ISYE 315
GROUP 7

TOMAHAWK
Metals, Inc.

TEAM DESIGN PROJECT

A NEW, PROPOSED, EFFICIENT LAYOUT UTILIZING PROJECTED MATERIAL FLOWS AND CAPACITY CONSIDERATIONS.

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EXECUTIVE SUMMARY

Tasked with finding out the most optimal welding approach for that of Tomahawk Metals, Inc.- whether to outsource or move onsite and ultimately that of the overall layout of the company- our group utilized analytical tools, such as capacity, payback, financial, factor, sensitivity, and sustainability analysis, to decipher which decision would best suit the financial growth and longevity of the company's long-term goals. After contrasting different layouts, and ultimately deciphering which layout most aligned with these previously determined initiatives, we were able to present a concluded report on an exact layout we feel as though- sustainably and efficiently- promotes sustainability and financial security for that of Tomahawk Metals, Inc.

KEY FEATURES

Refer to the Appendix IX: Final Layout to see an Application of these features

Layout Considerations:

- In accordance with our payback results, we have decided to outsource; so we didn't include the 2 welding machines in our machine shop layout.
- In creating the overall layout block diagrams, the main aspects taken into account were the non-flow considerations. Between the overall departments, there is minimal material flow relative to the machine shop. We utilized 6' aisles to connect the different departments and assumed the machine shop, shipping, and inventory have 9' forklift aisles within to accommodate for the transportation of products. The shipping

department is located on an exterior wall for minimal transportation from shipping to the outside of the facility.

- We decided to group that of similar processes near one another-such as different welding and milling machines along with the CNC and drill- as they often act as alternatives within the entirety of the process; therefore, depending on their placement, a product can move smoothly and efficiently from machine to machine. Furthermore, the people that work in similar processes have similar specializations; and would benefit from the close proximity.
- The main considerations in grouping the various departments was the amount of correspondence expected between the different areas and then separating departments with debris, noise, and heavy machinery from the office areas.
    - The computer server department was ranked especially important in being closely located to the various office spaces to ensure that every department has sufficient internet access.
    - The departments that contain the procedures that produce the materials needed for production were ranked of varying degrees of importance according to the assembly process order.
    - In order to reduce the fumes and noise coming into spaces like the conference rooms and offices, the machine shop, assembly area, and painting departments were ranked undesirable with respect to their proximity to each other.

- Another important factor was to have the office spaces relatively close to the conference rooms; those who hold office positions are most likely to utilize the conference rooms for meetings and presentations.
- In order to reduce the amount of distance finished products must travel, we considered the proximity of the shipping and receiving department and inventory storage to be absolutely necessary to minimize this length.

CAPACITY ANALYSIS

Refer to Appendix II for Capacity Analysis

In calculating the eKe produced each year, we found that the plant operates 18 hours a day for 350 days a year; each machine runs 6300 hours per year. To account for employee breaks, maintenance, etc. we included a capacity cushion of a minimum of 10%. If the utilization rate exceeded 90%, we added another machine. Using this information and the current years utilizations given we calculated the number of machines for each department over the 10 years into the future that we analyzed. Based on the capacity and payback analyses we recommend that the company continue to outsource welding due to lack of space and return from trying to bring it inhouse.

PAYBACK ANALYSIS

Refer to Appendix III for Payback Analysis

In order to calculate the payback analysis of bringing welding in house it was necessary to determine the rate at which our production would realistically grow over the next 10 years.

Given the values for 5% poor growth, 8% moderate growth, and 10% strong growth we used the formula [(5% + 4(8%) + 10%)/6] to get our expected rate of growth of 7.83%. Next the benefit of switching to in house welding was found using the unit cost savings of $2/unit multiplied by the number of parts we expected to produce in a given year. Subtracting the costs to purchase new machines based on capacity from the benefit each year yielded our yearly cash flow which was then converted to present worth using the MARR of 18% provided. Adding the present worth cash flows of each subsequent year to the beginning investment reveals the period in which it would take for in house welding to return its investment value. In this case we see that the investment would not regain its value within ten years of operation so bringing welding in house would not be a good investment. However, payback period is not a good indicator of the viability of a project so other forms of financial analysis are necessary.

FINANCIAL ANALYSIS

Refer to Appendix III for Payback Analysis

In order to further assist in the decision to bring welding in house, we calculated the net present value of the total cost of bringing welding in house and outsourcing, as well as the incremental net present value of bringing welding in house. We can see from the total in house and total outsource tables in Appendix III that since the net present value of the total cost of in house welding is more than the net present value for outsourcing that it would be beneficial to continue to outsource. In addition, we calculated the incremental rate of return for switching to in house welding which was 14%. Since the IRR is less than the minimum acceptable rate of return, and the incremental NPV is negative (IRR and NPV table in Appendix III) this tells us once again that it is not financially acceptable to bring welding in house.

FACTOR ANALYSIS

Refer to Appendix X for Factor Analysis

The five factors that we decided were most important to focus on when analyzing our project were safety, material handling, maintenance, storage effectiveness, and efficiency as we felt as though these factors- if properly implemented- are the main components that enable a corporation to safety and efficiently maximize profit (*further reasonings listed below*).

Safety is a very important consideration in terms of the safety of the workers and that of the equipment and products. When analyzing the safety of process a big thing to be considered is spacing, between departments and between machines. Spacing had to be analyzed for how transportation equipment will be able to fit and in terms of the spacing of machines throughout the shop layout to make sure that no fumes or debris cause any problems for the workers or for the parts.

We took material handling into account with the use of the heavy metal material used to make the chairs. The metal needed to be handled correctly to reduce accidents. When analyzing material handling we looked at the different materials that cycle through the process and what special considerations they might need to best be used by the workers and machines.

We assessed maintenance when evaluating the ease and efficiency of any repairs that might need to be done to the different machines and equipment used in the shop and within the different departments. When looking at storage we first looked at the work-in-process inventory to make sure we are maximizing our time and minimizing the amount of money needed to spend on storage for unfinished parts. The size and safety of storage used was also looked at.

To assess efficiency we looked at possible distractions or possible sources of time lost so that we could help create a more productive environment with better locations and less noise and accidents considering both that of the machines and that of the workers.

Together, optimizing these factors, factor analysis promoted the following layouts: ‘Machine Shop: Block Diagram 2’ and ‘Overall Layout: Block Diagram 1’.

SENSITIVITY ANALYSIS

Refer to Appendix III for Payback Analysis

We looked at different growth rates to see how sensitive the number of machines needed, total costs of staying inhouse or outsourcing, and the IRR would react. We used the minimum growth rate(5%) and the maximum growth rate(10%) to forecast the demand outside of the average growth rate we used initially in the project. From this we see that for both growth rates the IRR is below the MARR(18%) so the company will continue to outsource welding. As the growth rate increased we saw that the total cost of both outsourcing and staying inhouse increased. With a 5% growth rate the company would need 53 machines to bring welding inhouse and with a 10% growth rate the company would need 69 machines to bring welding inhouse.

SUSTAINABILITY ANALYSIS

A key feature to consider while designing a facility is sustainability. To do this we focused on the efficiency and waste minimization of building and maintaining the facility; a big part of sustainability is energy efficiency and designing the facility and its operations to minimize its energy consumption while being cost effective.

Due to the fact that the facility is located in Wisconsin- which is known for its harsh winters- a large portion of the facility's energy would be allocated to heating the facility. Finding alternative ways to heat the facility would help to make the facility more energy efficient and to help reduce expenses. To reduce energy consumption the facility should adopt certain features like LED lights, more windows, and insulation. LED lights require less energy and last longer than other lights, and windows allow in more natural light that can help to naturally heat the facility to reduce electricity and heating costs. Both of these features aren't the cheapest options, but in the long run they will make up the costs with the money they will save on their energy bills. Lastly the company will invest in insulating the walls of the facility. Foam insulation requires an installation fee, but it also provides heating and safety benefits that outweigh this fee. Insulation helps to keep in any hot or cold air in the building making it easier to heat up or cool down the building. Insulation is also fireproof and since it is in all of the walls of the building it helps to reduce the chance of fires in the facility which could save the company from having to pay for any future fire damage and any compromise in worker safety.

On a different note, the close groupings of departments and machine shops in our facility layout based on desirable relationships will help to reduce transportation and accident waste. We designed the layouts so that departments and machines with more interaction were closer together to reduce time between operations and less transportation time also helps minimize the risk of the materials being damaged and having to be thrown out and wasted. We have also incorporated some LEAN concepts into the design of the facility; the company will follow a ‘Just In Time’ system to reduce the inventory and overproduction waste and to decrease our inventory holding costs.

SOURCES:

[1]https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money

[2]https://www.thermaxxjackets.com/5-most-common-thermal-insulation-materials/

MATERIAL HANDLING

Refer to Appendix III for Payback Analysis

Material handling involves the movement of materials and parts between the departments within a facility, between areas within departments, and between the building and any transportation needed. Material handling is very important to consider because it encompasses the protection, storage, handling of the product and equipment. If any of these factors are handled incorrectly it can lead to an increased scrap rate and number of accidents along with a decreased profit margin.

Transporting Equipment: This includes equipment that can be used to move materials. For heavier materials, like the metal used to make the terrace chairs, we recommend that Tomahawk Metal use forklifts to decrease the time and increase the safety and efficiency of transportation. To accommodate the use of forklifts at Tomahawk Metal, we have determined the forklift aisles between departments to be 9’ and within the machine shop to be 10’ wide to ensure sufficient room for forklift travel.

Positioning Equipment: This includes equipment that can be used to make sure equipment and machines are placed correctly throughout the shop floor. Most of the time it isn’t cost effective to buy this kind of equipment, and it is just done by hand and using transportation equipment when necessary. Most positioning errors are minor and have little effects on efficiency. One situation where positioning equipment would be worth the cost would be for heavy materials that will need the help of equipment like an automated conveyor.

Storing Equipment: This includes basic equipment like shelving and pallets that can be used to hold parts and materials while they are being transported or in between processes. Tomahawk Metal is working towards keeping a small amount of work-in-process inventory in order to reduce costs so investing in large and complex storage systems are unnecessary.

