T.K. RIPPER

A MULTIDISCIPLINARY GROUP PROJECT

by

LOGAN HUNT

A Senior Project submitted

in partial fulfillment

of the requirement for the degree of

Bachelor of Science in Industrial Engineering

California Polytechnic State University

San Luis Obispo

Graded by: ____________________________ Date of Submission:_________________

Abstract

The purpose of this project is to provide solutions to objectives that require an industrial engineering (IE) background for a multidisciplinary group senior project. The group is creating a portable winch pulley, dubbed the TK Ripper, which will be used for extreme water sports. The group is interested in creating a business using this product, and has forecasted demand for the next three years. The objectives that were assigned from the group were a flow process chart, the cost of producing the product themselves in their own facility, the cost of producing the product if outsourced to China, how many units needed to sell at a profit, and a theoretical layout for their machine shop they may acquire in the future. Each objective was delivered and the results were satisfactory.

Outsourcing the product to China leads to a savings of $448.68 per unit. However, the cost of the minimum amount of material required to be purchased from suppliers in China was nearly five times the cost in the U.S. If the group wishes to have a lower investment cost, it is recommended that they produce the product themselves in the United States.

Table of Contents

Introduction

This report was conducted for a group of Cal Poly mechanical engineering students. This is a mechanical engineering group senior project consisting of five members including myself. Three members are mechanical engineering students; Zach Mckibbin, Vincent Priolo, and Charles Volk. The other member, excluding myself, is John Fitzergerald, a business student. For their senior project, the mechanical engineering students are creating a portable extreme sports winch, named the T.K. Ripper, that will be used for water sports such as wakeboarding or waterskiing.

The idea originated from Vincent himself, who is also the sponsor for this project. The ME students want to create a real-time business by producing the product in a facility within San Luis Obispo County and selling it on the market, most likely via internet. The team needed help in solving problems out of their expertise and educational background. As a result they added members from different majors; one being John, who is attaining double degrees in marketing and entrepreneurship, and the other being me, a general engineering student concentrating in Industrial Engineering. The members tasks were as follows: John was in charge of market research for the product and developing a business model for the group for production of the TK Ripper; Zach, Vincent, and Charles were in charge of designing and building the TK Ripper; and I was assigned objectives with Industrial Engineering aspects. The objectives assigned included:

- Evaluate welding methods and recommend the best method to use
- Fully Allocated Cost of the product

- Comparison of production alternatives such as producing the product in-house or outsourcing it to China in terms of cost per unit
- Break Even Analysis
- Facilities design and planning for their machine shop
- Flow Process Chart

To evaluate welding methods articles and journals were researched and inputs from professionals such as welding technicians and professors from Cal Poly were considered. With this research AHP analysis is used to recommend the best alternative. The flow process chart will be constructed using the Bill of Materials (BOM). To create the BOM, the part's list and assembly steps will be needed. For cost estimation, suppliers were researched for quotes on materials, welding and factory floor workers' wages, average rent and utilities in San Luis Obispo County, equipment needed, and other factors that will be needed to calculate the fully allocated cost (FAC), which consists of material cost, labor cost, and overhead cost. The same method is used calculate the FAC if the materials and assembly process was to be outsourced to China, except assumptions and rough estimates of wages and the cost of materials will need to be used. For facilities layout, local technicians were consulted on how a machine shop is usually designed, then use facilities planning methods to create a layout, such as SLP (Systematic Layout Planning).

Background

The objective of the group was to provide a less expensive way for people to participate in extreme water sports, expand the locations where extreme sports can be performed, and develop a plan for a profitable company. The problem for someone to participate in extreme water sports today is the large initial investment of a boat. If someone wants to water ski, wake board, or perform other water sports, they'll need a boat. Not only will they need this but also a trailer for the boat and a large vehicle, preferably a truck, to tow both the trailer and the boat. This can be expensive and takes a large amount of time to set up; to maneuver the boat into the water from the dock and to place the boat onto the trailer when returning to the dock.

The solution was to design a product that forgoes this large investment; the TK Ripper. The TK Ripper is a small pulley system machine that can be placed on a beach or dock. Once placed, the rope can be strung out for several hundred yards, then pull any one holding onto the rope back to the winch. The T.K. Ripper can pull a rider from 0-30 mph (with adjustable speeds) for 1000 ft and be placed anywhere on a beach of a lake or ocean.

The TK Ripper consists of a gasoline engine, an aluminum frame, a centrifugal clutch, and a spool of 1,000 feet of line. The engine provides power to the clutch which then transfers the power to the spool, which reels in the line. The rider holds on to the end of the spooled out line when participating in their extreme sport of choice and are pulled toward the TK Ripper. The entire product is given strength from an aluminum frame and covered with sheet metal for protection from rotating parts. A control system will eventually be incorporated into the design allowing for superior ease of use. The TK Ripper is 3 feet long, 1.5 feet wide, and 16 inches tall.

The group wants to create a business model because they want to place this product into a production run with a selling price of $2000 or less per unit. The group is interested in renting space to be used as a facility within San Luis Obispo County. They are also interested in know the cost of the product if produced domestically and if outsourced to China, a large manufacturing country known for cheap labor and materials. In the next section, many Industrial Engineering topics are discussed and provided the tools needed to complete the objectives.

Literature Review

Welding Alternatives

The three welding methods that are suitable for welding the aluminum tubes and plate together to create the frame are shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW).

SMAW is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination [8]. Because of the versatility of the process and the simplicity of its equipment and operation, shielded metal arc welding is one of the world's most popular welding processes and is ideal for maintenance and repair welding and can be used in the field.

GMAW, sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used [8]. Today, GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative

ease of adapting the process to robotic automation. Unlike welding processes that do not employ a shielding gas, such as shielded metal arc welding, it is rarely used outdoors or in other areas of air volatility [12].

GTAW, also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a nonconsumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma [8]. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing procedures such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques [12].

A quantitative method this report used was AHP, or Analytic Hierarchy Process. AHP is a structured technique for dealing with complex decisions. It is a method for ranking decision alternatives with multiple criteria. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. Once the hierarchy is built, the decision makers systematically evaluate its various elements in pair-wise comparisons. In making the comparisons, the decision makers can

use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal and allow a straightforward consideration [3].

Flow Process Chart

To design a layout, a flow process chart is needed to help understand the flow of material. A flow process chart gives an overview of the flow within a facility. It is also needed to understand labor costs as it explains some of the machining steps involved in making the parts needed [2]. However to start a flow process chart, a bill of materials (BOM) will need to be created first. A BOM is a structured parts list as it contains the information of the parts needed for a product plus information on the structure of the product. The structure of the product is broken down into levels, with level 0 being the finished product. Level 1 applies to subassemblies and components that feed directly into the final product; level 2 refers to the subassemblies and components that feed directly into the first level, and so on [6].

Cost estimation

Cost estimation is used to basically estimate the cost of a product or prototype before production begins. The goal is to estimate the cost as close as possible to the actual cost. Cost estimation, in this case, is also known as FAC, or Fully Allocated Cost. FAC is a sum of the material cost, direct labor cost, and overhead cost [11]. Overhead is broken into two categories:

ongoing and initial investment. Ongoing consists of fixed costs, such as rent, utilities, and transportation, and indirect labor. Indirect labor are employees that do not handle the product; they are usually office workers and the floor manager. Initial investment is the investment to the equipment bought for the company. Overhead is difficult to calculate per product, so the cost is spread out over the forecast demand of that year [11].

Offshore Outsourcing

When deciding whether to in-house the production line or outsource the process to another company or maybe even offshore to another country, it's best to understand the definitions of these terms.

Outsourcing is often viewed as involving the contracting out of a business function to an external provider. Almost any conceivable business practice can be outsourced for any number of stated reasons. The reasons the TK Ripper team would want to outsource would be: improve quality - achieve a step change in quality through contracting out the service with a new service level agreement; knowledge -access to intellectual property and wider experience and knowledge; operational expertise - access to operational best practice that would be too difficult or time consuming to develop in-house.

Offshoring describes the relocation by a company of a business process from one country to another—typically an operational process, such as manufacturing, or supporting processes, such as accounting. The economic logic is to reduce costs. Offshore outsourcing is the practice of hiring an external organization to perform some business functions in a country other than the one where the products or services are actually developed or manufactured.

After its accession to the World Trade Organization (WTO) in 2001, the People's Republic of China emerged as a prominent destination for production offshoring. China has a huge advantage of a large labor force offered at an extremely low hourly wage. The average Chinese factory worker can have a wage as low as 3% of the wage of a factory worker in the U.S. [14]. Rules are also more lenient and factory employees work 12 hours or more, as compared to the 8 hour days in the U.S. Materials purchased in China are more cheaply as well. There are areas of concern if choosing to offshore. Companies have a higher risk of losing control and visibility across their extended supply chain. Also, the transfer of knowledge outside a country may create competitors to the original companies themselves. Chinese manufacturers are already selling their goods directly to their overseas customers, without going through their previous domestic intermediaries that originally contracted their services [15].

Facility

To plan for a facility design, the systematic approach should be used. The steps are as follows: define the problem or goals; define the departments; define relationships between the departments; identify the space requirements; develop alternative layouts; evaluate the layouts; select a layout; and define, install, and maintain the layout [2]. Since this group will be starting small, research into small machine shops over large machine shops was needed. From research and advice from local Cal Poly technicians, the small machine shop the group would work in is most likely a centered fixed-material layout. This layout calls for most of the assembly process to take place in the center of the shop and have material flow to it from around the shop [12]. This is usually the case when one or two workers build one unit at a time.

