

RELOCATION OF SHEET METAL DEPARTMENT FOR C & D ZODIAC--SANTA MARIA, CA

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EXECUTIVE SUMMARY
RELOCATION OF SHEET METAL DEPARTMENT
FOR C & D ZODIAC--SANTA MARIA, CA

C & D Zodiac recently expanded their Santa Maria facility to include a new building in which they will be relocating their sheet metal department. There are limited or no records of the current layout, machinery, or process which are assessed in this report. The current process and layout were mapped out by using process flow, layout maps, and time studies. The operation was thoroughly understood by interviewing machinists, managers, planners, and industrial engineers. These findings were constructed into relationship-diagrams and workspace requirements were developed. From these numbers a systematic layout planning technique was employed, which yielded multiple proposed layouts. Each layout was evaluated by the criteria of material travel distance, worker movement, and footprint size. A final layout selection was then made and mocked in Solidworks and in a physical model. This layout will reduce the footprint of the department by 5638 sq ft. Value added distance will be reduced by 168.1 ft from the current layout to the proposed layout, and non-value added distance will be reduced by 204.1 ft. Total distance travelled for the entire process will be reduced by 393.2 ft. Recommendations to improve material flow and reduce process time were made. Implementing these suggestions into the proposed layout will create a greater material flow within a smaller area saving the operation time and money.

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INTRODUCTION AND BACKGROUND

C & D Zodiac is a rapidly expanding producer of aerospace parts. Recently, C & D Zodiac expanded their Santa Maria facility to include a new building. The new building will be shared by a variety of departments, including sheet metal. There are limited or no records of the current layout, machinery, or process which will need to be assessed. When moving the sheet metal department, C & D would like to maximize the production capacity and flow of materials. In this project, the following objectives should be met:

- Accurately document the current processes
- Prepare a proposed layout for the sheet metal department in the new building
- Compare and contrast the current layout and proposed layout to demonstrate benefits and limitations

In order to meet these objectives and solve the problem, a variety of steps need to be accomplished, including :

- Create a footprint of the current layout
- Conduct time studies to adequately understand the current process and decide on whether the line is balanced line
- Evaluate department relations
- Combine information to develop necessary workstation footprints
- Use systematic layout process model to develop potential solutions
- Employ metric to evaluate and decide on a proposed layout

In the completion of this project, the following deliverables will be provided:

- Final Report
- Physical Model built to scale
- Presentation

This report has been laid out such that the design and initial steps will be presented first. The design section will encompass all steps leading up to the initial layout proposals. The methodology section will then describe how each of the design proposals was evaluated. Presented in the results section will be the evaluation outcomes of each proposed layout. Finally, recommendations and a summary are given in the conclusions section.

DESIGN

In the design section, the project requirements will be presented followed by an overview of the current process and movements. Space requirements will be discussed. A relationship-diagram will then be presented

When designing a layout for the sheet metal department, there were a few constraints and requirements that had to be taken into account at the beginning of the project:

- The sheet metal department cannot exceed the 5124 sq ft area set by C & D Zodiac in the new building.
- The existing columns in the future sheet metal area occur approximately every 30 feet along the exterior walls.
- The management desired the least possible square footage be used to accommodate the sheet metal department.
- The location of shipping and receiving doors are set.

In order to determine a layout for the sheet metal department, first understanding the sheet metal process was crucial. In observations and evaluations of the sheet metal department, we found the following steps:

- **Retrieve raw material** - The operator has two different methods to approach getting raw materials.
 - 1 The first method is simply walking to the inventory located approximately 38 ft behind the shear and collect the material described in the work order.
 - 2 The second method is more complicated. In the case that the work order calls for a unique piece of material not located in the main inventory, the worker then has to travel 480 ft to the opposite end of the facility to the surplus inventory and retrieve the material. From there this process can become more rigorous and time consuming because nearly 75% the material is located on upper level of the surplus inventory. Because of the stacking method a forklift is needed to retrieve any material located on these upper levels.
- **Shear material** - During this process the operator uses the shear in order to cut sheet metal into desired quantities as well as dimensions based off of the work order for the Strippit LVD turret machine. The operator must account for the size and thickness of the sheets in this process, and in total this is not a time consuming process. However, when this process runs out of nearby inventory or

involves special order sheet metals it becomes very wasteful and time consuming to carry out duties as noted above.

