Tomahawk Metals, Inc.

ISyE 315 Team Design Project

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Team 14

Executive Summary and Recommendation

In this project, our goal is to provide our client Tomahawk Metals Inc with a long term solution for their facility layout to accommodate for potential future sales growths. Through our analysis, we have two recommendations to our client:

- Whether to keep welding operations outsourced:

With an extensive amount of capacity and payback analysis conducted over a ten year horizon with three possible growth rates, keeping welding operations outsourced is believed to be financially better than bringing it on-site. Compared to bringing welding jobs on-site, outsourcing welding is expected to save an estimate of $194,000 over the 10 years.

- An effective production layout for Tomahawk Metals to accommodate for different potential future sales growths while meeting high production standards. The proposed layout design accounts for production and energy efficiency, safety strategies, as well as sustainability initiatives. Detailed layout can be referred to in appendix **A.7.**

Key Features

Here are some key features of out layout design:

- Emergency exit
- Fire distinguisher
- Forklift as mean of transportation
- Straight and fast route for material transportation
- Allocated additional space in the case of increased sales
- All machines are accessible by forklifts

Capacity Analysis

A capacity analysis was conducted to understand the machine requirements to meet growing demand over the next years. Both welding alternatives were evaluated:

1. The current outsourcing welding option
2. On-site welding option.

The facility should address future capacity needs over the next ten years. Analyzing these machine requirements will help develop a practical layout to house all equipment with sufficient space for material handling and safe environments. This analysis will be informative about when each additional machine should be bought over the ten years for the payback analysis to see which option will be financially better for Tomahawk Metals. Sales are currently increasing at 10%, but the capacity analysis was conducted for both options at 5%,10%, and 12%. Using the requirements for 12% in the layout will help ensure that Tomahawk Metals has the equipment needed to meet any higher customer demand in the future. A capacity trigger is set at 90% to provide a 10% capacity cushion and reduce overload on the machines, which could lead to an increase in breakdowns and maintenance costs.

The capacity analysis runs from the current year (Year 0) to the tenth year (Year 10.)

For the on-site welding option, it is considered that TIG and MIG welders are bought in year 1 to meet next year's demand, but the four additional surface grinders are purchased in year 0 due to this 'immediate' need. Capacity was determined by forecasting sales and calculating the equipment requirement to meet the forecast. All machines are currently running at a certain utilization level, but as the growth rate is compounded over the planning horizon, the number of hours each machine should run to meet demand increases. Accordingly, the utilization rate is

calculated every year based on the demand production hours and theoretical hours per machine, and a new machine is purchased whenever the utilization rate exceeds 90%. The total number of machines needed in year ten can be seen in appendix table A.1 and A.2 with table A.5 depicting when each new machine should be purchased.

The capacity analysis provides insight about when purchases should be made and helps conclude that the layout should be designed to house an additional 29 machines by year 10. According to our analysis, the machine requirements after the planning horizon increase, with purchases needed starting in year 11. However, the layout is designed with space to allocate additional machines for at least two years beyond the planning horizon.

Payback Analysis & Financial Analysis

Using the machine requirements for both welding options, a payback analysis can provide information about which option between outsourcing and in-house welding is a more financially favourable option. Given the MARR of 15% and sales growth rate between 5-12% per year, we compared NPV cost of each option side by side.

Outsourced welding outperforms the inhouse welding for NPV cost at 5%, 10%, 12% annual sales growth rates (shown in appendix figure A.6). The favorable option is therefore continuing to outsource welding based on NPV calculations of the cost.

We also calculated the IRR of the in-house welding option and compared it against the MARR value of 15%. For all 5%, 10% and 12% average annual sales growth rates, the IRR values underperformed the MARR value that was given (shown in appendix figure A.7). The IRR values not exceeding the MARR values shows that investments for bringing welding in house is not

justified. Therefore, we conclude that outsourced welding is the more economical option considering the expected annual sales growth rate of 5 - 12% and MARR of 15%.

Sustainability Analysis

Tomahawk Metals should strive to keep up with the triple bottom line and as environmental stewardship is an integral component, the following initiatives will be taken by the firm:

1.Complete ISO 14000 certification : In the upcoming year, an ISO 14000 project will be conducted to follow standards for better environmental impact management. The firm hopes to meet quality standards and comply with regulations that adhere to ISO 14000 specifications.

2.Green Sourcing : Supplier relations will be formed based on if firms are environmental friendly and waste minimizing. Strengthening relations with firms who have the same objectives to create a sustainable way of sourcing and transporting material .

3.Clean Energy: Incorporate the use of solar panels in order to use renewable energy to run the machine shop. Additionally, install more windows to make the most use of natural light. In places where lighting is absolutely necessary, the firm can make use of CFL or LED bulbs.

4. Automation: The firm can make use of motion sensor lights in order to save energy when someone forgets to turn the lights off. Additionally, climate control can be incorporated by the use of thermostats that turn off automatically once the work-day is over. Include an "All off" switch for the office area - this switch will turn off all the lights/fan in the room. If someone is in a hurry, this switch can be useful and can help save time.

Factor Analysis

The factor analysis considers these factors:

- Compatibility with long-term plans: Tomahawk Metals values long-term growth

- Future expansion flexibility: as Tomahawk Metals grows in the coming years, and since they value flexibility in the production process
- Sustainable production: As “sustainability has been an increasingly important part of the business philosophy at Tomahawk Metals,” it is an important factor to consider when analyzing such a decision, given factor (1)
- Total cost: this is an important factor when it comes to any business decision from a monetary perspective
- Ease of supervision/control: in order to retain flexibility and provide maximum satisfaction to their customers, Tomahawk Metals needs to have more supervision and/or control over the production process in its entirety
- Material handling effectiveness: we need to consider how each layout impacts the flow of materials throughout the production process as this could affect the cycle time
- Flow: this depends on the proximity of each department to another
- Space utilization: effective use of space would allow for better flow and faster material handling, thereby aiming to speed up production
- Payback period: both alternatives require a significant investment, hence, we need to consider the payback period using the payback period analysis provided above

Each of these factors were ranked using a prioritization matrix that compared the relative importance of each factor to another, rated them, and then ranked them from 1-10 to derive the final weights for each factor.

From the obtained results of 141 and 146 for overall layout 1 and 2, respectively, there’s a relatively small difference between the two layouts. We need to further evaluate these options

using the aforementioned methods of analyses with respect to the machine shop layout within both layout options as this would provide more clarity on which layout we must select.

Material Handling Systems

Transport Equipment:

Material can be transported from one area to another using electric forklifts. We determined that this was the best method of transportation as it allows for quick transport between all departments, while also meeting Tomahawk Metals' sustainability goals. Additionally, the layout design has an aisle width of 10ft, and the aisles lead to all departments; this makes it much more convenient to use a forklift as the primary mode of transportation.

Positioning Equipment:

- Dock lever: used when moving items in and out of shipping/receiving along with a ball transfer table which can also be added to a conveyer belt to route parts to the next "station."
- Parts feeder: can be used to provide inspection capabilities in the machine shop.
- Industrial robots - if deemed financially feasible and process-accommodating - can be used to provide automation, and more importantly, flexibility in the production process in the long term

Unit Load Formation Equipment:

- Bins/baskets/racks - can be used to store loose, discrete items such as screws, etc., if these are being manually placed by workers to be screwed in automatically
- Stretch-wrapping: for packaging end product (irregularly shaped)

Storage Equipment:

- Unit load AS/RS - can be used in storage to store large palletized starting materials

- Miniload AS/RS - smaller starting materials/miscellaneous materials can be stored here

Both these methods allow for a more automated storage/retrieval system which can also accommodate for future storage needs

Identification and Control Equipment:

- Barcodes are a relatively cost effective and fast method of tracking equipment/materials throughout the production process

Sensitivity Analysis

To evaluate the effectiveness of the layout to different scenarios, a sensitivity analysis was conducted for the following criterias :

1.The effect of cost of make/buy decisions

The make/buy decision is sensitive to the MARR value and the prices of TIG, MIG, Surface Grinders. With the given price of TIG, MIG, and Surface Grinders at $55,000, $45,000, and $25,000, the financially favorable option is to pursue outsourcing welding for a sales growth rate between 5-12% and MARR at 15%. However, if the cost of each equipment is brought down to a certain point, the inhouse welding option becomes more financially favourable. The threshold is described further on table A8 in the appendix. Changes to MARR value can also be a deciding factor for which option is more financially favourable. If the MARR was set below 3%, even with the given price of the welders and surface grinders, the inhouse welding becomes more financially favourable. With this sensitivity analysis in mind, Tomahawk Mentals can navigate to the right option if there are any changes to the factors mentioned above.