Design & Methodology

In this chapter all requirements, specifications, overall approach, calculations, and specific steps including methods used to arrive at the solution of each objective is discussed.

Welding Alternatives

The T.K. Ripper has an aluminum frame consisting of several aluminum square tubing and an aluminum plate. The aluminum is welded together to form a strong frame and base for the rest of the material to be assembled in. There are several different welding methods that could be undertaken to build this product. The three main methods that were evaluated and are able to weld this frame are SMAW, GMAW, and GTAW. The definitions of each are described in the Literature Review. SMAW is the cheapest because of its low cost of equipment needed (no bottle, gas hose, flow meter, or wire feeder needed). It has a faster deposition rate than GTAW but slower than GMAW, and is ideal for shop jobs and field work such as repair or maintenance. It also requires more experience than GMAW but not nearly as much as GTAW. GMAW has a more complex and expensive process than that required for SMAW, but is both faster and easier to use than GTAW and SMAW, making it ideal for production welding. GTAW is used for high quality welding. Its quality is higher than the other two methods, but it is much slower than both and requires significant operator skill. The group wants a process that is quick, cheap, and requires little skill. SMAW is the cheapest, but GMAW is the quickest, easiest to learn, and is also cheap when considering the high production factor. Since it is also ideal for production welding, it is the perfect method for the group since they wish to put the product into production. However a quantitative analysis felt was needed and to do so an AHP analysis was applied.

AHP (Analytical Hierarchy Process) is a method for ranking decision alternatives with multiple criteria. Rankings are based on pair-wise comparisons between alternatives on each criterion. The alternatives are SMAW, GMAW, and GTAW. The criteria are cost, quality, the amount of time to complete a weld, and experience needed to use the method. When an alternative is compared to another alternative, it is given a value from the Standard Preference Scale (see Figure 1)

AHP Standard Preference Scale

1. Equally Preferred
2. Equally to moderately preferred
3. Moderately preferred
4. Moderately to strongly preferred
5. Strongly preferred
6. Strongly to very strongly preferred
7. Very Strongly preferred
8. Very strongly to extremely preferred
9. Extremely preferred

Figure 1

For example, when comparing SMAW to GTAW under the criterion “cost”, the value was given a 4, meaning SMAW is “moderately to strongly preferred” to GTAW, because SMAW is much more cheaper. These comparisons are done in a matrix with all the criteria, as shown in Figure 2. After all the values are assigned to each pair-wise comparison, each column is summed up, and then each pair-wise comparison is divided by that sum, giving a percentage. Each row is then summed together (See Figure 2).

Cost	SMAW	GMAW	GTAW
SMAW	1.00	3.00	4.00
GMAW	0.33	1.00	3.00
GTAW	0.25	0.33	1.00
	1.58	4.33	8.00

Cost	SMAW	GMAW	GTAW	Criterion Score
SMAW	0.63	0.69	0.50	0.61
GMAW	0.21	0.23	0.38	0.27
GTAW	0.16	0.08	0.13	0.12
	1.00	1.00	1.00	1.00

Figure 2

This is done with each criterion. The criteria are then place in pair-wise comparisons with each other. This shows the importance of one criterion to another. The pair-wise comparison of the criteria with their values is shown in Figure 3. These values were given by the group. After the values are assigned, the same process as described above is performed. The percentages of the criteria matrix is then multiplied with the alternative matrix and fractions of each alternative are produced. This is the ranking of each alternative, with the largest fraction being the highest rank; this is the alternative that should be chosen. The full process with the results of the final rankings is shown in Appendix B.

Criteria	Cost	Quality	Time	Experience
Cost	1.00	3.00	0.33	0.25
Quality	0.33	1.00	0.17	0.20
Time	3.00	6.00	1.00	2.00
Experience	4.00	5.00	0.50	1.00

Figure 3

Flow Process Chart

The team wanted flow process chart so as to have a clear understanding of the assembly process of the T.K. Ripper. A flow process chart may be viewed as an analog model of the overall production process; it also helped in designing the facility layout which will be discuss later in this section. To build a flow process chart, a bill of materials (BOM) is needed. A BOM is a structured parts list and explains what material is needed and how much. It is a list of subassemblies with all the parts needed for each one. Each subassembly is produced at a

certain level, with Level 0 being the finished product. Using the BOM, a flow process chart was created. Both the BOM and the flow process chart can be seen in Appendix A.

Cost Estimation

The team is interesting in knowing the cost of producing the TK Ripper if they were to purchase materials within the U.S. and assemble the product themselves. This is called domestic production. However the group is also interested in knowing the cost estimation of the product if offshore outsourced to a foreign country with materials purchased within that country. Outsourcing is to contract a process to a 3rd party while offshoring is to relocate a production process to another country, usually where cheap labor and material is available. Offshore outsourcing is contracting a process to a 3rd party in another country. In this case, the group is interested in knowing the cost of having another company in China build the product with materials purchased in China. China was chosen because it is known worldwide as a country possessing very cheap labor and materials.

The cost the group is interested in knowing is the FAC, or the Fully Allocate Cost per unit produced. The FAC is the sum of three different costs: material cost, labor cost, and overhead cost. Material cost is the cost of the amount of material used per unit. Labor costs are the wages and hours the direct labor have incurred while producing a single unit. Direct labor is labor that is directly involved in assembly the product. Overhead is split into two categories: ongoing and initial investment. Ongoing is the cost that incurs annually, such as rent, utilities, and indirect labor. Indirect labor costs are employees that do not handle the product or inventory physically or directly; they are employees such as accountants, managers, or janitors.

Initial investment is the cost of purchasing all the equipment needed for the company for that year.

Before proceeding with the cost estimation it is important to know the demand forecast. This was analyzed by the marketing student, whose demand forecast for the first year is 100 units, 200 units for the second year, and 400 units for the third. The process of obtaining the costs for both domestic and offshore outsource production will now be explained.

Domestic: Business Plan

For domestic production the group will rent a small facility to be used as a machine shop and storage of inventory. The group wishes to have enough material stored in the facility to produce a minimum of 12 units. They will receive the material from the suppliers, build the units themselves, and ship finished inventory to the customer using a 3rd party transport company such as UPS. In the view of their supply chain, they are the manufacturer of the product and sell directly to customers, thus bypassing the retailer and distributor. It is mainly a pull process as they will only build-to-order.

Material Cost

Using the parts list, a search for the materials was done online. The suppliers were contacted through email or by phone to acquire quotes for the amount of material needed. The amount of material needed, using the BOM, for 12 units were used to order the quantity from each supplier. The amount of material needed, the cost per unit of each material, the total cost of the material per T.K. Ripper, ROP, and the inventory turnover per year is shown in Appendix C. ROP (Reorder Point) is the point when inventory needs to be reordered from suppliers. This

happens when the amount of material in storage depletes to a certain limit. The equation for ROP is shown:

ROP = L x D

L = Lead time (days)

D = demand (units) per day

Lead time is the amount of time it takes for material to be received from a supplier once an order was sent. The average lead time for all the material is five days and this was used for each material. If the ROP is below the amount of material in storage that can produce 12 units, then there is no need to order more material over the minimum amount of material needed. If ROP is at or above 12, the minimum amount of material will need to increase in order to produce more than 12 units. ROP can only be used when the demand is assumed to be constant, which we are assuming for the sake of this analysis.

The “Order every (days)” column shows how many days it will be until a reorder of that material is needed. It is basically the ROP converted from units to days. This was done by taking the minimum amount of units needed on hand (the raw material in storage) and dividing by the demand per day.

Labor Cost

For the first year, the group has decided that only one worker will be used to weld and assemble the product and a factory worker to be used for inventory handling, including receiving and shipping. For the demand forecast given, this is fine up till year 3 in which case a second welder will be needed. The welder’s cost per unit was calculated by multiplying the

hours it takes to weld and assemble each unit, the hourly wage, and taxes. It takes 16 hours to build each unit. For hourly wage, the lowest range in the national average was used. The factory worker's cost per unit was calculated by dividing the amount of time in hours it takes to receive, inspect, and store material for every reorder plus the time it takes to package finished inventory, multiplied by average hourly wage and taxes. The factory worker only works when material arrives (to handle and store) and to package and ship each unit. Both the cost of the welder and the factory worker were summed to find the total labor cost per unit. This is displayed in Appendix C.

Overhead (OH)

For ongoing, the cost of rent per square foot was done by researching available machine shop/warehouse space in San Luis Obispo County and finding the average. The same was done with utilities. The amount of square footage was estimated in the facility design. One clerical employee will be used as the indirect labor aspect and is a full time job (8 hours a day). Indirect labor was calculated by multiplying hourly wage for 8 hours per day for 260 days, which is the amount of working days in a year in the U.S., and dividing by the amount of units produced for that year. Indirect labor, rent, and utilities are summed to find the ongoing cost.

The initial investment overhead cost was calculated by summing all the equipment purchased that year and dividing it by the life span of the equipment and again by the demand per year. All the equipment is purchased the first year and no more is needed until year 3, where another welding kit and assembly bench will be needed for the second welder/assembly

worker. The ongoing and initial investment costs are then summed to find the total overhead cost per unit.

Initial Investment = (cost of equipment) / (life span in years) / (demand)

Total OH = Ongoing + Initial Investment

After finding the material, labor, and overhead cost, they are summed to find the FAC.