- **Turret machine** - This process involves the machining of the sheared sheet metal into parts specified by the contractor. Work order dimensions are already pre-programmed into the machine for the operator to choose from. The job involves setting up the machine tools, programming the computer, running the machine, and monitoring the machine for jams and other complications.
- **Sand/Deburr** - The sand/deburr process involves the removal of imperfections from the Strippit LVD turret process. Parts must be sanded and deburred so that edges and holes are not jagged in the final product.
- **Brake** - The operator uses the braking machine to bend units according to the work order dimensions. Specified angles can be dialed into the machine to insure that correct angles are made on each part.
- **Tumbling** - The operator uses the tumbler machine to polish the units after they have been sanded/deburred. After a 30 minute session in the tumbler (50 pieces a session) the operator removes the units and begins a new batch. Then the operator uses an air compressor to “clean up” the units; during this time the operator also inspects the units for proper polishing, tossing any back in the tumbler that fail the inspection. Finally 25 units are stacked at a time, twice, and those two stacks are combined to make the original 50 pieces. That stack is strapped together and the work order is filled out and passes on to the next operation.
- **Pre-Check Quality** - The stacked units get sent out for anodizing and come back for final assembly.
- **Final Assembly**- The completed and pre-packaged work orders from a warehouse are delivered each morning to the facility. These boxes are picked up by the assembler and unpackaged. The parts are put together based on the dimensions and instructions provided with each work order by adding the necessary nuts, bolts, and rivets in order to complete the assemblies.
- **Final Inspection** - The inspector lays out each unit in a finished work order and inspects the batch for quality issues such as mismatched dimensions, burrs or defects in the metal, and other imperfections. If a unit fails inspection, the flaw is recorded into the computer and the unit is placed in a secured bin to be analyzed later. The units that pass inspection are packed for shipping and placed on the final shipping rack.
- **Shipping** - Final products get placed on a shipping rack where they are picked up twice a day and shipped out to the customer.

Once the process was understood, a series of time studies were taken to help determine the capacity of each machine and to assist in line balancing. Additionally,

since no current footprint of the sheet metal area existed, measurements were taken and transferred to Google SketchUp. In order to help understand the flow of information and material, space requirements, and the reliance of each process and department on another, interviews were conducted with managers, planners, and mechanics. Each had his or her own opinion and all were compiled to create a relationship-diagram and space requirements. Thirteen departments were defined as follows:

- Inventory
- Shear
- Turret
- Grind
- Sand
- Tumble
- Brake
- CNC
- Mill
- QC
- Shipping and Receiving
- Final Assembly
- Planners

The travel distance between each department is summarized in the following tables:

Table 1- Distances Traveled in Sheet Metal

From	To	Distance Traveled (Feet)
Main Inventory	Inventory	480
Inventory	Shear	37.4
Shear	Turret	34.6
Turret	Grind	77.8
Grind	Tumble	60.5
Tumble	Brake	20.2
Brake	Assembly \ Pre QC	95.0
Assembly \ Pre QC	Final QC	54.7

Table 2 -Distances Traveled in Metal Bars

From	To	Distance Traveled (feet)
Inventory	CNC	34.6
CNC	Mill	57.6
Mill	Assembly \ Pre QC	39.2
Assembly \ Pre QC	Final QC	54.7

C & D Zodiac had decided that only specific machines would be moving into the new location. In Table 3 below, each machine and its movement status can be found.

Table 3- Machines to be Relocated into the New Building

Station	Equipment	Moving	Staying
HASS Mill	2	0	2
Bridgeport Mill	3	2	1
Chop Saw	1	1	0
Band Saw	1	1	0
Sheet Shear	1	1	0
Strippit	2	1	1
Strippit Surface Grinder	1	1	0
90 Ton Press Brake	1	1	0
60 Ton Press Brake	1	1	0
Tumbler	2	1	1
Slip Roller	1	1	0
Vertical Bench Grinder	1	1	0
Drill Press	2	2	0
Shear Notcher	1	1	0

Timesaver	1	1	0
20" Disc Sander	1	1	0
Buffer	1	1	0
Radial Notcher	1	1	0
Clicker Press	2	1	1
Assembly	3	1	2
ID	1	1	0