2. The effect of the capacity trigger on machine requirements in year 10

A 90% capacity trigger was used in the capacity analysis. In the case that machine breakdowns are frequent and require high maintenance, this trigger could be lowered to 85%. When repeating the capacity analysis for a 12% growth with an 85% capacity trigger, only 6 additional machines are needed in year 10. The layout is designed with such changes in mind and so it will be able to allocate these 6 machines, indicating that the capacity trigger is not a sensitive factor.

1. The effect of a different sales growth rate on space requirements

A 12% growth rate was used to prepare the layout in handling any unexpected increase in demand. However, if planning is done according to current sales projections at 10%, a total of 15 fewer machines are needed to meet demand. This also saves 2795 square feet, which could be used to increase aisle space for better material handling. If layout is designed for 5%, the firm has additional space of 7649 square feet. These differences in requirements and space are significant and if actual demand growth is different from the 12% forecasted growth, the firm will have to endure higher costs to maintain unused machines and prevent them from deteriorating. A 'what if' analysis was also conducted at a 14% growth rate to check if the layout will be viable if designed for an even higher growth rate, however this layout would require an additional 3076 square feet allocated for equipment, which in not feasible due to the need for a non-clustered environment and ample transportation space. This explains that the growth rate is a sensitive factor.

4. The effect of the factor analysis on layout selection.

In order to determine whether or not the factor analysis may change our selection, i.e., our chosen overall layout (option 2), we decided to conduct a sensitivity analysis on the factor

analysis in three ways:

(i) Change the weights (importance) of the factors considered

(ii) Change the importance ratings (A,E,I,O,U) for each of the overall layout options, and

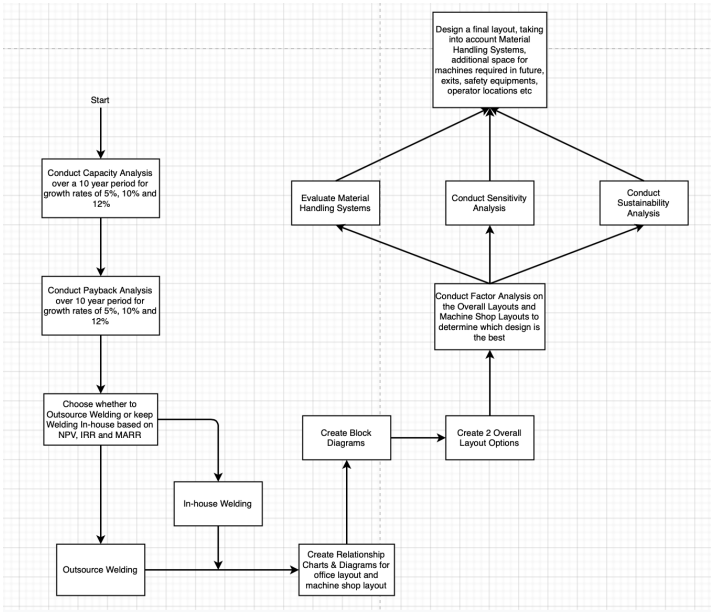
(iii) Change both the weight and the importance ratings for each of the considered layout options

This resulted in the following scores for each of the layouts (as shown in diagram A.22 of the Appendix)

By looking at the graph above, it is evident that the factor analysis is not sensitive in terms of changing the selected layout option; rather, the sensitivity analysis performed shows that the results of the same reinforce our choice to select overall layout option 2. Thus, the factor analysis is not a sensitive factor to our final layout. All tables related to the factor analysis can be found in the Appendix from A.18 to A.21.

Methodology

Below flowchart illustrates the process we took to navigate through the project as a team.



Lessons Learned

Working with incomplete information, making academic assumptions, and navigating through uncertainties are very important skill sets. This project helped give us an example of working as a team in a production setting. By working on this project, we have learned to apply learnings in the classroom to a real life problem that companies like Tomahawk Metals must solve. The process of arriving at the final report with a strong recommendation was not simple. When we didn't have enough facts and data, we made academic assumptions to fill the gaps, and that was a skill that we all had the opportunity to learn. In order to work effectively, we delegated tasks to each of the group members and met regularly to track progress. It was a good opportunity to tackle a case from beginning to end, as we were able to enhance our learnings and apply them to this project throughout the semester. Through good communication and teamwork we were able to tackle problems and help each other out. We not only got the opportunity to learn new softwares such as Excel, Draw.io, Visio etc but also got to implement material that we learnt from ISyE 313. Having finished the project, we are a level more confident to solve real world problems in our career as industrial engineers.

Appendix

A.1 Machine requirements in year 10 for outsourced welding

Machine working hours per year at 90% utilization = 4768 hours

Machine	5%	10%	12%
Shear Press	3	5	5
Laser Cutter	5	7	9
Vertical Milling Machine	5	8	9
Horizontal Milling Machine	5	7	8
Press Brake	5	7	9
Punch Press	6	10	12
CNC Lathe	5	7	8
Surface Grinder	6	9	11
Drill Press	5	7	9
Pipe Bender	5	8	9
Horizontal Band Saw	4	5	6

A.2 Machine requirements in year 10 for on-site welding

Machine	5%	10%	12%
TIG welders	7	11	13
MIG welders	9	13	15
Surface grinders	12	18	22

A.3 Calculations for machine requirements over ten years (outsourced welding)