FAC = Material Cost + Labor Cost + OH Cost

Offshore Outsource: Business Plan

For offshore outsourcing the team would buy materials from Chinese suppliers, store the inventory in a rented warehouse in China, deliver material to a Chinese manufacturing company where units will be produced, transport via air freight to U.S., store the finished inventory in a small rented warehouse in San Luis Obispo Country, and ship to customers when orders are received. Instead of using a build-to-order model the group will receive 12 completed units, except for packaging when sending to a customer, for every reorder. With this model, the company's supply chain is more push when compared to domestic production because they will have 12 completed units in storage, waiting to be shipped out when a customer order is received.

Material

The minimum amount of material needed will still be for 12 units for the sake of comparison. To find materials to use from China, international supplier websites such as Thomasnet.com were used to research quotes. However only a few suppliers responded; to

find the price of the rest of the materials, ratios were used. These ratios are the fractions of the price of materials from China to the price of the same materials from the U.S. This ratio is then applied to similar parts and materials from the parts list. The ratios of the found parts and materials from China are shown below:

Clutch (USA)	$65.99	Rope (USA)	244
Clutch (China)	51.91	Rope (China)	150
Ratio	0.786634339	Ratio	0.614754098
Average Ratio:	0.700694218		

Aluminum Plate:	Cost/lb
China	2.169
USA	4.97
Ratio	0.436418511

Once the ratios were applied, the material cost per unit was found. The minimum quantity to order from Chinese suppliers is far larger than the amount we can order in the U.S. For some materials, the minimum order is enough to build 50 units. For others, such as the aluminum tubing and plate, the amount of material ranges from 300 units to nearly 1000 units.

Labor

For the sake of comparison, only one welder from the Chinese manufacturer will be used. One factory worker will be used to handle inventory in the Chinese warehouse and another for the U.S. warehouse. The time to build each unit will be assumed to be 16 hours. Chinese workers have 12 hour days instead of the usual eight here in the U.S., so the production rate of each unit will be faster. The hourly wage is also considerably lower, which

was found using China's national average. This wage was applied to both the welder and the factory worker. The same calculations from the domestic section above were then performed to find the total labor cost per unit.

Overhead

The same method from the domestic section was applied to find the cost of rent, utilities, and indirect labor. Since the minimum quantity to order from suppliers is much larger in China, the Chinese warehouse would need more storage space as compared to the facility in the U.S. in the domestic production alternative. This was estimated by searching for the storage racks that would be used in the warehouse and using the square footage of the racks for the space they take occupy. Square footage was also estimated for pallet and packaging storage, receiving, trucker's lounge, trash disposal, receiving holding area, office, and handling equipment maneuvering. The U.S. warehouse would be much smaller since it only needs to store 12 completed units, plus space for receiving, packaging and office.

The indirect labor includes one clerical employee at the Chinese warehouse and another at the U.S. warehouse. Transportation costs, from transporting the material to the Chinese manufacturer and delivering finished inventory using air freight, was also considered. For transporting to the manufacturer, using a delivery truck was assumed. Average gas prices in China were found using online search. Air freight prices were taken from a company's website, which varies depending on the total weight you want transported.

Initial investment includes equipment purchased to be used in both the Chinese and U.S. warehouses. Since a larger amount of material would be stored in China, larger storage

racks and a forklift would be needed, but equipment such as a welding kit and machining benches would not be needed because another company is manufacturing the product. The data for overhead cost is shown in Appendix C.

The information and calculations for computing the FAC is once again the sum of the material, labor, and overhead costs. This was only done for year 1 as the group only wants to compare domestic and outsourcing for that year.

Breakeven

This analysis is used to find how many units, sold at a given price, will need to be sold to have zero profit, or the “breakeven” point. Each unit sold past this point becomes profit. The equation for profit is:

$$Profit = R - TC$$

Where R is revenue and TC is total cost. Revenue is the product of the unit sale price and the volume sold:

$$R = r \times Q$$

Where r is unit sale price and Q is volume sold. Total cost is given in the equation below:

$$TC = FC + vQ$$

Where FC is fixed cost and v is unit variable cost. Unit variable cost is the sum of the material cost and the labor cost. Fixed cost is the ongoing overhead cost for that year. With these equations, the breakeven point can be found using the equation below:

$$Q = FC / (r - v)$$

Since the goal of the group is to sell this product at or below $2000, r will equal $2000. The other variables change depending on the year. ROR (Rate if Return) is the return on each unit sold, which is the percentage of the ratio unit sale price to unit variable cost. The tables that show the assigned values, breakeven point, and ROR with graphs depicting revenue versus total cost are shown in Appendix D. The break even analysis was only considered for domestic production.

Facility Design

The facility layout was developed for the domestic production. The systematic approach from IME 443 Facilities Planning and Design class was used to plan and design the layout. Some steps were taken out however, such as develop alternative layouts and the evaluation of the alternatives. These were not included because the group's facility is much too small for more than one alternative to be considered and there is no original design to improve upon.

Define Goals:

The goal of this facility design is to create a theoretical layout that allows an efficient assembly process by proper placement of machining benches, assembly bench, and proper storage of equipment and material. This layout is not based on an existing building; it is only supposed to give the group an idea of the dimensions they should look for when renting a warehouse.

Define Departments:

Using the flow process chart as a guide, the departments were defined as: Receiving and Holding, Inventory, Machining Area, Assembly Area, Finished Goods, and Office. Receiving and

Holding is the area used to receive raw material from shipments, inspect the material, and maybe hold incase the material carries defects and thus is rejected. The Inventory department is the storage of inventory; the Machining Area is the area where material is machined, which consists of a horizontal band saw, drill press, and a lathe and mill. The Assembly Area consists of the workbench and surrounding area used to weld the aluminum frame and assemble the units including packaging. Finished Goods is the area where finished units are stored; even though the units are build-to-order, they will still need to be stored when waiting to be delivered or if an order was canceled. The Office department is the area used for office affairs, such as accounting, meetings, and other work of the similar type.

Systematic Layout Planning (SLP):

SLP was used to develop department relationships and space requirements, and ultimately a final layout. SLP creates a relationship diagram, a space requirement table, space relationship diagram, and a block diagram. The relationship diagram is used to see the value of the departments to one another in a pair-wise comparison. Comparisons are given relationship values, with A being “absolutely necessary”, E as “especially important”, I as “important”, O as “ordinary closeness okay”, and U as “unimportant”. The space requirements determine a department’s block size, which is a visual for how much space the department requires. The space relationship diagram shows the blocks and their relationships with other departments using connecting lines as a visual understanding. The thicker the line, the more important the block is to the other block it is connected to; this determined the placement of the blocks. The

placement of the blocks is called the block diagram, where blocks are placed in relation to each other depending on the value codes they were given. This process is shown in Appendix E.

After the block diagram was created, a layout was designed by placing equipment in their respected departments.

Equipment:

The equipment needed for the assembly process are a MIG welder, bench drill press, a horizontal band saw with a bench, lathe and mill with a bench, and an assembly table. Three storage racks with shelves will be needed to store inventory: one for the engines and two for the rest of the inventory. All parts besides the engine are small parts and will be stored in bins (24 bins total). The aluminum square tubing, before they are cut, come in 20 ft lengths and will be stored on a wall mounted cantilever. When they are cut into smaller pieces to be welded later, they will be stored in a bin.

No pallets will be used because of the small amount of material ordered from suppliers. Since the minimum amount of material needed to produce 12 units will stay the same through year three, the only area that will be expanded to accommodate growing demand will be the assembly area; another assembly table will be needed for the second welder. The dimensions of the machine benches, assembly benches, and storage racks are shown in the final layout design diagram in the Results section.

Results

In this chapter all the solutions to the objectives that were assigned are discussed as well as an economic analysis

Welding Alternatives

As explained in the design section, AHP was used to choose the best welding method with a ranking system of the alternatives as the result. The ranks are: GMAW at 0.56; SMAW at 0.32; and GTAW at 0.12. GMAW has the highest ranking and therefore it is recommended that the group use this method to weld together the aluminum frame. This confirms the research done before the analysis; the group wants to use a method that is fast and easy to learn, and GMAW fills those requirements better than SMAW and GTAW. The full process is shown in Appendix B.

Cost Estimation

Domestic

Material Cost

The full parts list, with the amount of material purchased, total cost, and the cost per TK Ripper, is shown in Appendix C. As the table shows, the cost per unit (a unit being a single TK Ripper) is $1373.19 and the total material purchased from suppliers is $17,293.56.

Labor Cost

The cost of with welder is $231.41 per unit and the cost of the factory worker is $13.78 per unit. This is a total labor cost of $245.19 per unit.

Overhead

For ongoing costs, the rent is $9498 per year, or $94.98 per unit for 100 units, and the Utilities are $5.76 per unit. The clerical employee will cost $263.74 per unit. This equates to a total of $364.49 ongoing costs. For initial investment, the total equipment cost is $3667.60, and with a life span of 15 years for all the equipment and a demand of 100 units, this equates to $2.45 per unit. The sum of the ongoing and initial investment costs gives a total OH cost of $366.93. The OH costs are shown in Appendix C.

FAC

After finding the material, labor, and overhead costs we can now calculate FAC as shown in Table 1 below.