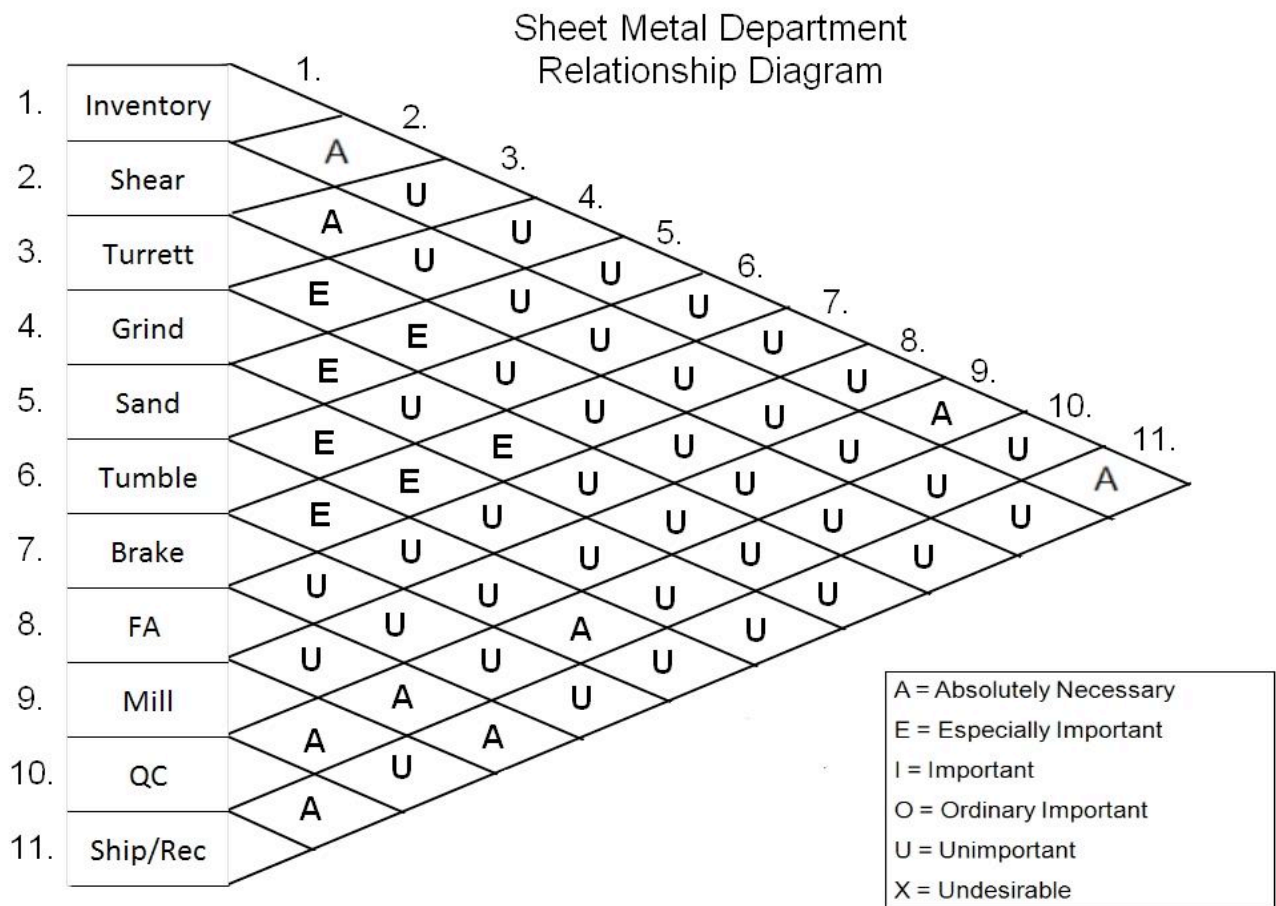
Additionally, each area had a certain number of square feet necessary in order to accommodate machine, workspace, aisle space, and work-in-process space. The amount of space needed for machines, workspace, and work -in-process was first calculated. Then, based on the largest load transversing an area, aisle space was added. Each department needed a different aisle allowance. Space requirements and aisle allowance percentages can be seen in Table 4 below. The space requirement includes people, machines, material, and aisle allowance.

Table 4- Space Needed per Departments

Department	Space Requirement (Sq Ft)	Aisle Allowance (%)
Inventory	1130	35
Shear	230	35
Turret	319	15
Grind	67	10
Sand	172	10
Tumble	158	10
Brake	213	15
Mill	708	35
QC	835	10
Final Assembly	70	10
Total	3902	--

A relationship-diagram was created to see the relationship between each department outlined above. The relationship-diagram can be seen in Figure 1 below. Due to the fact that neither of the CNC machines nor the planners will be moving to the new facility, only the remaining eleven departments were analyzed. The relationship strength between two departments can be denoted as A, “absolutely important”; E, “extremely important”; I, “Important”; O, “Ordinarily Important”; U, “Unimportant; and X, “Not Desirable.” The importance of one department to another was then scaled. An “A” was given a score of 1, an “E” was given .75, “I” was given .5, “O” was given .25, “U” was given 0, and “X” was given -1. Rankings were then formed in descending order, where the highest numbers should be closest to each other.

Figure 1- Sheet Metal Department Relationship Diagram



The rankings were formed. The following have a ranking of one:

- Inventory-Shear
- Inventory-Mill
- Inventory-Shipping and Receiving
- Shear-Turret
- Tumble-Quality
- Final Assembly-Quality
- Final Assembly-Shipping and Receiving
- Mill -Quality

The following have a ranking of .75:

- Turret-Grind
- Turret-Sand

- Grind-Sand
- Grind-Brake
- Sand-Tumble
- Sand-Brake
- Tumble-Brake

The remaining relationships were given a ranking of zero.

From this data, a systematic layout planning method was used to develop potential layouts for the future sheet metal department. These layouts allowed for the space requirements and dependency of departments to be integrated. Each layout had to fit within the restraints set by the footprint of the future facility.

Once these layouts were created, each was evaluated for feasibility, flow, ergonomic design, and footprint, which will be covered in the methodology and results section.

METHODOLOGY

The methodology section will give a detailed overview of the time studies, pareto charts, operation process charts, flow process charts, and flow diagrams that were used to understand the current process. How potential new layouts were evaluated will then be detailed.

In understanding and analyzing the process 5 different methodologies were used.

