds of types of wood that could be used for the type of products Mr. Meyer would like to produce. For the purpose of this analysis, only the following wood products outlined in Table 17 are considered in analysis.

The boards are listed in a board-foot unit, which is defined as the volume equal to 12" x 12" x 1", or 144 cubic inches. For example, if a board is 1" thick, 12" wide and 60" (or 5 feet) long it would represent 5 board feet and the listed board-foot rate would be multiplied by 5 (the number of feet in the board) for total cost of the board.

Table 17. A sample of wood products with associated costs

Materials	Cost/Board Foot	Blank
0.125" Baltic Birch	\$0.62	\$1.24
0.25" Baltic Birch	\$0.93	\$1.86
0.25" Red Oak	\$3.47	\$6.94
0.25 Black Walnut	\$9.18	\$18.36
0.25" Purple Heart	\$11.13	\$22.26
1" African Mahogany	\$6.83	\$13.66
1" Cherry	\$5.78	\$11.56

As was defined in Section 0, a blank, for the purposes of this work, is the fundamental unit of processing at is 12" x 24" in dimension. It's the largest piece of wood the Epilog Mini 24 Laser Engraver can accept (Epilog Corporation, 2018). To aid in sample checking expenses, the cost per blank was included in Table 17.

#### 4.2.1 Drink Coaster Review

Drink coasters are small, typically circular placeholders approximately 3"-4" in diameter that are used to place cups upon to prevent water from condensation from sliding down the outside of the cup and puddling on a wooden surface, possibly damaging it. The condensation is pooled on the coaster, and not the table.

Upon reviewing comparable products on Amazon.com, it was discovered they typically range from \$10 to \$30 for a pack of six with the higher price point being reserved for detailed decorative designs (Amazon, 2018). Upon reviewing comparable products on etsy.com, a website for marketing hand-crafted goods to consumers, the price point ranged from \$20 to \$50 for a set of 6 (Etsy, 2018).

While there could be some flexibility in the price point for the hand-made feel of the product marketed in a craft-themed shopping booth, to minimize risk its advised to stay below the \$5/unit price point for manufacturing in case the \$30/set is a hard-upper limit. If future experience proves there is flexibility with the price point, then adjustments can be made.

#### 4.2.2 Drink Coaster Material Costs

The drink coaster design provided by Mr. Meyer are 4" in diameter, and 18 units can be engraved and cut from a single blank. This allows a low cost per unit with even Purple Heart costing \$22.26 (one of the highest board-foot boards) per blank will still allow a unit cost of \$1.24/unit or \$7.42/set of six.

There is another material cost in the form of stains or paint. The choice of stain introduces a large time variance in the form of "drying" time. Some high finish stains are gel based which can take upwards of 9 hours to dry, other more products dry within 60-90 minutes. So, in the process of deciding what finish to apply, the repetitive nature of the manufacturing process should be taken into consideration to ensure the overall product time does not get too cost prohibitive. The material cost per blank for stains ranged from \$0.18/blank to 0.33/blank.

#### 4.2.3 Drink Coaster Material Waste Costs

Due to the circular nature of the drink coasters there will be wasted material. A 4" diameter coaster takes up a surface space of 12.6 square inches for a total of 226.8 square inches. A 12" x 24" blank consists of 288 square inches. This means without a change to the layout 61 square inches (or 21%) is wasted on each blank ran through the process.

So, the more expensive the material used to make the product, the more expensive the waste generated.

#### 4.2.4 Engraved Maps

Engraved Maps are map features engraved into a material, like wood and are generally used as wall decorations. Mr. Meyer's designs for engraved maps of various Alaskan areas are set as 6" x 6" and a 12" x 8" single layer designs.

Upon reviewing comparable products on Amazon.com, it was discovered they have a large range in pricing \$30 to \$300 with the higher price point reserved for multi-layered topographical maps (Amazon.com, 2018). Reviewing the craft site, Etsy.com revealed price points ranging from \$20 to \$180 (Etsy.com, 2018).

#### 4.2.5 Engraved Maps Material Cost

Mr. Meyer's designs for Engraved Maps contain two separate dimensions: 6" x 6" and 12" x 8", and single layer. Most of the products in the category were topographical in nature and required multiple levels.