Machine requirements for ten year period as per 5% growth:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Shear press - 2 at 70%											
Demand Hours	7280	7644	8026	8428	8849	9291	9756	10244	10756	11294	11858
Number of machines req	2	2	2	2	2	2	3	3	3	3	3
Utilization rate	0.700	0.735	0.772	0.810	0.851	0.893	0.625	0.657	0.689	0.724	0.760
Laser Cutter - 3 at 80%											
Demand Hours	12480	13104	13759	14447	15170	15928	16724	17561	18439	19361	20329
Number of machines req	3	3	3	4	4	4	4	4	4	5	5
Utilization rate	0.800	0.840	0.882	0.695	0.729	0.766	0.804	0.844	0.886	0.745	0.782
Vertical Milling - 3 at 84%											
Demand Hours	13104	13759	14447	15170	15928	16724	17561	18439	19361	20329	21345
Number of machines req	3	3	4	4	4	4	4	4	5	5	5
Utilization rate	0.840	0.882	0.695	0.729	0.766	0.804	0.844	0.886	0.745	0.782	0.821
Horizontal Milling - 3 at 75%											
Demand Hours	11700	12285	12899	13544	14221	14932	15679	16463	17286	18151	19058
Number of machines req	3	3	3	3	4	4	4	4	4	4	5
Utilization rate	0.750	0.788	0.827	0.868	0.684	0.718	0.754	0.791	0.831	0.873	0.733
Press Brake - 3 at 80%											
Demand Hours	12480	13104	13759	14447	15170	15928	16724	17561	18439	19361	20329
Number of machines req	3	3	3	4	4	4	4	4	4	5	5
Utilization rate	0.800	0.840	0.882	0.695	0.729	0.766	0.804	0.844	0.886	0.745	0.782
Punch Press - 4 at 82%											
Demand Hours	17056	17909	18804	19744	20732	21768	22857	24000	25199	26459	27782
Number of machines req	4	4	5	5	5	5	5	6	6	6	6
Utilization rate	0.820	0.861	0.723	0.759	0.797	0.837	0.879	0.769	0.808	0.848	0.890
CNC Lathe - 3 at 76%											
Demand Hours	11856	12449	13071	13725	14411	15132	15888	16683	17517	18393	19312
Number of machines req	3	3	3	3	4	4	4	4	4	4	5
Utilization rate	0.760	0.798	0.838	0.880	0.693	0.727	0.764	0.802	0.842	0.884	0.743
Surface Griner - 4 at 78%											
Demand Hours	16224	17035	17887	18781	19720	20706	21742	22829	23970	25169	26427
Number of machines req	4	4	4	5	5	5	5	5	6	6	6
Utilization rate	0.780	0.819	0.860	0.722	0.758	0.796	0.836	0.878	0.768	0.807	0.847
Drill Press - 3 at 80%											
Demand Hours	12480	13104	13759	14447	15170	15928	16724	17561	18439	19361	20329
Number of machines req	3	3	3	4	4	4	4	4	4	5	5
Utilization rate	0.800	0.840	0.882	0.695	0.729	0.766	0.804	0.844	0.886	0.745	0.782
Pipe Bender - 3 at 82%											
Demand Hours	12792	13432	14103	14808	15549	16326	17143	18000	18900	19845	20837
Number of machines req	3	3	4	4	4	4	4	4	5	5	5
Utilization rate	0.820	0.861	0.678	0.712	0.748	0.785	0.824	0.865	0.727	0.763	0.801
Horizontal Band saw - 2 @ 84%											
Demand Hours	8736	9173	9631	10113	10619	11150	11707	12292	12907	13552	14230
Number of machines req	2	2	3	3	3	3	3	3	3	3	4
Utilization rate	0.840	0.882	0.617	0.648	0.681	0.715	0.750	0.788	0.827	0.869	0.684

Machine requirements for ten year period as per 10% growth:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Shear press - 2 at 70%											
Demand Hours	7280	8008	8809	9690	10659	11725	12897	14187	15605	17166	18882
Number of machines req	2	2	2	3	3	3	3	4	4	4	5
Utilization rate	0.700	0.770	0.847	0.621	0.683	0.752	0.827	0.682	0.750	0.825	0.726
Laser Cutter - 3 at 80%	0.700	0.770	0.847	0.621	0.683	0.752	0.827	0.682	0.750	0.825	0.726
Demand Hours	12480	13728	15101	16611	18272	20099	22109	24320	26752	29427	32370
Number of machines req	3	3	4	4	4	5	5	6	6	7	7
Utilization rate	0.800	0.880	0.726	0.799	0.878	0.773	0.850	0.779	0.857	0.808	0.889
Vertical Milling - 3 at 84%											
Demand Hours	13104	14414	15856	17441	19186	21104	23215	25536	28090	30899	33988
Number of machines req	3	4	4	4	5	5	5	6	7	7	8
Utilization rate	0.840	0.693	0.762	0.839	0.738	0.812	0.893	0.818	0.772	0.849	0.817
Horizontal Milling - 3 at 75%											
Demand Hours	11700	12870	14157	15573	17130	18843	20727	22800	25080	27588	30347
Number of machines req	3	3	4	4	4	5	5	5	6	6	7
Utilization rate	0.750	0.825	0.681	0.749	0.824	0.725	0.797	0.877	0.804	0.884	0.834
Press Brake - 3 at 80%											
Demand Hours	12480	13728	15101	16611	18272	20099	22109	24320	26752	29427	32370
Number of machines req	3	3	4	4	4	5	5	6	6	7	7
Utilization rate	0.800	0.880	0.726	0.799	0.878	0.773	0.850	0.779	0.857	0.808	0.889
Punch Press - 4 at 82%											
Demand Hours	17056	18762	20638	22702	24972	27469	30216	33237	36561	40217	44239
Number of machines req	4	5	5	5	6	6	7	8	8	9	10
Utilization rate	0.820	0.722	0.794	0.873	0.800	0.880	0.830	0.799	0.879	0.859	0.851
CNC Lathe - 3 at 76%											
Demand Hours	11856	13042	14346	15780	17358	19094	21004	23104	25414	27956	30751
Number of machines req	3	3	4	4	4	5	5	5	6	6	7
Utilization rate	0.760	0.836	0.690	0.759	0.835	0.734	0.808	0.889	0.815	0.896	0.845
Surface Griner - 4 at 78%											
Demand Hours	16224	17846	19631	21594	23754	26129	28742	31616	34778	38255	42081
Number of machines req	4	4	5	5	6	6	7	7	8	9	9
Utilization rate	0.780	0.858	0.755	0.831	0.761	0.837	0.790	0.869	0.836	0.817	0.899
Drill Press - 3 at 80%											
Demand Hours	12480	13728	15101	16611	18272	20099	22109	24320	26752	29427	32370
Number of machines req	3	3	4	4	4	5	5	6	6	7	7
Utilization rate	0.800	0.880	0.726	0.799	0.878	0.773	0.850	0.779	0.857	0.808	0.889
Pipe Bender - 3 at 82%											
Demand Hours	12792	14071	15478	17026	18729	20602	22662	24928	27421	30163	33179
Number of machines req	3	4	4	4	5	5	5	6	6	7	8
Utilization rate	0.820	0.677	0.744	0.819	0.720	0.792	0.872	0.799	0.879	0.829	0.798
Horizontal Band saw - 2 @ 84%											
Demand Hours	8736	9610	10571	11628	12790	14069	15476	17024	18726	20599	22659
Number of machines req	2	3	3	3	3	4	4	4	5	5	5
Utilization rate	0.840	0.616	0.678	0.745	0.820	0.676	0.744	0.818	0.720	0.792	0.871

Machine requirements for ten year period as per 12% growth:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Shear press - 2 at 70%											
Demand Hours	7280	8154	9132	10228	11455	12830	14369	16094	18025	20188	22611
Number of machines req	2	2	2	3	3	3	4	4	4	5	5
Utilization rate	0.700	0.784	0.878	0.656	0.734	0.822	0.691	0.774	0.867	0.776	0.870
Laser Cutter - 3 at 80%	0.700	0.784	0.878	0.656	0.734	0.822	0.691	0.774	0.867	0.776	0.870
Demand Hours	12480	13978	15655	17534	19638	21994	24633	27589	30900	34608	38761
Number of machines req	3	3	4	4	5	5	6	6	7	8	9
Utilization rate	0.800	0.896	0.753	0.843	0.755	0.846	0.790	0.884	0.849	0.832	0.828
Vertical Milling - 3 at 84%											
Demand Hours	13104	14676	16438	18410	20619	23094	25865	28969	32445	36338	40699
Number of machines req	3	4	4	4	5	5	6	7	7	8	9
Utilization rate	0.840	0.706	0.790	0.885	0.793	0.888	0.829	0.796	0.891	0.874	0.870
Horizontal Milling - 3 at 75%											
Demand Hours	11700	13104	14676	16438	18410	20619	23094	25865	28969	32445	36338
Number of machines req	3	3	4	4	4	5	5	6	7	7	8
Utilization rate	0.750	0.840	0.706	0.790	0.885	0.793	0.888	0.829	0.796	0.891	0.874
Press Brake - 3 at 80%											
Demand Hours	12480	13978	15655	17534	19638	21994	24633	27589	30900	34608	38761
Number of machines req	3	3	4	4	5	5	6	6	7	8	9
Utilization rate	0.800	0.896	0.753	0.843	0.755	0.846	0.790	0.884	0.849	0.832	0.828
Punch Press - 4 at 82%											
Demand Hours	17056	19103	21395	23962	26838	30058	33666	37705	42230	47298	52973
Number of machines req	4	5	5	6	6	7	8	9	10	11	12
Utilization rate	0.820	0.735	0.823	0.768	0.860	0.826	0.809	0.806	0.812	0.827	0.849
CNC Lathe - 3 at 76%											
Demand Hours	11856	13279	14872	16657	18656	20894	23402	26210	29355	32878	36823
Number of machines req	3	3	4	4	4	5	6	6	7	8	8
Utilization rate	0.760	0.851	0.715	0.801	0.897	0.804	0.750	0.840	0.806	0.790	0.885
Surface Griner - 4 at 78%											
Demand Hours	16224	18171	20351	22794	25529	28592	32023	35866	40170	44990	50389
Number of machines req	4	4	5	5	6	7	7	8	9	10	11
Utilization rate	0.780	0.874	0.783	0.877	0.818	0.786	0.880	0.862	0.858	0.865	0.881
Drill Press - 3 at 80%											
Demand Hours	12480	13978	15655	17534	19638	21994	24633	27589	30900	34608	38761
Number of machines req	3	3	4	4	5	5	6	6	7	8	9
Utilization rate	0.800	0.896	0.753	0.843	0.755	0.846	0.790	0.884	0.849	0.832	0.828
Pipe Bender - 3 at 82%											
Demand Hours	12792	14327	16046	17972	20128	22544	25249	28279	31673	35473	39730
Number of machines req	3	4	4	4	5	5	6	7	7	8	9
Utilization rate	0.820	0.689	0.771	0.864	0.774	0.867	0.809	0.777	0.870	0.853	0.849
Horizontal Band saw - 2 @ 84%											
Demand Hours	8736	9784	10958	12273	13746	15396	17243	19313	21630	24226	27133
Number of machines req	2	3	3	3	3	4	4	5	5	6	6
Utilization rate	0.840	0.627	0.702	0.787	0.881	0.740	0.829	0.743	0.832	0.776	0.870