Unit Load Formation Equipment: This includes equipment that is used during longer distance transportations of parts and materials to protect it’s integrity. The use of unit load formation equipment would be relevant in the shipping of materials to and from the welding shop since we have concluded that it is more cost effective to outsource. Some examples of these would be interlocking parts to keep them connected so that they don’t fall off and get damaged during transportation.

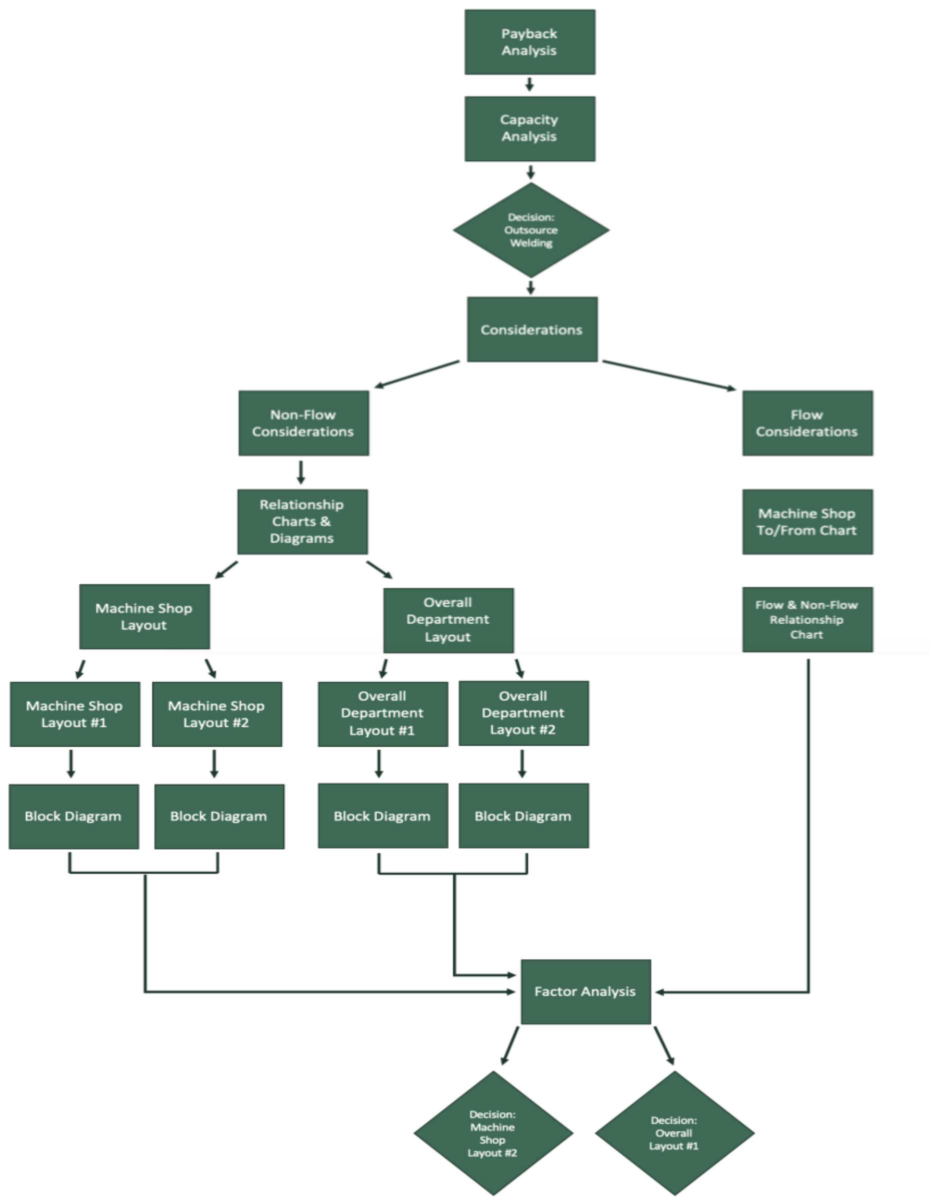
Identification and Control Equipment: This includes equipment to stamp parts and materials with barcodes upon entrance to the machine shop to track them throughout the manufacturing process. This equipment and method are typically low cost and easy for workers to use; essential as possible errors could come from a defective and or lost/forgotten barcode.

LESSONS LEARNED

Through the process of completing this project, we have been introduced to various engineering concepts used in decision making for a production environment; one of the challenges we came across during this project was becoming comfortable using the Visio program. Some of the members in our group had never before used the program which led to a lot of experimentation. However, our group was able to work together on facing this challenge and work through the new learning experience together- especially with creating the machine shop and overall department block diagram layouts. Another challenge we faced was learning how to apply the relationship charts and diagrams to a real-world scenario; we overcame this challenge by utilizing the resources and advice provided by our teaching assistant. Through completing the project, we can confidently say that we are able to comprehend the information being portrayed on these charts and diagrams- which will be applicable for professional uses. Furthermore, this project emphasized how in-depth the production planning process is here were numerous levels of analysis performed such as payback analysis, capacity analysis, to/from charts, and analysis of department and machine relationships. In addition to the big picture, we had to consider the smaller aspects of the factory like storage, aisles and walkways, and other material handling strategies; with adequate team member communication, time management, and the acceptance of constructive criticism, we successfully completed the project.

APPENDIX

Appendix I: Methodology



Appendix II: Capacity Analysis

Machines/Departments	Current Number of Machines	Current Calendar Year Utilization (Average % per machine)	Hours Used Currently
Shear Press	1	68%	4284
Laser Cutter	2	70%	8820
Vertical Milling Machine	3	72%	13608
Horizontal Milling Machine	2	78%	9828
Press Brake	1	83%	5229
Punch Press	2	72%	9072
CNC Lathe	2	88%	11088
Surface Grinder	4	60%	15120
Drill Press	2	70%	8820
Pipe Bender	3	82%	15498
Horizontal Band Saw	2	65%	8190
TIG Welding	3	80%	15120
MIG Welding	2	80%	10080

Hours Necessary										
Year	1	2	3	4	5	6	7	8	9	10
(1.0783)^n	1.0783	1.1627309	1.25377	1.35194	1.4578	1.57195	1.69503	1.82775	1.97086	2.12518
	4619.4372	4981.1391	5371.16	5791.72	6245.22	6734.22	7261.51	7830.08	8443.18	9104.28
	9510.606	10255.286	11058.3	11924.1	12857.8	13864.6	14950.2	16120.8	17383	18744.1
	14673.5064	15822.442	17061.3	18397.2	19837.7	21391	23066	24872	26819.5	28919.5
	10597.5324	11427.319	12322.1	13286.9	14327.3	15449.1	16658.7	17963.1	19369.6	20886.3
	5638.4307	6079.9198	6555.98	7069.31	7622.84	8219.71	8863.31	9557.31	10305.6	11112.6
	9782.3376	10548.295	11374.2	12264.8	13225.2	14260.7	15377.3	16581.3	17879.7	19279.6
	11956.1904	12892.36	13901.8	14990.3	16164.1	17429.7	18794.5	20266.1	21852.9	23564
	16303.896	17580.491	18957	20441.4	22041.9	23767.8	25628.8	27635.6	29799.4	32132.7
	9510.606	10255.286	11058.3	11924.1	12857.8	13864.6	14950.2	16120.8	17383	18744.1
	16711.4934	18020.003	19431	20952.4	22593	24362	26269.6	28326.5	30544.4	32936.1
	8831.277	9522.766	10268.4	11072.4	11939.4	12874.2	13882.3	14969.3	16141.4	17405.2
	16303.896	17580.491	18957	20441.4	22041.9	23767.8	25628.8	27635.6	29799.4	32132.7
	10869.264	11720.327	12638	13627.6	14694.6	15845.2	17085.9	18423.7	19866.3	21421.8

Utilization										
Year	1	2	3	4	5	6	7	8	9	10
	0.733244	0.790657	0.85257	0.91932	0.49565	0.53446	0.57631	0.62144	0.67009	0.72256
	0.75481	0.8139116	0.87764	0.94636	0.68031	0.73357	0.79101	0.85295	0.91974	0.74381
	0.776376	0.8371662	0.90272	0.73005	0.78721	0.84885	0.91532	0.78959	0.85141	0.91808
	0.841074	0.9069301	0.65196	0.70301	0.75806	0.81741	0.88142	0.95043	0.76864	0.82882
	0.894989	0.9650666	0.52032	0.56106	0.60499	0.65236	0.70344	0.75852	0.81791	0.88195
	0.776376	0.8371662	0.90272	0.64893	0.69974	0.75453	0.81361	0.87732	0.94601	0.76507
	0.948904	0.6821355	0.73555	0.79314	0.85524	0.92221	0.74581	0.80421	0.86718	0.93508
	0.517584	0.5581108	0.60181	0.64893	0.69974	0.75453	0.81361	0.87732	0.94601	0.85007
	0.75481	0.8139116	0.87764	0.94636	0.68031	0.73357	0.79101	0.85295	0.91974	0.74381
	0.884206	0.9534393	0.77107	0.83145	0.89655	0.96675	0.83395	0.89925	0.96966	0.87132
	0.700895	0.7557751	0.81495	0.87876	0.94757	0.68118	0.73451	0.79203	0.85404	0.92091
	0.86264	0.9301847	0.75226	0.81117	0.87468	0.94317	0.81361	0.87732	0.94601	0.85007
	0.86264	0.9301847	0.66868	0.72104	0.77749	0.83837	0.90402	0.7311	0.78835	0.85007

Machines Needed Without In House Welding										
Year	1	2	3	4	5	6	7	8	9	10
Shear Press	1	1	1	2	2	2	2	2	2	2
Laser Cutter	2	2	2	3	3	3	3	3	4	4
Vertical Milling Machine	3	3	4	4	4	4	5	5	5	6
Horizontal Milling Machine	2	3	3	3	3	3	3	4	4	4
Press Brake	1	2	2	2	2	2	2	2	2	2
Punch Press	2	2	3	3	3	3	3	3	4	4
CNC Lathe	3	3	3	3	3	4	4	4	4	5
Surface Grinder	4	4	4	4	4	5	5	5	6	6
Drill Press	2	2	2	3	3	3	3	3	4	4
Pipe Bender	3	4	4	4	4	5	5	5	6	6
Horizontal Band Saw	2	2	2	2	3	3	3	3	3	4

