A STROKE OF SHEAR GENIUS
The Development of the Blade Bandit

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Abstract

ABDULRAHMAN HAMID AND COLIN WATTIGNEY: A Stroke of Shear Genius

This thesis will document and analyze the experience of two members of the Shear Genius team, Mr. Abdulrahman Hamid and Mr. Colin Wattigney, as they worked to complete the CME Senior Capstone Project. This team, under the leadership of CEO Ethan Veazey, developed the Blade Bandit, a lawn mower blade sharpening system conceptualized by Mr. Jacob Moorhead. Ms. Kristen Gaddis, Mr. Nick Rocco, and Ms. Allie Winters were also members of Shear Genius. The team members had educational backgrounds in the realms of engineering, business and accountancy. The combination of these disciplines allowed for the simulation of a real business group and helped prepare the team members for the situations that they would face as members of industry.

After months of planning, designing, and redesigning, the Shear Genius team was able to develop a process in which a functional Blade Bandit could be produced quickly and consistently. The team gained vast amounts of experience and worked together as a cohesive unit to overcome the many obstacles that were faced. This thesis will describe iterations of the Blade Bandit, the business model used, and the changes made along the way. It will also provide insight into all decisions made over the course of the project.

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List of Abbreviations

CME – Haley Barbour Center for Manufacturing Excellence

TPS – Toyota Production System

CEO – Chief Executive Officer

DFA – Design For Assembly

DFMA – Design For Manufacture and Assembly

LLC – Limited Liability Company

1. Introduction

The Haley Barbour Center for Manufacturing Excellence (CME) Senior Capstone Project is designed to expose students to the entire process of bringing a product to market, from ideation to fulfilling customer orders. The educational program within the CME consists of three main disciplines: Accountancy, Business, and Engineering. In addition to fulfilling the degree requirements for their chosen discipline, CME students study lean manufacturing based on the Toyota Production System (TPS). Students from each discipline study and work together in manufacturing courses in an effort to break down barriers that typically exist between departments in industry. Thus, the students become proficient in their chosen major and familiar with the other two disciplines. This allows the students to be able to communicate effectively with coworkers in other departments and consider all aspects of business while doing their job. The CME capstone project aims to take this education a step further by allowing these students to work in interdisciplinary teams and create a viable business just as they would in the real world. This thesis will discuss the usage and effectiveness of Toyota Production System (TPS), lean manufacturing, and design for manufacture and assembly (DFMA) principles in the development of a product from inception to realization.

The project began in August 2014 with the ideation phase. Every student was charged with developing an idea for a product marketable to the Ole Miss/Oxford community that could be manufactured on the CME factory floor. Students were to then pitch their idea, in the form of an elevator speech, to a panel of judges consisting of CME faculty and industry specialists. The panel played the role of investors and selected three of these products. They divided the class into six groups. Teams then created a business plan and submitted it to the panel in late October. The purpose was to convince the investors to support the new venture.

With advice and feedback from the panel, the teams began building and drawing a simple mockup of their product to present. This mockup allowed investors to see what the business had in mind for their product and to make any suggestions about the product's design and functionality. Next, the teams began designing and building a fully functioning prototype of their current vision for the product. In December, this product was presented to the panel and demonstrated if necessary. The panel then gave their feedback on the design, function, and manufacture of the product.

The first half of the spring semester 2015 was spent optimizing the design and manufacture of the product. After optimization of the process occurred, two teams at a time were given a two week period to set up the manufacturing line, conduct trial runs, make last minute improvements, and produce a predetermined number of products in a timed production run observed by the faculty panel. The panel then assessed the production line and products and discussed their thoughts with the teams. The project concluded with a final presentation analyzing the project's successes and failures.

2. TPS and Lean Manufacturing

This thesis will discuss several TPS, lean, and DFMA principles and their use throughout the capstone project. Knowledge of the principles was obtained through coursework in the CME curriculum and honed by the work experience and projects throughout students' careers. Major ideas that drove decisions include one-piece flow, minimal inventory, and U-shaped assembly lines.

One-piece flow is the production of one part at a time. This method eliminates potential errors and confusion tied to batch operations as workers can devote their full attention to one part. They are not required to manage a large amount of material, which allows for smoother workflow. One-piece flow is also known as continuous flow as it allows for quick transitions between operations with very little time wasted or devoted to preparing for the next operation. It is intended to simplify and error-proof the manufacturing process by making each task simple and reducing the amount of inventory that sits on a manufacturing line at any point in time.

Limited, Just-in-Time (JIT) inventory principles are also incorporated in the development of the manufacturing process. Inventory is considered to be one of the seven wastes in manufacturing; limiting it to only what is necessary for production reduces cost, aids the operators, and improves the overall quality of the product. Physically, it removes clutter and allows for a clean and open workspace. It minimizes the likelihood of worker error by reducing the number of decisions the operator must make since only the material to be processed immediately is near.

A counterclockwise, U-shaped production line is generally the best method of facilitating one-piece flow and a JIT inventory system. In a U-shaped line, the workstations for operations are in order and adjacent to one another. The semi-closed nature of the U provides enough space for all workers to move around and communicate with each other without obstruction. It is very flexible as it can be divided between workers in a variety of ways, such as in short lines or small, inlying U's. U-shaped lines aid one-piece flow by allowing the product to be passed from one operation to the next with minimal wasted time. It is even more beneficial for a JIT system. The open end of the U is generally designed for loading of raw materials and removal of finished products for shipping. Having the two next to each other simplifies material delivery processes and keeps the area within the U free from a material handling team. If a line requires more than one raw material feed, a U-shaped line still allows for a JIT system that does not interrupt the flow of the line. In this case, material can be delivered and loaded from the outside of the U. The counterclockwise direction of motion is a standard of lean manufacturing. For right-handed people, who encompass the majority of the population, research has shown that it is more natural to begin an operation by pulling from the right side and ending it by pushing to the left.

Other principles that were utilized include the simplification of the assembly processes (sometimes at the cost of complicating manufacturing processes), the standardization of operations, and minimization of part count. Simplifying assembly is necessary as it can be incredibly time consuming, sometimes more so than manufacturing. This will be exemplified in the development of the grinder mount. Setting standardized work conditions is a method of implementing poka-yoke (error-proofing the process). The team utilized this in the creation of stencils and having workstations set in the ideal location for operations. The minimization of part count lowers inventory requirements and serves as another method of poka-yoke by reducing the likelihood of incorrect part placement.

3. Ideation

To begin the CME capstone project, each student was charged with developing a product to pitch. The requirements given for the product were as follows: the product must be marketable to the Oxford and University community, and it must be manufacturable in the CME without major capital expense. This open-endedness led to a wide range of products from the class.

Every student pitched a product idea to a panel consisting of CME faculty and industry specialists in marketing, accounting, and manufacturing. While the panel considered their personal opinions about the viability of the product ideas, they also considered more objective criteria when selecting the products. The panel eliminated ideas that were unreasonably priced for the average consumer and could not be manufactured alongside other products.

Ultimately, the panel selected three products for the project. The senior class was split into six groups of six with two groups assigned to each product. The three students whose ideas were chosen would be the CEOs of three groups, and three additional students were chosen by the panel to be CEOs of the remaining groups. Jacob Moorhead is one of the CEOs whose idea was chosen; his idea was for a device to assist with the sharpening of lawn mower blades. Ethan Veazey was chosen as the other CEO who would design and manufacture this product, and his company would become known as Shear Genius.

As the owner of a lawn care business, Mr. Moorhead has often struggled with dull lawn mower blades. Frequently replacing blades is expensive, but sharpening used blades by hand can be difficult and dangerous. It is especially difficult to achieve a consistent and sharp edge on a blade at the optimum cutting angle. These issues inspired a device that would assist with the sharpening process. It would create a sharp cutting edge on any type of blade at the optimum angle, and it would do so safely and quickly. Mr. Moorhead envisioned marketing this product to homeowners and lawn care businesses alike. His preliminary market research found interest in the product. The owner of a local lawn mower dealership indicated he would be interested in purchasing such a product for his shop, as did the Director of Landscape Services at the University of Mississippi. There was also interest among private consumers. This interest was communicated by word of mouth.

In Mr. Moorhead’s original pitch, he included a basic conceptual mockup of how this device might look and work. The drawing is shown in **Figure 1**. The concept included a mount to hold the lawn mower blade stationary on the base and a rod mounted above the base on which the grinder can slide from side to side.

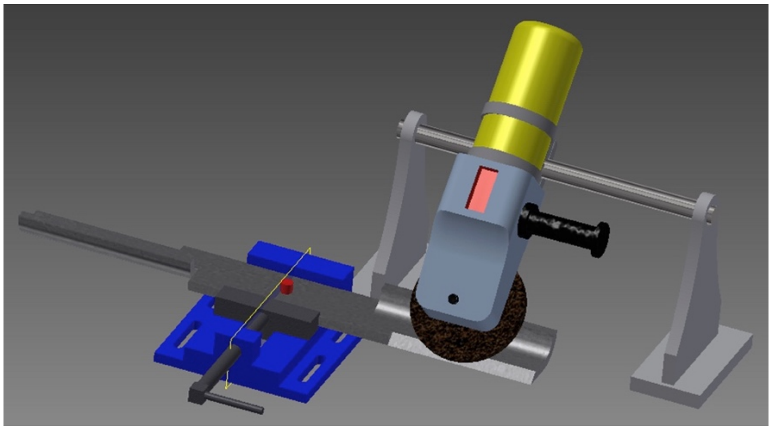

Figure 1: Original Concept of the Blade Bandit

4. Business Plan

As with any business, before the design and prototyping phase began, a business plan was created. This established a foundation upon which the business was based. This business plan was submitted and presented to the CME panel in order to earn their financial, professional, and academic support. It was divided into the following sections: Executive Summary, Operational Plan, Marketing Plan, and Financial Plan. The Operational Plan includes a description of the business, description of the product, manufacturing process, legal structure, management, personnel, record keeping/accounting, and insurance/security. The Marketing Plan includes the target market, marketing/sales, competition/advantage, and location/facility. This business plan was written as if Shear Genius were a real, registered business in Oxford and the CME was a potential investor. The entirety of the business plan is provided below with supplemental analysis following each section. The original report is italicized and quoted to distinguish it from the analysis. This business plan refers solely to the first prototype design; many product specifications have since been modified and will be discussed later in the report.

4.1 Executive Summary

"Shear Genius will serve the landscaping industry by providing a tool that will assist in the daily operation of a landscaping business. The Blade Bandit will allow [the consumer] *to sharpen a lawn mower blade more quickly and safely than ever before while achieving the perfect cutting edge every time. Currently, there are no other*

products on the market that function in the same manner as the Blade Bandit. This means businesses that have never purchased a blade sharpener will be inclined to give the Blade Bandit a chance.

The Blade Bandit will be primarily marketed to high volume users; these include landscaping companies and state and municipal maintenance groups. The marketing team will contact these groups [for sales]. *From there, each business will be visited and the product will be demonstrated to the potential customer. This hands-on approach to marketing will replace conventional advertising. By demonstrating the quality of the product, Shear Genius hopes to establish a strong reputation and get word-of-mouth advertising through the appropriate professionals.*

Shear Genius is estimating sales of 500 units in the first year. Within these 500 units, the company is estimating that sales will be evenly split between the two available models; 250 will be sold with a grinder and 250 without. Selling the product with the grinder allows for a bigger price markup, as it will be presented as the more convenient and accurate of the models. With increased sales of the high-end model, it is possible for the company to reach a reasonable profit within the first year of operation.

Shear Genius is seeking an investment of $30,000 from the CME for a 10% stake in the company. The investment will go towards the purchase of the required equipment and fixtures for manufacturing, which totals $22,161. The remaining $7,839 will be used in the purchase of the raw materials required to manufacture the initial products and to cover other unexpected expenses. Shear Genius expects a net income of $8,801.32 in the first year of operation, which is a 40% return on the purchase of its equipment. Shear Genius' five-year plan is to earn a net income of $31,574.57 by the year 2020 and have a *market valuation of $500,000. With this valuation the CME would have a 167% return on its investment in Shear Genius.*

To manufacture the Blade Bandit on the CME Factory Floor, Shear Genius will use the AccuSquare [panel] *saw, three drill presses, a manual foot shear, a horizontal band saw, a thread tap, a hammer, various sockets and ratchets, and several workstation tables. These machines will have to be repositioned on the factory floor in order to achieve proper flow throughout the process. The* [panel] *saw will be kept in place, as this is the largest and least mobile machine. The drill presses, band saw, and various workstations will be positioned around the saw according to the Operation Plan discussed later."* [1]

This executive summary sought primarily to introduce the CME panel to Shear Genius as a business. It briefly summarized the points covered in detail throughout the remainder of the Business Plan.

4.2 Operational Plan

Description of Business

"One problem many lawn mower owners and landscape businesses face is dull lawn mower blades. The blade may not seem like a huge deal, but it plays a vital role in the overall upkeep of a lawn. Without a sharp blade, one may be left with a lawn with uneven grass and a patchy finish. These problems can be easily avoided by using a sharper lawn mower blade. One solution is to buy a new blade every time the old blade gets dull, but this becomes expensive and wasteful. The most cost efficient solution is to sharpen the blade. Typically, a blade is sharpened by holding the blade against a bench grinder. This is not only time consuming, but also dangerous. Our product, the Blade

Bandit, is designed to provide a safe and efficient method for sharpening lawn mower blades. It is targeted to customers who own lawn care businesses or service lawn mowers. The Blade Bandit allows these customers to reduce the time spent sharpening blades and the risk of injuries.

The Blade Bandit uses a vise that holds the lawn mower blade in a fixed position. A grinder is attached to a slider on a bar that is elevated relative to the lawn mower blade. The slider allows the grinder to sharpen the entire cutting surface of the blade uniformly. Since both the blade and grinder are fixed to the platform of the device, the risk of slipping or other mishap is significantly reduced.

In order for Shear Genius to establish market share in its industry, an appealing product, competitive pricing, and marketing are crucial. This product relies on word-of-mouth recommendations as the product is targeted primarily to those who own landscaping businesses or service lawn mowers. Currently there are no products on the market that provide the safety and precision of the Blade Bandit. In the future, Shear Genius' competitive edge is to maintain a reputation of ease of use, reliability, and safety." [1]

This section established a background for the idea of a lawn mower blade sharpener and explained the need for this type of product. Common sense dictates that a dull lawn mower blade is not ideal for landscaping. A dull blade would tear the grass. This tearing requires more force than cutting and causes more wear on the equipment. The real issue being substantiated is the waste and danger incurred while sharpening a blade using anything other than the Blade Bandit. Many people might be inclined to throw away old, dull blades and buy new ones, which is wasteful of both material and money, and is not a sustainable model. More commonly, shops and consumers will use a bench grinder to sharpen dull blades until they are no longer useful. A bench grinder is stationary on a stand or workbench, and the operator holds the blade against the grinding wheel to remove material and create a sharp cutting edge (see **Figure 2**). The two main issues with this method are quality and safety. Lawn mower blades should have between a 35° and 45° cutting edge, depending on the type of blade and grass being cut. Using a bench grinder, it is difficult for anyone but the most experienced professional to achieve the exact desired angle on the blade and to do so consistently. Many large lawn mower decks have three or more blades; inconsistent cutting angles among these blades will cause an uneven finish on a lawn. This method is also inherently dangerous for the operator who holds the blade with his or her hand very close to the grinding wheel. A small slip could result in the hand making contact with the grinding wheel. Moreover, the grinding wheel could pull the blade as it makes contact, yanking the blade out of the operator's hands or jamming the grinder. Blade Bandit solves both of these problems by fixing both the blade and grinder to a base platform.