For the 6" x 6" unit size, 8 units can be made per batch. Assuming the use of a Cherry Wood, at \$11.56 per blank, this would provide a base unit cost of \$1.45 / unit. Considering the double layering of the wood, the lower level wood could be of a lower costing material, such as Baltic Birch which is \$1.24/blank, this would only raise the cost per unit to \$1.60/unit.

For the 12" x 8" unit size, 3 units can be made per batch. With the larger dimension, and lower unit count, the use of Cherry Wood, at \$11.56/blank, will provide a base unit cost of \$3.85/unit. As above, considering a less expensive bottom layer could increase the value of the end product, the same Baltic Birch at \$1.24 / blank would raise the unit cost to \$4.27 / unit. Well below the sell price point.

The material costs for stain or paint would also play a factor, but all considered stain products are less than \$0.35/blank but do run the risk of introducing a variance in the process time due to drying time.

#### **4.2.5.1 Engraved Maps Material Waste Costs**

As long as the unit shapes were of rectangular in nature and were sized to be easily divisible from the blank, waste would be kept to a minimum.

#### **4.2.6 Themed Plaques**

Themed plaques are simple decorative units that contain an inspirational quote or branded logo. They can come in a wide variety of sizes from small 2" by 2" refrigerator magnet size to multi-section pieces spanning several feet.

Like the previous products, a comparative review was made on Amazon.com and Etsy.com to gauge rough price points for the products Mr. Meyer has designed. Due to the similarity in size and material the Themed Plaques had price points similar to the Engraved Maps on both Amazon.com and Etsy.com.

##### **4.2.6.1 Themed Plaques Material Cost**

Mr. Meyer's designs for Themed Plaques contain two separate dimensions: 6" x 6" and 12" x 12", and single layer.

For the 6" x 6" unit size, 8 units can be made per batch. Assuming the use of a Cherry Wood, at \$11.56 per blank, this would provide a base unit cost of \$1.45 / unit.

For the 12" x 12" unit size, 2 units can be made per batch. With the larger dimension, and lower unit count, the use of Cherry Wood, at \$11.56/blank, will provide a base unit cost of \$5.78/unit.

The material costs for stain or paint would also play a factor, but all considered stain products are less than \$0.35/blank but do run the risk of introducing a variance in the process time due to drying time.

##### **4.2.6.2 Themed Plaques Material Waste Costs**

As with the Engraved Maps, as long as the unit shapes were of rectangular in nature and were sized to be easily divisible from the blank, waste would be kept to a minimum.

### **4.3 Product Analysis Conclusions**

This analysis looked at the basic material costs that go into the product concepts provided by Mr. Meyer. It does not address the creation of intrinsic value by having an appealing design.

By designing for multiple units per blank, we lower the material cost per unit.

There are potentially high variance variables in replicating a design in one wood over another. For example, if a 12" x 24" Baltic Birch blank

was used to create two Themed Plaques and it took 120 minutes to complete. Repeating that with a different wood is not the same as running the same program again. Due to the density of the wood and other physical features, more power or slower cutting speed may be required. This introduces a high time variance into the process that needs to be tested and quantified before a product manufacturing process is finalized.

Another potential high variance variable would be in detail staining or painting of a product. This would increase a per unit process time and would be have the greatest impact on the overall batch process time. This could be mitigated by the creation of stencils that allow faster application of stain over a set space, and different stencils could be used for the various parts that require different staining.

There could be opportunity to lower the waste by-products like the Drink Coasters by cross-seeding the batch with a smaller product to take up the space, such as 1" diameter sized units that take up the wasted space. This is done at the increase of the overall job speed and may not be worth the additional time to save the material from being wasted.

## **5 Conclusion**

To bring this project to closure, the initial objectives from Section 0, need to be brought forward to be reviewed.

### **Business Financials**

- 1) Outline the company financial statements, cash flow, and projected cash flow for the next 5 years.
- 2) Calculate overhead and equipment depreciation.
- 3) Calculate the break-even point for initial business investment, calculate a Return On Investment (ROI) for the equipment purchase.
- 4) What is the most cost-effective method of managing business software, subscription or purchase?

### **Process Development & Review**

- 1) What would be an optimal manufacturing process given 3 categories of common product types?
- 2) How can an optimal manufacturing process be expanded to increase manufacturing volume?

### **Product Cost Analysis**

- 1) Examine a simple Inventory Management process and cost analysis of inventory.
- 2) What tools could be added to the business to provide a shorter return on investment?