Utilization With Welding In House										
Year	1	2	3	4	5	6	7	8	9	10
TIG Welding	0.86264	0.9301847	0.75226	0.81117	0.87468	0.94317	0.81361	0.87732	0.94601	0.85007
MIG Welding	0.86264	0.9301847	0.66868	0.72104	0.77749	0.83837	0.90402	0.7311	0.78835	0.85007
Surface Grinder	0.517584	0.5581108	0.60181	0.64893	0.69974	0.75453	0.81361	0.87732	0.94601	0.85007

Machines Needed With Welding In House										
Year	1	2	3	4	5	6	7	8	9	10
TIG Welding	3	4	4	4	4	5	5	5	6	6
MIG Welding	2	3	3	3	3	3	4	4	4	4
Surface Grinder	5	5	5	5	5	5	5	5	6	6

Appendix III: Payback Analysis

Payback Analysis				
year	benefit	cash flow	PW cash flow	Payback
0		$195,000.00	$195,000.00	$195,000.00
1	43132	$27,868.00	$23,616.95	$218,616.95
2	46509.2356	46509.2356	$33,402.21	$185,214.74
3	50150.9087	50150.90875	$30,523.39	$154,691.35
4	54077.7249	54077.7249	$27,892.69	$126,798.66
5	58312.0108	$25,312.01	$11,064.11	$115,734.55
6	62877.8412	$24,877.84	$9,215.54	$106,519.01
7	67801.1762	$67,801.18	$21,284.49	$85,234.52
8	73110.0083	$20,110.01	$5,350.03	$79,884.49
9	78834.5219	$78,834.52	$17,773.72	$62,110.77
10	85007.265	$85,007.26	$16,241.87	$45,868.90

Total In House Cost										
Year	Expected Parts	Unit Costs	TIG Needed	TIG Cost	MIG Needed	MIG Cost	SG Needed	SG Cost	Machine Costs	Total Cost In House
0	20000		3	$99,000.00	2	$76,000.00	1	$20,000.00	$195,000.00	$195,000.00
1	21566	$496,018.00	1	$33,000.00	1	$38,000.00			$71,000.00	$567,018.00
2	23255	$534,856.21								$534,856.21
3	25075	$576,735.45								$576,735.45
4	27039	$621,893.84								$621,893.84
5	29156	$670,588.12	1	$33,000.00					$33,000.00	$703,588.12
6	31439	$723,095.17			1	$38,000.00			$38,000.00	$761,095.17
7	33901	$779,713.53								$779,713.53
8	36555	$840,765.10	1	$33,000.00			1	$20,000.00	$53,000.00	$893,765.10
9	39417	$906,597.00								$906,597.00
10	42504	$977,583.55								$977,583.55
									NPV In House	$2,707,321.24

IRR and NPV	
Year	Incremental CF
0	$195,000.00
1	$27,868.00
2	$46,509.24
3	$50,150.91
4	$54,077.72
5	$25,312.01
6	$24,877.84
7	$67,801.18
8	$20,110.01
9	$78,834.52
10	$85,007.26
IRR	13%
Incremental NPV	$38,871.95

Total Outsourcing Cost		
Year	Expected Parts	Cost
0	20000	Cost not included
1	21566	$539,150
2	23255	$581,365
3	25075	$626,886
4	27039	$675,972
5	29156	$728,900
6	31439	$785,973
7	33901	$847,515
8	36555	$913,875
9	39417	$985,432
10	42504	$1,062,591
	NPV outsource	$2,668,449

Appendix IV: Sensitivity Analysis

5% Growth Rate

Machines Needed With In House Welding										
Year	1	2	3	4	5	6	7	8	9	10
Shear Press	1	1	1	1	1	2	2	2	2	2
Laser Cutter	2	2	2	2	2	3	3	3	3	3
Vertical Milling Machine	3	3	3	3	4	4	4	4	4	4
Horizontal Milling Machine	2	2	3	3	3	3	3	3	3	3
Press Brake	1	2	2	2	2	2	2	2	2	2
Punch Press	2	2	2	2	3	3	3	3	3	3
CNC Lathe	3	3	3	3	3	3	3	3	4	4
Surface Grinder	5	5	5	5	5	5	5	5	5	5
Drill Press	2	2	2	2	2	3	3	3	3	3
Pipe Bender	3	4	4	4	4	4	4	5	5	5
Horizontal Band Saw	2	2	2	2	2	2	3	3	3	3
TIG Welding	3	3	4	4	4	4	4	4	5	5
MIG Welding	2	2	3	3	3	3	3	3	3	3

Payback Analysis				
year	benefit	cash flow	PW cash flow	Payback
0		$195,000.00	$195,000.00	$195,000.00
1	42000	$42,000.00	$35,593.22	$159,406.78
2	44100	-26900	$19,319.16	$178,725.94
3	46305	46305	$28,182.65	$150,543.29
4	48620.25	48620.25	$25,077.78	$125,465.50
5	51051.2625	$51,051.26	$22,314.98	$103,150.53
6	53603.82563	$53,603.83	$19,856.55	$83,293.98
7	56284.01691	$56,284.02	$17,668.96	$65,625.02
8	59098.21775	$26,098.22	$6,943.12	$58,681.90
9	62053.12864	$62,053.13	$13,990.25	$44,691.64
10	65155.78507	$65,155.79	$12,448.96	$32,242.69

IRR and NPV	
Year	Incremental CF
0	$195,000.00
1	$42,000.00
2	$26,900.00
3	$46,305.00
4	$48,620.25
5	$51,051.26
6	$53,603.83
7	$56,284.02
8	$26,098.22
9	$62,053.13
10	$65,155.79
IRR	14%
Incremental NPV	$27,324.31

Total Outsourcing Cost		
Year	Expected Parts	Cost
0	20000	Cost not included
1	21000	$525,000
2	22050	$551,250
3	23153	$578,813
4	24310	$607,753
5	25526	$638,141
6	26802	$670,048
7	28142	$703,550
8	29549	$738,728
9	31027	$775,664
10	32578	$814,447
	NPV outsource	$2,357,285

Total In House Cost										
Year	Expected Parts	Unit Costs	TIG Needed	TIG Cost	MIG Needed	MIG Cost	SG Needed	SG Cost	Machine Costs	Total Cost In House
0	20000		3	$99,000.00	2	$76,000.00	1	$20,000.00	$195,000.00	$195,000.00
1	21000	$483,000.00	0	$0.00	0	$0.00	0	$0.00	$0.00	$483,000.00
2	22050	$507,150.00	1	$33,000.00	1	$38,000.00	0	$0.00	$71,000.00	$578,150.00
3	23153	$532,507.50	0	$0.00	0	$0.00	0	$0.00	$0.00	$532,507.50
4	24310	$559,132.88	0	$0.00	0	$0.00	0	$0.00	$0.00	$559,132.88
5	25526	$587,089.52	0	$0.00	0	$0.00	0	$0.00	$0.00	$587,089.52
6	26802	$616,443.99	0	$0.00	0	$0.00	0	$0.00	$0.00	$616,443.99
7	28142	$647,266.19	0	$0.00	0	$0.00	0	$0.00	$0.00	$647,266.19
8	29549	$679,629.50	1	$33,000.00	0	$0.00	0	$0.00	$33,000.00	$712,629.50
9	31027	$713,610.98	0	$0.00	0	$0.00	0	$0.00	$0.00	$713,610.98
10	32578	$749,291.53	0	$0.00	0	$0.00	0	$0.00	$0.00	$749,291.53
									NPV In House	$2,384,608.93

10% Growth Rate

Machines Needed With In House Welding										
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Shear Press	1	1	2	2	2	2	2	2	2	2
Laser Cutter	2	2	3	3	3	3	4	4	4	5
Vertical Milling Machine	3	3	4	4	4	5	5	6	6	7
Horizontal Milling Machine	2	3	3	3	3	4	4	4	5	5
Press Brake	2	2	2	2	2	2	2	2	3	3
Punch Press	2	2	3	3	3	3	4	4	4	5
CNC Lathe	3	3	3	3	4	4	4	5	5	6
Surface Grinder	5	5	5	5	5	5	6	6	7	7
Drill Press	2	2	3	3	3	3	4	4	4	5
Pipe Bender	4	4	4	5	5	5	6	6	7	8
Horizontal Band Saw	2	2	2	3	3	3	3	4	4	4
TIG Welding	3	4	4	4	5	5	6	6	7	7
MIG Welding	2	3	3	3	3	4	4	4	5	5

Payback Analysis				
year	benefit	cash flow	PW cash flow	Payback
0		$195,000.00	$195,000.00	$195,000.00
1	44000	$27,000.00	$22,881.36	$217,881.36
2	48400	48400	$34,760.13	$183,121.23
3	53240	53240	$32,403.51	$150,717.72
4	58564	25564	$13,185.63	$137,532.10
5	64420.4	$26,420.40	$11,548.60	$125,983.49
6	70862.44	$17,862.44	$6,616.81	$119,366.68
7	77948.684	$77,948.68	$24,470.04	$94,896.64
8	85743.5524	$5,256.45	$1,398.42	$96,295.06
9	94317.90764	$94,317.91	$21,264.54	$75,030.51
10	103749.6984	$103,749.70	$19,822.88	$55,207.63

Total Outsourcing Cost		
Year	Expected Parts	Cost
0	20000	Cost not included
1	22000	$550,000
2	24200	$605,000
3	26620	$665,500
4	29282	$732,050
5	32210	$805,255
6	35431	$885,781
7	38974	$974,359
8	42872	$1,071,794
9	47159	$1,178,974
10	51875	$1,296,871
	NPV outsource	$2,938,934

IRR and NPV	
Year	Incremental CF
0	$195,000.00
1	$27,000.00
2	$48,400.00
3	$53,240.00
4	$25,564.00
5	$26,420.40
6	$17,862.44
7	$77,948.68
8	$5,256.45
9	$94,317.91
10	$103,749.70
IRR	12%
Incremental NPV	$46,786.13