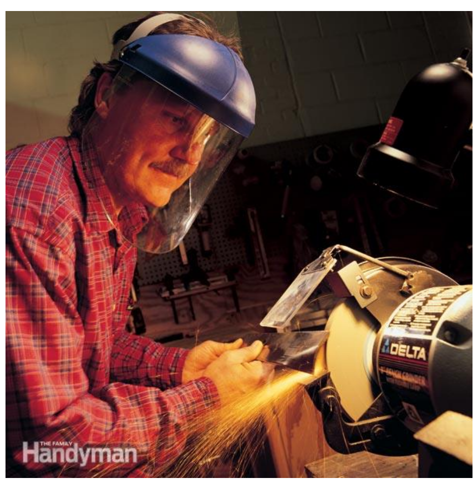

Figure 2: Sharpening a Lawn Mower Blade with a Bench Grinder. [2]

Product

"The Blade Bandit functions by [setting] *a grinder at a specified* [cutting] *angle against a lawn mower blade. The operator slides the angle grinder along a spindle that is parallel to the blade. The system requires that the angle grinder have a handle diameter of three to five inches. Also, the system works best with angle grinders that have power switches on the top or side; angle grinders with the power switch on the bottom may interfere with the grinder attachment. The Blade Bandit offers an optional Welbilt angle grinder that can be purchased with the system and meets the design specifications. The degree of the angle grinder is adjustable from 30°, which is ideal for mowing yard grass when a sharp blade is desired, to 45°, which is ideal for mowing thick brush when a blunt blade is desired. The lawn mower blade is held in a vise attached to the base of the system to prevent blade movement during sharpening. The angle adjustments are made by loosening the wing* [bolts] *and sliding the vise toward or away from the spindle. In addition, the vise acts as a safety precaution to prevent pushback that can occur when holding the blade against a grinder. Since the cutting edge of a lawn mower blade ranges from approximately six to twelve inches, the grinder has a translating range of twelve inches on the spindle.*

Table 1 *shows a bill of materials for the Blade Bandit and their respective suppliers. The Blade Bandit has five material suppliers: The Home Depot, MSC Industrial Supply Co., Harbor Freight, Northern Tool and Equipment, and J.W. Winco, Inc. These are large international companies that have operated for decades. Each company's website shows that the desired materials are readily available for order.*

Table 1: Materials and Suppliers

Material	Supplying Company
Wood for Baseplate	Home Depot
Metal Cover	MSC Industrial Supply Co.
Sliding Spindle	MSC Industrial Supply Co.
Vise	Harbor Freight
Steel Side Brackets (2)	MSC Industrial Supply Co.
Wing Screws (4)	J.W. Winco, Inc.
Baseplate Screws (4)	MSC Industrial Supply Co.
Screw for Brackets	MSC Industrial Supply Co.
Tee-Nuts (12)	MSC Industrial Supply Co.
Hose Clamps (2)	MSC Industrial Supply Co.
Washer (4)	MSC Industrial Supply Co.
Washers (6)	MSC Industrial Supply Co.
Welbilt Angle Grinder	Northern Tool + Equipment

The 23/32" x 11-½" x 24" pressure treated wood baseplate is the anchor for the entire system. Tee-nuts are inserted into the wood to provide solid attachments between components. A thin aluminum sheet covers the top of the baseplate for protection from sparks. Two ½" x 3" x 7-½" steel bars form the side brackets of the system that function to hold a 16" spindle between them. A metal slider with clamps that holds an angle grinder is attached to the spindle. The slider is made from two ½" x 1-½" x 3" steel [bars]. *A ½" hole is drilled between them, [through which the spindle will pass]. Two bolts attach the brackets with two hose clamps between them. The spindle is 16" long, which allows the angle grinder to have 12" of lateral movement. A vise is attached to the baseplate beside the left bracket by four screws. The vise has four sliding joints that allow for repositioning the vise. The screws holding the vise are wing screws, which allow tool-less adjustments. All* [bolts] *in the assembly are* [¼"-20 UNC] *to allow for easy assembly. The equipment required for manufacturing is listed in* ***Table 2.*** *It will be purchased from the CME for $22,161 and will require rearranging. All of the equipment* *can be easily rearranged except the AccuSquare panel saw; the layout is designed around that machine.”* [1]

Table 2: Equipment and Cost

Equipment	Cost
Panel Saw	$4,099
20" Var Spd Drill Press Vectrax 1Spd Mtr 3hp/220V	$1,999
Tennsmith Manual Foot Shear 52-1/4	$2,520
20" Var Spd Drill Press Vectrax 1Spd Mtr 3hp/220V	$1,999
20" Var Spd Drill Press Vectrax 1Spd Mtr 3hp/220V	$1,999
Roll-In Saw HS1418 Horizontal Band saw	$8,395
Rockford Belt sander	$650
Tools and Fixtures	$500
Total	**$22,161**

The vise will be mounted directly to the base, and its position will be adjustable. Moving the vise farther from the grinder spindle will decrease the angle, and moving it closer will provide a blunter cutting edge. The customer can choose at which angle to sharpen the blade according to the application. Finer grass with high-lift blades will require a sharper angle, while mulching blades will require a blunter angle. During this design phase, the Blade Bandit was going to be offered for sale with and without an included angle grinder. The model including the grinder would be recommended, as this model would provide higher revenue. Furthermore, there are specific design specifications for the grinder to ensure compatibility with the Blade Bandit. Purchasing the grinder with the Blade Bandit would eliminate any compatibility issues, as the product was designed around the Welbilt grinder.

At this design phase, the grinder was going to have two degrees of freedom: one along the spindle and one rotating about the spindle axis. The original grinder mount assembly can be seen in **Figure 3** below. These limit the grinder to only the motion deemed necessary at the time to sharpen the blade, which greatly reduces the possibility of mishaps with the grinder. The spindle was long enough to cover the cutting edge of a typical lawn mower blade, which is around six inches.

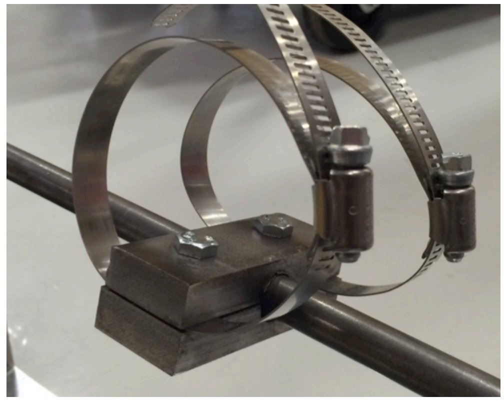

Figure 3: Original Grinder Mount Assembly

When selecting materials to be used in the design of the Blade Bandit, extra care was taken to choose materials that were easy and cheap to acquire. The wood baseplate, aluminum sheet cover, vise, wing screws, bolts, nuts, washers, and hose clamps are all common items that are available at hardware stores. The spindle and side brackets are produced from common sizes of raw materials that are readily available from industrial material suppliers. The grinder is readily available from industrial equipment providers. Keeping the materials simple and accessible is crucial for a new business as it minimizes cost and logistical issues. Similarly, the suppliers were carefully chosen to maximize reliability and convenience and minimize cost.

A detailed description of the parts of the Blade Bandit is provided in the Product section. There were many key decisions made in choosing and designing these parts that affect design for manufacture, assembly, environment, and ergonomics. First, wood was chosen for the baseplate instead of metal because metal would have been unnecessarily heavy, expensive, and difficult to machine. Wood is sufficiently strong as a baseplate, except when it comes to fastening the other parts to the baseplate. Wood screws would not provide the strength or precision required in this product, especially with a relatively thin sheet of plywood. To solve this issue, tee-nuts (shown in **Figure 4**) were used on the underside of the baseplate. This provides steel threads for a bolt to screw into, which creates a much stronger connection than a small wood screw. This also allows the exclusive use of ¼”-20 UNC bolts throughout the design, which is ideal for assembly simplicity. To address issues of durability on the surface of the baseplate, it is going to be covered with a thin sheet of aluminum. This will protect the wood from nicks, protect the user from splinters, and prevent sparks from making contact with wood.

Figure 4: Tee-nut

The two side brackets and grinder mount pieces were made from the same 3” x ½” 1018 cold finished steel bars, which minimized the amount of different materials required. The 3” width was selected to provide stability for the side brackets and to provide enough space within the mount for a spindle through-hole, two hose clamps, and two bolts. The ½” thickness was chosen to provide the space needed to drill and tap holes in the bottom of the side brackets. It also provided space to drill a ½” through-hole in the assembled mount for the spindle to pass through while retaining structural rigidity.

The spindle was selected as a ½” rod. A cylindrical shape was chosen to allow the grinder to be rotated about the axis of the spindle. The ½” diameter was selected to achieve the proper flexural strength and maximize supplier accessibility. The team opted to use a pre-purchased vise since they can be acquired cheaply and easily. Designing and building a proprietary mechanism for holding the blade would be unnecessarily expensive and time consuming.

Selecting the equipment used in the manufacture of the Blade Bandit followed many of the same mindsets used in material selection. They are simple and inexpensive machines that are manually operated, and all except one can be easily moved to accommodate different manufacturing layouts. These criteria are crucial for a new business, as they minimize initial capital cost and logistical issues. These machines, as well as the manufacturing process, are discussed further in the next section.

Manufacturing Process

"The manufacture of this product will begin with the wooden baseplate. This baseplate will be cut from a large (48"x 96") sheet of plywood using the AccuSquare panel saw. The edges and splinters will be removed from the baseplate using the belt sander. It will then be taken to a drill press and drilled at all ten hole locations. A pre-drilled template will be placed over the baseplate to align holes. This allows all holes to be consistently placed without requiring meticulous measurement of every part. Once all holes are drilled, ¼" tee-nuts will be hammered into the underside of the baseplate in each hole.

After the wooden baseplate is completed, the aluminum cover will be cut to size using a foot shear and placed over the baseplate. Hole locations will be drilled in the sheet to match those in the wood using an identical pre-drilled template. The baseplate is completed as the cover is bolted to the wood at four locations.

While the baseplate is being constructed, work will begin on the side brackets. Two 3" x 7-½" bars will be cut using a horizontal band saw. Two 1" x 3" segments of this bar will also be cut to be used for the grinder mount assembly later in the process. After the bars are cut, they will need to be deburred for the safety of the employee and the customer. Each 3" x 7-½" bar will be taken to a second drill press where a ½" diameter and ¼" deep hole marked ¾" from the top of the bar will be drilled and milled for an even surface. A ¼" hole will be drilled into the center of this hole through the bracket [this process is explained further and illustrated in the following analysis]. *These holes are to be used to mount the sliding bar subassembly. Two more ¼" diameter holes will be tapped into the bottom of the bracket that align with those in the bases. This process will be repeated for the second bracket to create an identical part.*

After the brackets are completed, the sliding bar subassembly can be constructed. The two 1" x 3" bars will then be clamped together and taken to the drill press. There, two ¼" holes will be drilled through both plates simultaneously. Both of the holes on one of the plates are then tapped and the two plates are bolted together. With the bars mated, a ½" hole will be drilled through the center of the 3" edge. After the hole is drilled, the bars are separated. [This process is explained further and illustrated in the following analysis.]

The spindle will be cut to size using a horizontal band saw. Once the rod is cut, the two slider mount bars will be loosely bolted together around the spindle with a washer set between the two. The hose clamps will then be connected to the assembly in the gap created by the washers. Once the mount is assembled, the two bolts will be tightened.

This subassembly will be bolted to the side brackets, which will be fastened to the baseplate. The vise will then be bolted to the baseplate. Depending on the customer choice, a grinder will be set in the mount at a predetermined location. A final inspection will check the tightness of all bolts and review the product's structural integrity. Visual inspections after every step will be required to ensure quality and to check for flaws in the manufacturing process.

For this process to be completed in the most efficient manner possible, some changes will need to be made to the current layout. For the baseplate process, the belt sander will need to be placed to the left of the panel saw. Immediately to the left of that will be a drill press. The shear used for the sheet will be across from this drill press. The rest of the processes, as they all begin with the horizontal band saw, will be oriented differently. Two drill presses will need to follow the band saw for all the requisite [drilling]. *Small worktables will be scattered throughout for storage and for manual tasks. The baseplate process line and the bracket assembly line would be placed in complementary U-shaped lines that would meet for a final assembly as seen in* ***Figure 5*** *below.*

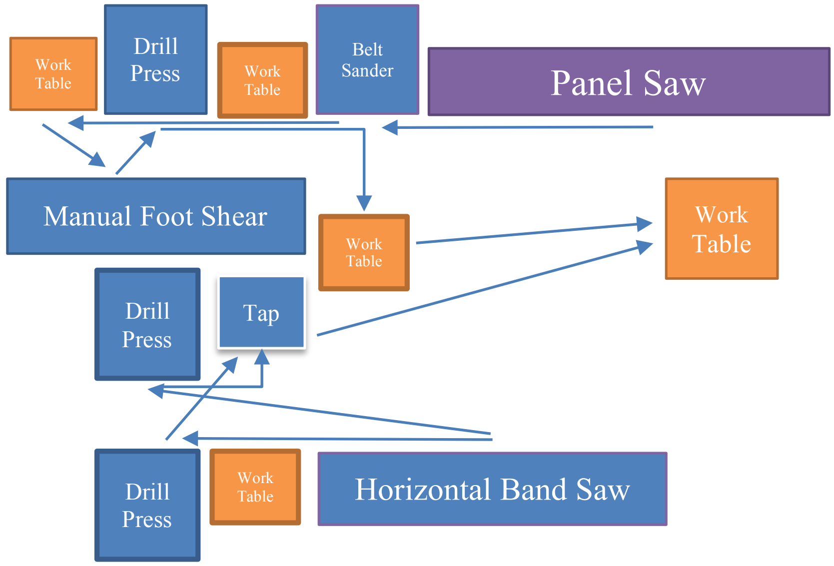

Figure 5: Original Manufacturing Process Line

To make this process possible, some tooling needs to be prepared in advance. A hole template for the baseplate and cover will need to be prepared and cut to the exact size on the baseplate. There are also several fixtures that need to be prepared for the work on the drill press. Due to the many complex holes, quality fixtures would greatly reduce the possibility of error and the time needed to work on each part." [1]

The wooden baseplate was 12" by 24". A standard sheet of plywood is 48" by 96", which allowed sixteen of these baseplates to be cut from a single sheet with no scrap assuming no material was lost in the cutting process. In this original process design, it was decided that the panel saw alone would be sufficient, but it was later seen that an additional table saw would be beneficial. The belt sander was chosen to smooth out the edges because of its efficiency; it can smooth out an edge of the baseplate with one short pass.

The baseplate had ten holes. Four holes were for the vise, two were for each of the side brackets, and two were used in the empty corners to hold the baseplate cover down as seen in **Figure 6**. The two corner holes were half an inch from the two edges, but this location was arbitrary and did not require a tight tolerance. The four vise holes required a tolerance of ¼", as their location directly affected the range of angles at which the blade can be sharpened. The four holes that hold the side brackets in place required an extremely tight tolerance of ±0.005" because the bolts going through these holes had to match perfectly with the holes tapped in the bottom of the side brackets. A template was planned to maximize efficiency and minimize errors. Extra care would be taken in measuring and machining the template, which would be clamped to each production baseplate to be used as a guide. These holes would be 9/32" to allow tee-nuts to be placed inside; this diameter was later increased to ease the placement. Once drilling was complete, the tee-nuts were hammered into place in six holes. The tee-nuts should be placed and hammered one at a time. If any other nuts are placed, they will bounce loose during hammering. The side bracket holes do not need tee-nuts, as they were bolted from the underside to the baseplate.

Figure 6: First Prototype Baseplate Design

The baseplate cover would then be cut from a sheet of aluminum. It comes from the supplier as a 2' x 50' roll and would be cut to size on the manual foot shear. The same baseplate template would be clamped to this sheet and used as a guide to drill the 10 holes to ensure the holes match perfectly. The cover would be fastened to the baseplate with ¾" long ¼"-20 UNC bolts in the two corner holes.

During production of the baseplate subassembly, work on the side brackets would begin on a different manufacturing line. As mentioned earlier, the raw material for this part came in the form of 3" x ½" steel bar in 3' sections and would be cut on the horizontal band saw. Four cuts of this bar would be made for each part, and the measurements would be marked using a T-square. The bar would be marked at 7-½", 15", 16", and 17". A short mark would be sufficient since the horizontal band saw ensures a square cut. Each side bracket would be 7-½", and each side of the grinder mount would be 1". All cuts needed to be made slowly, and lubrication would be required to prevent overheating. The parts would be filed to remove any burs and shards.

A second drill press would be used for the ½" hole to prevent having to change drill bits between processes and to allow one-piece flow. The ½" hole provided a ¼" deep pocket in which the spindle would sit for maximum strength and durability. This hole would be started with a drill press, but would be finished on the mill to provide a square-edge wall against which the spindle would be fastened (ordinary drill bits create a conical shape). The ¼" hole was a through-hole for the bolt that fastens the spindle and was drilled on a third drill press. The ½" pocket and ¼" through-hole can be seen on the prototype side bracket in **Figure 7**. This same drill press would be used to drill the two holes in the bottom of the side brackets. The bracket would be clamped into the drill press vise, and a fixture was planned to guide the drill bit into place without requiring measurement. Again, this required a very tight tolerance to ensure the holes mated with those on the baseplate. These holes would be tapped to accept ¼”-20 UNC threads and are shown in **Figure 8** below.

Figure 7: Pocket and Through-Hole in Prototype Side Bracket

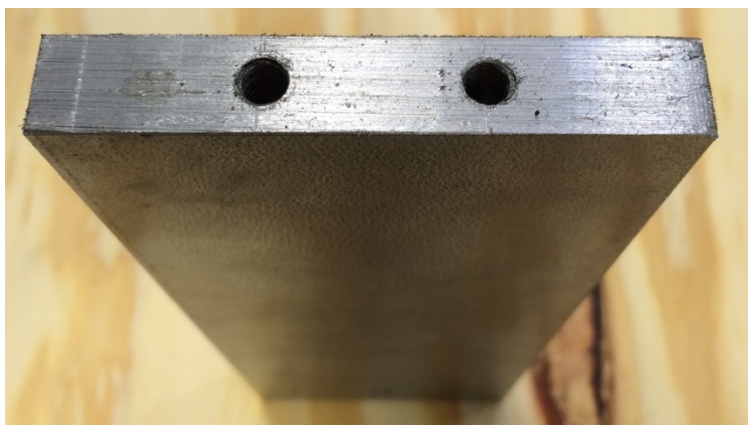

Figure 8: Two Threaded Holes in Bottom of Prototype Side Brackets

The two 1” bars for the grinder mount would be clamped into the drill press vise together. They would be aligned by hand and drilled simultaneously; this eliminated any potential misalignment. The holes would be centered along the 1” section, and ½” from each edge on the 3” section. These two parts would be bolted together around the spindle. Thus, they would be prepped further to accept bolts. The holes on one of the bars would be tapped to accept the bolts, and the holes on the other bar would be larger than the bolt to allow it to pass through. A semi-circle had to be drilled into each bar such that a full circle would be created when clamped together; the spindle passed through this circle.