- 1 Times studies: Direct observation of a task using a stopwatch to record the time to accomplish the task.
 - a For every work element of all operations the performance ratings, allowances and times were recorded.
 - b The time was recorded using the flyback timing method.
 - c Using this data the standard time and average time per part of each procedure were found.
(see appendix B for full time study data)
- 2 Pareto Chart: Graph that identifies the the major vs. minor causes of waste using the 80/20 principle.
 - a From outlining the causes of waste in terms of time (in secs), the pareto chart was able to be created. It highlighted the major causes of waste that will be discussed in the results section.
 - b Using the pareto chart we were able to target the 3 sections that made up nearly 95% of the waste in the facility.
 - c From the revealed data a further investigation for the shear, assembly, debur and inspection processes were determined to be needed. From the deeper investigation takt time can be eventually reduced thus increasing productivity and efficiency.
- 3 Operation process chart: Symbolic representation of the operations to produce a final product.
 - a This diagram was created after every work element for all operations was determined. It gives an overall view of the flow of material from process to process. The operation process chart can be seen in Appendix C.

- 4 Flow process charts: Symbolic representation of all the activities needed to produce a product.
 - a Using the flow of the material, this chart was created to record and analyze how material is handled and processed. One was created for each operation as well as one for the entire process.
- 5 Flow/Spaghetti Diagrams: Diagram of the location of activities and routes followed by material to complete a task.
 - a After multiple observations of each cycle, the flow of material was determined for the entire process.
 - b Flow diagrams were also created for processes that involved a large area of space such as the shear and inspection stations.
- 6 5S Organization (sort, straighten, scrub, standardize, sustain): Simple lean tool that eliminates wasted time searching for parts, cuts extensive movement, and prevents errors.
 - a 5S organization was implemented for the onsite inventory that is used during the assembly operation.
 - b Considering the inventory will be relocated then organized in the new facility, a simulation of 5S organization was performed.

Evaluation

The following metrics were used to evaluate the feasible designs:

- Material travel distance
- Footprint size

The material travel distance was measured by following the material from initial inventory through each process to shipping and subsequently from receiving through final assembly. Footprint size is measured by the square footage used. In determining each metrics weight, interviews with managers and industrial engineers were taken into account. Aaron Buckley, the manufacturing engineer overseeing the project, noted that upper-level management was looking to minimize the footprint of the sheet-metal department. Aaron, along with Erickson Parker, a planner in the sheet metal department, and Jesse Santana, first shift manager, all mentioned that material flow was something that they wanted to increase in the future design.

Not included in the weighted matrix, but considered, were the following:

- Accessibility
- Ease-of-use and movement
- Ergonomics
- Worker movement
- Machine dimensions

Worker movement was evaluated after a proposed layout was selected and machines were placed.

In order to accurately present the layout that was eventually decided upon, a physical model was created. The building was scaled using 2.5 feet equivalent to 1 inch. To begin the model, “walls” were placed where walls would be present in the new layout. The area was then populated using scaled machines, tables, WIP, and inventory racks.

Each of these methodologies then feeds into the results presented in the following section.

RESULTS

Presented in the results section are the time studies, pareto chart, operation process chart, spaghetti diagram results.

From the time studies, standard times for each process was determined

1 Time Studies:

Table 5--Observed Time:calculated from direct observation (flyback timing)

Process:	Observed time (Per Part):
Strippit LVD Turret	43.5 seconds
Shear	84.5 seconds
Shear (waste)	3.8 minutes
Sand/Deburr	20.53 seconds
Brake	17.37 seconds
Tumbler	49.83 seconds
Inspection	49.77 seconds
Total observed time (no waste):	4.43 minutes
Total observed time (waste):	6.82 minutes

Table 6--Standard time:calculated from the observed time, performance rating, normal time and allowances

Process:	Standard Times (Per Part):
Strippit LVD Turret	65 seconds
Shear (normal)	95.6 seconds
Shear (waste)	4.34 minutes
Sand/Deburr	24.54 seconds
Brake	19.9 seconds
Tumbler	55.5 seconds
Inspection	56 seconds
Total time per process (no waste):	5.28 minutes
Total time per process (waste):	8.02 minutes

See Appendix B for full time studies

Pareto Chart:

- a From Pareto chart 1, the biggest three operations that contribute nearly 99% of wasted time are exposed. The first and largest being the assembly process which consumes 45 minutes of waste for each occurrence. Next is the inspection process that yield approximately 10 minutes of waste per occurrence. Finally, there is the shear process which recorded in at 6 minutes of waste per occurrence. The other 1% of wasted time per occurrence belongs to the deburr process that wastes 30 seconds.
- b From Pareto chart 2, frequency of occurrence (per day) is established for each operation. The waste per frequency of occurrence for deburring and inspection occurs every cycle and is variable for how many work orders are completed, thus the two operations were put to be 100% of occurrence. The next greatest frequency of occurrence belonged to the shear which occurred at a maximum of 4 times a day. Wasting a total of 24 minutes per day. Following that was the waste during the assembly process which occurred at a maximum of twice a day. Totaling in 90 minutes wasted a day, a little over 1/8th of a standard shift.