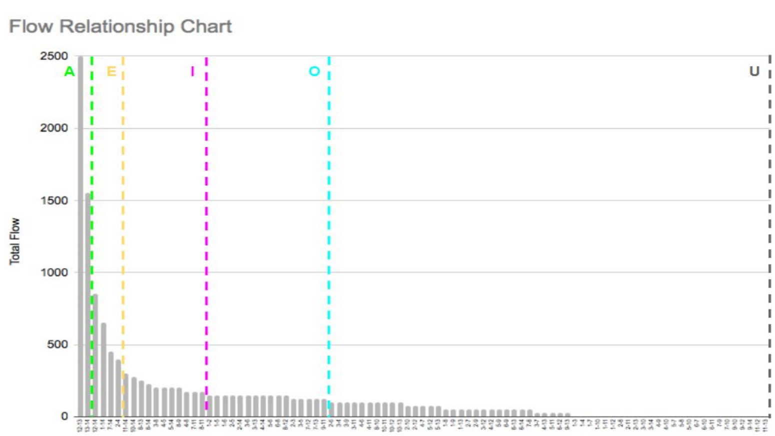
Total In House Cost										
Year	Expected Parts	Unit Costs	TIG Needed	TIG Cost	MIG Needed	MIG Cost	SG Needed	SG Cost	Machine Costs	Total Cost In House
0	20000		3	$99,000.00	2	$76,000.00	1	$20,000.00	$195,000.00	$195,000.00
1	22000	$506,000.00	1	$33,000.00	1	$38,000.00	0	$0.00	$71,000.00	$577,000.00
2	24200	$556,600.00	0	$0.00	0	$0.00	0	$0.00	$0.00	$556,600.00
3	26620	$612,260.00	0	$0.00	0	$0.00	0	$0.00	$0.00	$612,260.00
4	29282	$673,486.00	1	$33,000.00	0	$0.00	0	$0.00	$33,000.00	$706,486.00
5	32210	$740,834.60	0	$0.00	1	$38,000.00	0	$0.00	$38,000.00	$778,834.60
6	35431	$814,918.06	1	$33,000.00	0	$0.00	1	$20,000.00	$53,000.00	$867,918.06
7	38974	$896,409.87	0	$0.00	0	$0.00	0	$0.00	$0.00	$896,409.87
8	42872	$986,050.85	1	$33,000.00	1	$38,000.00	1	$20,000.00	$91,000.00	$1,077,050.85
9	47159	$1,084,655.94	0	$0.00	0	$0.00	0	$0.00	$0.00	$1,084,655.94
10	51875	$1,193,121.53	0	$0.00	0	$0.00	0	$0.00	$0.00	$1,193,121.53
									NPV In House	$2,985,720.33

Appendix V: Flow Considerations

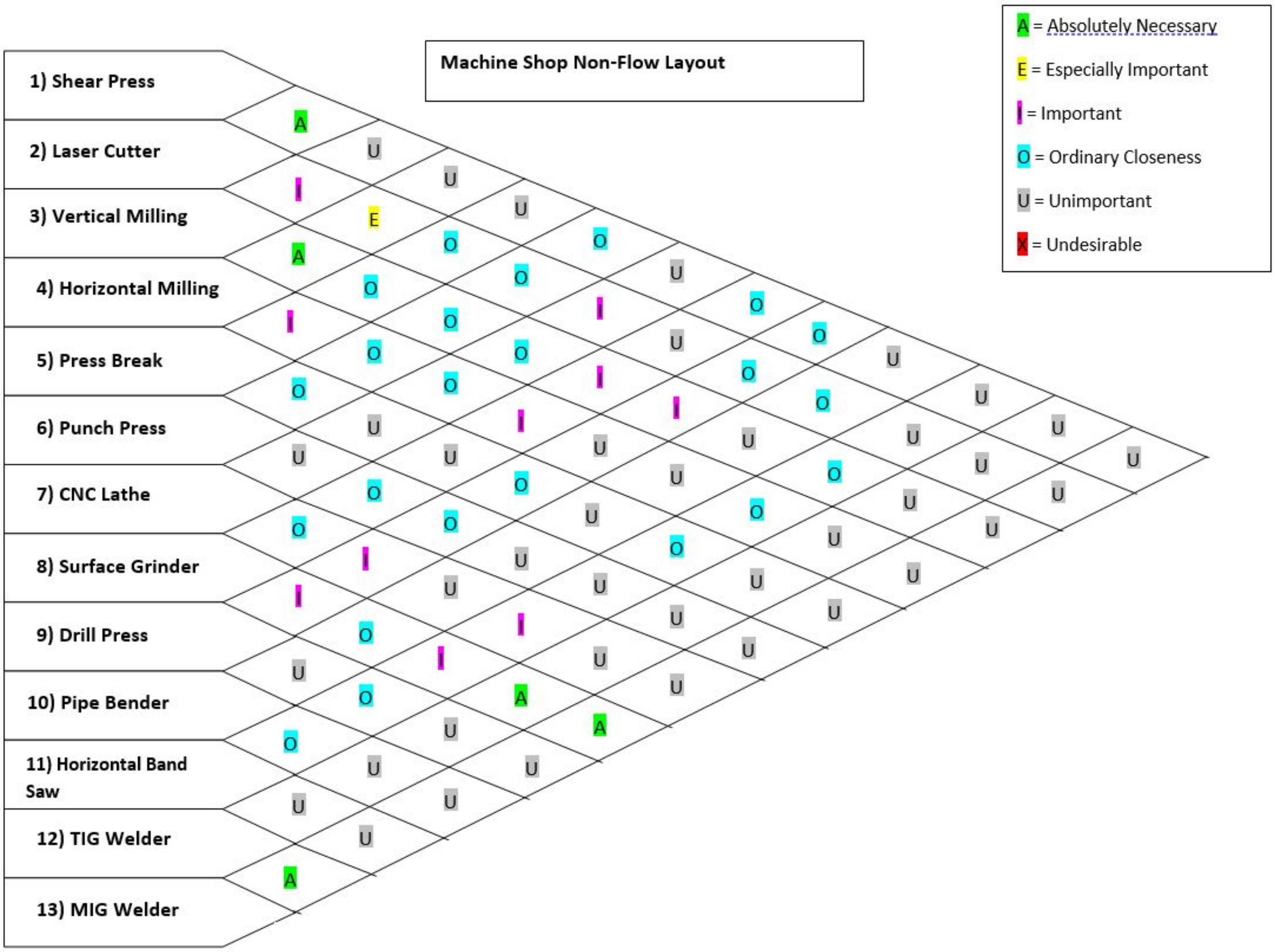
FROM:	1. Shear Press	2. Laser Cutter	3. Vertical Milling	4. Horizontal Milli	5. Press Brake	6. Punch Press	7. CNC Lathe	8. Surface Grinder	9. Drill Press	10. Pipe Bender	11. Horizontal Ban	12. Painting	13. Assembly Area	14. Shipping/Recei	TOTAL (FROM)
1. Shear Press		150			150	150		50	50				50	650	1250
2. Laser Cutter			125	400	150	100	50		50	75		75		150	1175
3. Vertical Milling Machine				100	125	150	25	200	100		100	50	150		1000
4. Horizontal Milling Machine					200	100	75	175			100	50	25	150	875
5. Press Brake						150			50		25	75	75	200	575
6. Punch Press								150	50			25	50	50	325
7. CNC Lathe								50			175	125	125	450	925
8. Surface Grinder									200	100	175	150	250	225	1100
9. Drill Press											125		25		150
10. Pipe Bender											100	100	100	275	575
11. Horizontal Band Saw														300	300
12. Painting													2500	850	3350
13. Assembly Area														1550	1550
14. Shipping/Receiving															0
TOTAL (TO)	0	150	125	500	625	650	150	625	500	175	800	650	3350	4850	

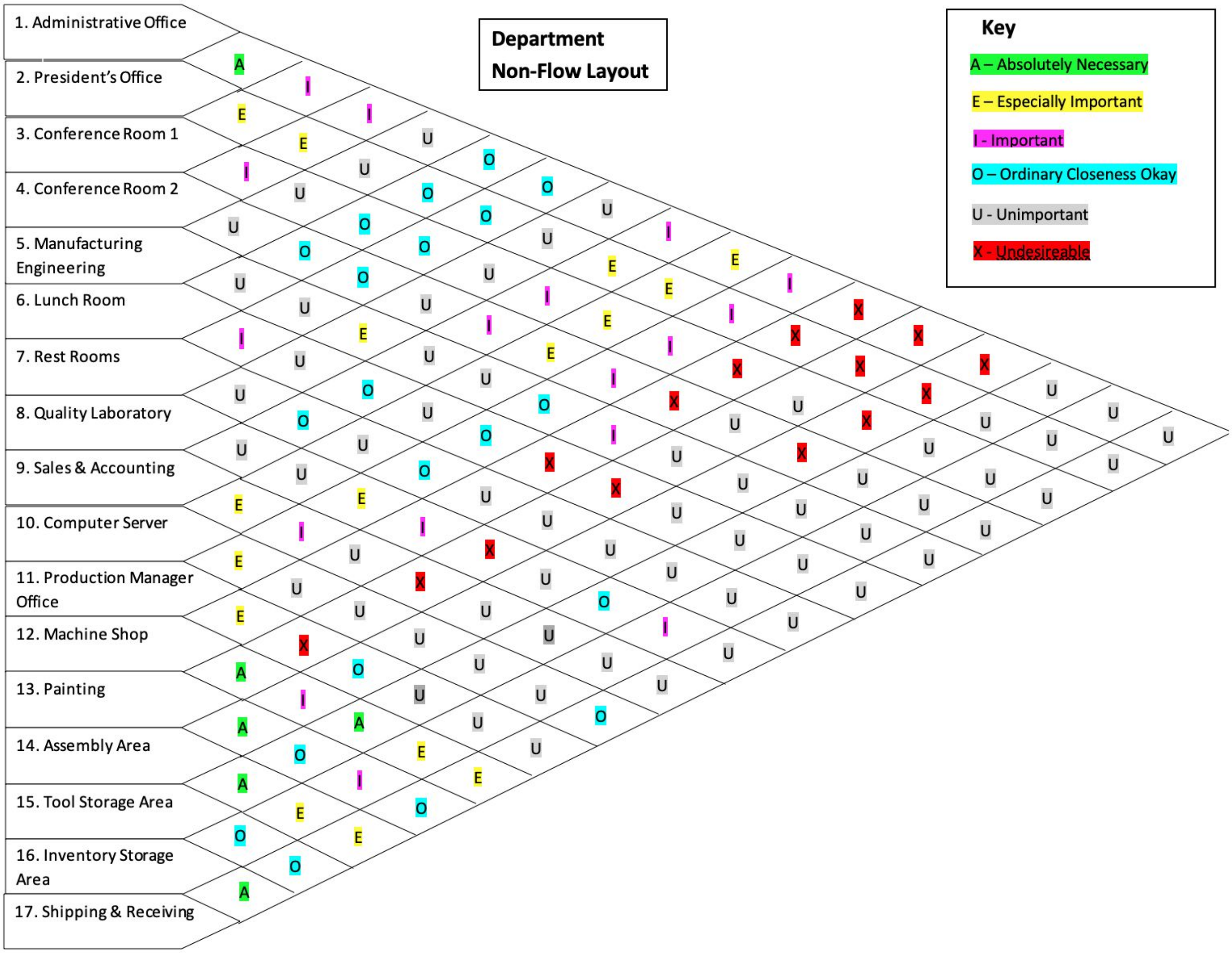
Relationship	Percentage	Calculated Number of Flows
A	< 5%	4.55
A & E	< 12%	10.92
A, E, & I	< 25%	22.75
O	--	2.73
U	> 50%	45.5
X	< 5%	4.55