Monetary Cost, Year 1		
Days/year	365	
Demand/yr	100	
Demand/day	0.27	
Lead Time in days	5	
ROP	1.37	~ 2
Material in Inventory (units)	12	
Reorder every	36.5	
Inventory turnover (times/yr)	10.00	
Material Cost ($/unit):	1373.19	
Total Labor Cost ($/unit)	245.19	
Total OH cost ($/unit)	366.93	
FAC	1985.31	

Table 1

As shown, the FAC is $1985.31. This completes the goal of being able to sell the TK Ripper at $2000 for each unit. The ROP is 2 units, so when the amount of material reaches this limit, a reorder of material must be made. This equates to a reorder every 37 days. For year two

and three the material and labor costs stay the same but overhead changes because of the increase in demand. This is shown below in Table 2.

Monetary Cost, Year 2			**Monetary Cost, Year 3**		
Days/year	365		Days/year	365	
Demand/yr	200		Demand/yr	400	
Demand/day	0.55		Demand/day	1.10	
Lead Time in days	5		Lead Time in days	5	
ROP	2.74	~ 3	ROP	5.48	~ 6
Material in Inventory (units)	12		Material in Inventory (units)	12	
Reorder every (days)	21.90		Reorder every (days)	10.95	
Replenish (times/yr)	16.67		Replenish (times/yr)	33.33	
Material Cost	1373.19		Material Cost	1373.19	
Labor Cost	245.19		Labor Cost	245.19	
Overhead:			Overhead:		
Ongoing	182.25		Ongoing	91.12	
Initial Investment	1.02		Initial Investment	0.66	
Total OH Cost	183.27		Total OH Cost	91.78	
FAC	**1801.65**		**FAC**	**1710.16**	

Table 2

As the results show, overhead in year two decreases to $183.27 per unit, creating an FAC of $1801.65. For year three, the overhead decreases to $91.78 and the FAC lowers to $1710.16, a noticeable drop. The ROP in year two is three units, or a reorder every 22 days, and 6 units in year three, or a reorder every 11 days. The cost per unit decreases continually through year three. When comparing year three to year 1, the FAC decreases by 14%. This decrease shows a substantial increase in profits which will be explained in the breakeven analysis next.

Outsource

- Year 1

Material Cost

The full parts list from China, with the amount of material purchased, total cost, and the cost per TK Ripper, is shown in Appendix C. As the table shows, the cost per unit (a unit being a single TK Ripper) is $935.80 and the total material purchased from suppliers is $51,641.50. The materials from China are much cheaper, however the minimum amount to order from suppliers is 3 times more than here in the U.S., which means there will be a higher investment cost if the group decides to outsource.

Labor Cost

The cost per unit of the workers is as follows: $18.67 for the China welder; $1.06 for the China factory worker; $8.27 for the U.S. This is a total labor cost of $27.99 per unit. This information is shown in Appendix C.

Overhead Cost

The ongoing and initial investment costs are shown in Appendix C. For a warehouse space of 1745 sq ft in China, the rent is $7957.20 per year, or $79.57 per unit for 100 units. The utilities for the China warehouse are $4.81 per unit. In the U.S. warehouse, for a space of 322 sq ft the rent is $2998.46 per year, or $29.99 per unit, with utilities of $1.86 per unit. Under indirect labor, the cost of the clerical employee in the China warehouse is $24.34 per unit and $131.87 for the U.S. worker. As you can see, the worker in China works full time and is extremely cheap while the U.S. worker only works part-time (because of the large amount of time it takes to sell and reorder 12 units) and costs nearly 6 time as much. The cost of

transporting materials from the warehouse in China to the Chinese manufacturer, from the manufacturer to the U.S. via air freight, and from an airport in the U.S. to the warehouse in San Luis Obispo County is $284.98. The total ongoing cost is $557.41.

The initial investment cost is $7575, or $5.05 per unit. It is more than the initial cost in the domestic alternative because of the forklift and extra racks in the China warehouse. The total over head cost is $562.46 per unit.

FAC

With the material, labor, and overhead cost acquired, the FAC becomes $1,536.63 per unit when using the first year demand forecast of 100 units. This is 22.6% cheaper than the FAC for the domestic alternative during the first year. If assuming a selling price of $2000, the ROR becomes 30.2%, a much more attractive return than domestic production. However, the initial material cost in this alternative is considerably higher than the material investment in the U.S., which means a larger loan we be needed to pay for this investment.

Even if the FAC from outsourcing is cheaper than the FAC from domestic production, there are problems and costs that are not accounted for. These problems are the increase in difficulty of communicating with suppliers and the manufacturer from China, unforeseen delays, production problems resulting from the poor communication, and even the increased risk of the design being copied and stolen. These problems can translate to more costs which are difficult to estimate.

Breakeven

The values assigned to the variables in the analysis for each of the three years are shown in Appendix D. Each breakeven analysis is accompanied with a graph to help visualize where the breakeven point is. This analysis is assuming the selling price stays at $2000 per unit. The analysis shows that the breakeven point is at around 92 or 93 units, so units sold past this point is when the team will begin making profit. The breakeven point stays constant over the three years because the variable cost and fixed cost stays constant. This is because material and labor costs do not change in any of the three years and neither does fixed cost, since the team does will use the same facility and no change in indirect labor.

As shown in the graphs, as the demand increases, the group's profits increase substantially. First year's profits are around $3000; second year's profits are around $41,000; and third year's profits are $117,000. This means profits increase 1367% from year one to year two, and an increase of 285% from year two to year three. The ROR on each unit sold stays the same for each year because the variable cost does not change (labor and material costs stay constant for all three years). However, if measuring against the FAC, the ROR starts small and increases ever year. This is shown below in Table 3.

Year	FAC ($)	Selling Price ($)	ROR ($)
1	1972.36	2000	1.4%
2	1796.61	2000	11.3%
3	1709.08	2000	17.0%

Table 3

Facility Design

After the analysis of SPL, a layout was designed. This can be seen below in figure 4. As displayed, the facility will need to be at least 34 ft by 30 ft and works as a central fixed-material layout. The receiving and holding area is at the entrance, the inventory is located on the left and top of the layout, the machine benches are located on the left, the office is in the lower left corner, the assembly tables are located in the middle, and the finished inventory is located on the left side near the entrance. The entrance is a roll up door that is 10 ft wide. The Receiving and holding area will be around 135 sq ft and the office 98 sq ft. The office can either be a separate room or in the open.

The flow of material throughout the facility is as follows: material from suppliers is received through the dock entrance at the receiving and holding area. The material is unloaded and inspected, then stored in inventory. Inventory is split into three categories: engine, small inventory, and aluminum tubing. The Tecumseh engines are stored on the engine rack, which has three shelves. These engines measure 1 ft by 1 ft in length; this rack can accommodate 18 engines, more than enough for the 12 unit requirement. The aluminum square tubing is shipped from the supplier at 20 ft lengths and would be stored on wall-mounted cantilevers. The rest of the material and parts will be stored in bins on the two small inventory racks, which are the same racks as the engine rack.

The aluminum tubes flow to the machining benches that hold the horizontal band saw and the drill press. The tubes will be by the band saw, than stored in the small inventory rack. How many tubes are cut is up to the group. The aluminum plate also flows to the machine bench to have holes drilled into it by the drill press. After all the plates are drilled, they are

stored into small inventory. When the assembly starts, the welder will grab the sawed aluminum tubes and a plate and weld the frame together on the assembly table with the MIG unit located nearby. Since the workbench is located next to the inventory storage, there will be short travel time between the assembly table and inventory. After the product is finished and packaged, it is stored on the finished inventory rack until it can be picked by the shipper.

The layout allows for expansion in the assembly area. This is because of the forecast of increased demand in year 3, in which case a second welder will be needed. This means both welders will be working concurrently, so a second workbench will be needed, hence the area for expansion. Since this is a theoretical layout, the group should look for warehouse space with these dimensions or close to them.