Each category is reviewed in the following sections and concluding thoughts are presented.

### **5.1 Business Financials**

One of the challenges facing small business owners, and especially craft-based businesses, is budgeting sufficient pricing to cover all expenses, especially a livable wage. It's very common that business owners in fear of offending people with their prices which include sufficient overhead to pay the business owner a wage will sell their wares at a price that barely covers the cost of materials (Tiffany, 2002).

To address this short coming, the budgets and projected expenses covered overhead expenses that included equipment lifecycle replacement, contingency funds for equipment failure, facilities rent and to pay the Mr. Meyer an hourly wage.

An idealized model was created to use as an example of the possible expenses and income over the next seven years. Within that model a return on investment was calculated that showed a potential for recovering the

investment monies within a few years of starting business. Additionally, a depreciation method was selected that would help offset business income with equipment depreciation. The model also showed the possibility of any deferred debts being paid within three years of starting the business while maintaining sufficient profits to reinvest in the business raw materials needs and equipment upkeep.

Lastly, a detailed review of currently used software and available subscription models revealed a possible 70% savings if Mr. Meyer feels he'll commit for at least 7 months without cancelling his subscriptions that he'd save 70% of his subscription costs by switching to annual subscriptions.

The difference in the subscription costs would help reduce the risk of a discovered Laser Tube failure issue where users of the Epilog Laser Engraver systems reported a high variance in the Mean Time Between Failures (MTBF) on Laser Tubes, a critical piece of the system. To address this risk of failure, a 1,500-hour replacement life was added to the Laser Cost of Ownership calculations. Prior to business launch, this risk can be mitigated by the change in software subscription costs and saved toward the risk of failure.

## 5.2 Process Development & Review

During the evaluation of the guiding questions for this section it was discovered that optimal was a bit ahead of the curve. Before optimal could be developed a foundational process needed to be developed.

Upon reviewing the environment where prototyping takes place, the necessary space for clean, efficient workflow is not possible and there was not sufficient storage adequate for when the business launched. To address that need, a new layout incorporating the first three concepts of the 5S's was developed. While it does increase the overall travel distance of the operator of the process, each station has sufficient space to be compartmentalized, and storage areas are created that address the storage issue.

Addressing future expansion of the process will be an evolutionary process where each step of the process is refined over time to reduce time delays. Additional equipment can be reviewed for addition to the process and a new process analysis can be performed to determine its efficacy.

## 5.3 Product Cost Analysis

Mr. Meyer provided three concept prototype products to be reviewed. After a cursory review of two large online market places the products he's selected do have potential to have market appeal. However, any success the products may have will depend greatly on the end products' craftsmanship and intrinsically assigned value. So, while the products have a theoretical potential, Mr. Meyer will need to refine his process and settle on the details that will allow his products to stand out.

It was discovered that there would be approximately 20% material waste on his coasters unless a secondary product to be placed among the primary product to use the space, but only if the secondary product does not add significantly to the engraving and cutting time of the Laser Engraver.

It was also discovered that as long as the geometry of the shapes of his products stayed relatively consistent with the blank size and the unit's shapes easily divisible of the shape of the blank, material waste would be minimized.

Lastly, a potential high variance in process time was reviewed in the form of detailed painting or staining of units. The per unit portion of the process is the most susceptible to multiplicative effects of a repeating process and small amounts of time adding up quickly. A suggestion of using stencils to make the stain application faster was suggested.

## 5.4 Key Indicators of Business Readiness

To aid Mr. Meyer in his decision making process on if, and when, he should start his business are a few simple benchmarks to consider.

**Product Variation** – Product variation is a derivative of a main product concept. For example, having two styles of drink coasters one with a large silhouette of a leaf, and another with a large silhouette of a bear paw. This allows variation of products with minimal design investment. Mr. Meyer should have 4-5 variations for each product type prior to business launch. This will minimize a risk of a single poorly received product design from disproportionately impacting his sales.

**Process Time Stability** – Process Time is the total processing time it takes to take a batch from raw material to finished product. Due to the high time variance in laser engraving time and staining/painting, several batches need to be executed and the process time logged for each product prototype. When the deviation in process time is down to within 10%, which for a 4 hour process would +/- 24 minutes for each product type. This will provide stable estimation of labor and equipment costs to appropriately price the units.