This circle would be drilled after the bars were bolted together, just as they would be on the final product. This is shown in **Figure 9**. **Figure 10** shows the two slider mount bars fully machined but disassembled. The bar on the right has two tapped holes, while the bar on the left has two through-holes.

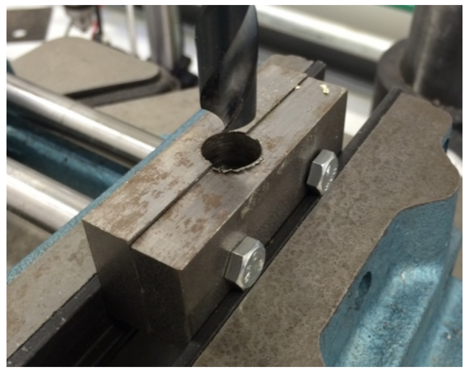

Figure 9: Prototype Slider Mount during Through-Hole Drilling

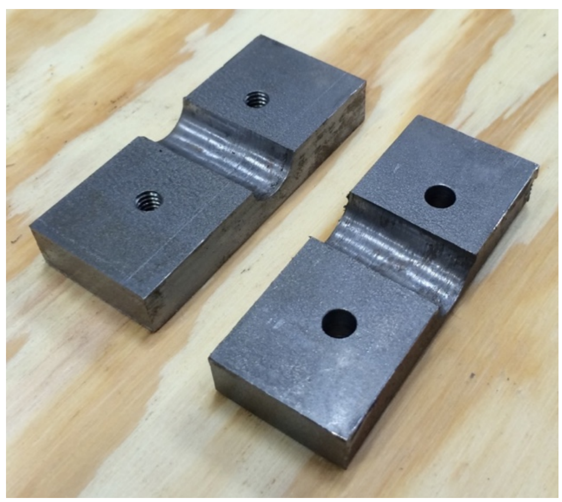

Figure 10: Prototype Slider Mount Bars, Disassembled

The business plan left out the process of drilling and tapping holes into the ends of the spindle. Once the spindle was cut on the horizontal band saw, ¼" holes would be drilled into each end, and the holes would then be tapped to accept ¼-20 UNC bolts, as shown in **Figure 11**, to allow mounting onto the side brackets.

Figure 11: Tapped Hole in End of Prototype Spindle

After this, the slider subassembly began. The two grinder mount bars would be bolted around the spindle, and washers would be placed between them to create a gap through which the hose clamps were fed.

With the grinder mount in place on the spindle, the two side brackets would be bolted to the spindle. They would be bolted loosely at first to allow room for alignment. The slider subassembly is shown below in **Figure 12**, sitting upside down as it would be during fastening to the baseplate. Once the side brackets were bolted to the baseplate, the spindle bolts would be tightened fully. The vise would then be bolted in place in the same manner.

Figure 12: Slider Subassembly Sitting Upside Down

The layout of the process was meant to implement one-piece flow as effectively as possible. The product has two distinct subassemblies: the baseplate assembly and the bracket assembly. These assemblies were made of very different materials and did not use any of the same machines. Thus, they would be made simultaneously on different lines and meet at the end of the process for final assembly. U-shapes are favorable in lean manufacturing; this layout implemented two separate U's. One flowed clockwise, and the other counterclockwise. This allowed the subassemblies to meet in the middle. It did limit communication between the two lines, but it provided easy access for incoming materials at the panel saw, shear, and band saw. Ideally, the two subassemblies would take similar amounts of time to complete. The number of workers on each line could be adjusted to equalize cycle time for each line.

Legal Structure

"Shear Genius is a small company with few employees outside of the owner/manager team; thus, a simple legal structure is desired. As the Blade Bandit can potentially cause injuries, it poses a risk to the company; legal protection is required for the owners. A limited liability company provides the best combination of simplicity and protection. It allows flexibility in the management and operation of the company, effectively giving the members equal treatment as if they were in a partnership. It also provides protection from personal liability for business decisions or actions. A limited liability company requires much less startup capital and record keeping. It also allows the sharing of profits among members according to each member's role and contribution." [1]

The legal structure was first narrowed down to partnership or limited liability company (LLC). A partnership was considered because of its simplicity, but ultimately the limited liability company was chosen because of its legal protection. While the Blade Bandit does make the process of sharpening lawn mower blades much safer, there is still risk of injury for the user. If Shear Genius were to be registered as an actual business, the six team members would share equal ownership, responsibility, and profit. They would also be responsible for manufacturing the product; no additional employees would be required under this business plan.

Management

"When our group was created, Ethan Veazey was appointed as our chief operating officer. This puts Ethan in charge of scheduling, facilitating our meetings, and making sure our team stays on task and meets all deadlines. [His planned schedule is shown] *in* ***Figure 13.*** *Beyond this, Ethan's contributions will be similar to other team members'. He will assist with the design of the product and selecting the appropriate materials. He will also be in charge of acquiring the necessary materials for prototyping and production. He will assist in designing the manufacturing process and will oversee prototyping and production." [1]*

Figure 13: Original Gantt Chart

When analyzing Mr. Veazey's true role and contributions, he can be considered as much a project manager as a CEO. He plans and organizes meetings, schedules production, places material and equipment orders, and keeps all the team members in line with the company vision.

Personnel

"The remaining members will all contribute equally to certain aspects of the project by using his or her unique skills to contribute to other aspects. Because everyone is familiar with the field of lean manufacturing, we will all assist in the design of the product and manufacturing process. We will all also assist in manufacturing the product on the factory floor. Kristen Gaddis, Abdul Hamid, Ethan Veazey and Colin Wattigney each have a specific background in engineering. They will contribute more heavily to the design of the product and the selection of the appropriate materials to use in the design.

Nick Rocco, who studies business administration, will spearhead our business issues. He will be the leader in all issues involving the marketing and sales of our *product. Allie Winters will handle accounting and record keeping. She will handle the costing of our product, keep records of all our financial transactions, provide a monthly cash flow, and project the profit and losses. Our team was designed to provide a solid mixture of skills and talents. Just as is necessary in a professional workplace, accountants, businesspeople, and engineers are collaborating for a common goal of turning a profit by selling a desirable product.*

Record Keeping and Accounting

Shear Genius will gather financial records via an Excel spreadsheet. The accounting department will use this information to keep track of labor hours, costs, profits, and cash flows. This data will be analyzed on a monthly basis and at each calendar year end. Projections of these data can be seen in the Financial Plan which begins on page 36.

Insurance/Security

If Shear Genius were to take this product idea to the next level and create a registered business, the company would have to consider a few additional issues. Insurance is needed for both the members/employees and property. As of now, this business will remain relatively small and does not require hiring additional help outside of the six members. That being said, the six members would need health insurance, life insurance, and disability insurance. The building that houses our offices, manufacturing floor and warehouse will need property insurance. Additionally, because of the potential dangers involved with using our product, the business would need liability insurance to protect against any potential lawsuits that might arise. The second issue to consider is security. The building would need a full security system with paid monitoring to protect *against break-ins, vandalism, and theft. Shear Genius would also have a server to store the company's and customers' financial and client information, tax records, etc. This server would need the appropriate firewall and encryption to protect this information. If our business grows further, it would need an inventory control system to track parts and product inventory.*

4.3 Marketing Plan

Target Market

The Blade Bandit will be target landscaping businesses, government landscaping teams, and homemakers. Landscaping businesses depend on a quality cut for customer satisfaction, and government landscaping teams rely on a quality cut to keep their city looking its best. The Blade Bandit will also help private customers keep a beautiful yard by safely sharpening dull blades with the perfect cutting angle, saving money by reusing blades and avoiding pricey shop charges." [1]

Shear Genius recognized that customers with large amounts of grass to cut or numerous lawn mowers to service would be the most likely to be interested in the Blade Bandit. As such, the primary targets are lawn mower dealerships/repair shops and corporate or government landscaping departments. These types of customers sharpen a high volume of blades and would greatly benefit from a faster, safer, and more consistent method. However, the Blade Bandit would also work at home on a garage or home workshop. Anyone who sharpens their own blades could benefit from this product, so it would be marketed to businesses, government departments, and private consumers alike.

Marketing/Sales

"To market the Blade Bandit, it will be taken to businesses to demonstrate how it works and highlight the results that can be achieved. A sample pitch is provided below.

If you are looking for the perfect lawn or have a stubborn field and your blade just won't cut it, the Blade Bandit will grind the blade into shape. The Blade Bandit combines hands-on experience with the minds of engineers to bring a simple-to-use product to your shop. With a revolutionary design, you can achieve the perfect cutting edge every time. Unlike other tool sharpeners, the Blade Bandit's unique design takes the human error out of sharpening by fixing the position of the blade and the grinder. When your lawn needs to look its best, trust the Blade Bandit for the cutting edge." [1]

Shear Genius also recognized that potential customers may not be immediately interested in the Blade Bandit. They have been sharpening their blades the same way for years, and most probably do not see any issue with the methods they have become accustomed to. Therefore, in-person demonstrations would be conducted with potential customers. This applies more to businesses and government agencies than private consumers. A team member would bring the Blade Bandit to the customer's business or shop, and offer to sharpen a dull blade. Safety, speed, and quality would be emphasized during the demonstration. After the demonstration, the team member would explain why it is important to have a consistent and proper blade angle. The member would then offer to compare the newly sharpened blade to one sharpened on a bench grinder (or whatever method being used at that shop). Blade angle and uniformity would be highlighted. When lawn mower dealerships or repair shops purchase the Blade Bandit, they would be offered a deal to sell the Blade Bandit to their customers; this is how direct consumers would be reached.

Competition/Advantage

"The Blade Bandit's competitors in the market are products such as Work Sharp, Magna Matic, and Yellow Hornet. Each of the competitors' products offers a different type of machine, but all have one commonality: the user must hold either the blade or the sharpening tool. Error in the desired angle of the blade is likely with this method. With the Blade Bandit, the blade is fixed in a vise and a grinder is fixed to a jig, eliminating human error and creating a repeatable and accurate pass every time.

Competitor Products:

- *Work Sharp, model no. WSKTS (**Figure 14**) - $89.95 (set angles at 20° or 25°)*

Figure 14: Work Sharp WSKTS [3]

- *Work Sharp, model no. WSKTS-KO - $149.95 (fully adjustable between 15° and 30°) Note: this model appears identical to the Work Sharp WSKTS.*
- *Magna Matic Mag 8000 (**Figure 15**) - $1,195.00*

Figure 15: Magna Matic Mag 8000 [4]

- *Yellow Hornet (**Figure 16**) - $129 (closest design)*

Figure 16: Yellow Hornet [5]

*The Blade Bandit will use the cost-plus method for the final selling price. All materials come out to a total of $66.52. There will be a 120% profit margin to give a selling price of $149. The material suppliers and costs are listed above in **Table 1** and in **Table 3*** [in section 4.4]*."* [1]

Shear Genius understands that if this product were taken to market, a detailed patent search would be necessary to ensure no infringement occurred. This search was deemed unnecessary since the product would not be sold. Shear Genius saw these specific models as the main competitors to the Blade Bandit. These products were competitors in that they serve to sharpen a lawn mower blade (or in some cases, any type of tool), but none of them work like the Blade Bandit. The first, Work Sharp WSKTS, is a handheld tool; it does not provide the safety of the sharpener or blade being locked in place. It also cannot set angles for lawn mower blade. The Magna Matic Mag 8000 utilizes a fixed grinding wheel but requires the operator to hold the blade by hand and apply it to the grinding wheel. At $1,195, it is also priced extremely high, which would likely be a huge hurdle for most potential customers. The Yellow Hornet is the closest design to the Blade Bandit. It utilizes an ordinary angle grinder fixed to a simple base but, like the Magna Matic, it requires the user to hold the blade by hand. This reduces the safety factor and leaves more room for inconsistencies. Furthermore, the Yellow Hornet can only sharpen blades at one set angle. The Blade Bandit provides a combination of safety, consistency, quality, customization, and affordability that none of its competitors matched. At $149, the Blade Bandit provides enough revenue to make a profit with relatively low sales but it was not so expensive that it turned customers away.

Location/Facility

"The CME floor will accommodate the manufacturing of the Blade Bandit; modifications are needed to the equipment locations for an ideal process to be implemented." [1]

The CME already owned all equipment needed for the manufacture of Blade Bandit. Shear Genius "purchased" or "rented" this equipment as appropriate. It had to be rearranged according to the layout discussed in the manufacturing section. This was done only during the two week production run. The proposed layout required very little space and would take up only 1000 square feet on the CME factory floor.

4.4 Financial Plan

*"Shear Genius is seeking from the CME an investment of $30,000 for 10% interest in the company. The money raised from the sale of equity will go towards purchasing the needed equipment, tools, fixtures, and raw materials, beginning wages, and overhead. The equipment that Shear Genius requires to manufacture the Blade Bandit is shown in **Table 2*** [in section 4.2 on page 15]. *The equipment, tools, and fixtures have a total cost of $22,161. The six original employees of Shear Genius split the other 90% interest in the company equally. In the event of liquidation of Shear Genius the CME would have the first right to the equipment.*

*Shear Genius estimates sales for the Blade Bandit in the first year to be 500 units and expects that half of the units will have the included angle grinder option. The direct materials are shown in **Table 3**. The direct materials cost per unit is $90.51 with the angle grinder and $66.52 without the angle grinder. The total direct materials for the year are found by multiplying the 250 projected sold units with the grinder and the 250 sold units without the grinder by their respective unit materials' cost.*

Table 3: Original Cost of Materials

Material	Cost/Unit
Wood Baseplate	$3.00
Metal Cover	$6.60
Sliding Bar	$3.74
Vise	$16.99
Sides (2)	$17.50
Wing Screw (4)	$4.88
Baseplate Screw (4)	$0.36
Screw for Brackets	$0.46
Tee-Nut (6)	$0.60
Hose Clamps (2)	$4.00
Washer (4)	$5.20
Washers (6)	$0.18
Grinder	$23.99
Shipping	$3.01
Blade Bandit (with Grinder)	**$90.51**
Blade Bandit (without Grinder)	**$66.52**

Since the demand for the Blade Bandit is expected to be 500 units in the first year, Shear Genius' employees are part time only. The direct labor for the Blade Bandit is determined by first estimating the total cycle time of each product to be 1.2 hours, multiplying by 500 units, and multiplying by Shear Genius' labor rate of $10/hour. A fringe rate of 33% is added to total the direct labor.

Shear Genius' overhead is divided into two main categories: depreciation expense and CME shop floor expenses. The depreciation expense is found using straight-line depreciation over fifteen years with zero salvage value. The depreciation is calculated to be $1,477 per year for all equipment. The CME shop floor expense includes insurance, janitorial services, and rent on the factory. This expense is estimated from 44% of the direct labor-fringe and direct materials, which is $20,784.28 per year. The total overhead is projected to be $22,261.68.