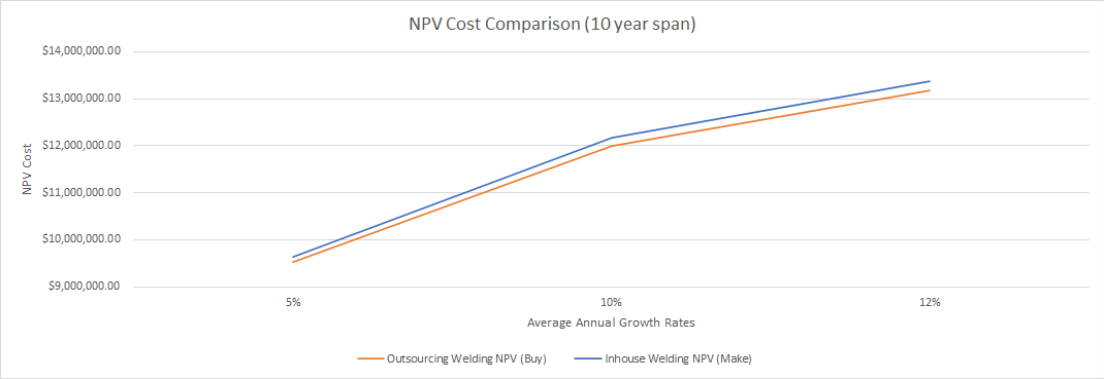
A.5 Calculations for welders and overall surface grinders for on-site welding (for 5%, 10%, 12%)

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
TIG Welders - 5 at 80%											
Demand Hours	N/A	20800	21840	22932	24079	25283	26547	27874	29268	30731	32268
Machines needed	N/A	5	5	5	6	6	6	6	7	7	7
Utilization	N/A	0.800	0.840	0.882	0.772	0.810	0.851	0.893	0.804	0.844	0.886
MIG Welders - 6 at 80%											
Demand Hours	N/A	24960	26208	27518	28894	30339	31856	33449	35121	36877	38721
Machines needed	N/A	6	6	6	7	7	7	8	8	8	9
Utilization	N/A	0.800	0.840	0.882	0.794	0.833	0.875	0.804	0.844	0.886	0.827
Purchasing additional Surface Grinder											
Surface Griner - 4 at 78%											
Demand Hours	32448	34070	35774	37563	39441	41413	43483	45658	47940	50337	52854
Number of machines req	7	8	8	9	9	9	10	10	11	11	12
Utilization rate		0.819	0.860	0.803	0.843	0.885	0.836	0.878	0.838	0.880	0.847

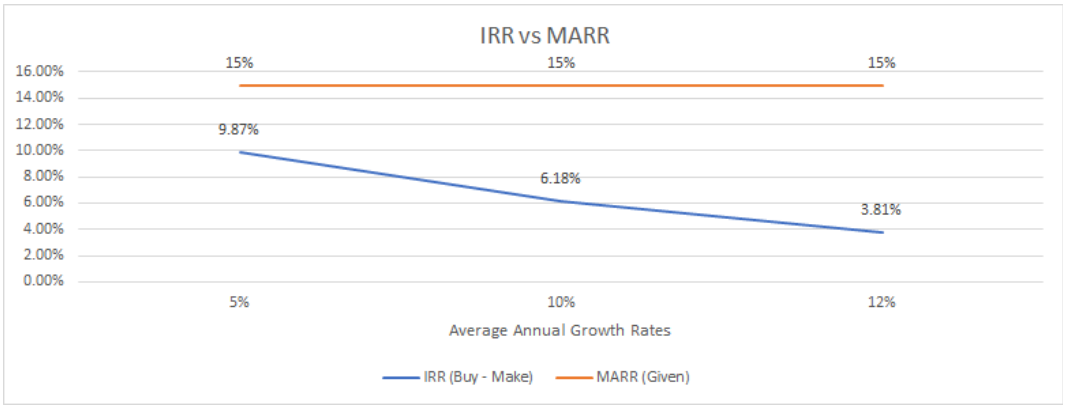
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
TIG Welders - 5 at 85%											
Demand Hours	N/A	20800	22880	25168	27685	30453	33499	36848	40533	44587	49045
Machines needed	N/A	5	5	6	6	7	8	8	9	10	11
Utilization	N/A	0.800	0.880	0.807	0.887	0.837	0.805	0.886	0.866	0.857	0.857
MIG Welders - 6 at 85%											
Demand Hours	N/A	24960	27456	30202	33222	36544	40198	44218	48640	53504	58854
Machines needed	N/A	6	6	7	8	8	9	10	11	12	13
Utilization	N/A	0.800	0.880	0.830	0.799	0.878	0.859	0.850	0.850	0.857	0.871
Purchasing additional Surface Grinder											
Surface Griner - 4 at 78%											
Demand Hours	32448	35693	39262	43188	47507	52258	57484	63232	69555	76511	84162
Number of machines req	7	8	9	10	11	12	13	14	15	17	18
Utilization rate		0.858	0.839	0.831	0.831	0.837	0.850	0.869	0.892	0.866	0.899

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
TIG Welders - 5 at 85%											
Demand Hours	N/A	20800	23296	26092	29223	32729	36657	41056	45982	51500	57680
Machines needed	N/A	5	5	6	7	7	8	9	10	12	13
Utilization	N/A	0.800	0.896	0.836	0.803	0.899	0.881	0.877	0.884	0.825	0.853
MIG Welders - 6 at 85%											
Demand Hours	N/A	24960	27955	31310	35067	39275	43988	49267	55179	61800	69216
Machines needed	N/A	6	6	7	8	9	10	11	12	14	15
Utilization	N/A	0.800	0.896	0.860	0.843	0.839	0.846	0.861	0.884	0.849	0.887
Purchasing additional Surface Grinder											
Surface Griner - 4 at 78%											
Demand Hours	32448	36342	40703	45587	51058	57184	64047	71732	80340	89981	100779
Number of machines req	7	8	9	10	11	13	14	16	18	20	22
Utilization rate		0.874	0.870	0.877	0.893	0.846	0.880	0.862	0.858	0.865	0.881

A.6 NPV cost comparison between outsourcing weling and inhouse welding depending on the annual growth rate of the company.