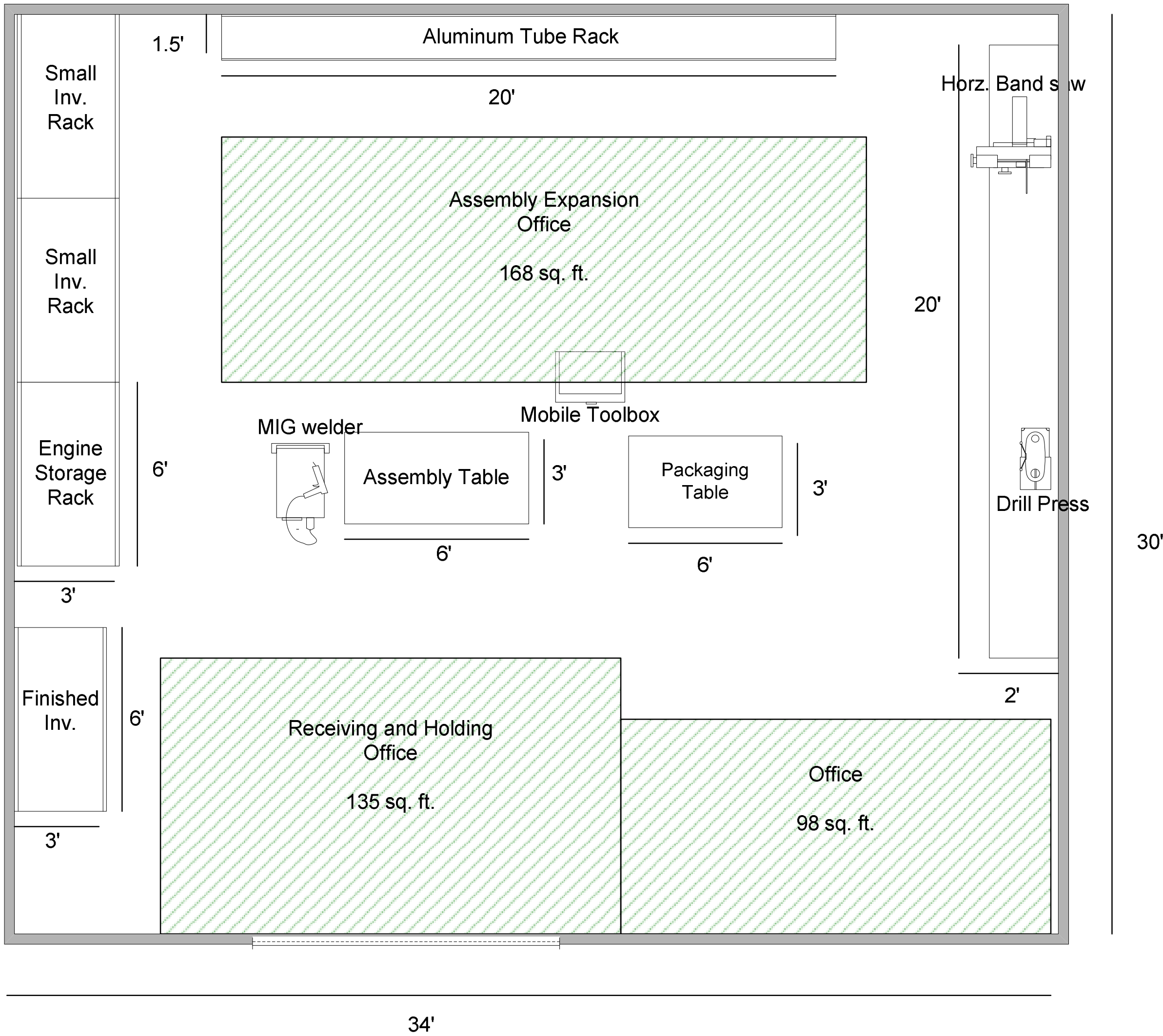

Aluminum Tube Rack
1.5'
20'
Small Inv. Rack
Small Inv. Rack
Engine Storage Rack
6'
3'
Finished Inv.
6'
3'
Assembly Expansion Office
168 sq. ft.
Mobile Toolbox
MIG welder
Assembly Table
3'
6'
Packaging Table
3'
6'
Horz. Band saw
20'
Drill Press
30'
2'
Receiving and Holding Office
135 sq. ft.
Office
98 sq. ft.
34'

Figure 4

Conclusion

The purpose of this report is to provide solutions to Industrial Engineering objectives provided by a group of Cal Poly mechanical engineering students who are working on their senior project. They are creating a winch engine to be used for extreme water sports. They also have their minds on creating a real-time business with this product and needed help from other students to answer questions out of their scope. The IE objectives that were assigned were: create a BOM and flow process chart; an evaluation of welding methods with a recommended selection of one; cost estimation of the product if produced domestically; cost estimation of the product for the first year if outsourced to China; a breakeven analysis of the domestic alternative; and finally a layout design for their machine shop.

The FAC for the domestic alternative in all three years is under $2000, which was a goal of the team. The breakeven analysis shows the team that they will need to sell more than 92 units to start making a profit. The FAC for the outsourced alternative looks very attractive, however the initial investment cost in materials is much greater in China than in the U.S. This means a larger loan would be needed to pay for these materials and a longer payback period will result.

Each objective was accomplished during the duration of this project. This project exposed to me a great deal of project management, as I had to deal with multiple objectives with sometimes delayed information, such as a part's list. Overall, this was a great project to be a part of and I recommend any future IE students to jump on multidisciplinary group projects.

Bibliography

[1] American Welding Society. Standard Welding Terms and Definitions. Miami, FL, 1989.

[2] Tompkins, J.A., White, J.A., Bozer, Y.A., & Tanchoco, J.M.A. Facilities Planning, 3rd Edition. John Wiley & Sons, Inc. Hoboken, NJ, 2003.

[3]Hillier, Frederick S., Lieberman, Gerald J. Introduction to Operations Research, 9th Edition. McGraw-Hill, NY, 2010.

[4]Chopra, S., Meindl, P. Supply Chain Mangement: Strategy, Planning, and Operation, 4th Edition. Pearson Education, NJ, 2010.

[5] Wickens, C.D., Lee, J.D., Liu, Y., Gordon Becker, S.E. An Introduction to Human Factors Engineering, 2nd Edition. Pearson Education, NJ, 2004.

[6] Kanawaty, George. Introduction to Work Study, 4th Edition. International Labour Office, Geneva, 1992.

[7] Tucker, Spencer A., Profit planning decisions with the break-even system. New York, NY, 1980.

[8] Saunders, H. L. Welding aluminum : theory and practice. Washington, D.C. : The Association, c1991.

[9] Greer, Willis R; Nussbaum Jr., Daniel A. Cost analysis and estimating : tools and techniques. Springer-Verlag, New York, c1990.

[10] Blank; Tarquin, Engineering Economy 6th Edition, McGraw-Hill, 2005.

[11]Riggs, Henry E., Financial Economic Analysis for Engineering and Technology Management, 2nd Edition. Wiley, Hoboken, NJ, 2004.

[12] Minnick, William H. Gas Metal Arc Welding Handbook Textbook. Tinley Park: Goodheart-Willcox, 2007.

[13] Reid, R. Dan; Sanders, Nada R. Operations Management. John Wiley & Sons, 2002.

[14] Roberts, Dexter. “How Rising Wages Are Changing The Game In China”. Businessweek, March 27, 2006

[15] “China: The Pursuit of Competitive Advantage and Profitable Growth”. Boston Consulting Group, July 2003

Appendices

Appendix A

Table A.1: BOM

Bill Of Materials			
Product:	TK Ripper	Prepared by:	Logan Hunt
Date:	4/20/2010		
Level	Part Name	Quantity/unit	Make or Buy
0	TK Ripper	1	Make
1	Brakes	1	Make
1	Wheel System	1	Make
1	Main Assembly	1	Make
2	Disk Brake Hub	1	Buy
2	Disk Brake Hub Bolts	6	Buy
2	Disk Brake	1	Buy
2	Brake Caliper	1	Buy
2	Caliper Bracket	1	Buy
2	Wheel Axle	1	Buy
2	Conduit Bracket	2	Buy
2	Wheels	2	Buy
2	Spool	1	Buy
2	Rope	1	Buy
2	Body Assembly	1	Make
3	Spool Adapter	3	Buy
3	Axle	1	Buy
3	Spool Rods	1	Buy
3	Spool Washer	8	Buy
3	Nuts	8	Buy
3	Engine Mount Bolt Washers	3	Buy
3	Engine Mount Bolts	1	Buy
3	Spool Ends	2	Buy
3	Bearings	2	Buy
3	Engine	1	Make
3	Frame	1	Make
4	1"x2"x1/8" Aluminum Tubing	11 ft	Buy
4	1"x1"x1/8" Aluminum Tubing	10 ft	Buy
4	Aluminum Plate	1	Buy
4	Engine Bolts	4	Buy
4	Clutch	1	Buy
4	Clutch Springs	1	Buy
4	Torque Converter	1	Buy
4	Chain	1	Buy
4	Sprocket	1	Buy
4	Motor	1	Buy
4	Nuts	4	Buy