Sales and administrative expenses include sales travel and marketing tools, such as a demo product. The selling and administrative expenses are estimated at 10% of the total sales and total $8700. The selling price for each option is approximately 120% of the cost of the direct materials. The units that include the angle grinder are sold for $199, and the units that exclude the angle grinder are sold for $149. Since the sale of the 500 units is evenly split between the two options, the projected sales are $37,250 for the units without the angle grinder and $49,750 for the units with the angle grinder, which totals $87,000. An income statement with the total cost estimates for one year is shown in ***Table 4****.*

Table 4: Income Statement for Year Ending Dec. 31, 2015

Sales		$87,000.00
Cost of Goods Sold		$69,498.68
Direct Materials	$39,257.00	
Direct Labor	$7,980.00	
Overhead	$22,261.68	
Depreciation Expense	$1,477.40	
Use of Building	$20,784.28	
Sales and Administrative Expenses		$8,700.00
Net Income		$8,801.32

The Blade Bandit is projected to have seasonal sales, with the highest sales coming from May to August. The seasonal sales result from the fact that our customers' businesses are related to the spring and summer grass growth. Since sales will begin in January in the low sale months, the first few months will have a negative cash flow. However, in the peak months of June and July, the cash flow will each have a monthly positive balance of $3,070.60. A statement of cash flows is presented below in ***Table 5****.*

Table 5: Monthly Cash Flow

Monthly Statement of Cash Flows - For Year Ended 2015							
	Month 0	Jan	Feb	Mar	Apr	May	June
Cash Raised from Equity Sale	$30,000						
Sales		$1,740.00	$1,740.00	$6,960.00	$6,960.00	$13,920.00	$17,400.00
With grinder		$995.00	$995.00	$3,980.00	$3,980.00	$7,960.00	$9,950.00
Without grinder		$745.00	$745.00	$2,980.00	$2,980.00	$5,960.00	$7,450.00
COGS		$1,360.44	$1,360.44	$5,441.76	$5,441.76	$10,883.52	$13,604.40
Direct Materials		$785.15	$785.15	$3,140.60	$3,140.60	$6,281.20	$7,851.50
Direct Labor		$159.60	$159.60	$638.40	$638.40	$1,276.80	$1,596.00
Overhead		$415.69	$415.69	$1,662.76	$1,662.76	$3,325.52	$4,156.90
Selling and Administrative Expense		$725.00	$725.00	$725.00	$725.00	$725.00	$725.00
Equipment Purchase	$22,161						
Cash flow from Operations	$7,839	-$345.44	-$345.44	$793.24	$793.24	$2,311.48	$3,070.60
	July	Aug	Sept	Oct	Nov	Dec	Total
Cash Raised from Equity Sale							
Sales	$17,400.00	$10,440.00	$3,480.00	$3,480.00	$1,740.00	$1,740.00	$87,000.00
With grinder	$9,950.00	$5,970.00	$1,990.00	$1,990.00	$995.00	$995.00	$49,7500.00
Without grinder	$7,450.00	$4,470.00	$1,490.00	$1,490.00	$745.00	$745.00	$37,250.00
COGS	$13,604.40	$8,162.64	$2,720.88	$2,720.88	$1,360.44	$1,360.44	$68,022.00
Direct Materials	$7,851.50	$4,710.90	$1,570.30	$1,570.30	$785.15	$785.15	$39,257.50
Direct Labor	$1,596.00	$957.60	$319.20	$319.20	$159.60	$159.60	$7,980.00
Overhead	$4,156.90	$2,494.14	$831.38	$831.38	$415.69	$415.69	$20,784.50
Selling and Administrative Expense	$725.00	$725.00	$725.00	$725.00	$725.00	$725.00	$8,700.00
Equipment Purchase							
Cash flow from Operations	$3,070.60	$1,552.36	$34.12	$34.12	-$345.44	-$345.44	$6,277.68

Selling and administrative costs may increase over the company's life. This growth will be caused by the increased focus on marketing and internal company structure. As the span of the company's geographical reach expands, the marketing and selling costs associated with the growth will also expand.

Over the course of the first year of business, Shear Genius is projected to have a profit of $8,801. This profit results in a 40% return on the $22,161 of equipment. For the next five years Shear Genius will grow by expanding its market into new geographical *areas by first concentrating on the Southeast and expanding as the market sees fit. At the end of the first five years of business, Shear Genius expects to have enough sales to support four full time employees working on the assembly line. This translates to 6667 units/year and $1,159,884 in sales. Even with an increase in wages of to $13/hour and a 20% increase in sales and administrative costs, a net income of $31,574.57 will be realized. With the company functioning at this level of profitability, it will grow into a valuation of $500,000. Therefore, the equity purchased by the CME would be worth $80,000 at the end of five years, which is a 167% return on investment. A projected income statement for year-end 2020 is available in* ***Table 6****."* [1]

Table 6: Income Statement Year 2020

Blade Bandit		
Income Statement		
For Year Ended Dec. 31, 2020		
Sales		$1,159,884.00
Cost of Goods Sold		$954,326.83
Direct Material	$523,380.99	
Direct Labor	$138,320.00	
Overhead	$292,625.84	
S&A		$173,982.60
Net Income		$31,574.57

The estimated sales volume of 500 units, as well as the 50/50 split between units with and without the included grinder, were arbitrary numbers given to the Shear Genius CEO by the CME panel. This was an optimistic estimate and would require an intense marketing effort well outside the Oxford community. While it was unlikely this estimate would be met in the first year, it was not an unreasonable estimate for years to come. The 1.2 hour cycle time estimate was based on the team members' experiences with each process. It was understood that this estimate could be inaccurate, but it served as a foundation for costing. The rest of the values calculated in the Financial Plan were based on this 500-unit assumption. Looking back on the sales estimate of 6667 units/year, it became apparent that it was an optimistic goal that was likely far out of reach. At the time, it seemed suitable due the potential growth that was suggested by the CME panel and the Shear Genius team.

5. Prototyping

After the business plan was submitted, work was completed to create a prototype for the final product. This work began by ordering the materials researched in the business plan. Following this, the team met on the CME facility to begin work. The group began by discussing the format for the work that was to follow. The need to be adaptive and patient was emphasized; the group understood that the theorized process flow might not be the most effective method when using the equipment available. It was also understood that during the prototyping that the work may move much slower than should be expected during production as team members were not very familiar with all of the processes utilized.

Once the plan was clear, materials were gathered to complete the build. Since not all of the materials listed in the business plan were available at the appropriate time, some substitutions were made. The aluminum sheet was replaced with stainless steel sheet that was provided by the CME as was the plywood used for the baseplate.

During the build, all of the raw materials were meticulously marked to ensure that any processing that occurred was in the correct location. As this prototype consisted of several parts that were difficult to machine, this process was incredibly time consuming and left very little room for error. Despite this, mistakes were still made during the machining of parts; the most impactful of these errors was a misplaced hole in a side bracket.

The errors reinforced the idea that fixtures needed to be made to maintain the quality of all produced parts. These fixtures would be instrumental in maintaining tolerances and improving manufacturing cycle times. At this stage in prototyping, these tools were envisioned as complex parts that would have to be fabricated using a five-axis mill and made of wood, nylon, or aluminum. However, simpler solutions would be formulated and will be discussed later.

After the parts were measured and marked, the team members worked together and constructed the prototype using the manufacturing process outlined earlier. The first piece to be processed was the wooden baseplate. This initial part was also the first to deviate from the original manufacturing plan. As the raw material being used for the baseplate was much smaller than what was to be ordered, a table saw was used in place of the panel saw; this enabled the team to make more precise and less strenuous cuts at dimensions of 12" x 24". The baseplate was then taken to a belt sander and any rough edges were smoothed.

The next part to be processed was the stainless steel sheet used to cover the baseplate. This material was cut to the same size of the wooden plate using a manual shear. The sheet was placed on the plate to ensure proper dimensioning and it was then seen that it was slightly too large. The steel left incredibly sharp corners, so the team decided to remove a ⅛" strip of material from both the horizontal and vertical dimensions. After these cuts were made, the part was still slightly too wide and another ⅛" strip was removed from each side so the sheet became smaller than the baseplate.

Once the team was satisfied with the size of the sheet and baseplate, the two pieces were clamped together using EZ-Grip clamps. After this, the assembly was taken to a drill press where ten 9/32" holes were made at previously marked locations. The parts were then disassembled and the team moved on to the processing of the sliding bar assembly.

The first step in making the bar subassembly was the cutting of all of the steel parts. The 3" x 36" bar was cut into two 8-½" bars that would become the side brackets and two 1" strips that would serve as the basis for the mount subassembly. After these were cut, the cold rolled steel rod was cut at a length of 18". These materials were all then taken to a worktable where they would be measured and marked for new holes.

The side bracket pieces were then taken to a drill press where many holes were drilled. The first was a ¼" through-hole; this was done by placing both pieces on top of one another and match drilling to ensure the alignment of the hole. This was followed by a ¼" deep hole first drilled with a ½" diameter drill bit. A ½" mill bit was then used to smooth the inner surface of the hole to create a pocket and allow the rod to sit in a secure manner. The ½" drill and mill was done for each side bracket. Once these holes were completed, two 0.207" holes were drilled into the bottom of each piece. A 0.207" bit, also known as a #7 drill bit, is the recommended size for a hole to be tapped for a ¼" bolt.

These holes would then be hand-tapped. The tapping process was found to be incredibly time consuming and led the team to scrap a part. A tap broke inside one of the side brackets, and it is nearly impossible to remove a broken tap from a hole. The use of threading also calls for the use of different size drills bits; threaded holes must be drilled smaller than their unthreaded mates. As there were eight holes originally set to be threaded, the team later decided to look into new processing methods.

After the side brackets were completed, work began on the grinder mount. The two 1-½" pieces were stacked on top of another and two ¼" holes were match drilled through the top piece and deep enough to leave a well-defined mark on the second piece. These holes were spaced far enough apart to allow for the sliding rod and two hose clamps to fit without butting into each other or into the bolts used to connect the two small plates. On the second piece, two .207" holes were drilled in the marked locations and tapped. The two pieces were then bolted together and placed on the drill press to allow for a ½" through-hole to be drilled in the center of the subassembly.

At this stage, the only material that required further processing was the sliding rod; ¼" diameter, ½" deep holes needed to be drilled and tapped using a ¼"-20 UNC tap in each end of the rod. The team attempted to drill the hole using a drill press, but this became much less realistic during the prototyping phase. It was clear that the theorized processing method for this part would be ineffective and would cause many quality concerns. It was then suggested that the team use a lathe to drill the hole. This was discussed and agreed upon, and the team also saw that the lathe could be used to begin the tapping process.

Once the rod was completed, the mount was fixed around it and the hose clamps were set in place. This new subassembly was then bolted to the side brackets, and after this was done it was necessary to complete the baseplate.

This called for tee-nuts being hammered into several holes in the baseplate. The stainless steel sheet was then fixed to the baseplate by fixing three bolts in the tee-nuts. The mount, rod, and side bracket subassembly were then fixed to the baseplate. At this point, it was found that one of the holes in the bottom of the side bracket was not placed as precisely as necessary and did not align with its mate in the baseplate. Despite this, the subassembly was placed firmly and did not wobble. The vise was then attached to the baseplate followed by the grinder itself. The finished prototype is shown below in **Figure 17**.

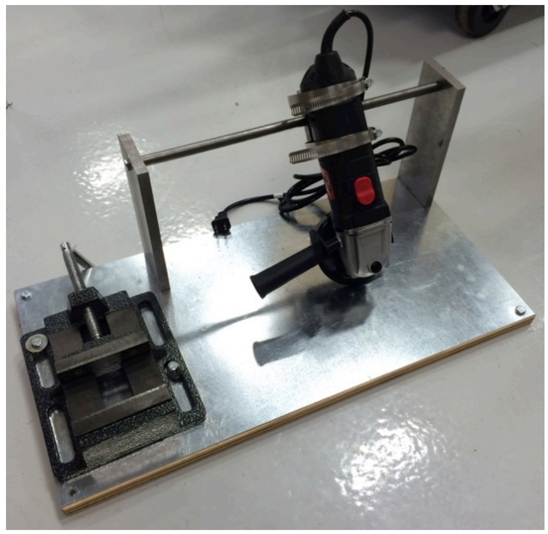

Figure 17: First Prototype of the Blade Bandit

The team decided to test this presumably finished prototype and noticed some flaws in its functionality. The through-hole cut in the mount was too tight and did not allow for easy sliding. A larger, 9/16" hole was then drilled in its place but the team found that this was too large and caused the mount to misalign and jam. A new mount was later machined, this time using 1-¼" pieces to provide stability and a 17/32" bit was ordered to give tighter fit without adding friction. The team was satisfied with these changes and moved on to other tasks for the project.

When the process was set, the team began to re-evaluate the manufacturing process layout. The team found that the conjoined U-shaped flow did not allow for a simple process when only one person was building the product. Another issue with this layout was that one of the U's required a clockwise flow; counterclockwise flow is generally preferred.

When all members gained an understanding of the process, the members paired up in order to propose new layout designs. Three layouts were then prepared and discussed side by side. The first layout proposed was a sigma shaped layout that promoted counterclockwise flow and simpler steps. This was convenient for a single operator but posed a problem when multiple operators were utilized; there was a long walking distance between finished goods and the raw materials and this did not allow for a quick restart of processing. This layout can be seen in **Figure 18**.

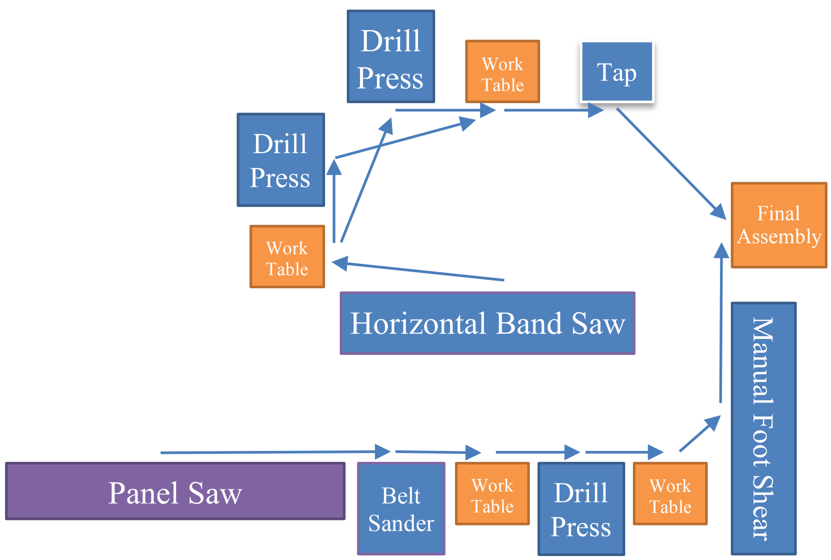

Figure 18: Counter Clockwise Sigma Shaped Process Layout

Another layout proposed was simply a modification of the original. The two U's that sat next to one another were modified and rearranged to sit in line with one another. This allowed one person to easily move across the entire process; the large U can also be split into two smaller ones to accommodate multiple operators. The main problems created by this layout were a lack of open space and the transport of materials after the metal working processes to finished goods. This layout can be seen in **Figure 19**.

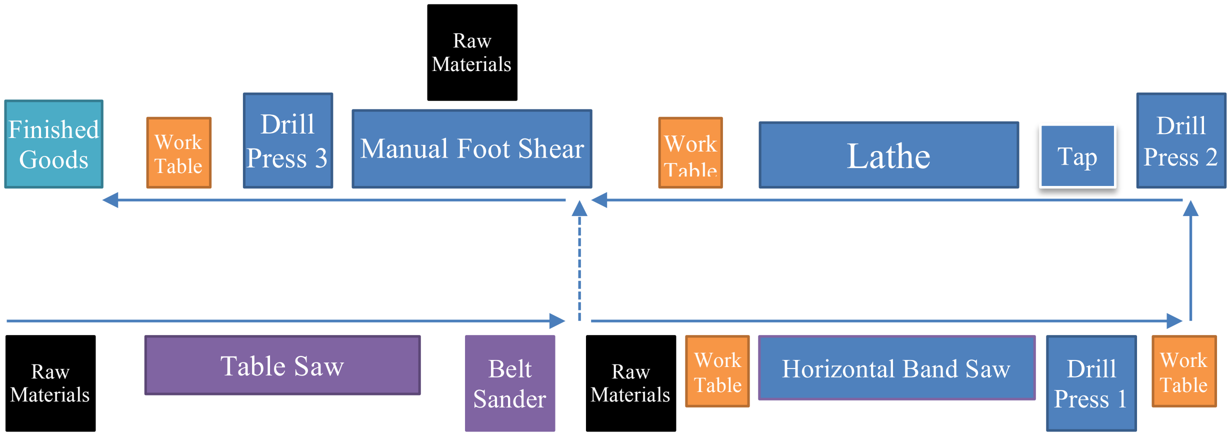

Figure 19: Inlying U-Shaped Counter Clockwise Layout

Of these layouts, the inlying U-shaped process was chosen. The team felt that it provided the best overall use of space and the most flexibility of the proposed layouts. By making the finished goods and raw materials accessible from the outside of the line, there was less traffic within the line and less of a safety hazard. It provided built-in quality checkpoints and easy communication between operators to prevent any faulty parts from making it out of the manufacturing facility.

Once the decision was finalized, demand was reevaluated using an estimate of 500 units to be sold per year with peak sales in the spring and summer. Units were to be manufactured as they were ordered, and it was determined that it was not necessary to have full-time employees to build the product.

6. Optimization

After the prototyping phase was complete, a new report was submitted to the CME panel to discuss the changes made since the original business plan in October and first prototype presentation in December. That report is presented below in its entirety, with supplemental analysis.

6.1 Introduction

"The purpose of this report is to provide an update on the Blade Bandit's design, supply chain, and manufacturing process layout. After the December prototype presentation, Shear Genius analyzed the design for improvement opportunities. The team concluded that the current design was not versatile enough to sharpen all lawn mower blades, and that the manufacturing and assembly processes were overly complicated and time consuming; Shear Genius focused on redesigning the Blade Bandit to improve these issues. A new slider mechanism for the spindle was designed to add a third degree of freedom (longitudinal motion of the grinder) to the system, which allowed the Blade Bandit to sharpen even the most worn lawn mower blades and increase the sliding smoothness. Preassembled brackets and spindle locks were utilized to eliminate the time-consuming tapping operations during manufacturing.