A.7 IRR values calculated through comparing make vs buy options, and those values of IRR (in blue) are compared with the given MARR value (in orange) .



A.8 Payback Sensitivity analysis.

Equiptment	Expected Inhouse Equiptment Cost	What-if Cost -1	What-if Cost -2	What-if Cost -3
TIG	$ 55,000.00	$ 50,000.00	$ 45,000.00	$ 40,000.00
MIG	$ 45,000.00	$ 40,000.00	$ 35,000.00	$ 30,000.00
Surface Grinders	$ 25,000.00	$ 20,000.00	$ 15,000.00	$ 10,000.00

Sales Growth Rate	Expected Inhouse Equptment Cost	IRR	What-if Cost -1	IRR	What-if Cost -2	IRR	What-if Cost -3	IRR
5% (Inhouse)	$ 9,625,376.51	9.87%	$ 9,538,763.12	14.70%	$ 9,452,149.74	20.79%	$ 9,365,536.35	29.04%
5% (Oursourcing)	$ 9,533,900.08		$ 9,533,900.08		$ 9,533,900.08		$ 9,533,900.08	
10% (Inhouse)	$ 12,160,550.21	6.18%	$ 12,043,850.53	12.41%	$ 11,927,150.85	19.88%	$ 11,810,451.18	29.65%
10% (Outsourcing)	$ 12,000,496.84		$ 12,000,496.84		$ 12,000,496.84		$ 12,000,496.84	
12% (Inhouse)	$ 13,375,350.92	3.81%	$ 13,243,834.16	11.17%	$ 13,112,317.41	19.61%	$ 12,980,800.65	30.31%
12% (Outsourcing)	$ 13,181,219.20		$ 13,181,219.20		$ 13,181,219.20		$ 13,181,219.20	

A.9 Capacity trigger and growth rate sensitivity analysis

Square feet requirement

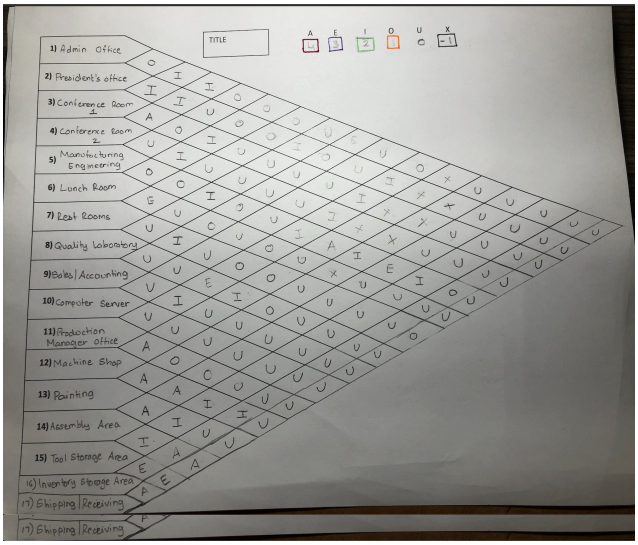
Machine	5%	10%	12%	14%
Shear Press	1080	1800	1800	2160
Laser Cutter	2420	3388	4356	4840
Vertical Milling Machine	1125	1800	2025	2475
Horizontal Milling Machine	840	1176	1344	1680
Press Brake	1280	1792	2304	2560
Punch Press	600	1000	1200	1400
CNC Lathe	1120	1568	1792	2240
Surface Grinder	486	729	891	1053
Drill Press	320	448	576	640
Pipe Bender	540	864	972	1188
Horizontal Band Saw	400	500	600	700
Total space requirement	10211	15065	17860	20936

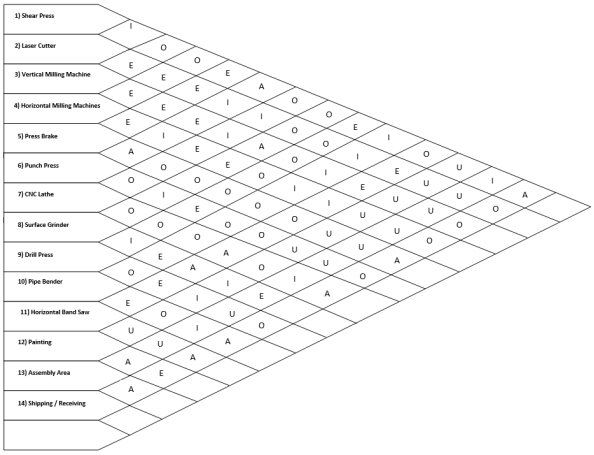
Additional machines

Machine	85% utilization	Extra needed
Shear Press	6	1
Laser Cutter	9	0
Vertical Milling Machine	10	1
Horizontal Milling Machine	9	1
Press Brake	9	0
Punch Press	12	0
CNC Lathe	9	1
Surface Grinder	12	1
Drill Press	9	0
Pipe Bender	9	0
Horizontal Band Saw	7	1