Relationship	Actual Number of Flows
A	2
E	4
I	11
O	16
U	58
X	0



Appendix VI: Non-Flow Considerations

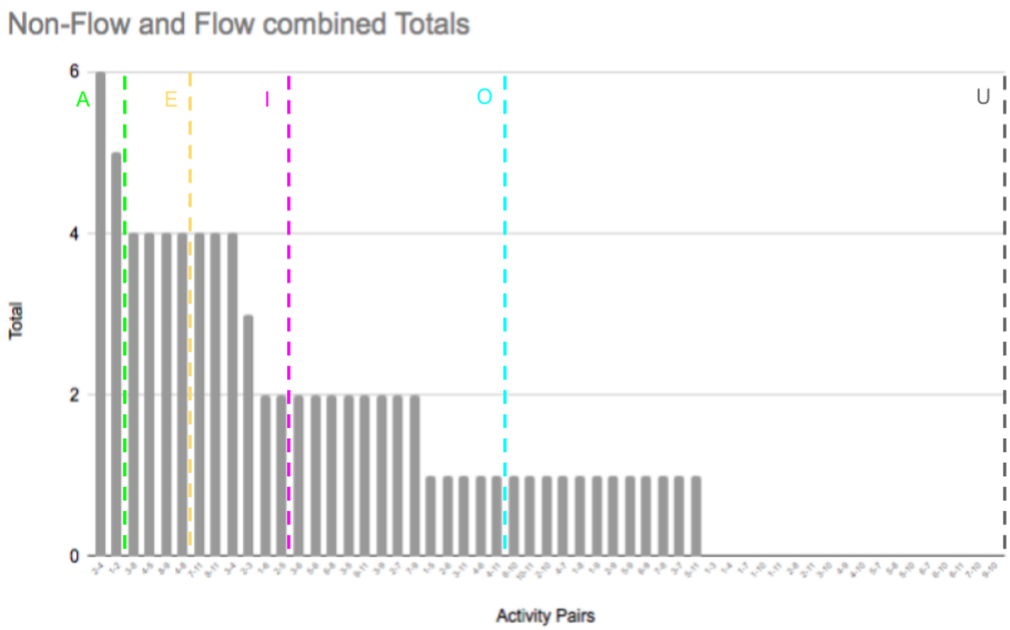


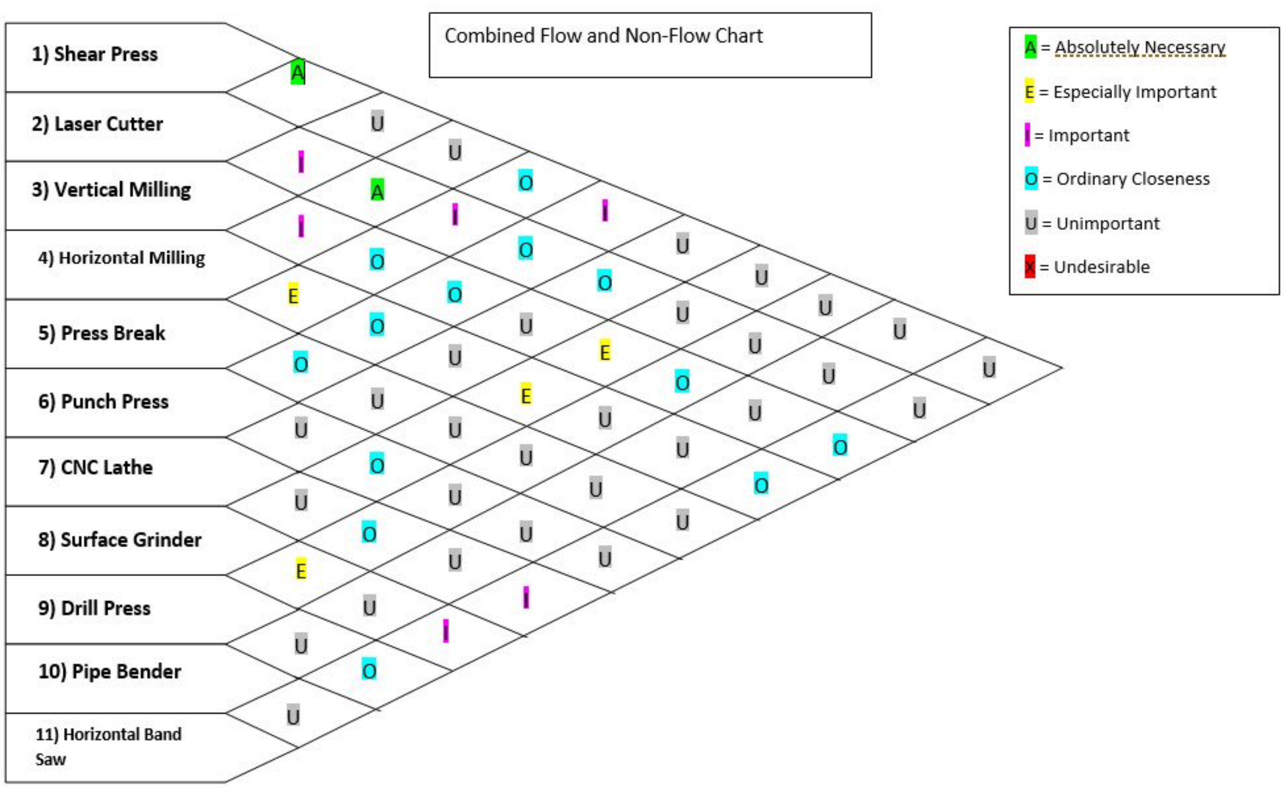


Flow and Non-Flow Charts

Activity Pairs	Flow	Non-Flow	Total
2-4	3	3	6
3-8	2	2	4
4-5	2	2	4
8-9	2	2	4
4-8	2	2	4
7-11	2	2	4
8-11	2	2	4
1-2	1	4	5
1-5	1	0	1
1-6	1	1	2
2-5	1	1	2
3-6	1	1	2
5-6	1	1	2
6-8	1	1	2
2-3	1	2	3
3-5	1	1	2
9-11	1	1	2
2-6	0	1	1
3-4	0	4	4
3-9	0	2	2
3-11	0	1	1
4-6	0	1	1
4-11	0	1	1
8-10	0	1	1
10-11	0	1	1
2-10	0	1	1

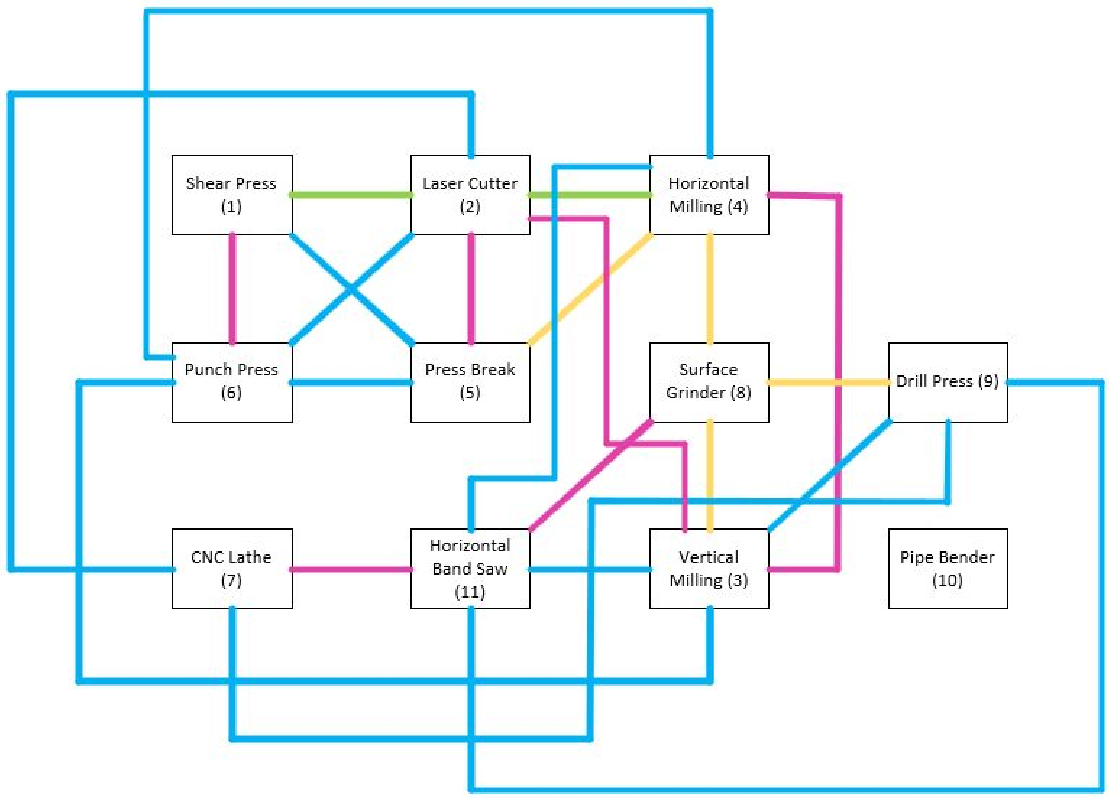
Activity Pairs	Flow	Non-Flow	Total
4-7	0	1	1
1-8	0	1	1
1-9	0	1	1
2-7	0	2	2
2-9	0	1	1
5-9	0	1	1
6-9	0	1	1
7-8	0	1	1
3-7	0	1	1
5-11	0	1	1
1-3	0	0	0
1-4	0	0	0
1-7	0	0	0
1-10	0	0	0
1-11	0	0	0
2-8	0	0	0
2-11	0	0	0
3-10	0	0	0
4-9	0	0	0
4-10	0	0	0
5-7	0	0	0
5-8	0	0	0
5-10	0	0	0
6-7	0	0	0
6-10	0	0	0
6-11	0	0	0
7-9	0	2	2
7-10	0	0	0
9-10	0	0	0