6.2 Description

Shear Genius' target market for the Blade Bandit remains individuals and companies with landscaping or lawn mower servicing businesses. After consultation with a marketing professional, the original goal of 500 unit sales for northern Mississippi was deemed unrealistic. However, since Shear Genius' employees are from different areas throughout Mississippi and southeast Louisiana, it can expand its target customer region by utilizing its employee contacts in their original home areas. The entire state of Mississippi and southeast Louisiana area are the regional markets that Shear Genius is now targeting. According to Entrepreneur there are an estimated 22,000 lawn mowing services in the United States. There is approximately one individual lawn mowing service for every 14,500 people. From this factor, the market for the target region is determined to be approximately 290 lawn-mowing services and landscapers [6]. Shear Genius aims to penetrate 10% of this market in the first year and anticipates selling approximately 30 units. Because of the low sales volume, Shear Genius cannot maintain profitability after purchasing the manufacturing equipment, so all equipment must be rented. In addition, Shear Genius is now selling the product only with the angle grinder. This decision ensures the quality of the Blade Bandit and increases the profitability per unit. An updated equipment list is shown in ***Table 7****.* ***Table 8*** *shows other required tools/supplies and their acquisition status. Shear Genius anticipates additional financial impacts from its product design and manufacturing process changes. An updated income statement is shown in* ***Table 9****. Note that the income statement does not include design and prototype expenses; see Cost Analysis for details on those expenses." [7]*

Table 7: Equipment List

Factory Floor Equipment	Qty	Rate Per Hour	Time per Unit (sec)	Total Cost per Unit
Panel Saw	1	$40	30	$0.33
Safety Table Saw	1	$40	30	$0.33
Roll-In Saw HS1418 Horizontal Band saw	1	$40	222	$2.47
20" Var Spd Drill Press Vectrax 1Spd Mtr 3hp/220V	3	$40	379	$4.21
Haas mini Office Mill	1	$100	180	$5.00
Tennsmith Manual Foot Shear 52-1/4	1	$40	32	$0.36
Total	-	-	-	**$12.70**

Table 8: Tools/Supplies List

Other Supplies/Equipment	Number	Obtained	Course of Action
Rolling Carts	5	CME	Complete
Shelf	1	CME	Complete
Hammer	1	CME	Complete
File	1	CME	Complete
Stencil	5	No	Being Constructed
5/ 16" Nut Driver	2	No	Order Requested
7/16" Ratcheting Wrench	1	No	Order Requested
7/16" Wrench	1	No	Order Requested
1/8" Alan Wrench	1	No	Order Requested
1/4" Drill Bit	1	No	Order Requested
.297" Drill Bit	1	No	Order Requested
33/64" Drill	1	Yes	Complete
1/8" Mill Bit	1	Yes	Complete

Table 9: Income Statement

Income Statement		
For Year Ended December 31, 2015		
Sales		$5,085
Cost of Goods Sold		$2,688
Materials	$2,157	
Labor	$150	
Overhead	$381	
Sales and Administrative Expenses		$509
Net Income		**$1,889**

Much research was done and several changes made regarding the selling of the Blade Bandit since the original plan was submitted in October. As mentioned earlier, the 500-unit goal for the first year of sales was an arbitrary number, and it was deemed unrealistic by Shear Genius and the CME panel. Seeking a new goal, Shear Genius researched the national landscaping industry and concluded that 290 landscaping businesses are located in the target market, but this is not necessarily accurate. This calculation assumes landscaping services are evenly spread among all citizens of the U.S., but they will instead be most concentrated in suburban areas, with some also in rural areas and few in urban areas. Mississippi and southeast Louisiana are mostly suburban and rural, which means landscaping services will be more heavily concentrated in these areas. Specific data about the concentration of landscaping services was not available, so the broader generalizations were assumed. Additionally, the 10% market penetration is a conservative estimate that should be achievable. Planning for this conservative estimate of 30 Blade Bandits ensures Shear Genius can remain operational and expand its geographic market even with a slow start to sales.

Other aspects of the business plan were adjusted to compensate for this reduced goal. The decision to only sell the Blade Bandit with the included angle grinder was made with more than just revenue in mind. It not only increases the profitability of each unit, it ensures the quality of the customer experience. The Blade Bandit was designed around this specific model of angle grinder. Originally, the team thought it would work easily with most ordinary angle grinders, but this mindset changed as the design became more sophisticated and precise. The placement of the grinder on the mount plate is crucial for the proper sharpening angle and should be set during the manufacturing process.

Moreover, the power switch must be on the top of the grinder, and the circumference of the grinder must fit within the hose clamps

6.3 Product Description and Process Layout

"The Blade Bandit is a fixed-position lawn mower blade sharpener. A vise holds the blade in place, while a grinder is attached to a movable mount. The vise's position can be adjusted to provide a range of angles at which the blade can be sharpened. Recommended blade angles differ between manufacturers but generally range between 35° and 45°. The grinder moves side to side along a spindle to span the cutting edge of the blade. It also slides fore and aft in the mount to reach blades at different positions and to follow the curvature of heavily worn blades.

6.4 Design Changes

During the testing stage of R&D, the team recognized that the preliminary design could not successfully sharpen a mulching blade. After some brainstorming, changes were made to improve the functionality of the Blade Bandit and cut costs through material selection.

Instead of using 3" x ½" steel bar for the side brackets, a cheaper 2" x 1/8" steel bar was selected. Instead of tapping holes in the bottom, a 90° L bracket with pre-drilled holes will support each side bracket. Use of the L brackets has allowed the team to cut down on machining time by eliminating the need to tap the bottom of the side brackets. It has also created a need to drill four additional holes, increasing the total number of drill operations to attach the side brackets to the baseplate from eight to twelve.

The next improvement was made to the spindle. It had an original length of 16", which has since been reduced to 11". The original 16" was unnecessary as the cutting *edge of a lawn mower blade is typically around 5" long. In the previous design, the ends of the spindle were tapped so that it could be bolted to the side brackets. It was determined that the spindle did not need to be rotationally fixed, so the threads and bolts were replaced with simple collar clamps. To accommodate the new spindle, 33/64" holes were drilled in each side support to allow the spindle to easily pass through the side brackets. The side supports sit 10" apart, and the 11" spindle protrudes ½" on either side. The clamps are placed on the inside surface of each side bracket to lock the spindle in place while allowing free rotation of the spindle. After reducing the length of the spindle, the length of the baseplate was reduced from 24" to 18".*

Another design improvement alters how the grinder mounts to the spindle. The original design used two steel plates, each with a semi-circular groove; when they were clamped together through the drilling and tapping process, the spindle could slide between the two plates. This design only allowed two degrees of freedom for the grinder: sliding along and rotating about the spindle. The new design added a third degree of freedom: longitudinal motion. With this, the Blade Bandit is now capable of sharpening complex mulching blades and extremely worn blades. The new mount is machined out of a solid block of nylon instead of the thick steel plates, which drastically reduces weight and friction. It measures 1.5" x 1.5" x 3" with a 33/64" through-hole (includes 1/64" clearance) for the spindle and a 2.045" x 0.156" slot (includes 0.045" clearance) and ±0.005" tolerance milled parallel to the through-hole for the 2" x 1/8" mount plate. The grinder is fixed to the mount plate with two standard 3.5" hose clamps. This new grinder mount is shown in ***Figure 20****.*

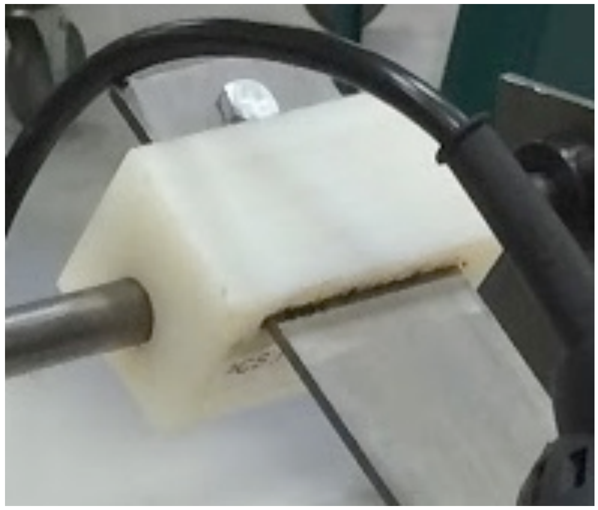

Figure 20: Grinder Mount.

After solving the issue of mulching blades and highly worn blades, attention was turned to the angle of the cutting edge. On the original prototype, the guard on the grinder would make contact with the teeth of the mulching blade. To address this issue, the height of the spindle was raised from 7" to 9-⅝" to provide necessary clearances. The vise was moved 1" away from the spindle to compensate for the increased height and retain appropriate sharpening angles for standard and mulching blades. With this adjustment of the spindle location, the baseplate had to increase in width from 12" to 13".

Other, minor design changes were made regarding material selection, aesthetics, design for assembly (DFA), and safety. All bolts used in this product are ¼-20 UNC threaded, which means all nuts are the same. All bolts and nuts have a 7/16" head. Bolts with a ½" length will be used for the side brackets. To allow the use of these same ½" bolts on the baseplate, the thickness of the plywood was reduced to 5/8". The vise still requires 1" long bolts because of the thickness of the vise mount. All bolts going through the baseplate will fasten to tee-nuts hammered into the bottom of the baseplate holes.

Aluminum sheeting of 0.01" thickness is used to cover the baseplate to protect the wood. All machined edges that have sharp corners were filed to reduce the risk of cutting an operator's hands or arms. A label with position markings that correspond to the degrees of pitch of the angle grinder was placed next to the vise. This label aids in the placement of the vise for the desired angle. Lastly, a label with the Blade Bandit logo was adhered to the blank space on the baseplate cover. A picture of the final Blade Bandit is shown in ***Figure 21****, and a CAD drawing is provided in* ***Figure 22****. The vise and grinder to be used with the product are not included in the 3-D model." [6]*

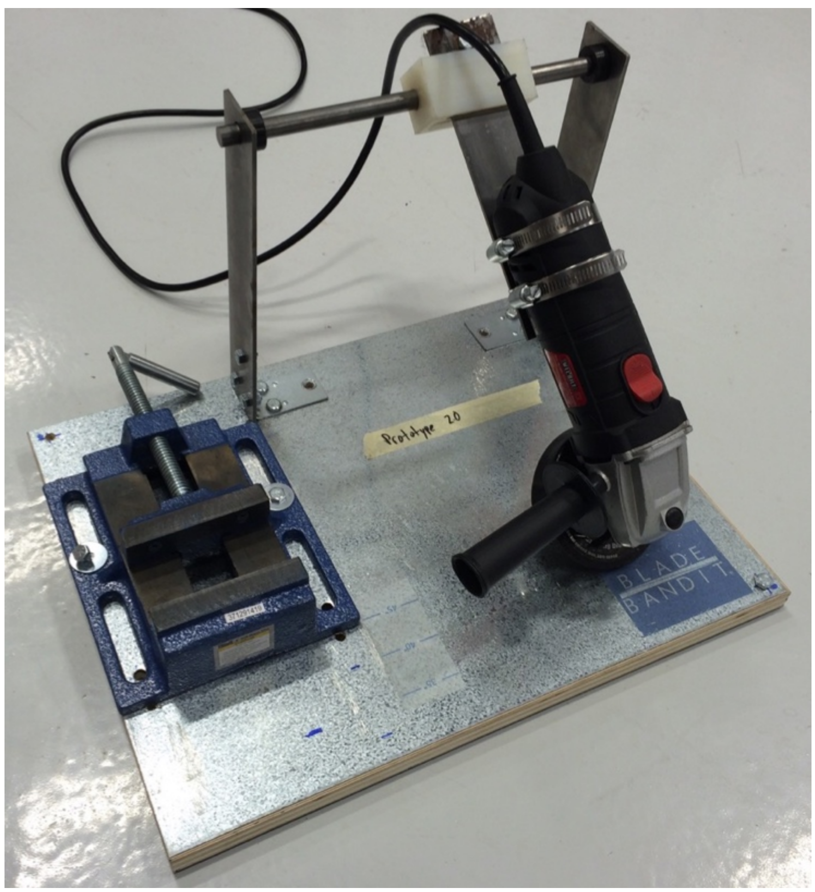

Figure 21: Second Prototype of the Blade Bandit.

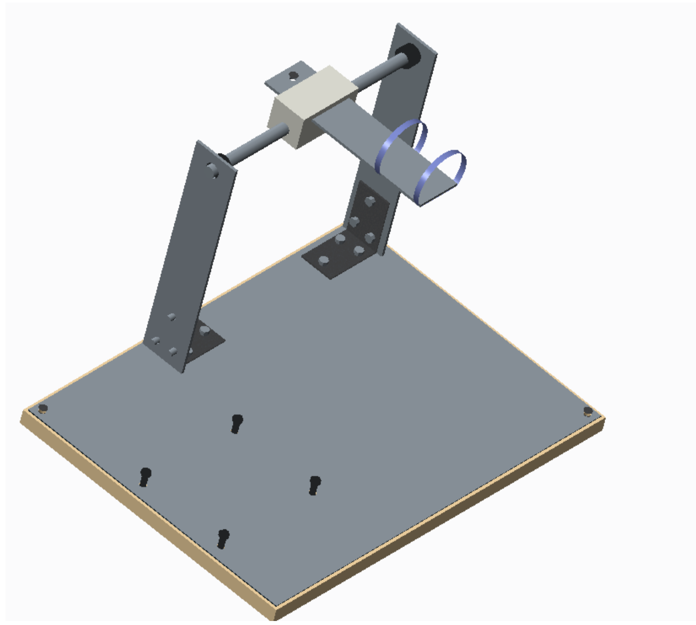

Figure 22: Final Blade Bandit Design as a CAD Drawing.

When building the first prototype of the Blade Bandit in December 2014, the most problematic process was tapping the holes in the bottom of the side brackets and in the spindle. It is a very time-consuming process with expensive tools. Taps are also fragile tools that require generous lubrication; a tap was broken during production of the prototype. Thus, the first goal of optimization was to eliminate tapping altogether. This goal led to other improvements, such as the drastically reduced thickness of the side brackets, which reduced both cost and weight. This necessitated the drilling of additional holes, but they could be drilled far more easily and quickly than the original tapped holes. It also required more nuts and bolts, but, again, overall cost and cycle time for this part is drastically reduced.

The new side bracket design eliminated the need for the lathe and mill bit. The reduced thickness of the side brackets allowed for a through-hole to be easily drilled, so the best option for mounting the spindle was to extend it beyond the side bracket through-holes and secure it with collar clamps. The team found that the L brackets were actually slightly less than 90°, which caused the side brackets to tilt toward each other and cause a slight trapezoidal shape. This was addressed by moving the collar mounts to the inside of the side brackets and setting them such that they push the side brackets apart creating 90° angles. The force of the brackets squeezing together held the spindle in place, but the brackets could also be pulled apart by hand to remove (or place) the spindle, which simplified assembly. The through-holes are drilled at 33/64" to provide a tight tolerance between the hole and the spindle while also keeping tool cost and accessibility reasonable. This same size is also used for the through-hole in the grinder mount.

The grinder mount was also problematic in the original design. The preliminary solution performed identically to the current solution, but used three steel plates bolted together with spacers and rollers between them. The spindle would slide between bottom and middle plates while the mount plate would slide between the middle and top plates as shown in **Figure 23** below. This design provided the proper functionality but was far too complicated for production. It required the addition of many assembly parts which came in different sizes, conflicting with many DFMA principles. This led to the current design, which is machined from a block of nylon. The new design addressed all of the main objectives for this part but it does, however, require the use of a CNC mill. A manual mill was tested but took nearly five times longer to machine the part, which negated the benefit of the lower capital cost.

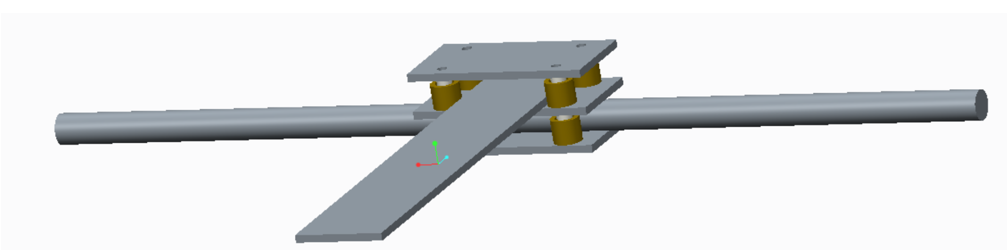

Figure 23: Original Grinder Mount Redesign

On the original design, the grinder was mounted on top of the spindle. With the new design, the grinder is mounted forward of the spindle, which pushes it more toward the blade. This required pushing the vise forward to compensate for the difference. Increasing the width of the baseplate from 12” to 13” means only three rows of baseplates can be cut from a standard sheet of plywood, but reducing the width from 24” to 18” provides room for five rows of baseplates. Thus, the number of baseplates per sheet of plywood decreased by only one to 15.