Figure 2--Pareto Chart: Wasted Time vs. Operation

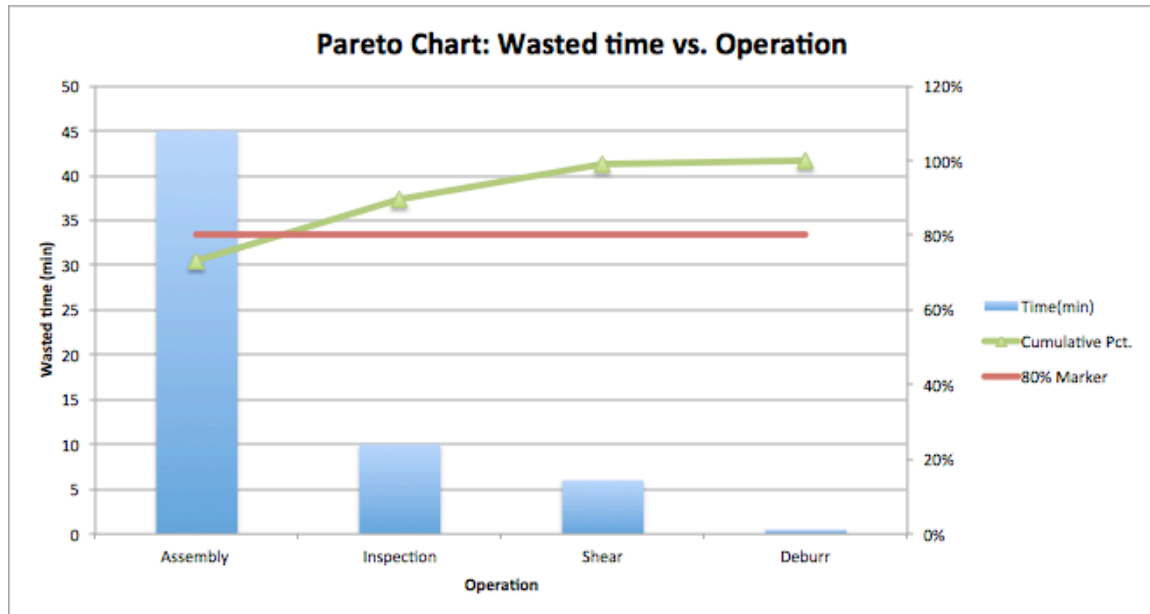
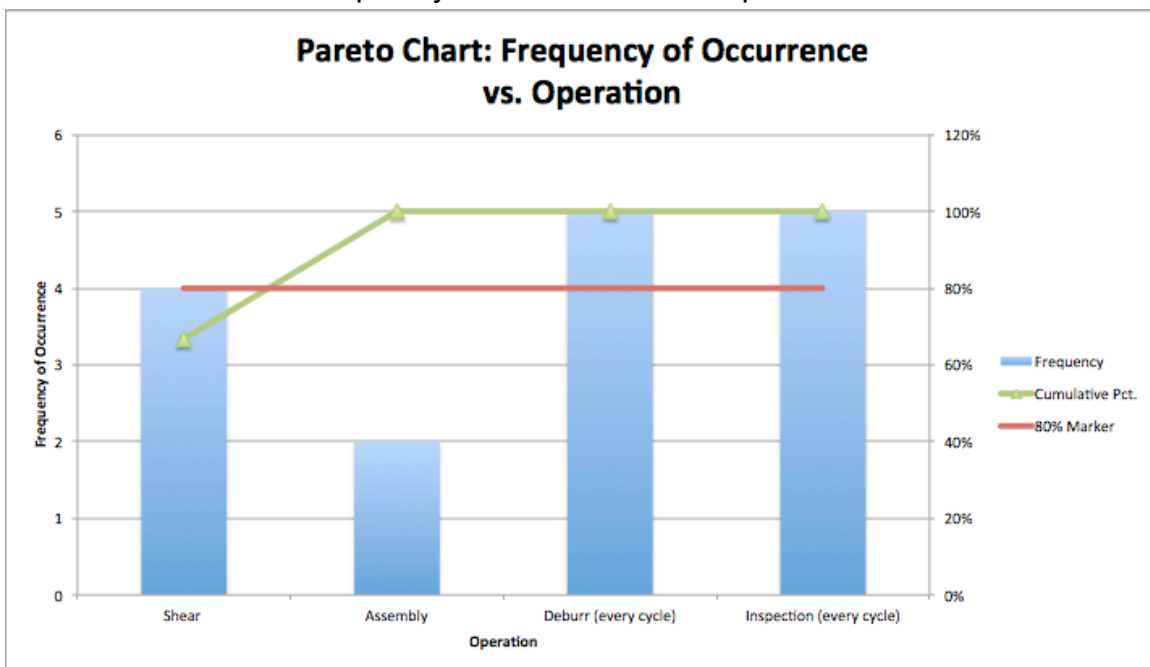