Non-Flow and Flow combined Totals
6
4
2
0
A
E
I
O
U
Total
Activity Pairs


1) Shear Press
2) Laser Cutter
3) Vertical Milling
4) Horizontal Milling
5) Press Break
6) Punch Press
7) CNC Lathe
8) Surface Grinder
9) Drill Press
10) Pipe Bender
11) Horizontal Band Saw
Combined Flow and Non-Flow Chart
A = Absolutely Necessary
E = Especially Important
I = Important
O = Ordinary Closeness
U = Unimportant
X = Undesirable

Appendix VII: Relationship Diagrams

Machine Shop Relationship Diagram: Option 1

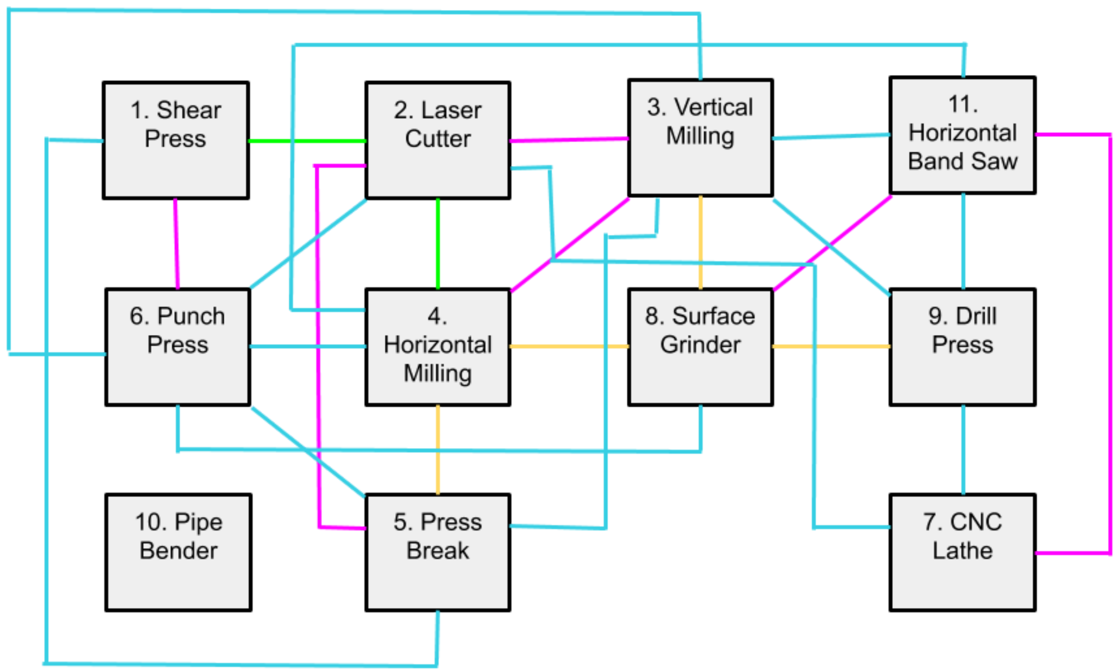


Flow Analysis: A = 4 points, E = 3 points, I = 2 points, O = 1 point, U = 0 points, X = -1 point
Every diagonal is worth that of two points; every right angle is worth that of one; straight lines directly from one machine to the next are allocated that of one point.

A: 4*(1+1) = 8 Points
E: 3*(1+1+1+2) = 15 Points
I: 2*(1+1+1+2+2+3) = 20 Points
O: 1*(2+2+3+1+3+4+3+1+2+3+3) = 27 Points
U = Negligible
X = N/A

Measure of Effectiveness, Total Flow: 70 Points

Machine Shop Relationship Diagram: Option 2



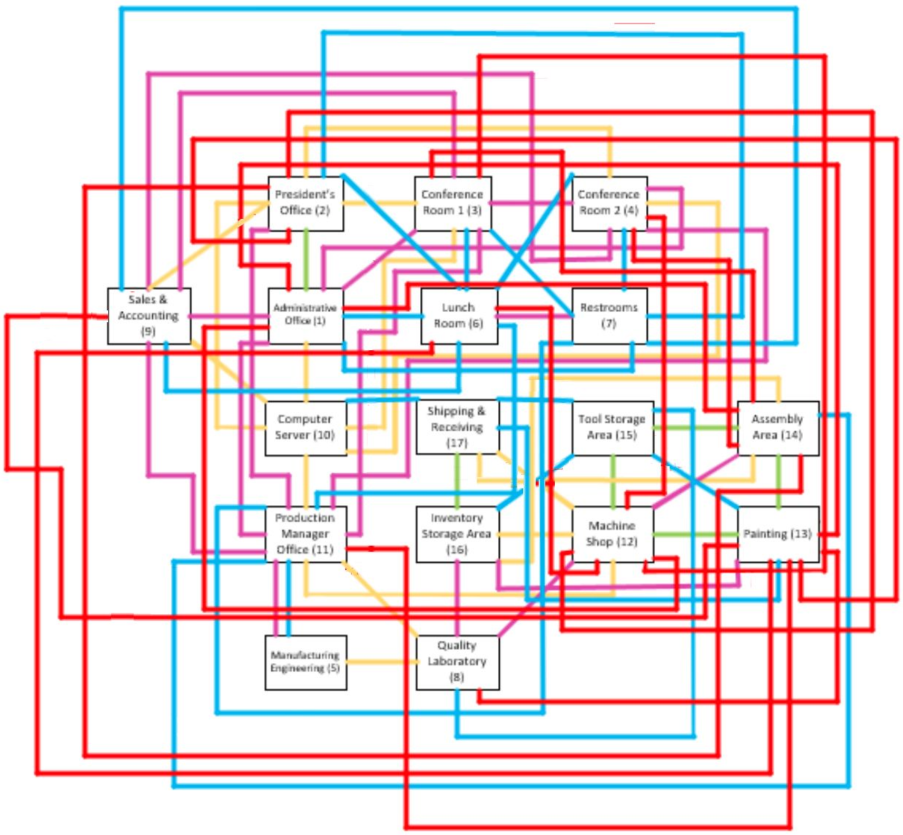
Flow Analysis: A = 4 points, E = 3 points, I = 2 points, O = 1 point, U = 0 points, X = -1 point
Every diagonal is worth that of two points; every right angle is worth that of one; straight lines directly from one machine to the next are allocated that of one point.

A: 4*(1+1) = 8 Points
E: 3*(1+1+1+1) = 12 Points
I: 2*(1+1+2+2+2+2) = 20 Points
O: 1*(3+2+4+4+3+2+1+3+1+1+2+1+2) = 29 Points
U = Negligible
X = N/A

Measure of Effectiveness, Total Flow: 69 Points

Choose Option 2

Overall Layout Relationship Diagram: Option 1



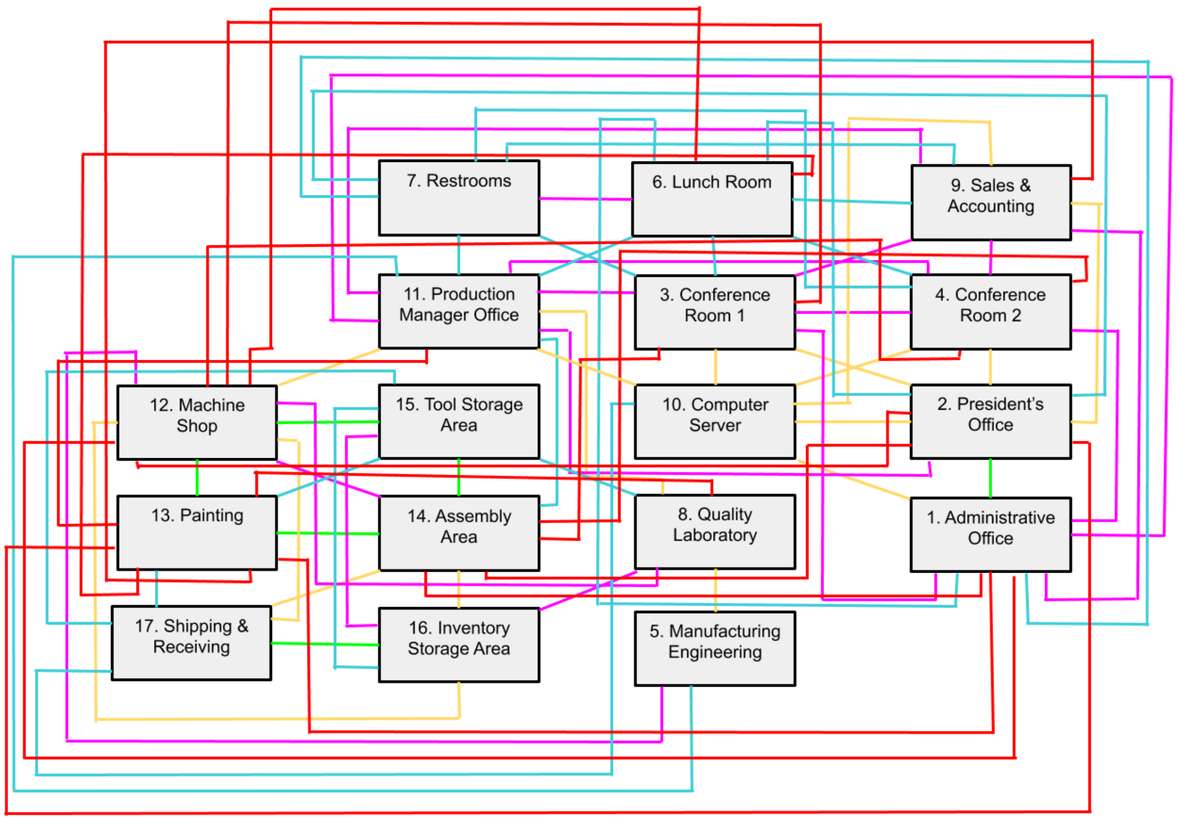
Flow Analysis: A = 4 points, E = 3 points, I = 2 points, O = 1 point, U = 0 points, X = -1 point
Every diagonal is worth that of two points; every right angle is worth that of one; straight lines directly from one machine to the next are allocated that of one point.