Another goal of the redesign was to eliminate the need for tools during ordinary use of the Blade Bandit. Tools were needed to adjust the position of the grinder in the hose clamps and to adjust the vise. The third degree for the grinder omitted the need to adjust its position, and wing nuts allow the user to easily loosen and secure the vise by hand (these were planned from the beginning but were never implemented). The hex-head and wing bolts are both the same thread count, allowing the use of the same tee-nuts in the baseplate. The tee-nuts extend into the wood ⅜”, which was thought to be enough for ½” bolts to fasten when going through the ⅝” plywood. It was later discovered that these specifications were not compatible with one another.

6.5 Process Changes

"The process used in the manufacture of the Blade Bandit changed substantially along with the design changes. Many of the design changes discussed were made to simplify the manufacturing and assembly processes and increase quality and efficiency. Tapping was eliminated from the process entirely through the use of thinner materials, nuts, or new assemblies altogether.

Production begins by placing the raw sheet of plywood onto the panel saw and cutting a 48" x 18" strip. This strip is taken to a table saw where the 13" dimension of the baseplate is cut from the 48" side of the strip. Three baseplates are cut from each strip. After the wood is cut, the covering sheet is marked with a stencil and cut using a manual foot shear. The sheet is cut to the dimensions of 12-¾" x 17-¾" so it does not protrude off the edge of the wooden plate. The sheet is then placed between the baseplate and a wooden stencil and taken to a drill press. Twelve 19/64" holes are drilled through the plate and sheet simultaneously.

The full mount assembly begins at the horizontal band saw. Here, the side brackets (10-¼"), mount plate (8"), spindle (11") and nylon mount (1-½") are marked and cut to size. All sharp edges are then filed off.

The side brackets and nylon mount are taken to another drill press for the 33/64" through-hole. The mount is drilled first so that it can be immediately taken to the next step; its hole is marked and drilled at the lowest rotational speed (400 rpm). This low speed is necessary for drilling the side brackets in the next step and is used for the nylon to prevent the operator from unnecessarily adjusting the speed between steps. The side brackets are then placed onto the drill press, along with a stencil, and drilled together.

The side brackets are then taken to the next drill press with a ¼" bit, where they are secured with another stencil. The holes needed for the pre-cut L brackets are drilled. The mount plate is also drilled once at this station.

While the holes are being drilled, the through-slot for the mount plate (2.045" ± .005" x 0.156") is milled into the nylon mount. This process is executed on a CNC mill and takes approximately 4 minutes and 30 seconds to set up and mill. After this part is completed, all parts are collected and taken to a worktable for final assembly.

The first step in final assembly is the placement of tee-nuts in every hole in the bottom of the baseplate through a manual hammering operation. After the tee-nuts are placed, the two corner holes of the sheet are bolted to the wooden plate using the ½" bolts. Once this is secured, the L brackets are bolted to side brackets using ½" long bolts and nuts. These assembled brackets are then bolted tightly to the baseplate. The mount is assembled by placing the mount plate through the slot in the nylon mount; a ½" bolt and nut are secured in the hole to act as a stopper. The collars and mount assembly are placed on the side brackets. The collars are then tightened at pre-marked locations and checked for stability. The grinder is placed on the mount plate and secured using hose clamps. The vise is set at the 35° location using 1" wing screws. Finally, labels are placed and the product is inspected for quality.

To accommodate this new manufacturing process, the layout was also changed. This new layout is shown in ***Figure 24*** *below. Some notable changes are the removal of the lathe as the sliding rod no longer needs to be tapped, and the addition of a CNC mill to machine the nylon mount.*

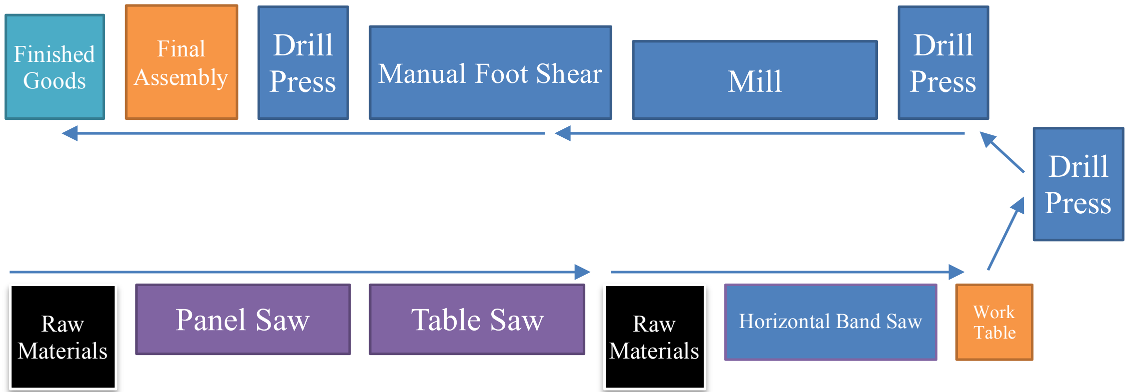

Figure 24: Manufacturing Process Layout after Optimization

Figure 25 *below shows the layout to scale with respect to the factory floor." [6]*

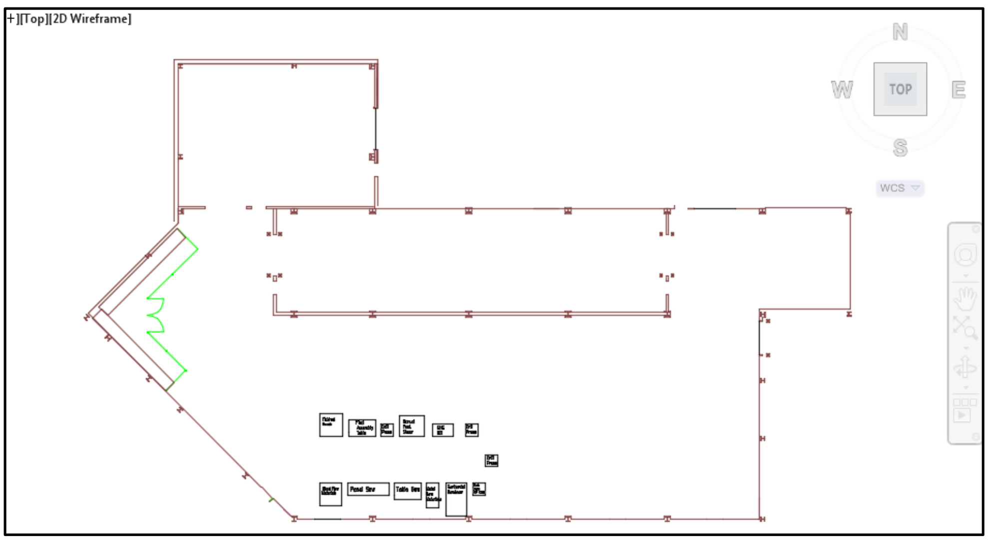

Figure 25: Space Utilized on Factory Floor By Layout

The first step of cutting the baseplate will vary from unit to unit, as the 18" cut on the panel saw will only need to occur after every third unit. Stencils are heavily utilized throughout the process to ensure consistent, quality parts while eliminating measuring time. The cover was drilled simultaneously with the baseplate and stencil to eliminate alignment issues. The 19/64" hole diameter was selected to allow the tee-nut to be easily hammered into the hole while still holding it snug.

The stencils for all band saw operations are strictly for tracing the line; they are not to be placed on the part during the process like at the drill press. The side brackets, mount plate, spindle, and nylon mount all have stencils to trace the length onto the raw material. All parts are traced and then cut individually. Mechanical stops were not used because the four different lengths would require tooling changes between operations. The same stencil is used to trace the length of the nylon mount and its through-hole. This hole will be drilled later, but it is traced at the same time that the length is traced. The stencil is shown in **Figure 26**. The 1.5” length is traced onto the nylon block and hole is traced into the side of the block.

Figure 26: Nylon Mount Stencil

The two side brackets are aligned with the stencil by hand and clamped with the vise grip pliers. They are then placed in the drill press vise and drilled, as shown in **Figure 27**. Different drill presses are used to prevent changing bits between operations; appropriate stencils are provided at each drill press. The through-holes in the side brackets and the nylon mount are both drilled on the same drill press. The mount is drilled first so it can move on the semi-automated CNC mill while the operator continues with the side brackets and mount plate.

Figure 27: Side Brackets and Stencil in the Drill Press Vise

A ratcheting wrench will be used to tighten the bolts in final assembly to speed up the process while eliminating clearance issues with a socket and ratchet. The stencil used to trace the length of the spindle will also have slots to mark the location of the collar clamps. The hose clamps are the only hex head parts that cannot be tightened using a 7/16" tool. A nut driver will be used to tighten these to ensure the different size tools are not confused.

The new layout was developed based on many key lean manufacturing principles: counter-clockwise, one-piece flow, adaptability to changing demand, easy communication, a U shape, and minimal inventory. The process involves the separate baseplate and grinder mount subassemblies that each create their own U and meet at final assembly. With high demand, the line would have four workers. The first worker would cut the baseplate on the two wood saws, place it on a cart, and pass it to the next worker at the foot shear. That first worker would then move on to the horizontal band saw. Those parts would then be drilled and milled by the second worker. The third worker would receive the wooden baseplate from the first worker, cut the baseplate cover, drill them together, and hammer in the t-nuts. The fourth worker would handle final assembly. The processes are combined strategically such that the overall cycle time is the same for each worker, eliminating bottlenecks and built-up inventory. In a low demand situation, a single worker could work the entire line. He or she would place the baseplate on a cart after it is cut and place it in a holding area, retrieving it before reaching the shear. The U shape allows all the workers to easily communicate with each other visually and audibly, so defects can be spotted and addressed immediately or the line can be stopped if a safety issue arises. The equipment is arranged such that their working interfaces are on the same plane, eliminating zigzag as the operator moves between machines.

6.6 Gantt Chart

*"The Gantt chart shown in **Figure 28** displays Shear Genius' projects and their status of completion. The projects in the category "Improve Design of Prototype" focused on redesigning the Blade Bandit, preparing for production, and reporting on the team's progress. The "Redesign Slider," "Redesign Spindle Attachment," "Redesign Side Bracket Attachment," and "Rebuild Prototype" projects focused on redesigning the Blade Bandit to simplify the manufacturability and assembly. The "CAD Drawing," "Order Materials for Production," "Create Stencil," and "Improve Manufacturing Layout" projects aimed to prepare for the production of the Blade Bandit. The "On Floor Mockup" and "Work on Written Report" projects' objective were to update the CME panel on the status of the business. The remaining tasks, "Order Materials for Production" and "Create Stencil," will be completed by March 6, 2015, to allow time for the raw materials to arrive and any unforeseen problems with the stencil to be handled.*

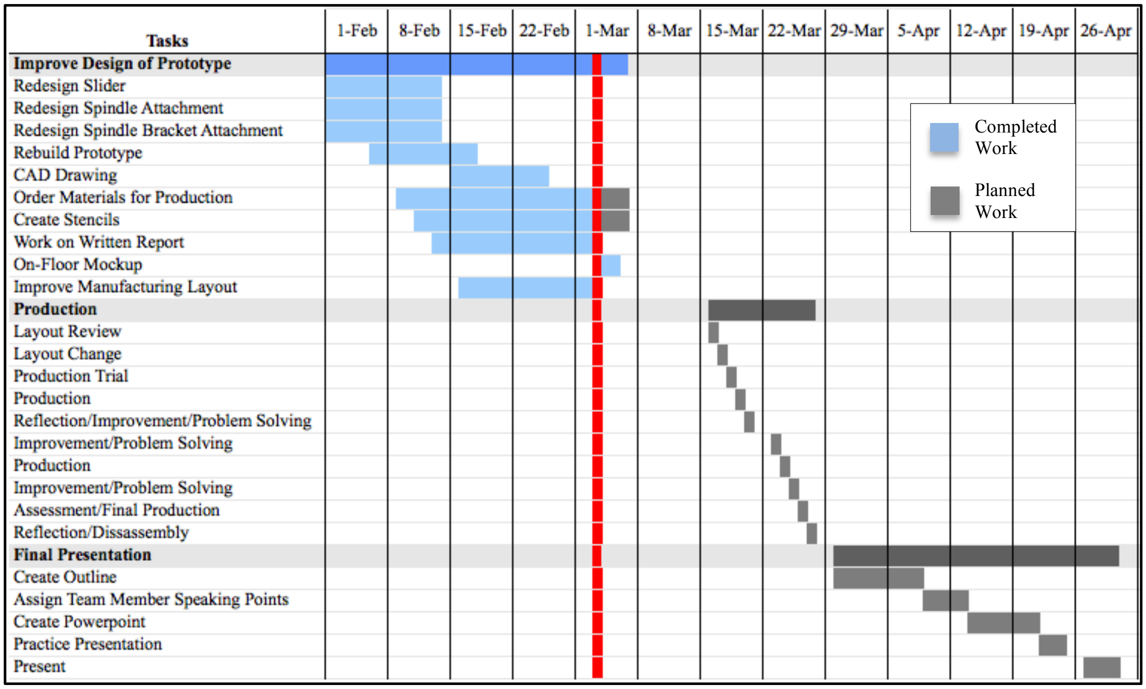

Figure 28: Gantt Chart

6.7 Manufacturing Bill of Materials

A manufacturing bill of materials is shown in ***Table 10****. The values in the "Total Qty" column are based on the amount of raw material required, and the cost/unit is based on the cost of the raw material required to produce one Blade Bandit. The manufacturing bill of materials is divided into the side bracket assembly, the baseplate assembly, and overhead supplies. The cost of the Blade Bandit's raw materials has been reduced by 10% since the original Business Plan.*

Table 10: Manufacturing Bill of Materials

ID#	Description	Type	Item #	Total Qty	UM	Preferred Supplier	Cost/Unit
A	**Side Bracket Assembly:**						
1	Spindle Clamp	Item	35463652	2	EA	MSC Direct	$3.28
2	1/4"-20 X 1/2" Screws	Item	88548706	6	EA	MSC Direct	$0.79
3	1/4"-20 Nuts	Item	67471045	6	EA	MSC Direct	$0.19
4	1/8" x 2" x 36" Steel Bar	Item	3893740	0.750	EA	MSC Direct	$7.60
5	½" Steel Rod	Item	70872502	0.313	EA	MSC Direct	$2.95
6	Nylon Block	Item	63400790	0.125	EA	MSC Direct	$6.74
7	L Bracket	Item	5392907	1	PKG	ACE Hardware	$5.99
B	**Baseplate Assembly**						
8	Plywood	Item	166081	0.067	EA	Home Depot	$1.50
9	Stickers	Item	B00B9Q9QY0	0.031	EA	Office Depot	$0.18
10	Metal Shim Cover	Item	-	0.030	EA	ACE Hardware	$1.98
11	Vise	Item	30999	1	EA	Harbor Freight	$16.99
12	Wing Screws	Item	806898	4	EA	Home Depot	$4.40
13	Tee Nuts	Item	67300848	12	EA	MSC Direct	$1.21
14	Hose Clamp	Item	40779662	2	EA	MSC Direct	$1.61
15	Washer	Item	87920112	4	EA	MSC Direct	$0.20
16	Welbilt Grinder	Item	21403	1	EA	Northern Tool	$23.99
17	1/4"-20 X 1/2" Screws	Item	88548706	9	EA	MSC Direct	$1.19
C	**Overhead Supplies**						
18	Coolant	Item	-	0.001	EA	Machemicals	$0.16
19	Paper Towels	Item	-	0.25	EA	Wal-Mart	$0.29
	Total						**$81.24**

6.8 Cost Analysis

Shear Genius has spent $338.77 on research, design, and prototype construction of the Blade Bandit. The total expenses for the prototype and design are listed in ***Table 11****. The grinder, tee-nuts, steel rod, steel bar, and vise (items # 1, 2, 3, 4, and 5, respectively) were the raw materials used to construct the prototype for the December 4 presentation.*

The nylon bar is the raw material used in the current prototype and design for the slider. The steel bar, item #7, was purchased as a raw material for the prototype in the current design that functioned as the side brackets and mount plate. However, it was too wide, so a new steel bar, item #8, was ordered to replace it. Clamp collar A and clamp collar B were ordered to test the effectiveness of each design. The washers were ordered to ensure a proper fit for holding the vise. The bracket, item #12, was ordered to test its effectiveness in anchoring the side brackets.

The 17/32" drill bit was purchased to drill the spindle attachment for the metal slider in the first prototype. The 33/64" drill bit was ordered to drill the holes in the side brackets to ensure a tighter fit for the spindle. The mill bit was ordered to provide the necessary length to drill through the nylon bar for the slot during production. The steel bar, item #16, was ordered for the construction of a stencil.

As a result of the research and design, Shear Genius has reduced the material cost by $6.71/unit and the value-added time per unit by 34 minutes. Considering only labor and materials costs, this reduction results in a savings of $206 in the first year. The savings from the potential scrap parts and non-value-added time resulting from the manufacturing difficulty of the old design should also be considered. However, these savings are difficult to quantify since neither design has been in production.