Figure A.1: BOM

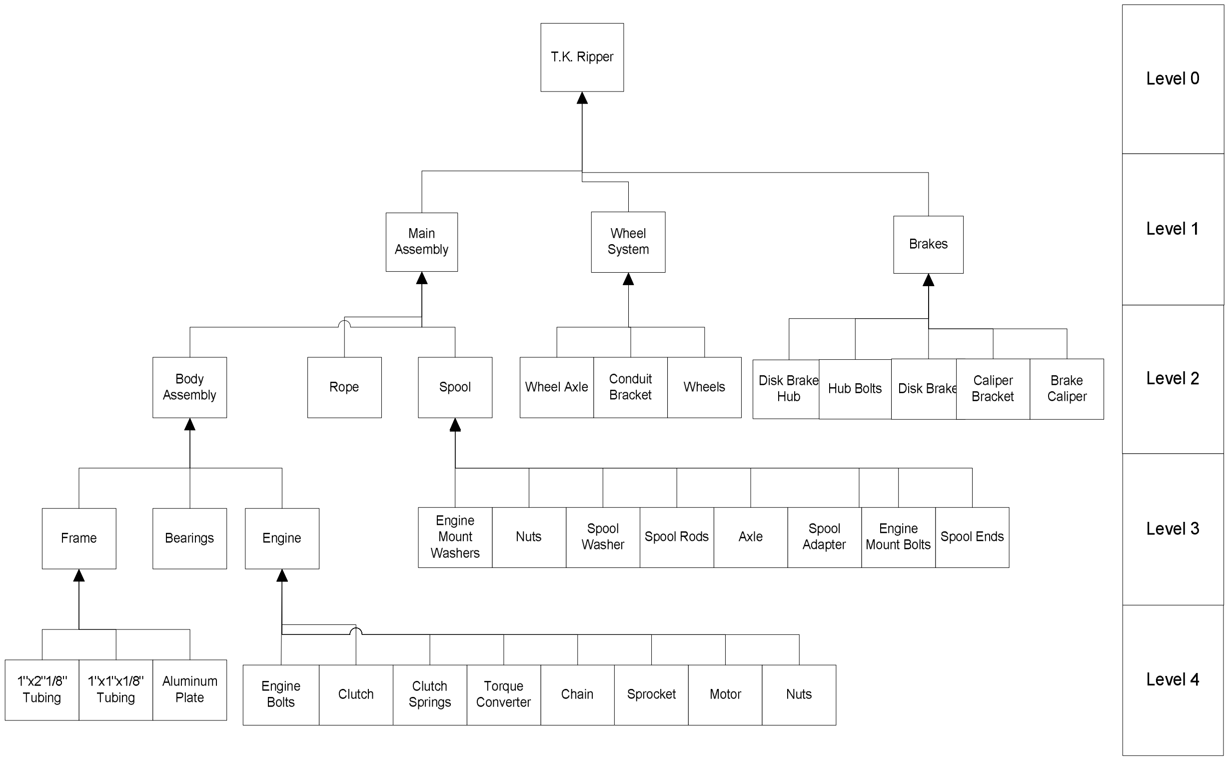
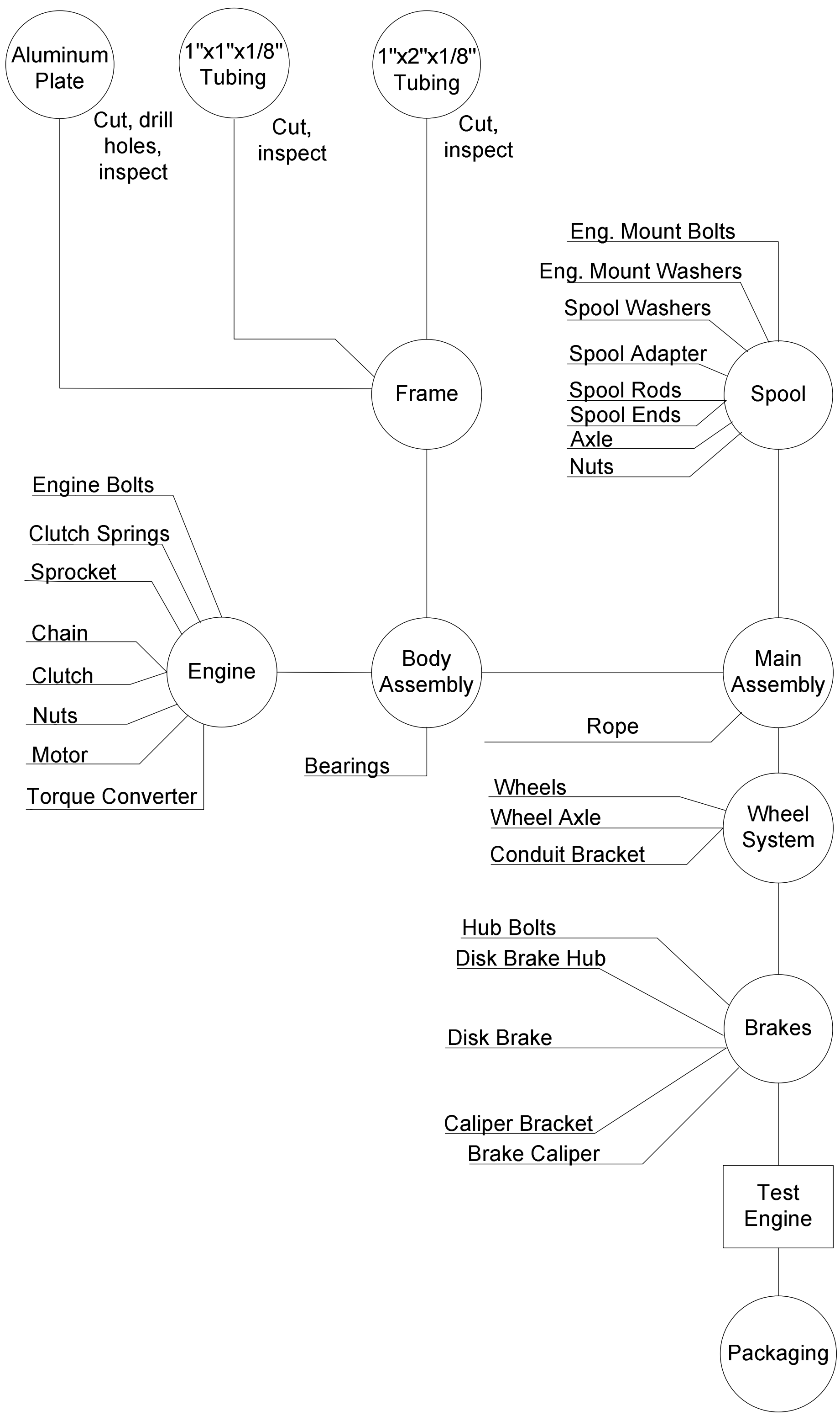


Figure A.3: Flow Process Chart



Appendix B

Figure B.1: AHP

AHP Analysis for Welding Alternatives

Welding Alternatives:		SMAW	GMAW	GTAW
Criteria:	Cost	Time	Quality	Experience

Cost	SMAW	GMAW	GTAW		***Cost***	SMAW	GMAW	GTAW	Criterion Score
SMAW	1.00	3.00	4.00		SMAW	0.63	0.69	0.50	0.61
GMAW	0.33	1.00	3.00		GMAW	0.21	0.23	0.38	0.27
GTAW	0.25	0.33	1.00		GTAW	0.16	0.08	0.13	0.12
	1.58	4.33	8.00			1.00	1.00	1.00	1.00

Quality	SMAW	GMAW	GTAW		***Quality***	SMAW	GMAW	GTAW	
SMAW	1.00	0.50	0.20		SMAW	0.13	0.11	0.12	0.12
GMAW	2.00	1.00	0.50		GMAW	0.25	0.22	0.29	0.26
GTAW	5.00	3.00	1.00		GTAW	0.63	0.67	0.59	0.63
	8.00	4.50	1.70			1.00	1.00	1.00	1.00

Time	SMAW	GMAW	GTAW		***Time***	SMAW	GMAW	GTAW	
SMAW	1.00	0.33	5.00		SMAW	0.24	0.22	0.42	0.29
GMAW	3.00	1.00	6.00		GMAW	0.71	0.67	0.50	0.63
GTAW	0.20	0.17	1.00		GTAW	0.05	0.11	0.08	0.08
	4.20	1.50	12.00			1.00	1.00	1.00	1.00

Experience	SMAW	GMAW	GTAW		***Experience***	SMAW	GMAW	GTAW	
SMAW	1.00	0.33	7.00		SMAW	0.24	0.23	0.47	0.31
GMAW	3.00	1.00	7.00		GMAW	0.72	0.68	0.47	0.62
GTAW	0.14	0.14	1.00		GTAW	0.03	0.10	0.07	0.07
	4.14	1.48	15.00			1.00	1.00	1.00	1.00

Alternative	Cost	Quality	Time	Experience
SMAW	0.61	0.12	0.29	0.31
GMAW	0.27	0.26	0.63	0.62
GTAW	0.12	0.63	0.08	0.07

Criteria	Cost	Quality	Time	Experience
Cost	1.00	3.00	0.33	0.25
Quality	0.33	1.00	0.17	0.20
Time	3.00	6.00	1.00	2.00
Experience	4.00	5.00	0.50	1.00
	8.33	15.00	2.00	3.45

Criteria	Cost	Quality	Time	Experience	Criterion Score
Cost	0.12	0.20	0.17	0.07	0.14
Quality	0.04	0.07	0.08	0.06	0.06
Time	0.36	0.40	0.50	0.58	0.46
Experience	0.48	0.33	0.25	0.29	0.34
	1.00	1.00	1.00	1.00	1.00

Criteria Rank			**Ranks**	
Cost	0.12		SMAW	0.324441
Quality	0.07		GMAW	0.556948
Time	0.47		GTAW	0.118612
Experience	0.34			

Appendix C

Table C.1: Material Cost (domestic)

Order Amount						
Material	Order Amount	Cost/order	Cost/unit	Parts per unit	Total Cost/TK Ripper	Total Units Worth
Tecumseh Engine	12	$4,800.00	$400.00	1	$400.00	12.00
Torque Converter	12	$2,006.16	$167.18	1	$167.18	12.00
Clutch	12	$791.88	$65.99	1	$65.99	12.00
Cluth Springs	12	$360.00	$30.00	1	$30.00	12.00
Chain	12	$168.00	$14.00	1	$14.00	12.00
Sprocket	24	$258.72	$10.78	1	$10.78	24.00
Spool Adapter	100	$958.00	$9.58	3	$28.74	33.33
Axle	12	$455.76	$37.98	1	$37.98	12.00
Spool Ends	24	$191.52	$7.98	2	$15.96	12.00
Spool Rods	12	$504.00	$42.00	1	$42.00	12.00
Bearings	24	$223.20	$9.30	2	$18.60	12.00
Wheels	24	$407.28	$16.97	2	$33.94	12.00
Wheel Axle	12	$74.88	$6.24	1	$6.24	12.00
Conduit Bracket	24	$20.16	$0.84	2	$1.68	12.00
Rope	12	$2,928.00	$244.00	1	$244.00	12.00
Disk Brake Hub	12	$300.00	$25.00	1	$25.00	12.00
Disk Brake	12	$960.00	$80.00	1	$80.00	12.00
Brake Caliper	12	$960.00	$80.00	1	$80.00	12.00
Caliper Bracket	12	$8.16	$0.68	1	$0.68	12.00
Nuts	250	$135.00	$0.54	16	$8.64	15.63
Disk Brake Hub Bolts	100	$60.00	$0.60	6	$3.60	16.67
Engine Mount Bolts	50	$11.50	$0.23	4	$0.92	12.50
Engine Bolts	50	$9.50	$0.19	4	$0.76	12.50
Spool Washer	100	$19.60	$0.20	8	$1.57	12.50
Engine Mount Washer	100	$19.60	$0.20	8	$1.57	12.50
Aluminum Frame	------------------	----------------	--------------	-------------------	---------------------	------------------------
1x2x1/8 (20 ft pcs)	7	$390.60	$2.79/ft	11ft	$30.69	12
1x1x1/8 (20 ft pcs)	6	$212.40	$1.77/ft	10 ft	17.7	12
5.5x14x1/4	12	$59.64	$4.97	1	$4.97	12
Total Initial Material Cost		**$17,293.56**		**Total Cost per unit**	**$1,373.19**	