A.10 Relationship chart

Overall layout of office space

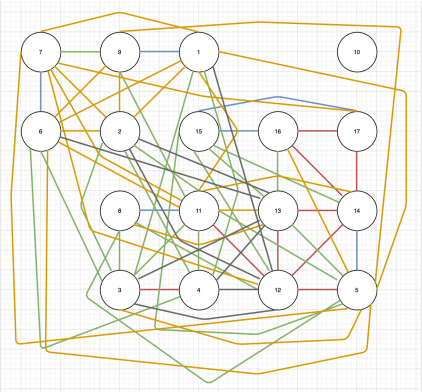




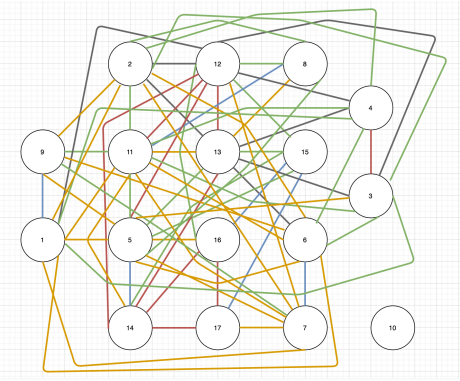
Outsourced Welding

A.11 Relationship Diagram

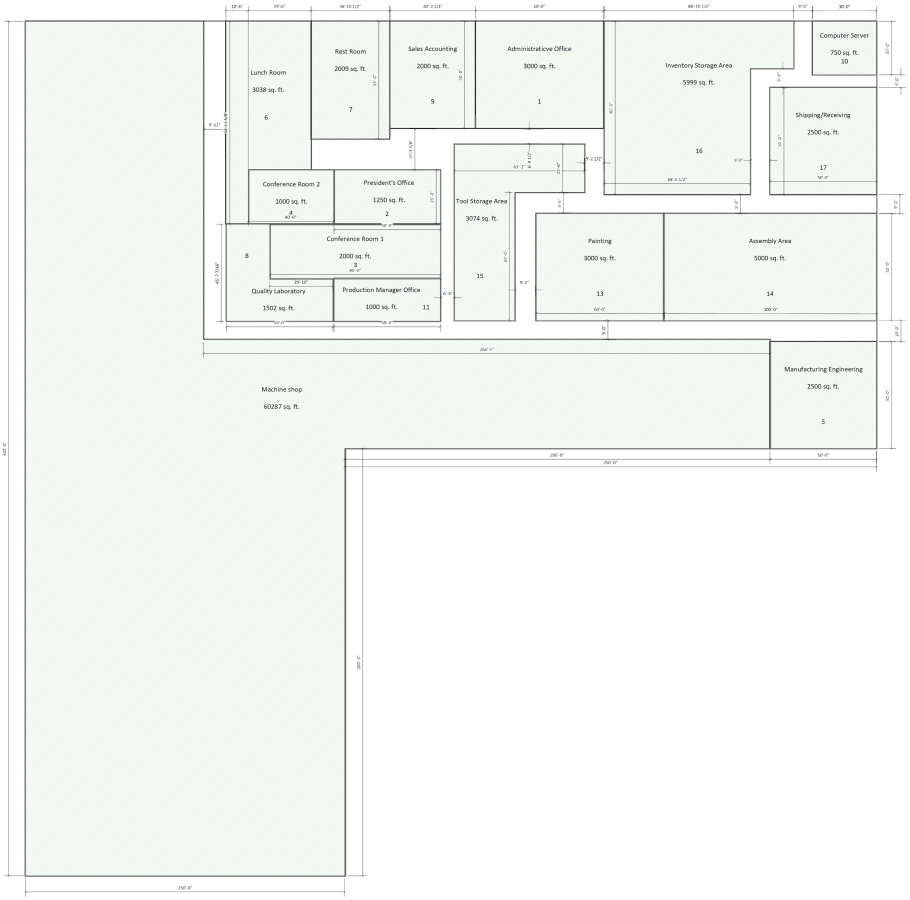
Overall Layout Option 1



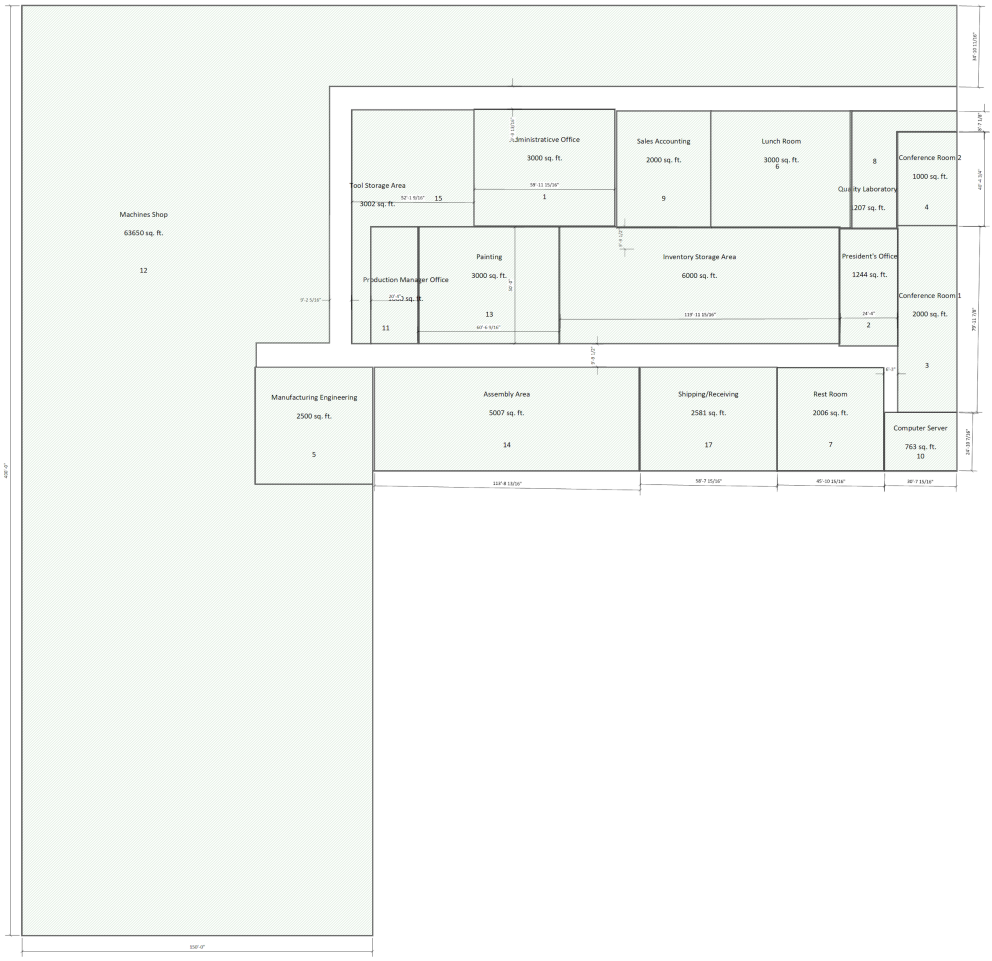
Overall Layout Option 2



A.12 Block Diagram for Overall Layout Option 1