Table 11: Expenses

Expenses						
Item	Date	Item	Supplier	Cost/Unit	Qty	Cost
Purchases for Design or Prototype						
1	10/22/14	Grinder	Amazon	$25.67	1	$25.67
2	11/19/14	½" Steel Rod	MSC	$59.71	1	$9.21
3	11/19/14	1/8" x 2" Steel Bar	MSC	$49.71	1	$49.71
4	11/19/14	Tee Nuts	MSC	$10.33	1	$10.33
5	11/25/14	Vise	MSC	$15.51	1	$15.51
6	1/29/15	Nylon Bar	MSC	$53.89	1	$53.89
7	1/29/15	Steel Bar	MSC	$20.96	1	$20.96
8	2/5/15	Steel Bar	MSC	$10.13	1	$10.13
9	2/10/15	Clamp Collar A	MSC	$8.66	2	$17.32
10	2/10/15	Clamp Collar B	MSC	$3.28	2	$6.56
11	2/10/15	Washer	MSC	$3.34	1	$3.34
12	2/17/15	Bracket	Ace	$5.99	1	$5.99
Prototype Total						**$228.62**
Purchases for Production						
13	11/19/14	17/32" Drill Bit	MSC	$17.62	1	$17.62
14	2/17/15	33/64" Drill Bit	MSC	$17.61	1	$17.61
15	2/5/15	1/8" Mill Bit	MSC	$41.20	2	$82.40
16	2/17/15	1/8" Steel Bar	MSC	$10.13	1	$10.13
Production Total						**$127.76**
				Total Cost		**$356.38**

*Shear Genius estimates the production cost of the Blade Bandit by using Cost of Goods Sold as shown in **Table 12**. Materials, labor, and overhead are the components of cost of goods sold. The "materials" are only the materials that are assembled into the product. Labor is the cost of labor to produce one product. The cost of labor is estimated by a new total cycle time of 30 minutes and an hourly wage of $10/hour. The overhead for the equipment is determined by the hourly shop rates for the equipment used in production. The cost of goods sold to produce one completed unit is $98.94. The equipment rental number is based on direct labor time at each machine. It doesn't, however, include downtime between operations.*

Table 12: Cost of Goods Sold

Materials	$81.24	
Labor	$5.00	
Equipment Rental	$12.70	
Cost of Goods Sold		**$98.94**

6.9 Safety, Instructions, and Assembly Notes

Before using the Blade Bandit, it is important to read all the safety instructions. Shear Genius' ultimate goal is to provide not only the perfect cutting edge for lawn mower blades, but also safe usage of the machine.

Like any power tool, extreme caution should be used while operating the Blade Bandit. The operator should always wear safety glasses and gloves. The sharpening process generates sparks that could injure the eyes, and the newly sharpened blade could injure the fingers or hand. The Blade Bandit should only be used on a flat, stable surface. The original Welbilt Grinder instruction and safety precaution manual will be included with the Blade Bandit documentation and should be followed by the customer. The Blade Bandit is shipped fully assembled, negating the need for assembly instructions. A list of specific operator instructions and safety considerations are shown below.

Instructions

1. *Adjust the vise to the position corresponding to your blade's OEM suggested sharpening angle.*
2. *Place the lawn mower blade in the vise and tightly close the vise.*
3. *Verify the grinder is secure within grinder mount.*
4. *Plug the grinder into a proper electrical outlet.*
5. *Turn the grinder on and slide it side to side along the cutting surface of the blade. Use the edge of the grinder wheel. Continue until desired sharpness is achieved.*

Safety

1. *Safety glasses are required.*
2. *Gloves are required to protect from sparks.*
3. *The safety guard must be on the grinder while in use.*
4. *Avoid loose fitting clothing while in use.*
5. *Be cautious of any corners or edges on the machine.*
6. *Follow all Welbilt Grinder instructions for use of the angle grinder*

Overall Assessment

Shear Genius has significantly simplified the design of the Blade Bandit with respect to its manufacturability and assembly time. The required value-added time has been reduced from 54 minutes at the December presentation to 19 minutes, a 65% reduction in time. In addition, the material cost has been reduced by 10%. Shear Genius' main concern with the production trial is potential shipping delays with material orders. To counter this, all raw materials required for production will be ordered by March 7. Shear Genius is confident in its ability to produce quality parts efficiently in its production." [6]

7. Production

7.1 Week 1: Final Preparations and Trial Run

Shear Genius' two-week production period began on March 16, 2015. By this point, all raw materials and production tools had been ordered and were received by the CME or were in transit. Upon final review of the materials selected for the Blade Bandit, it was determined that the aluminum sheet metal that was ordered was not suitable as the baseplate cover. It was initially selected because it was readily available and very cheap. The sheet metal was found to be too thin; this had multiple negative side effects. From a customer perspective, the cover looked and felt cheap and was susceptible to dents and scratches from very light impacts. Tightening the bolts into the baseplate would cause the material around the bolt to bubble up. From a manufacturing perspective, the material was so flimsy that it became difficult to handle on the foot shear and on the drill press; normal handling during production would also cause creases in the shim. Thus, the team decided to switch back to the original galvanized sheet steel cover. This cover did not dramatically increase the cost, but solved nearly all of the aforementioned issues.

Once all materials were finalized, the team began creating the production line on the CME Factory Floor. The location of the relatively small line within the factory floor was dictated by the location of the panel saw. While not the most difficult machine to move, it takes up the most physical space; there was not another good place to put the machine. Moreover, the area around the panel saw was relatively empty, allowing other machines to be easily moved to it. The horizontal band saw and CNC mill required special electrical hookup to a 240-volt source. To minimize movement of large machines, a tabletop drill press was used as drill press 2. However, this drill press does not have variable speed control, sits very high on the table, and has a small platform. Consequently, it was deemed unsuitable for the process, and the last remaining drill press in the CME was moved into the production line. This drill press, now known as drill press 2, is a much heavier-duty drill press than the operation requires and must be connected to a 240-volt power source. Financially, Shear Genius is treating it as if it were an ordinary drill press like drill presses 1 and 3.

After all machines were in place, material feeds were set in place. Raw materials enter the process at the panel saw, horizontal band saw, foot shear, and final assembly. Plywood is used at the panel saw, which is the first station on the process. The panel saw can hold an entire sheet of plywood on the saw, so a feed is not required. One sheet is enough for 15 parts, which is more than Shear Genius will be producing during this run. A wire shelf was placed at the horizontal band saw to hold the 1/8" steel bars, 1/2" steel rod, and nylon blocks, as well as the stencils and markers. A second shelf was placed at the foot shear to hold the galvanized steel sheets. A large worktable is used for final assembly, which requires multiple raw material feeds. Small bins were set to hold all bolts, nuts, washers, collars, brackets, and stickers. A shelf was also placed on the final assembly table to hold the vises and grinders within easy reach of the worker. The final assembly station is shown in **Figure 29**.

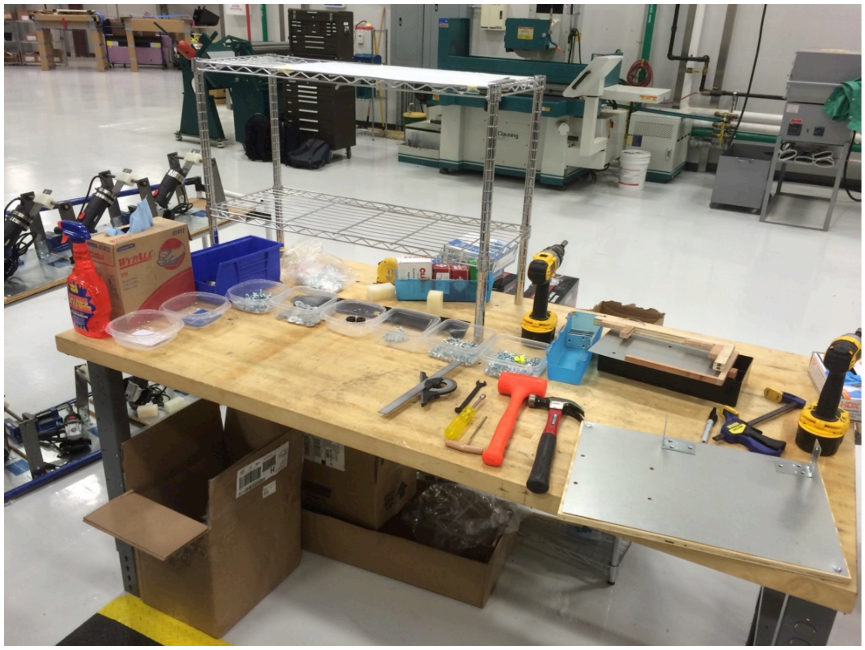

Figure 29: Final Assembly Station.

Next, small hand tools and various other production supplies were set up along the line. A stop was clamped into place on the panel saw to eliminate the need to measure and mark the plywood before cutting the 18” strip. The built-in table saw guide was set to eliminate a measurement at that station. A roll of paper towels was placed at the horizontal band saw to wipe off coolant and chips. Stencils were placed at the band saw, drill presses, and foot shear. Vise grip pliers were placed at drill press one. All necessary hand tools were placed at final assembly. All labels and wrapping materials were removed from raw materials. The L brackets, vises, and grinders were removed from their packaging and placed in their designated areas. The grinders also required some pre-assembly. After three days of preparation, the first trial run was set for Thursday, March 26, 2015.

For this first trial run, one worker ran the entire line to allow for a simple cycle time analysis. Mr. Rocco was the operator and was given a final run-through of the process before the trial. The production run was then executed according to the plan detailed earlier. Several small obstacles were encountered during the trial, along with one major obstacle. The smaller obstacles began on drill presses 1 and 3. On both presses, during a drilling operation, the drill bit jammed in the part and came loose from the press. Both instances required production to stop while the bits were removed from the part and placed back into the machine. The major production issue happened at drill press 3 because of two separate problems. First, after drilling the twelve holes through the baseplate and cover using the methods described earlier, it was discovered that many holes on the baseplate and cover did not line up properly, and the cover was not centered on the baseplate, as shown in **Figure 30**. Secondly, the holes themselves did not match up with the tight tolerances of the "L" brackets. Furthermore, it was also discovered that the holes in the side brackets did not line up with the "L" brackets either. The mount plate was found to be slightly too short to comfortably and easily mount the grinder and reach the necessary distance to the blade. The 1/2" bolts were too short to go through the bracket, cover, and 5/8" baseplate and reach the tee-nuts below. Finally, the logo and degree scale stickers did not stick well to the baseplate cover due to oil and dirt on the cover.

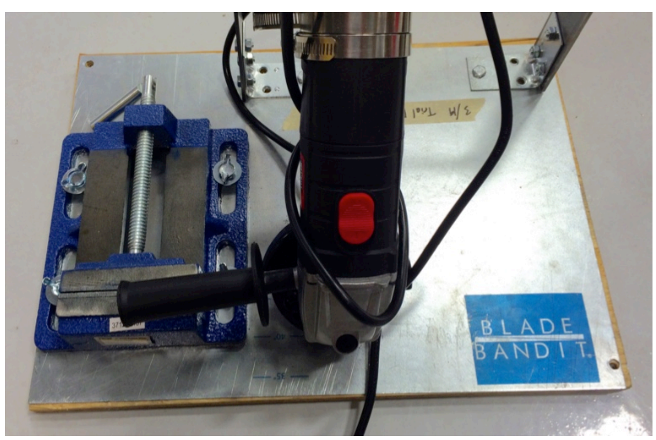

Figure 30: Baseplate of First Production Run

Once the product was as complete as possible given the various production issues, the Shear Genius team and CME professors discussed and analyzed the problems. The simplest fix involved the loose drill bits; more care must be taken to ensure the drill bits are sufficiently tightened in the drill presses.

The hole pattern on the L brackets is an asymmetrical triangle, which makes matching the holes difficult with manual tools and hand measurements. The stencil eliminated the need for measurement, but the parts drilled with the stencil still did not align with the bracket. While discussing the issue, Dr. McClurg pointed out that the tolerances on the side brackets may be too tight to match the holes on the "L" brackets. This means the stencil might have been perfect for the part it was based on, but may not work for all other parts. However, the holes being drilled in the side bracket exactly matched the ¼" holes in the L brackets. This tight clearance was deemed unnecessary, especially considering the bolts themselves are ¼" in diameter. The size of the holes in the side brackets was increased to 19/64" to provide additional clearance. This allows the bolts to pass through even if the holes aren't perfectly centered with each "L" bracket. This would also compensate for inconsistencies in the hole locations from the supplier and allow the bolt to pass through with less resistance.

While the mount plate was long enough to perform correctly, it proved difficult to assemble. The most likely reason is that in prototype construction two people worked together to assemble the units, whereas one person was working alone during the production trial. Without two sets of hands, it was difficult to hold the grinder and mount plate together while maneuvering the two hose clamps with very little wiggle room on the mount plate. To make one-person assembly easier, the mount plate was extended by one half of an inch.

The bolts were chosen as ½" long to be able to pass through the L bracket and/or baseplate cover, through the ⅝" baseplate, and into the tee nuts, which extend ⅜" into the baseplate from the underside. However, the ½" bolts did not make contact with the tee-nuts in the trial run. Upon further investigation, it was found that what was considered ⅝" plywood is actually closer to ¾". To eliminate this issue, the ⅝" plywood was replaced with ½" plywood. All other parts involved stayed the same.

Another major issue that arose during the trial run revolved around the baseplate template. This template had three main issues. The first was alignment. The baseplate cover is ¼" smaller than the baseplate in both directions to allow its edges to rest inside boundaries of the baseplate. This requires the cover to be centered perfectly on the baseplate for both aesthetic and safety reasons. The original baseplate used staples along the edges to keep the cover centered. This was sufficient for the metal shim cover but did not work for the thicker and heavier sheet metal cover that replaced the shim cover. Thus, the cover was significantly off-center and shifted between drilling processes. The second main issue was the imprecision and softness of the wood template. The template was being used as a guide during the actual drilling process, meaning each hole was being drilled through during production. In practice, this is a poor method because the hole expands with each pass as the bit inevitably rubs against one side of the hole. This ruins the precision and defeats the purpose of the template. The third and final issue was inaccurate hole locations on the template. The six holes used for the two L brackets require extreme precision and tiny tolerances, as they must line up perfectly with the brackets. However, the holes in the template were not perfectly placed, and they did not align with the brackets. Unlike the side brackets, these holes could not simply be expanded, as the tee-nuts must fit tightly in the holes.

These issues necessitated a complete reimagining of the process of drilling the baseplate and cover. The solution had to keep the cover centered on the baseplate, prevent it from shifting, produce consistent, precise hole locations, and account for inconsistent “L” brackets from the supplier. The team immediately made two major changes: the template would be used to mark the hole locations, not drilled through, and three templates would be used instead of one. The team decided the two corner holes, whose sole purpose is to hold the baseplate in place, should be drilled and bolted first to keep the baseplate centered and stationary. A simple corner stencil was constructed of wood and sheet metal to mark these two holes. The worker aligns the cover on the baseplate by hand and clamps the two together with an EZ Grip clamp. With the corner stencil, the operator traces the hole location, removes the stencil, and uses a punch and hammer to create a center indention in which the bit self-aligns. The worker then drills the two holes, hammers the tee-nuts into the underside, and bolts the cover onto the baseplate. This keeps the baseplate in place and centered; the EZ Grip clamp is now removed. Next, a second corner stencil, constructed in the same fashion as the first one, was created to mark the hole locations for the four vise bolts. A third stencil was made to hold the L brackets in place on the baseplate. Since each L bracket could be slightly different, the specific brackets used for that Blade Bandit unit are to trace the holes. The stencil guides the placement of the L bracket, and the three holes from each bracket are traced onto the cover. The L brackets are then placed on the worktable so the same brackets will be bolted to that unit. After the ten holes for the vise and L brackets are marked, they all are center punched and drilled. The vise and L brackets are then bolted in place. These three stencils are shown in **Figure 31**.

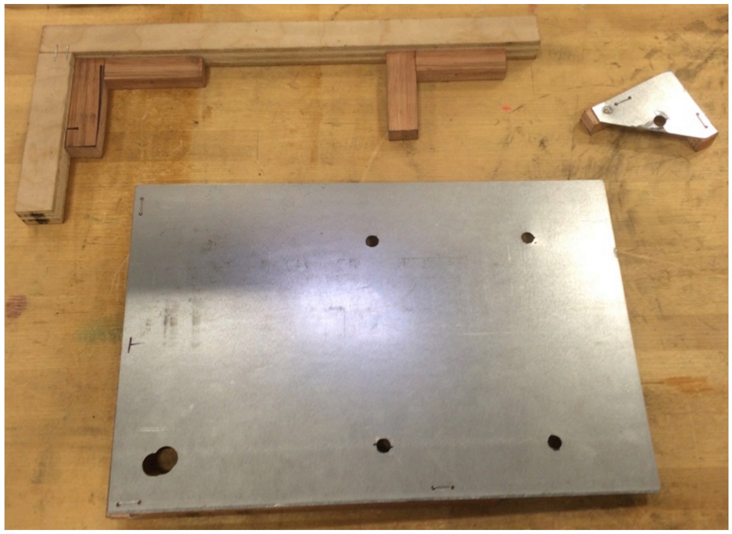

Figure 31: Stencils Used on Baseplate.