Figure 3--Pareto Chart: Frequency of Occurrence vs. Operation

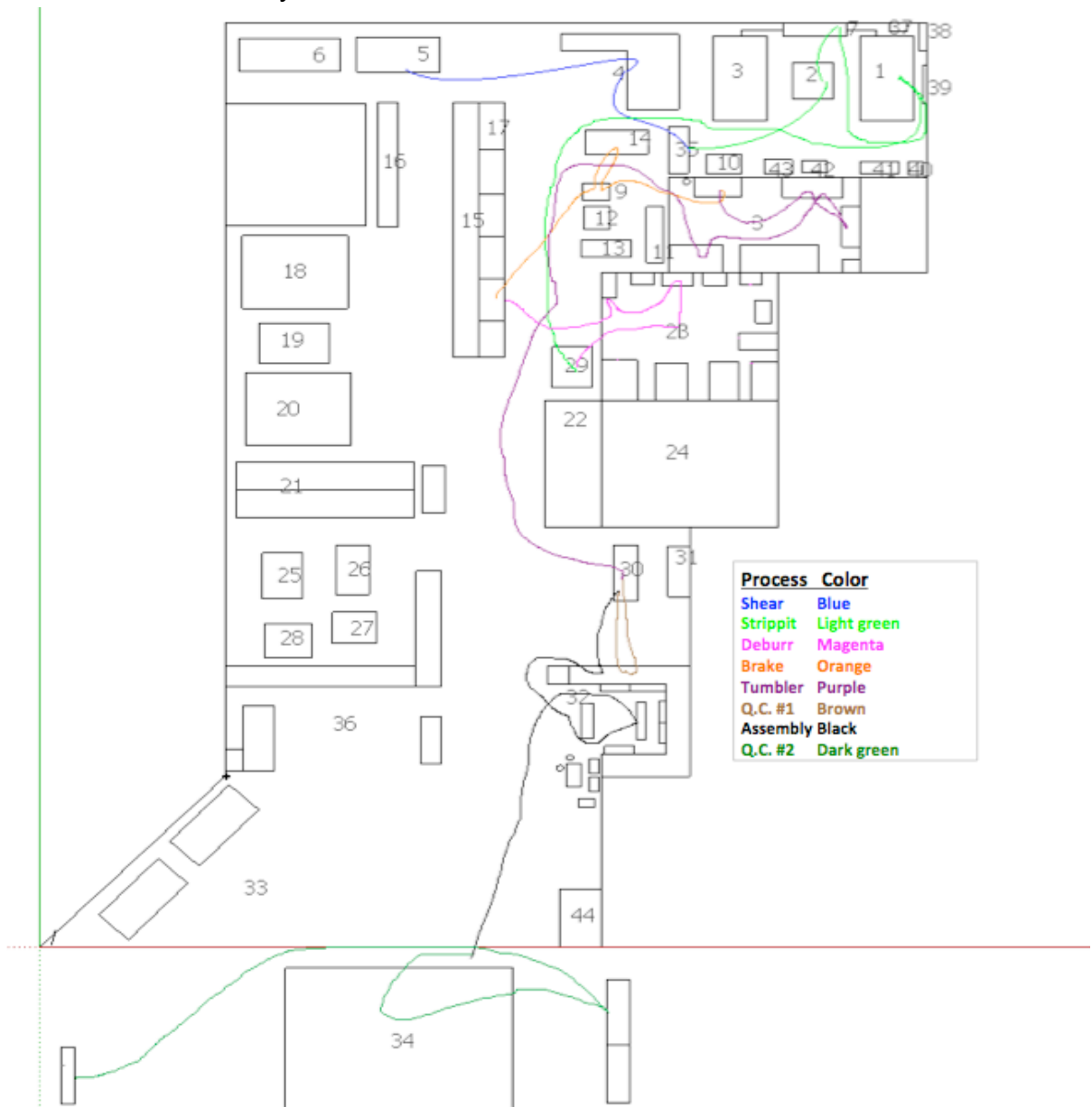


2 Flow/Spaghetti Diagrams:

- The spaghetti diagram revealed that the current process is poorly laid out due to lack of streamlined production.
- In the diagram below, the processes are color coordinated to easily show the differences between them.