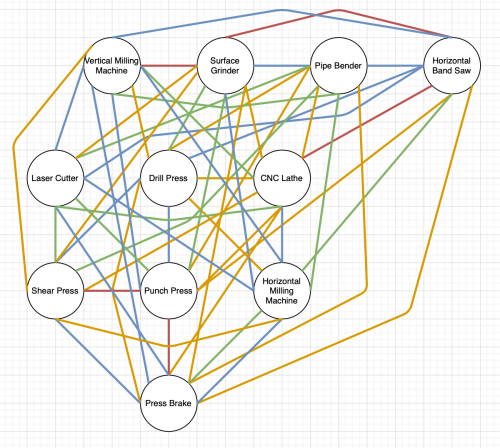


A.13 Block Diagram for Overall Layout Option 2

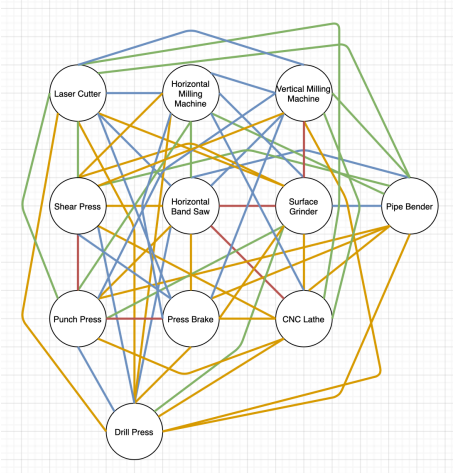


A.14 Relationship Diagram

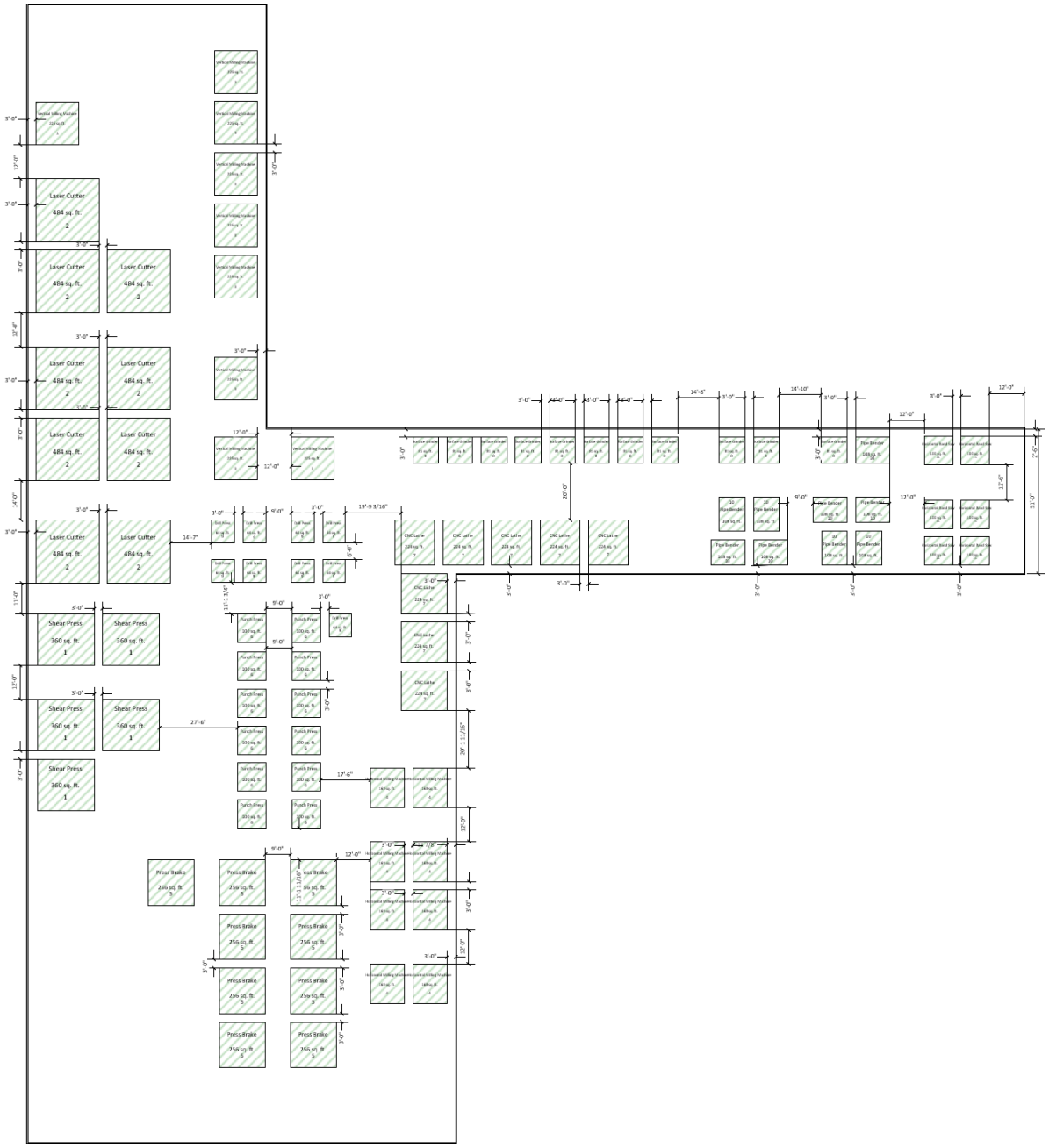
Machine Shop Layout Option 1



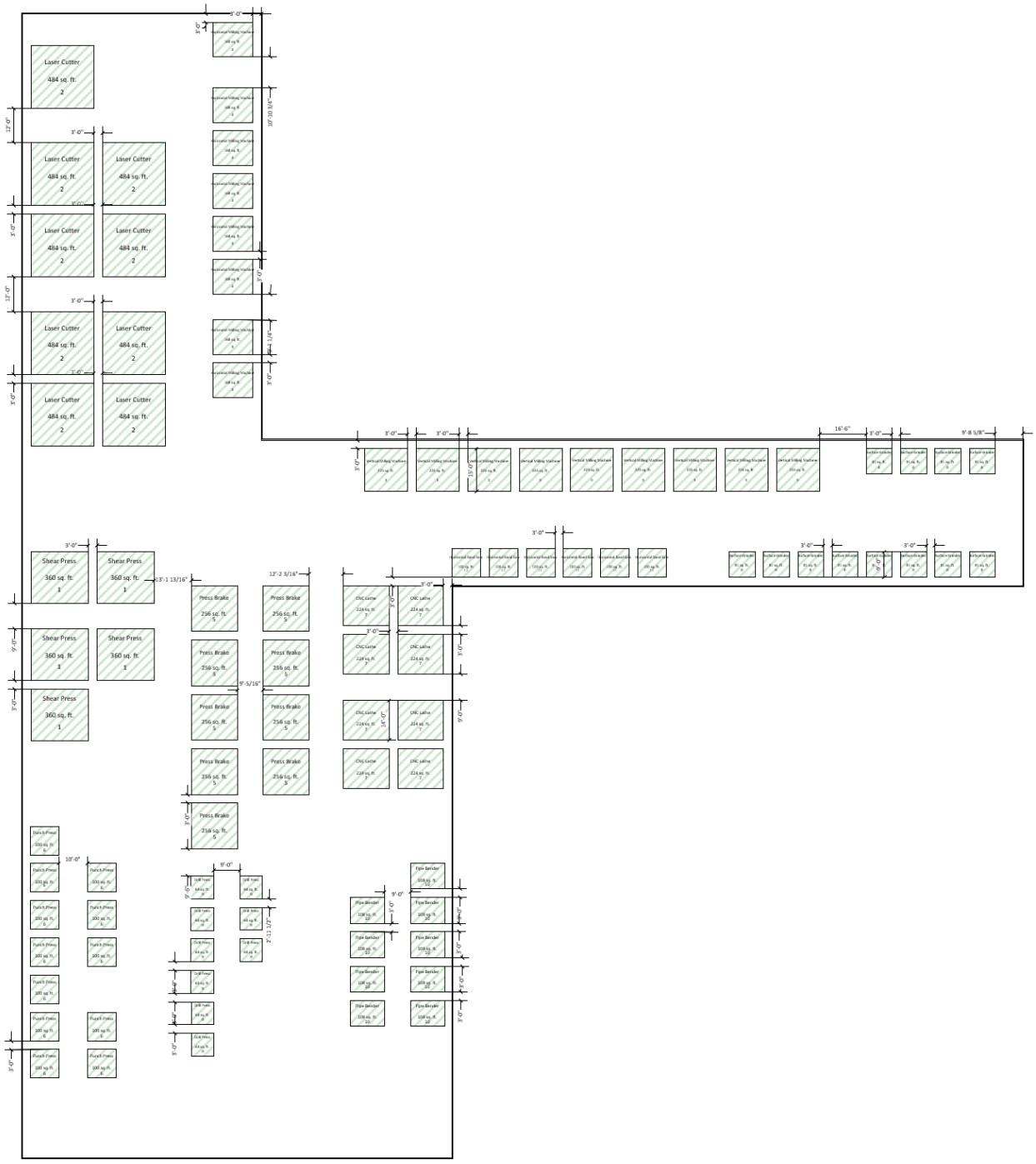
Machine Shop Layout Option 2



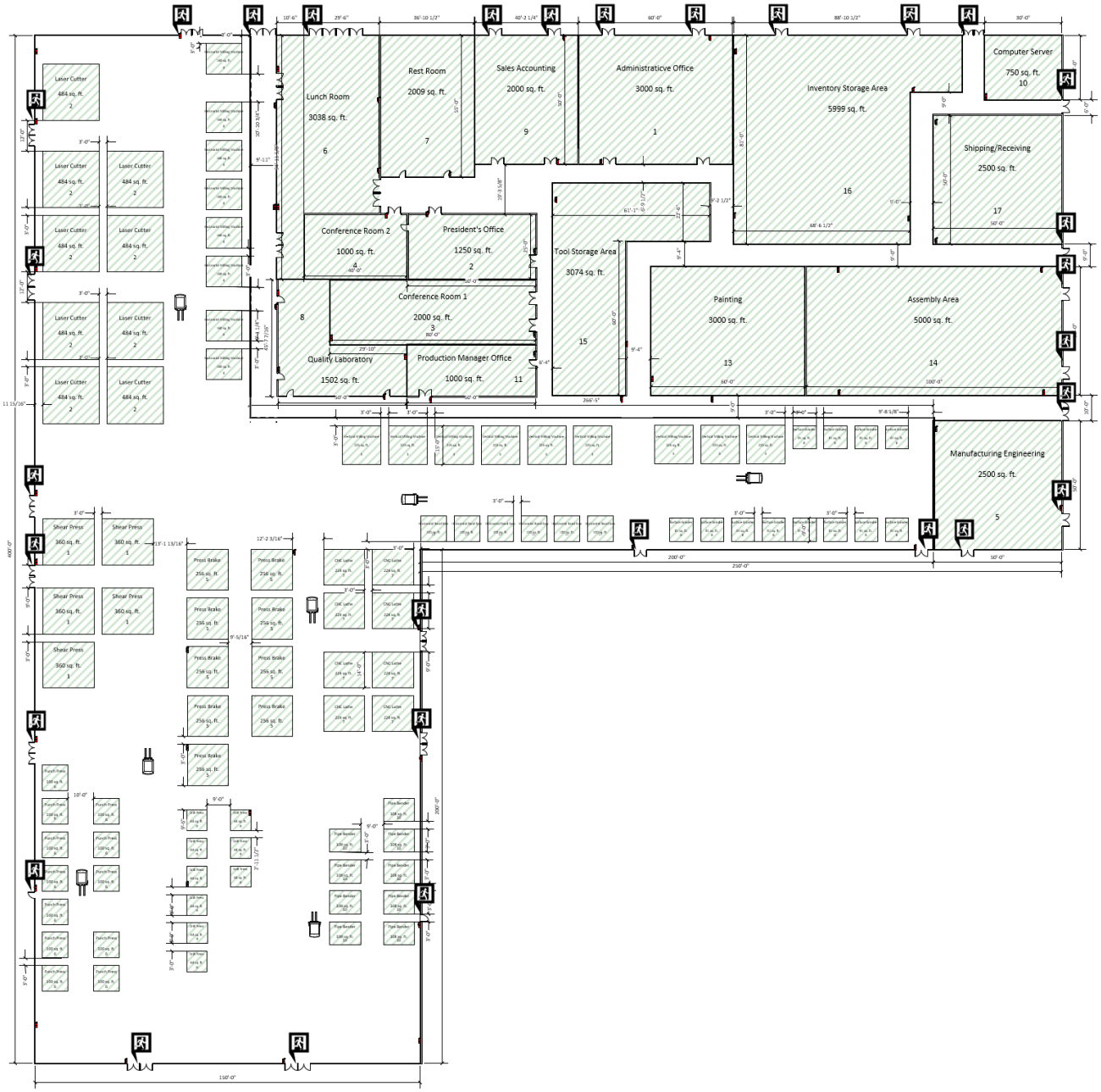
A.15 Block Diagram for Machine Shop Layout Option 1