A: 4*(1+1+1+1+1+1) = 24 Points
E: 3*(2+2+2+2+2+2+2+2+2+1+1+1+1+1+1+3+3+4) = 93 Points
I: 2*(4+2+3+1+2+3+1+2+4+5+1+1+2+1+3+2+2) = 78 Points
O: 1*(1+2+2+3+1+2+2+1+1+2+3+3+4+3+1+4+2+3+2+1) = 43 Points
U = Negligible
X =-1*(4+5+4+5+4+4+6+3+3+3+6+5+4+3+3) = -62

Measure of Effectiveness, Total Flow: 176 Points

Choose Option 1

Overall Layout Relationship Diagram: Option 2



Flow Analysis: A = 4 points, E = 3 points, I = 2 points, O = 1 point, U = 0 points, X = -1 point
Every diagonal is worth that of two points; every right angle is worth that of one; straight lines directly from one machine to the next are allocated that of one point.

A: 4*(1+1+1+1+1+1) = 24 Points

E: 3*(2+3+2+2+3+1+1+2+1+2+1+2+3+1+1+2) = 87 Points

I: 2*(1+3+2+3+2+1+1+1+3+4+2+3+3+4+2+2+2) = 78 Points

O: 1*(3+2+1+4+2+2+2+1+2+4+1+2+2+3+4+5+1+2+3+4) = 50 Points

U = Negligible

X =-1*(5+2+5+3+3+3+2+6+3+5+4+3+4+4+3) = -55

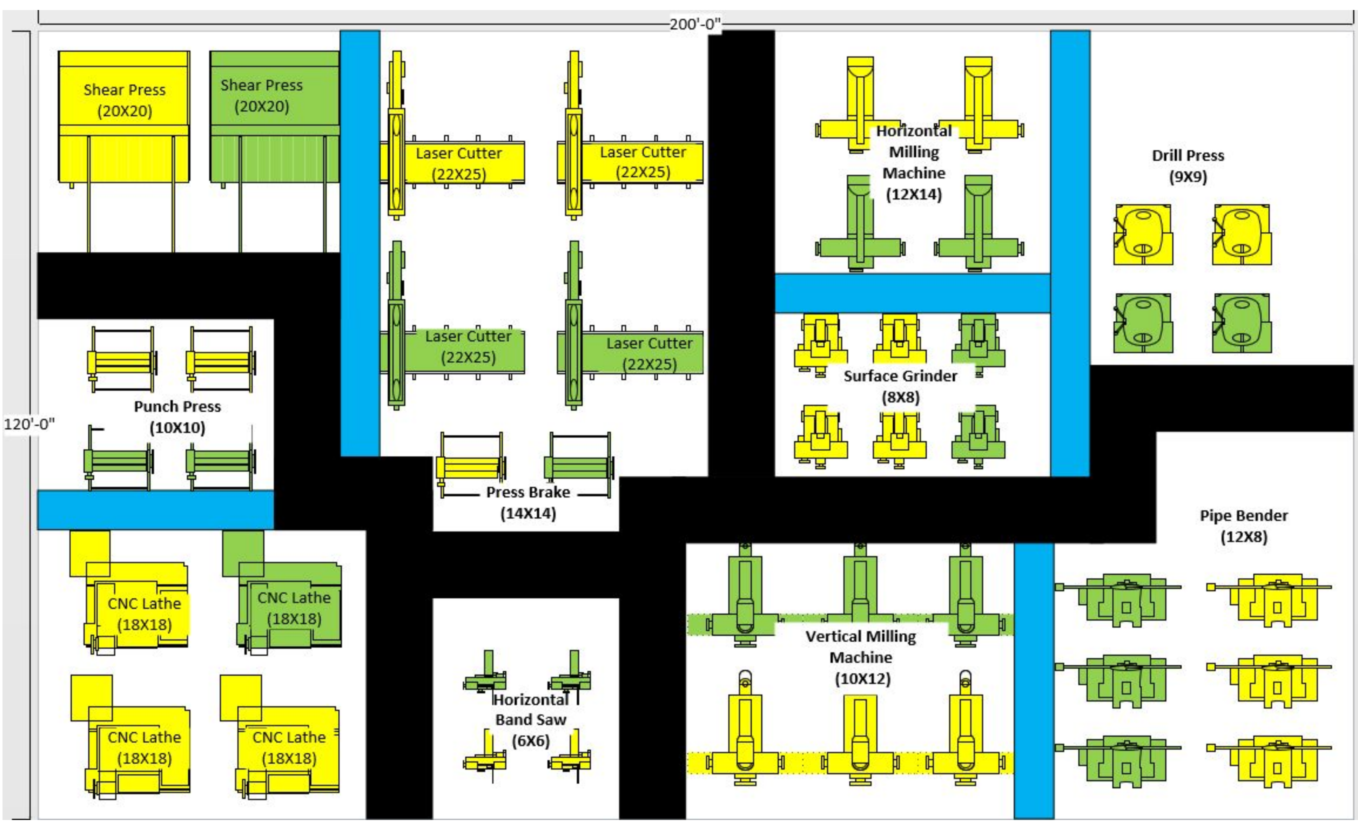
Measure of Effectiveness, Total Flow: 184 Points

Appendix VII: Block Diagrams

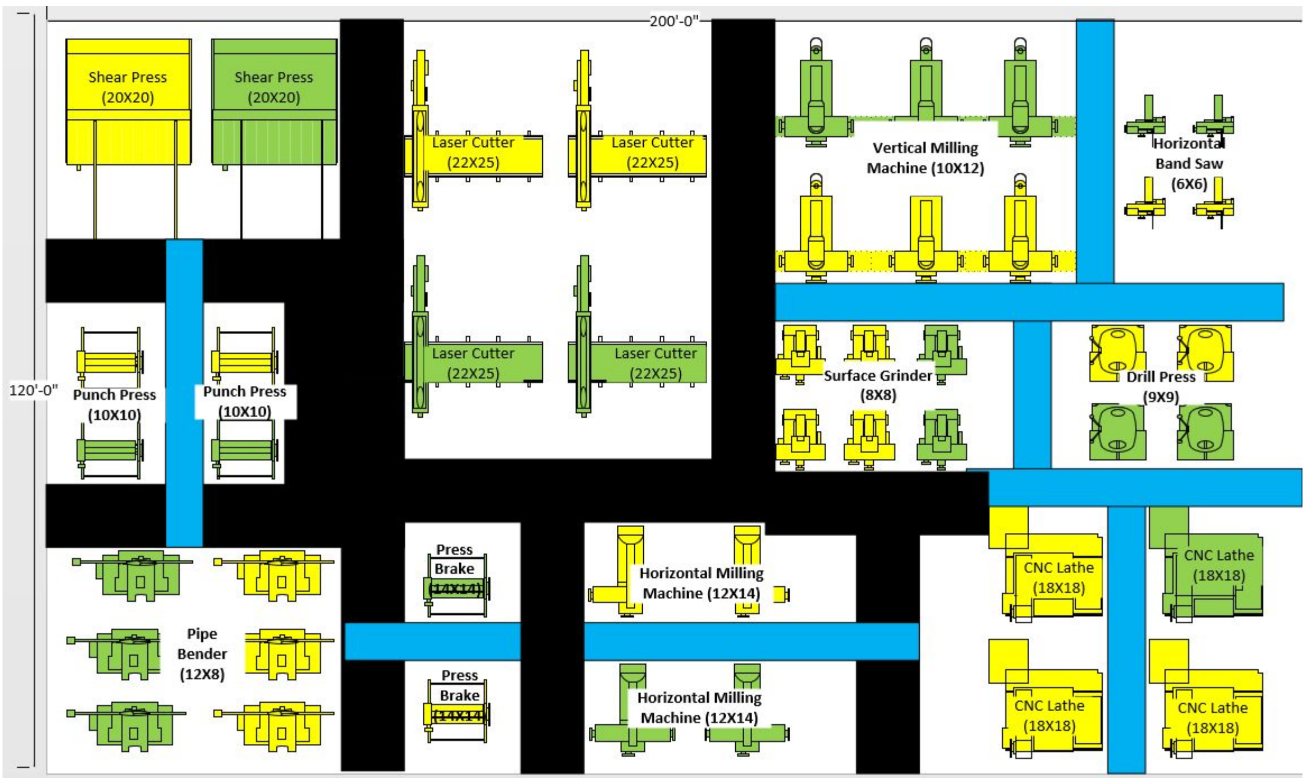
Block Diagram Color Key

Color	Specification
Black Aisle	10 ft. Aisles
Blue Aisle	6 ft. Aisles
Yellow Box	Machines Needed in Year 1
Green Box	Future Machines Needed through Year 10