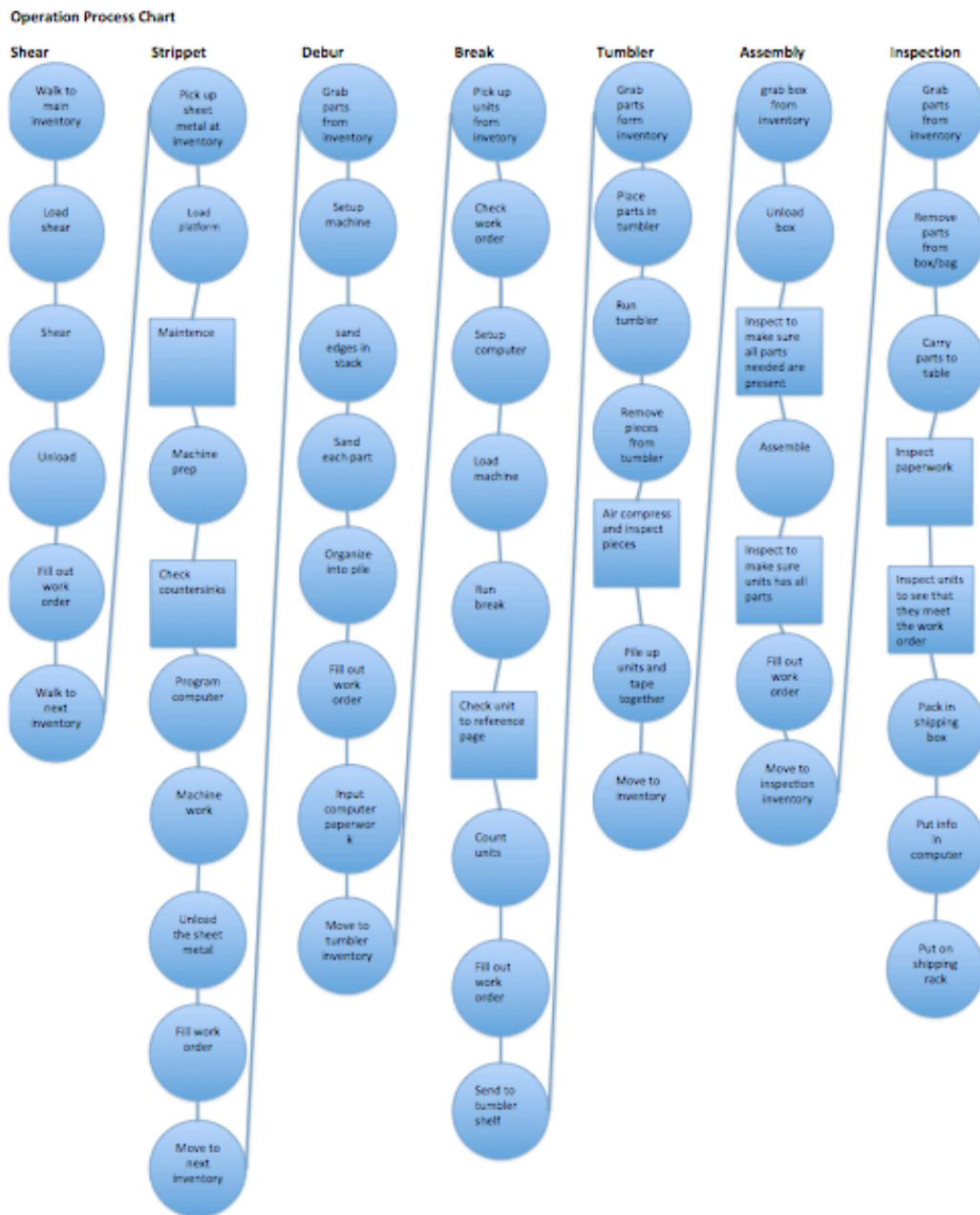
- c With the newly redesigned layout, the issues with wasted motion and time are targeted. For example, the deburr station (in magenta) is not in close proximity to the computers needed in order to complete the work orders, which creates a 30 second to 1 minute delay round trip per each work order. The Strippit LVD Turret (in bright green) is a greater distance than necessary to the following inventory station. The new design will incorporate a layout that will promote better flow with shorter distances between each station.

Figure 4: Flow of Current Layout



- 3 Operation Process Chart:
In Figure 5, the each process of the operation is laid out.

Figure 5--Operations Process Chart for Sheet Metal Process



- a The operations process chart produced a symbolic representation of the operations to produce the final product.
- b From the operations process chart an accurate description of the processes in chronological order was supplied.

- c Value added vs. Non-value added is exposed. All assembly processes represented as circles are value added. While all inspection processes represented as squares are non-value added but necessary.
- 4 Flow Process Charts:
 - a The flow process charts assisted in determining an accurate description of the process as well as value added vs. non-value added processes.
 - b Value added distance totalled to 279.1 ft for the current layout and 111 ft for the proposed layout. This would result in a 168.1 ft reduction in value added distance.
 - c Non-value added distance totalled to 532.1 ft for the current layout and 328 ft for the proposed layout. This would result in a 204.1 ft reduction in non-value added distance.
 - d The total distance traveled for the current process equals 806.2 while the new layouts total distance traveled equals 413. This would result in a total reduction of 393.2 ft for the entire process.
 - e Determined total time spent in a process for operations, inspections, delay, transport, and storage to be 9645.7 seconds (160.8 minutes).

Each of the current processes has now been greatly detailed and can be evaluated into recommendations, presented in the next section.

Recommendations

Recommendations for each process are first presented. Then potential layouts are proposed and evaluated.