A.16 Block Diagram for Machine Shop Layout Option 2



A.17 Overall layout of production with 12% growth rate and Welding operations outsourced



A.18 Factor Analysis - Main Result

		Weighted Rating	
Factor	**Weight**	**Option 1**	**Option 2**
1 Compatibility with long-term plans	10	20	20
2 Future expansion flexibility	9	18	36
3 Sustainable production	9	18	18
4 Total cost	8	24	16
5 Ease of supervision/control	8	24	32
6 Material handling effectiveness	6	18	12
7 Flow	4	12	8
8 Space utilization	2	6	4
9 Payback period	1	1	0
Total		141	146

A.19 Factor Analysis - Sensitivity Analysis Result 1

Sensitivity Analysis 1 Result		**Ratings and Weighted Ratings**	
Factor/Consideration	**Weight**	**A**	**B**
1 Compatibility with long-term plans	10	I 20	I 20
2 Total cost	9	I 18	A 36
3 Sustainable production	9	I 18	I 18
4 Future Expansion Flexibility	8	E 24	I 16
5 Ease of supervision/control	8	E 24	A 32
6 Material handling effectiveness	7	E 21	I 14
7 Flow	4	E 12	I 8
8 Space utilization	2	E 6	I 4
9 Payback period	1	O 1	U 0
Total		142	148

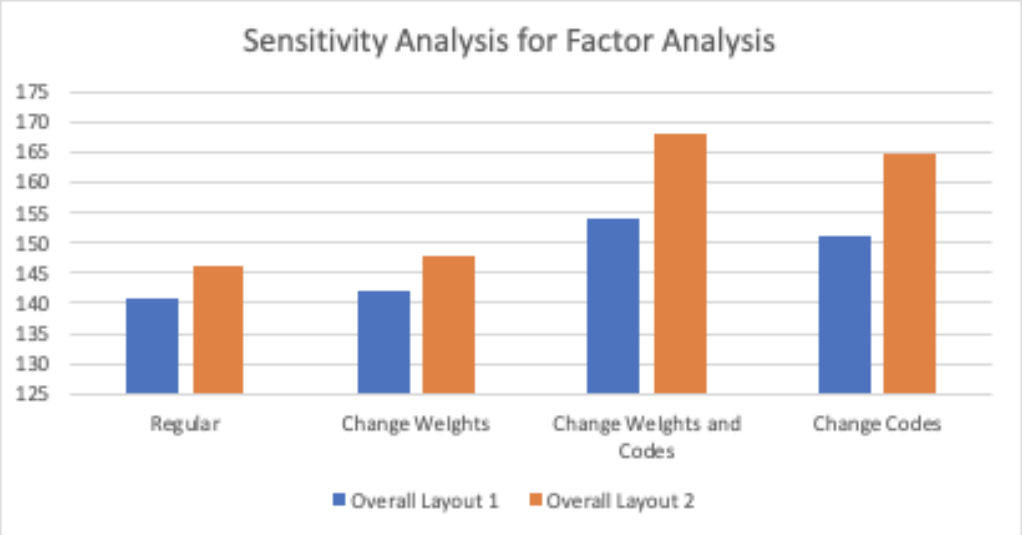
A.20 Factor Analysis - Sensitivity Analysis Result 2

Sensitivity Analysis 2 Result		**Ratings and Weighted Ratings**	
Factor/Consideration	**Weight**	**A**	**B**
1 Compatibility with long-term plans	10	E 30	E 30
2 Total cost	9	I 18	A 36
3 Sustainable production	9	I 18	I 18
4 Future Expansion Flexibility	8	E 24	I 16
5 Ease of supervision/control	8	E 24	A 32
6 Material handling effectiveness	7	E 21	E 21
7 Flow	4	E 12	I 8
8 Space utilization	2	E 6	E 6
9 Payback period	1	O 1	O 1
Total		154	168

A.21 Factor Analysis - Sensitivity Analysis Result 3

Sensitivity Analysis 3 Result		Ratings and Weighted Ratings	
Factor/Consideration	**Weight**	**A**	**B**
1 Compatibility with long-term plans	10	E 30	E 30
2 Future expansion flexibility	9	I 18	A 36
3 Sustainable production	9	I 18	I 18
4 Total cost	8	E 24	I 16
5 Ease of supervision/control	8	E 24	A 32
6 Material handling effectiveness	6	E 18	E 18
7 Flow	4	E 12	I 8
8 Space utilization	2	E 6	E 6
9 Payback period	1	O 1	O 1
Total		151	165

A.22 The effect of changing weights and importance ratings on the factor analysis results



A.23 NPV calculations of payback analysis (12% growth)

	Outsourced welding (12% growth)		
Year	Cost / Unit	Volumn	Cost / Year
0	$38	40000	
1	$38	44800	$1,702,400
2	$38	50176	$1,906,688
3	$38	56197.12	$2,135,491
4	$38	62940.7744	$2,391,749
5	$38	70493.66733	$2,678,759
6	$38	78952.90741	$3,000,210
7	$38	88427.2563	$3,360,236
8	$38	99038.52705	$3,763,464
9	$38	110923.1503	$4,215,080
10	$38	124233.9283	$4,720,889
		NPV:	**$13,181,219.20**

	Inhouse welding (12% growth)			
Year	Cost / Unit	Volumn	Equiptment Cost	Cost / Year
0	$35.50	40000	100000	100000
1	$35.50	44800	545000	$2,135,400.00
2	$35.50	50176	25000	$1,806,248.00
3	$35.50	56197.12	125000	$2,119,997.76
4	$35.50	62940.7744	125000	$2,359,397.49
5	$35.50	70493.66733	95000	$2,597,525.19
6	$35.50	78952.90741	125000	$2,927,828.21
7	$35.50	88427.2563	150000	$3,289,167.60
8	$35.50	99038.52705	150000	$3,665,867.71
9	$35.50	110923.1503	250000	$4,187,771.84
10	$35.50	124233.9283	150000	$4,560,304.46
			NPV:	**$13,375,350.92**

A.24 IRR calculation of make vs buy (12% growth)

Year	Marginal Profit
0	($100,000.00)
1	($433,000.00)
2	$100,440.00
3	$15,492.80
4	$32,351.94
5	$81,234.17
6	$72,382.27
7	$71,068.14
8	$97,596.32
9	$27,307.88
10	$160,584.82
IRR:	**3.81%**