**Process Error Stability** – Process Error is the total errors during the execution of the manufacturing process. Process errors manifest in each step of the process. For example, during the laser engraving phase, a vector cut step where the laser is used to cut completely through a material, and due to power fluctuations or changes in wood density is not able to complete the cut. During the pre-business time, as Process Time stability is being derived, Process Error should also be documented and each error investigated to determine root-cause in an effort to minimize their occurrence. During this time, establish a Process Error Rate, and minimize it to an acceptable level as determined by wasted material costs.

## 5.5 Closing Thoughts

Mr. Meyer has a great opportunity ahead of him to fully realize the potential of his investment and to see significant returns. However, given the financially inflexible position he'll find himself in an early retirement stage of life he'll want to minimize his risk of overextension. The principal investment is already made, and now he simply needs to work towards making a return on the investment by incrementally growing his business by reinvesting his profits into the business raw material and operational needs.

To that end, it's recommended that prior to retirement, he works a deal with an existing Crafts Vendor or local souvenir shop to do a the short-run consignments. These short consignment runs will provide an opportunity to gauge public acceptance of his product ideas without a large raw materials investment and will help him perfect his product concept.

Lastly, in the time prior to the launch of his business, Mr. Meyer will need to gain proficiency in the software tools and equipment for his business. The better this proficiency, the easier the product development process will go and the more easily manufacturing adjustments can be made.

It's the author's sincerest hope that Mr. Meyer is successful in his endeavors and realizes the success he seeks.

## 6 Future Work

Listed below are possible follow up work to further refine this analysis:

- 1) **Manufacturing Simulation Model** – In the scope of the analysis for this project, the author started a Matlab model of the manufacturing steps to fully explore the step-by-step dependencies of the process to look for bottlenecks.

By continuing that work, changes to the process could be simulated prior to using materials to get the best system capacity possible.

- 2) **Refined Cost Model** – As the business gets closer to launch, a review of the cost model and updating any outdated values would provide a more accurate review of the projected business expenses. Including additional analysis for changing in insurance costs necessary to provide sufficient coverage for the Mr. Meyer’s business interests and the impact to the home owner’s insurance for hosting the business.
- 3) **Continued Implementation of 5S Methodology** – As the business grows, and the manufacturing workspace is built, the continued adoption of the 5S methodology is recommended. This will allow for clean, compartmentalized work areas that will allow Mr. Meyer to expand his labor force quickly and easily since each station will have a defined set of procedures.
- 4) **Systematic Method for Increasing Quality** – As the products evolve prior to business launch, review key characteristics that could add intrinsic value.

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**Appendix**

**Power usage data Collected**

The power usage of the Epilog Laser Engraver is variable and depends greatly on the usage. To attempt to quantify the usage four 2-hour jobs were used to sample the power usage data. An Insignia WIFI-enabled Smart Plug with built-in Metering was purchased for the data collection. The Smart Plug was plugged into the electrical outlet, and the Laser Engraver, Air Filtration System and Air-Assist Air Compressor were all plugged into the Smart Plug via a power strip.

The Smart Plug come with a phone app that showed power usage in Kilowatt-hours, this data was recorded every 15 minutes through the batch job. Using MS Excel, the average and deviation was calculated using built-in functions.

Batch	Time (min)	Power Usage (KWhr)	Average (KWhr)	Derivation
1	0:15	0.74	1.38	0.28
	0:30	0.98		
	0:45	1.43		
	1:00	1.45		
	1:15	1.41		
	1:30	1.87		
	1:45	1.29		
2	2:00	1.89	1.28	0.44
	0:15	0.74		
	0:30	0.91		
	0:45	0.91		
	1:00	1.62		
	1:15	1.90		
	1:30	1.90		
3	1:45	1.48	1.35	0.37
	2:00	0.80		
	0:15	0.74		
	0:30	0.99		
	0:45	1.85		
	1:00	1.65		
	1:15	1.47		
4	1:30	1.81	1.39	0.51
	1:45	1.47		
	2:00	0.83		
	0:15	0.73		
	0:30	0.79		
	0:45	1.01		
	1:00	0.99		
<b>Total</b>			<b>1.4</b>	<b>0.4</b>

Average power consumption was 1.4 Kilowatt-hours with a standard deviation of +/- 0.4 Kilowatt-hours.