Machine Shop Block Diagram: Option 1



Machine Shop Block Diagram: Option 2

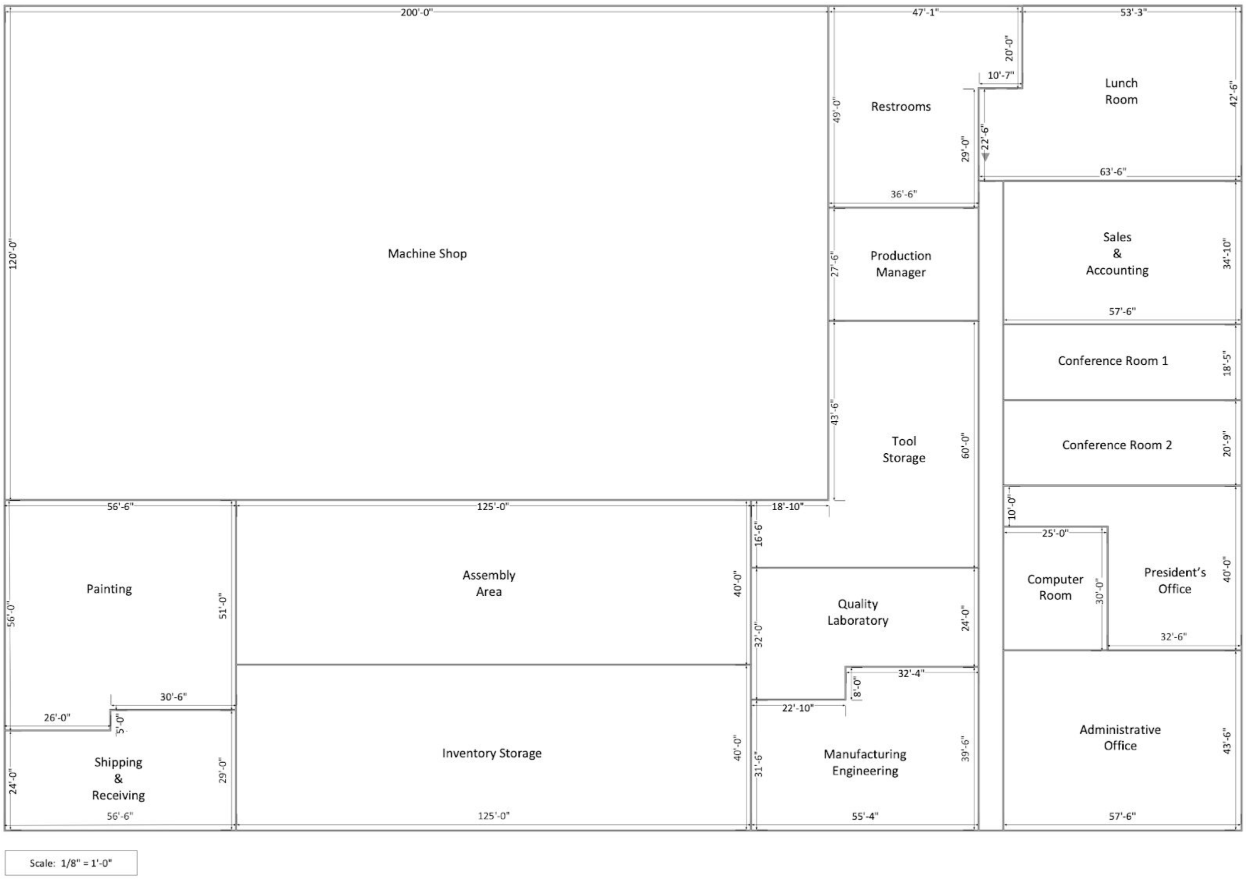


In creating the overall layout block diagrams, the main aspects taken into account were the non-flow considerations. This is because between the overall departments, there is minimal material flow relative to the machine shop. We utilized 6' aisles to connect the different departments and assumed the machine shop, shipping, and inventory have 9' forklift aisles within to accommodate for the transportation of products. The shipping department is located on an exterior wall for minimal transportation from shipping to the outside of the facility.

Overall Layout Block Diagram: Option 1

Overall Department Block Diagram 1	
Department	Dimensions (ft.)
Administrative Office	50' x 35'6" + 44' x 16'6"
President's Office	50' x 28'6" + 3' x 25'
Conference Room 1	53' x 18'6" + 3' x 6'6"
Conference Room 2	50' x 20'
Manufacturing Engineering	44' x 45'6"
Lunch Room	36'3" x 38'6" + 86'3" x 12'11"
Restrooms	57'6" x 32'6" + 21'3" x 9'
Quality Laboratory	50' x 30'
Sales/Accounting	86'3" x 18'7" + 42'3" x 10'
Computer Server	44' x 17' 1"
Production Manager's office	44' x 22'9"
Machine Shop	120' x 200'
Painting	37'9" x 80'
Assembly Area	62'6" x 80'
Tool Storage	57'6" x 38'6" + 36'3" x 9'
Inventory Storage	50' x 100'
Shipping/Receiving	44' x 34' 2"

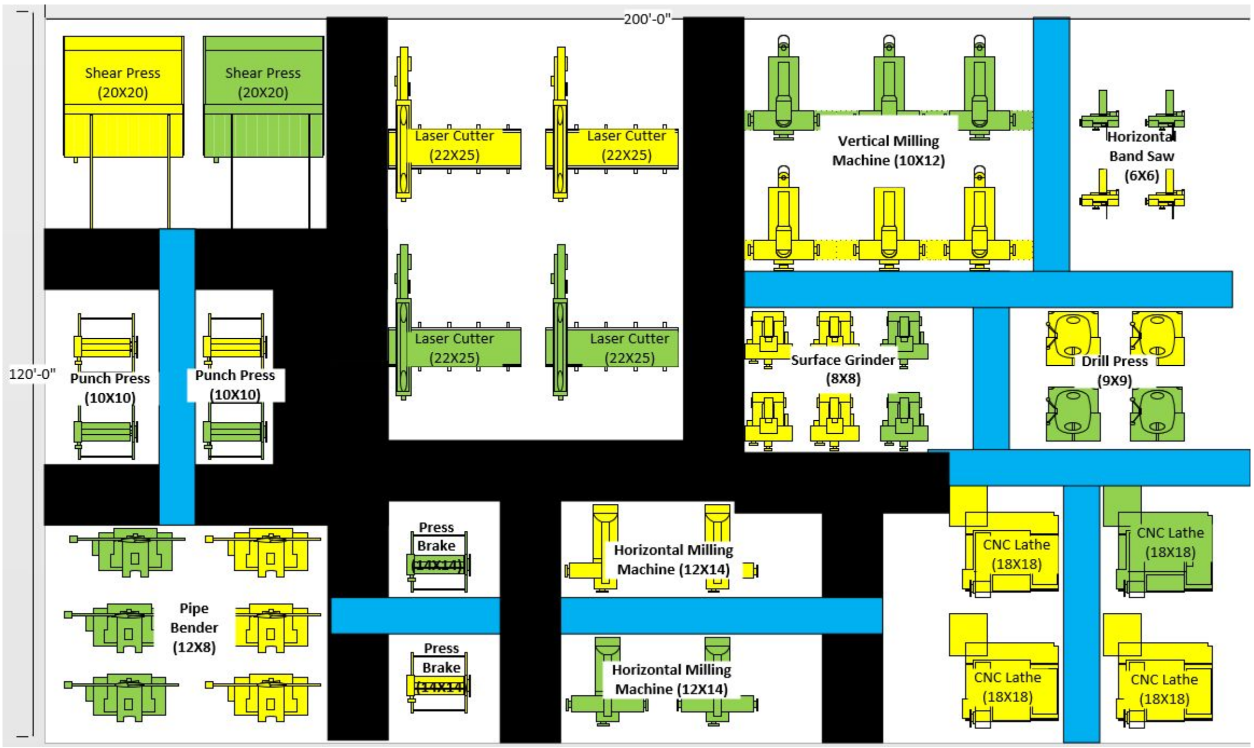
Overall Layout Block Diagram: Option 2



Overall Department Block Diagram 2	
Department	**Dimensions (ft.)**
Administrative Office	57'6" x 43'6"
President's Office	32'6" x 40" + 25' x 10'
Conference Room 1	57'6" x 18'5"
Conference Room 2	57'6" x 20'9"
Manufacturing Engineering	55' 4" x 31'6" + 32'4" x 8'
Lunch Room	53' 3" x 42' 6" + 10' 7" x 22' 6"
Rest Rooms	36'6" x 49' + 10' 7" x 20'
Quality Laboratory	55' 4" x 24' + 22' 10" x 8'
Sales/Accounting	57'6" x 34' 10"
Computer Server	25' x 30'
Production Manager's office	36'6" x 27' 6"
Machine Shop	200' x 120'
Painting	56' 6" x 51' + 26' x 5'
Assembly Area	125' x 40'
Tool Storage	36' 6" x 60' + 18'10" x 16'6"
Inventory Storage	125' x 40'
Shipping/Receiving	56' 6" x 24' + 30' 6" x 5'

Appendix IX: Final Layout

Final Layout: Machine Shop



Final Layout:

Pros

- *Via payback, financial, factor, and sensitivity analysis, this layout optimizes the financial projections of the organization*
- *Groups similar machines close together maximizing efficiency; departmental grouping*
- *Promotes previously mentioned sustainability initiatives*
- *Incorporates non-flow and flow needs*
- *Minimizes undesirable relationships while maximizing desired relationships*

Cons

- *There is only one restroom area in the facility; not optimal and could cause congestion*
- *Expansion may be difficult due to the rigid design*
- *More complex production control*

Appendix X: Factor Analysis

Prioritization Matrices

Factor	Safety	Maintenance	Efficiency	Material Handling	Storage Effectiveness	Total	(%)	Weight
Safety	1	10	5	1	10	27	44.7	10
Maintenance	1/10	1	1/5	1/5	1/5	1.7	2.81	1
Efficiency	1/5	5	1	1/5	1	7.4	12.25	4
Material Handling	1	5	5	1	5	17	28.15	6
Storage Effectiveness	1/10	5	1	1/5	1	7.3	12.09	4

Alternative Evaluation

Factor	Weight	Machine Shop: Block Diagram 1	Machine Shop: Block Diagram 2	Overall Layout: Block Diagram 1	Overall Layout: Block Diagram 2
Safety	10	I / 20	E / 30	I / 20	O / 10
Maintenance	1	E / 3	I / 2	O / 1	A / 4
Efficiency	4	O / 4	A / 16	E / 12	E / 12
Material Handling	6	I / 12	I / 12	E / 18	I / 12
Storage Effectiveness	4	O / 4	O / 4	A / 16	O / 4
Total		43	**64**	**67**	42

Choose Machine Shop: Block Diagram 2

Choose Overall Layout: Block Diagram 1