Table C.2: Labor Cost (domestic)

Welder				Factory Worker			
Taxes		Cost		Taxes		Cost	
FICA	0.124	Hours/unit	16	FICA	0.124	Material Handling	5
Mcare	0.029	Wage	10.85	Mcare	0.029	(hrs)	
FUTA	0.054	($/hr)	1.333	FUTA	0.054	Matierial Handled	12
UI	0.034	Taxes	231.4	UI	0.034	(in units)	0.5
SDI	0.011	Cost/unit	1	SDI	0.011	Packaging (hr/unit)	10
ETT	0.001	($)		ETT	0.001	Wage ($/hr)	1.503
Comp	0.08			Comp	0.25	Taxes	13.78
Total	0.333			Total	0.503	Cost/unit ($)	

Total Labor Cost $245.19

Table C.3: OH Ongoing Cost (domestic)

Ongoing					
Rent:			Utilities:		
Rent per mo ($/sq.f	0.776		Kwh/mo	459.14	
Space (sq.ft)	1020		$/Kwh	0.1046	
mo/yr	12		mo/yr	12	
cost/unit	$94.98		cost/unit	$5.76	
Clerical Employee:					
Taxes	FICA	0.124		Wage ($/hr)	10
	Mcare	0.029		hrs/day	8
	FUTA	0.054		days/yr	260
	UI	0.034		Taxes	1.268
	SDI	0.011		Cost/unit	$263.74
	ETT	0.001			
	Workers Comp	0.015			
	Total	0.268			
Total Ongoing per unit	**$364.49**				

Table C.4: OH Initial Investment Cost (domestic)

Initial Investment		
Equipment	Cost	Yr Purchased
gloves	9.90	1
apron	17.70	1
MIG gun pliers	10.00	1
drill press set	29.00	1
bench drill press	177.00	1
lathe	200.00	1
endmill set	75.00	1
assembly bench	350.00	1
basic tool set	73.00	1
horizontal band saw	352.00	1
MID welding package	519.00	1
wall mounted cantilever	60.00	1
storage racks (3)	375.00	1
machine tables	800.00	1
truck dolly	20.00	1
Office Equipment	500.00	1
Storage bins (24)	100	1
Total	3667.60	1
Life (yrs)	15.00	1
Cost/unit	2.45	

Table C.5: Material Cost (outsourced)

Order Amount (China)						
Material	Order Amount	Cost/order	Cost/unit	Parts per unit	Total Cost/TK Ripper	Total Units
Tecumseh Engine	50	$14,000.00	$280.00	1	$280.00	50.00
Torque Converter	50	$5,857.00	$117.14	1	$117.14	50.00
Clutch	50	$2,595.50	$51.91	1	$51.91	50.00
Cluth Springs	50	$1,051.00	$21.02	1	$21.02	50.00
Chain	50	$490.50	$9.81	1	$9.81	50.00
Sprocket	50	$335.50	$6.71	1	$6.71	50.00
Spool Adapter	150	$1,132.50	$7.55	3	$22.65	50.00
Axle	50	$1,330.50	$26.61	1	$26.61	50.00
Spool Ends	100	$559.00	$5.59	2	$11.18	50.00
Spool Rods	50	$1,471.50	$29.43	1	$29.43	50.00
Bearings	100	$652.00	$6.52	2	$13.04	50.00
Wheels	100	$1,189.00	$11.89	2	$23.78	50.00
Wheel Axle	50	$218.50	$4.37	1	$4.37	50.00
Conduit Bracket	100	$59.00	$0.59	2	$1.18	50.00
Rope	34	$5,100.00	$150.00	1	$150.00	50.00
Disk Brake Hub	50	$876.00	$17.52	1	$17.52	50.00
Disk Brake	50	$2,803.00	$56.06	1	$56.06	50.00
Brake Caliper	50	$2,803.00	$56.06	1	$56.06	50.00
Caliper Bracket	50	$24.00	$0.48	1	$0.48	50.00
Nuts	800	$320.00	$0.40	16	$6.40	50.00
Disk Brake Hub Bolts	300	$126.00	$0.42	6	$2.52	50.00
Engine Mount Bolts	200	$32.00	$0.16	4	$0.64	50.00
Engine Bolts	200	$26.00	$0.13	4	$0.52	50.00
Spool Washer	400	$56.00	$0.14	8	$1.12	50.00
Engine Mount Washer	400	$56.00	$0.14	8	$1.12	50.00
Aluminum Frame	-------------------	-------------------	---------------	-------------	-------------------	----------------
1x2x1/8 (lbs) (5.8m segments)	2000	$2,600.00	1.3	11ft	$14.30	225
1x1x1/8 (lbs)(5.8m segments)	2000	$1,540.00	0.77	10 ft	7.7	390
5.5x14x1/4 (lbs)	2000	$4,338.00	$2.17	1.167 ft	$2.53	927
Total Initial Material Cost		**$51,641.50**		**Total Cost per unit**	**$935.80**	

Table C.6: Labor Cost (outsourced)

Welder (China):			Factory Worker (China):	
Hours/unit	16		Send out Material (12 units)	
Mo. Wage	280		Hours/time	8
Hours per day	12		Replenish Time/yr	8.33
Hours per Mo.	240		Wage ($/hr)	1.17
Wage ($/hr)	1.17		Cost per unit	0.78
# of workers	1		Restock material (50 units)	
Cost/unit ($)	18.66667		Hours/time	12
			Replenish times/yr	2
			Cost/unit	0.2808
			Total Cost per unit	1.06
Factory Worker (USA)				
Taxes:			Hours/day	3
FICA	0.124		Replenishment Time/yr	8.33
Mcare	0.029		Wage ($/hr)	10.00
FUTA	0.054		Total Cost per yr	249.9
UI	0.034		Units handled/time	12
SDI	0.011		Pckg & ship unit (hrs)	1
ETT	0.001		Taxes	1.503
Workers Comp	0.25		Cost per unit	8.2665
Total	0.503			
Total Labor Cost per unit	**27.99**			

Table C.7: OH Ongoing Cost (outsourced)

Ongoing:						
Rent						
China Warehouse						
Space:		Rent per month ($/sq.ft)	0.38		Utilities:	
Inventory racks	200	Space (sq.ft)	1745		Kwh/mo	801.19
aluminum racks	400	mo/yr	12		$/Kwh	0.05
Engine racks	40	Cost per year	7957.2		mo/yr	12
Trucker's Lounge	150	Cost/unit	79.572		cost/unit	4.80714
Receiving	400					
Equipment manuevuring	300					
Office	125					
Receiving hold area	100					
Trash Disposal	30					
Total sq.ft.	1745					
US Warehouse						
Space:		Rent per month ($/sq.ft)	0.776		Utilities:	
# of Finished Inv. On Rack	12	Space (sq.ft)	322		Kwh/mo	147.8421
# of storage racks	1	mo/yr	12		$/Kwh	0.105
Area of rack (inluding maneuverability)	48	Cost per year	2998.464		mo/yr	12
Receiving (sq.ft)	100	Cost/unit	29.98464		cost/unit	1.86281
Office	125					
Packaging	36					
Total sq.ft	322					

Indirect Labor:						
Clerical Employee (China)			Clerical Employee (US)			
Wage ($/hr)	1.17		Taxes:		Wage ($/hr)	10
Hours/day	8		FICA	0.124	hrs/day	4
days/year	260		Mcare	0.029	days/yr	260
Cost/unit	24.336		FUTA	0.054	Taxes	1.268
			UI	0.034	Cost/unit	131.872
			SDI	0.011		
			ETT	0.001		
			Workers Comp	0.015		
			Total	0.268		

Transportation:							
China			Air Freight			USA	
Gas ($/gal)	2		weight/unit	94.877		Gas ($/gal)	3.13
Truck (mi/gal)	6		units	12		Truck (mi/gal)	6
Transport in miles	30		total lbs	1138.52		Transport in miles	30
Transp. Cost	10		cost/lb	2.5		Transp. Cost	563.4
Cost/unit	0.833		cost to trans.	2846.31		Cost/unit	46.95
			Cost/unit	237.193			

Table C.8: OH Initial Investment Cost (outsourced)

Initial Investment:	
China	
Forklift	5000
Storage racks	875
Aluminum racks	500
Office Equipment	1000
USA	
Storage racks	150
Packaging Table	50
Total	7575
Life (yrs)	15
Cost/unit	5.05