As discussed earlier, the L brackets on the prototype were slightly less than 90°, creating a trapezoidal shape with the side brackets. This allowed two collar clamps on the spindle to be placed inside the side brackets to expand them to a rectangular shape with compression holding the spindle in place. However, the production L brackets were from a different supplier and did not create this trapezoidal shape. Thus, they did not create the tension necessary to hold the spindle in place. This necessitated two additional collar clamps. The final design utilizes collar clamps on both sides of each side bracket.

The stickers for the Blade Bandit logo and the blade angle scale were not sticking properly to the baseplate due to oil and dirt on the raw material from the supplier. To solve this issue, a degreaser solution will be used to clean the surface of the baseplate cover, allowing the stickers to adhere properly.

The placement of the manual foot shear was realized to be counterintuitive, as it required the operator to walk completely around the machine to retrieve the part off the floor. The shear was rotated 90 degrees so the worker approaches the operating side and performs the cut. A platform was built to catch the part and prevent it from falling to the floor. The part now falls onto the platform, which is in line with the production line; it is now much more conducive to continuous flow.

One CME faculty member voiced concerns about sharp edges on the side brackets. While the operator filed the edges by hand after cutting on the band saw, it still left a fairly sharp edge and did not remove every burr. Thus, a belt sander was added to the production line after the band saw. The belt sander is as quick as the file but removes much more material, leaving smooth, curved edges that eliminate the risk of injuring the customer. Another faculty member pointed out the need for trash receptacles throughout the line. A trashcan was placed at every machine that created scrap, burrs or dust.

7.2 Week 2: Improvements and Final Production

Further work was done during the second week; these improvements were aimed at improving the reliability and speed of the process. To test the functionality and flexibility of the line, two people were set to operate the line in conjunction with one another, utilizing the inlying U described earlier. The first operator would begin at the panel saw, use the table saw, then skip directly to the foot shear and work through final assembly of the product. The second operator would begin at the horizontal band saw and work through drill press 1 and drill press 2 and finish at the CNC mill.

To successfully implement this process, it was determined a cart system was needed. Three carts would need to be placed on the line: one before the panel saw, another before the horizontal band saw, and the last before the foot shear. Each cart marked a starting point for an operator and needed to be loaded with parts that had been processed by the hypothetical previous production run. The first cart was empty as the panel saw is the first machine in the process. A wooden baseplate already cut to its final 13” x 18” sat in the cart before the horizontal band saw. The cart that sat in front of the foot shear contained the spindle, both fully drilled side brackets, the drilled mount plate and a drilled and milled nylon mount. To ensure that the carts had all parts before being moved to later operations, locations were marked for each part in the cart, as shown in **Figure 32**.

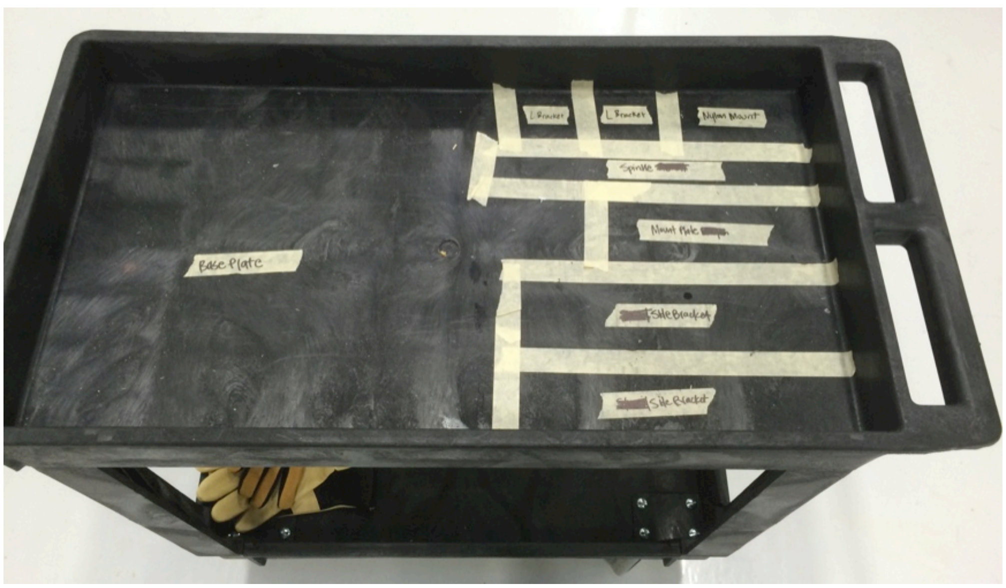

Figure 32: Cart Used in Manufacturing Process.

After the carts were preloaded, two operators began the manufacture and assembly of the product. The first operator moved through the cutting and shearing of the baseplate materials with no issues; the new marking and drilling process proved to be more effective than the previous technique. Problems were encountered, however, during final assembly. The operator had difficulties placing tee-nuts and spent an inordinate amount of time doing so. A large amount of time was also used in the placement of the bolts on the unit as they were secured using a ratchet wrench. A third process, the securing of the angle grinder onto the mount plate, also took a large amount of time as the hose clamps that were used were loose and needed to be tightened. A great deal of adjustments in the handling of the parts and tools slowed assembly.

The second operator faced fewer obstacles but did encounter an abnormality halfway through his process. The cutting and sanding operations flowed seamlessly but when the side brackets were taken to drill press 1, a strangely hard bit of metal slowed the cutting dramatically. One of the holes was nearly impossible to drill through and required an extra 5 minutes of processing. Use of the belt sander in place of a file did prove to be more effective at removing burrs and edges and did not alter the time in any significant way.

In total, the first operator required 27 minutes to complete his work while the second required only 19 minutes, even with the aforementioned abnormality. This time is higher than what was shown in the cost model, but as this was the first production run, some unforeseen issues occurred that were later addressed. This is to be expected with any first trial run and is not indicative of what the process is capable of. With these times taken into consideration, it was decided that the line should be run using three operators instead of two to allow the product to be built within a 12 minute takt time. This takt time is based on the request by the CME panel to build five parts in one hour. It should also be noted that the cycle time would decrease as manufacturing issues were solved.

The first operator again began at the panel saw and moved to the table saw but, this time, went to the CNC mill instead of directly to the foot shear. The second operator's process was nearly identical as it was during the first trial except that it ended after drill press 2. The third operator was entirely dedicated to final assembly and began with the placement of tee-nuts after all holes had been drilled. The addition of the third operator made it possible to produce a part within the Takt time.

Some minor changes were made to the cart system to accommodate the additional operator. The first two carts remained in front of the panel saw and band saw with no change in loading. The third cart was moved so that it sat in front of the CNC and the nylon block that sat in it had yet to be milled. A fourth cart was added for the third operator. This cart was loaded with all parts needed for final assembly. The final layout with these changes included is shown below in **Figure 33.**

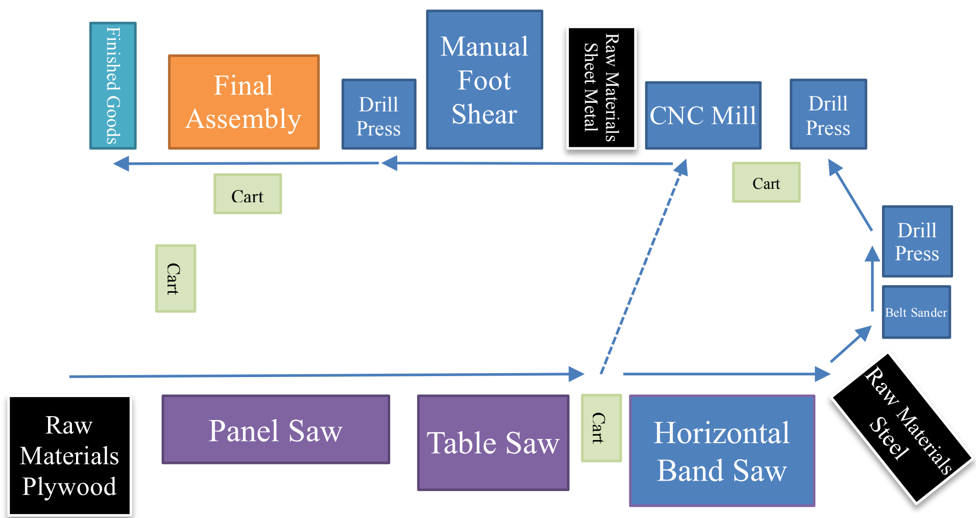

Figure 33: Final Layout Used in Blade Bandit Production

Some minor process changes were also implemented in this transition. To tighten the bolts at final assembly, the third operator was given a power drill. This allowed for a significant reduction in assembly time and more consistent quality. Another change was the labelling of the L-brackets in the hand-off from the first operator to the third; to ensure that the brackets used to mark the holes in the baseplate were placed in the same location during assembly, they were marked “L” or “R” to indicate their location. Cut resistant gloves were also given to the first two operators.

Production during this run went rather seamlessly. The first operator took approximately 11 minutes to complete his operations, the second took 12 minutes and 42 seconds and the third took very little time at 8 minutes and 40 seconds. The work of the first two operators was evaluated to find wasted steps and eliminate non-value added time. It was deemed necessary to utilize the wait time created by the speed of the third operator, so a detailed quality check was added to the process. This quality check involved a final tightening of bolts and a verification of the cutting angle.

One problem did arise in the CNC mill. A mill bit broke near the end of its run, and the part in it had to scrapped. After some investigation, the cause for the break was found. The team had been using a thin piece of PVC in the mill vise to sit under the nylon mount and prevent the bit from running into the vise itself. This PVC was not secured and would begin to move when the bit made contact. The movement of the PVC caused a bending moment on the brittle carbide bit and caused it to break. To combat this problem, the PVC was removed from the vise after the nylon mount was secured during every run, leaving a gap between the mount and the vise surface.

The next day, manufacturing continued with three operators. To prepare for an afternoon run, parts were created to preload the line and the CNC mill was warmed up for operation. After some discussion, it was decided that coolant was no longer needed during the milling operation and it was cut off. All other conditions remained the same as the previous day; once it was deemed that the line was ready, manufacturing began.

The first run through the line presented few problems, but there was an issue discovered at the quality check during final assembly. The cutting angle was far out of spec but, after some adjustment, was brought closer to its intended design. It was discovered the parts made to preload carts earlier in the day were manufactured using slightly different techniques. The side brackets were aligned with the stencil using a different edge, which caused misalignment of the side brackets and “L” brackets.

During the second run, a part had to be scrapped at the CNC mill. As the coolant was off, the nylon began to get very hot and melted. By the time it was taken out, it had solidified and was unusable. The coolant was then reconnected, and the next part was placed. All other operations proceeded as planned.

Before the third run could begin, another problem was found in the CNC mill. Due to some miscommunication and misunderstanding, the coolant was disconnected mid-operation. As a result, the mill bit began melting the nylon again, jammed and broke. Production was halted for the day and the team returned the next day to troubleshoot further problems in the CNC mill.

The next day (the day before final production), the team began work to create a safety stock of mounts. A new bit had been placed in the mill, and a part was tested after production ended Tuesday. New nylon parts were cut, drilled, and taken to the mill. While the first part of the day was being milled, another bit broke. Coolant was running and there was nothing under the nylon, so the cause of the failure was unclear. It was postulated that the cause had to do with the depth of each pass. The mill had been set to remove 1/16” material per pass, and it was thought that, as the bit moved further into the part, that this may cause a high amount of resistance as the bit began changing direction. To test this theory, the drop rate was changed to 1/32." Though this change in depth doubled the operation time, it improved the cut quality and resulted in a lower failure rate. The feed rate was also tested, but it was found that failure would not occur at the old feed rate in the new program. Three parts were made during these trials: one to replace a scrap part from the previous day and another two to serve as safety stock if another failure occurred during final production.

Once the problems with the CNC mill were thought to be solved, preparations were made for the final production run on Thursday. More minor process changes were made in the first operator's process. To remove some wasted movement, the stencil and most recently used raw material at the foot shear would be left at the machine. The waste bins were moved to more convenient locations and a towel rack was added at the CNC mill to clean the coolant from the mount. The last, more significant change was the removal of the center punch in the marks to drill at the baseplate. This center punch guided the drill bit to the center of the marked hole but was determined to be a non-value added process. It was removed because the holes could be drilled with same accuracy with only the markings and the laser alignment on the drill press. This change was tested before production began to verify that quality was maintained.

Production then began with a target of five Blade Bandits produced in 60 minutes. The first part was built with no issues, and all operators finished their processes at nearly the same time. There was a minor problem in the CNC mill during the assembly of the second part; excess shavings built up over the coolant filter and prevented the coolant from flowing correctly. The CEO, serving in a support role, cleared the debris and restarted the process. He then placed one of the parts from the safety stock in the cart for the first operator to use. This problem did not interrupt production but, as the first operator was no longer required to complete an operation, a time gap was later created. The first operator finished approximately thirty seconds before the second operator and had to fill the wait time by cleaning up other machines.

Other problems were also encountered, but production was not harmed. These obstacles were all encountered during the production of the fifth and final Blade Bandit. At the beginning of the line, the power cord for the panel saw became wrapped around its blade and was severed. When this occurred, the first operator contacted the maintenance team who disconnected the panel saw from its power source and cut the wire free. To compensate for the machine being taken out of operation, the remaining operations were performed on the table saw. Later in the process the belt on the belt sander broke while the mount plate was being deburred. The process was finished using a file and the belt was then replaced.

Despite the minor issues that were encountered, the production team still met its targets and completed the five units faster than expected. A takt time of 12 minutes was the initial goal, but during the run, no parts took longer than 10 minutes to roll off of the line. The five products were completed in under 50 minutes, and there were no true defects in the products. The only faults identified by the coaches were the orientation of the grinders and the positioning of the vise on the finished goods rack. Some grinders sat a slight angle; it was suggested that this may affect the quality and angle of the cut. The vise position was noted purely for aesthetic reasons, and all parties acknowledged that the vises should all be in the same final position, whether open or closed. The five parts produced in the final production run are shown in **Figure 34**.

Figure 34: Finished Goods.

8. Conclusion

The CME Capstone Project was an eye-opening experience that revealed the complexities involved with bringing a new product to market. The Blade Bandit is a relatively rudimentary machine but still required a team of six to spend many months planning and designing. Even so, there are many business aspects required that Shear Genius did not execute, such as business registration, permits, facilities, payroll, packaging, and distribution. While issues like these were covered in the Business Plan, there is a stark difference between discussing them and implementing them.

Overall, the Shear Genius team achieved the goals of the CME Capstone Project: start with a product idea, create a business plan, design the product and process, apply knowledge obtained in previous CME courses to improve the product and process, and manufacture a set number of products. The project was a truly collaborative effort among the three disciplines involved and relied on strong teamwork. The level of improvement between the first prototype and the final product is monumental. The first prototype took four members four hours to build and did not function as well as desired. It was unnecessarily large and heavy and featured materials and designs that were excessive for the application. A team of three could push a final product off the manufacturing line every ten minutes. The final product is smaller, more refined, cheaper, easier to manufacture, safer, and, most importantly, it functions properly. The progression from the first concept of the Blade Bandit to the final product is shown in **Figure 35**.

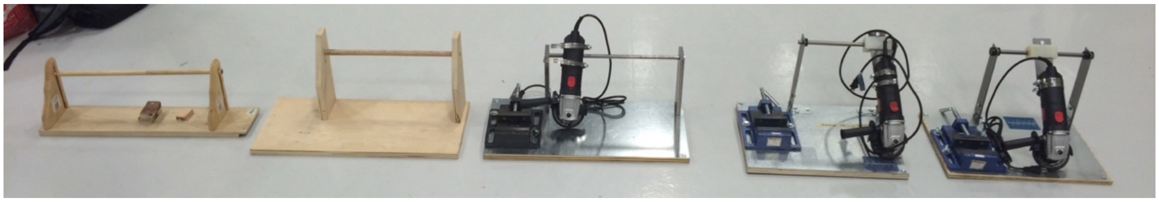

Figure 35: The Progression of the Blade Bandit.

The project was also a humbling experience for the team. Some ideas were rejected, and some ideas were implemented and ultimately failed. On several occasions, the team was very confident in the product or the process, only to have it function improperly or produce a part of poor quality. These instances provided a reality check for the team and introduced the type of issues that will occur in real manufacturing applications. However, the Shear Genius team always pulled together and formulated solutions until a satisfactory product and process was achieved. These types of issues happen on a daily basis in startup business and in manufacturing plants around the world. The members of the Shear Genius team would be invaluable to these companies. While they will certainly encounter new issues, they already have experience bringing a new product to market. The members know how to address the fundamental issues encountered with Shear Genius before they happen in the real world, and they know how to solve new problems as they arise. This is what makes the CME Capstone Project a true success.

9. References

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