Appendix D

Table D.1: Year 1 breakeven

Year 1						
FC	34866		r	2000	ROR (%)	23.36112
v	1621.26		TC	196991.6		
Q	100		R	200000		
VC	162125.6		Profit	3008.37		
			Breakeven (units)	92.05698		

Graph D.1: Year 1 breakeven

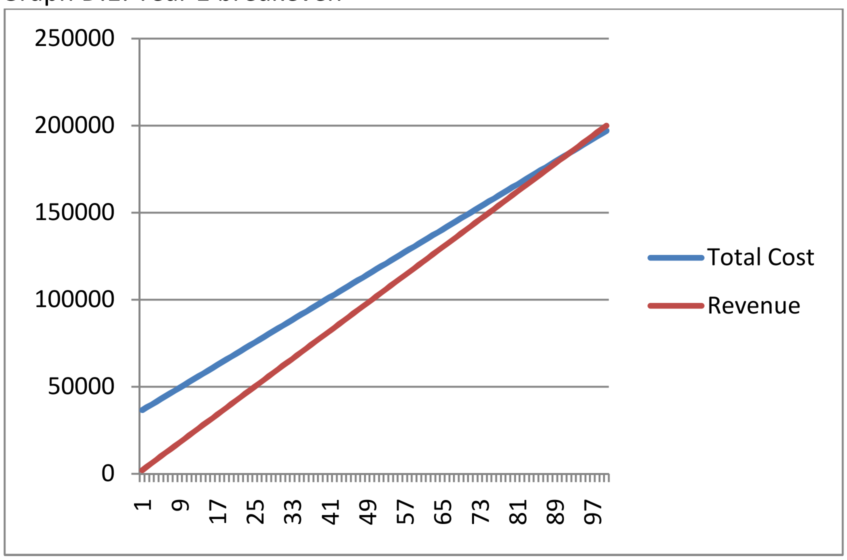


Table D.2: Year 2 breakeven

Year 2						
FC	34866		r	2000	ROR (%)	23.36112
v	1621.26		TC	359117.3		
Q	200		R	400000		
VC	324251.3		Profit	40882.74		
			Breakeven (units)	92.05698		

Graph D.2: Year 2 breakeven

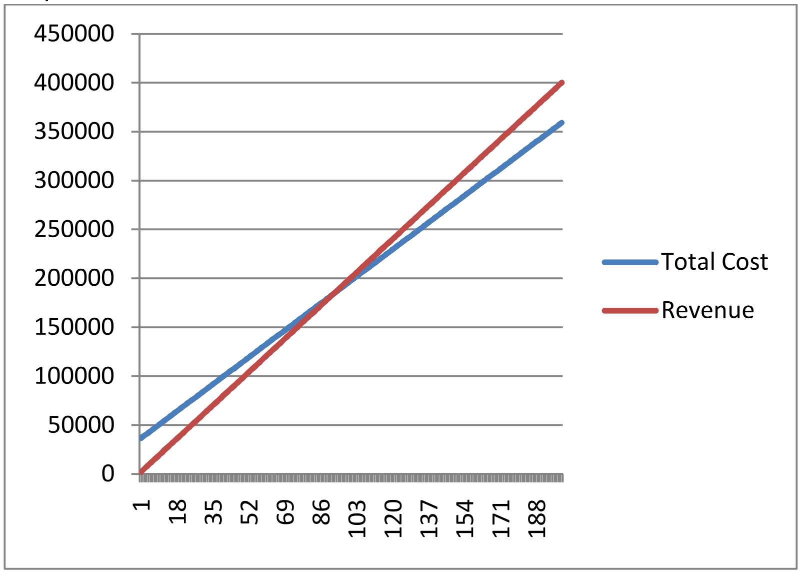
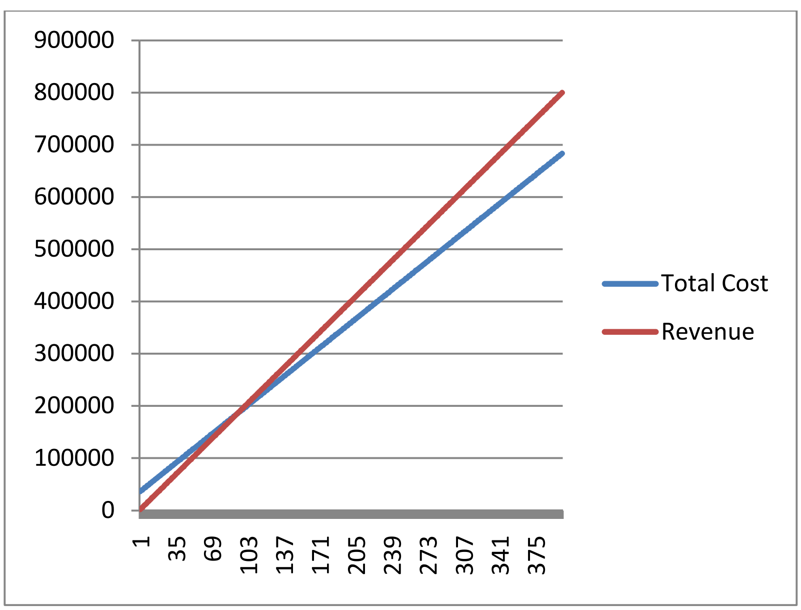


Table D.3: Year 3 breakeven

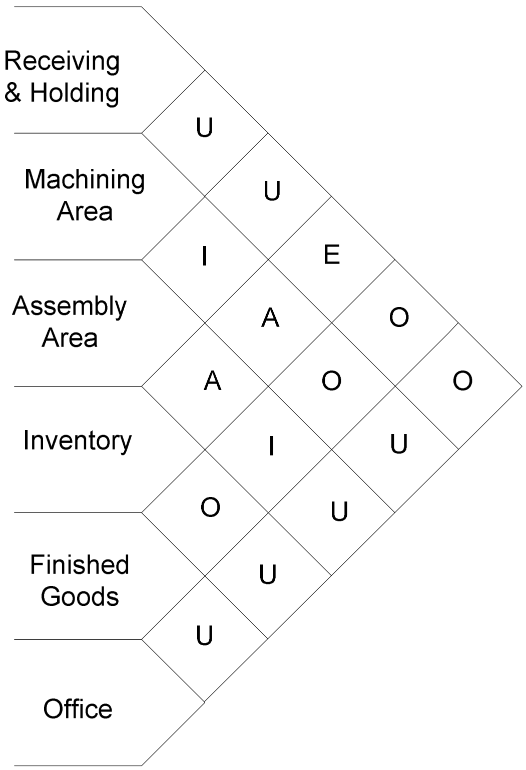
Year 3						
FC	34866		r	2000	ROR (%)	23.36112
v	1621.26		TC	683368.5		
Q	400		R	800000		
VC	648502.5		Profit	116631.5		
			Breakeven (units)	92.05698		

Graph D.3: Year 3 breakeven



Appendix E

Figure E.1: Relationship diagram



Value	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness okay
U	Unimportant

Table E.2: Space requirements

Department	Sq. Ft
Receiving & Holding	135
Machining Area	138
Assembly Area	336
Inventory	224
Finished Goods	35
Office	98

Figure E.2: Space Relationship diagram

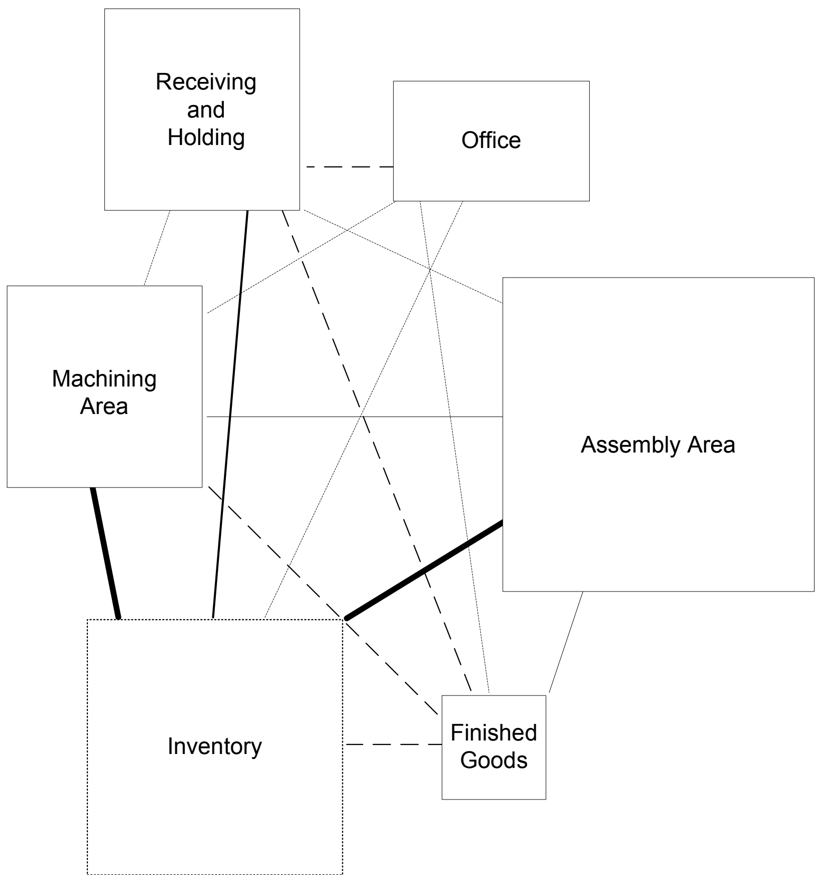


Figure E.3: Block diagram