- Shear
 - Sheet metal inventory closer to the process, the current layout requires a two minute round trip in wasted motion.
 - Better organized shelving system for the special order sheet metal inventory, sheets laying in horizontal shelving would eliminate the use of a forklift to retrieve sheet metal from bottom layers which adds 15 to 20 minutes to the process.
- Strippit LVD Turret
 - Implementation of line balancing techniques so that both machines are used equally in order to minimize takt time and increase productivity.
- Sanding/Deburr
 - Locate computers and storage closer to the process, the current process requires 90 seconds per work order of wasted motion.
- Brake
 - Tool holding rack is too close to the brake on both racks, more clearance is necessary so that larger parts can be more accessible.
 - Move tables farther from brake in order to suit worker's needs of space and maneuverability
- Tumbler
 - Place storage rack closer to tumbler for ease of access for the operator.
- Assembly
 - Recommended better quality control for work orders coming from the warehouse. Mismatched and missing parts or blueprints create a 30 minute to 1 hour delay.
 - 5S organization of available nuts, rivets, and bolts supply cubbies would save time and wasted motion in searching for the right size hardware. In addition to prevent error when assembling hardware.
- Inspection
 - 5S organization of tools under or on inspection table to eliminate wasted time walking back and forth from drawers or lockers to get needed tools.
 - Reorganize shelving to suit larger boxes. Or upgrade to larger shelves. This will eliminate the use of the carts that hold and move larger shipping boxes.
 - Upgrade computers to eliminate delay time produced by slow processors.

- General
 - Implementing 5S would greatly benefit the system. It is outlined below:
5S Organization: sort, straighten, scrub, standardize, sustain
 - f Sort: remove everything that is not needed to do the job. Red-tag them, set them aside before dispose them.
 - i Remove all mismatched hardware in the existing cubbies.

Figure 6-- Sorting of Final Assembly Area



Plastic bags were chosen to be removed because it creates wasted time when retrieving hardware and can easily cause error if put back in the wrong location vs. putting a single bolt/nut back.

- g Straighten: Designate a place for every tool or object that is needed to do the job. Mark the place with labels, shadow boxes.
 - i As you can see in the image above this is already complete; however a recommendation would be to include a small picture of the hardware on each box to prevent error in assembly and delays down the production line in the inspection process.

Figure 7--Assembly Straightening Recommendation



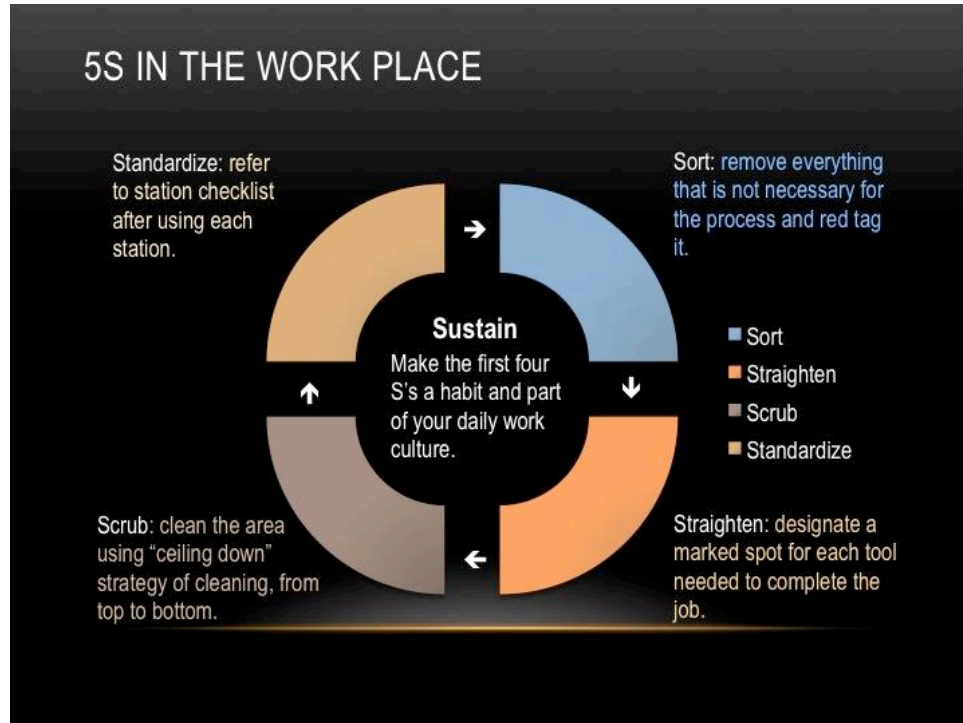
- h Scrub: Thoroughly clean the work area to reduce accidents and improve quality.
 - i Loose tools and hardware on the floor could cause serious injury to the workers.
- i Standardize: Find the best methods and practices and standardize them to other workstations.
 - i 5S can be implemented in other work stations where tools are involved such as the Strippit LVD turret, brake, and inspection stations.
 - ii Below is another work station for the assembly process.

Figure 8--Example of Standardization in Assembly Area



- j Sustain: Maintain the changes once they are in place, prevent the workplace from falling back to the “old ways”.

Figure 9-Diagram of Sustaining Organization



Five potential layouts were prepared from the systematic layout planning process. Hand drafts of each of the five layouts can be found in Appendix E. When each layout was evaluated, the material movement and footprint were evaluated. In Table 7 below, the measurements for each proposed layout and the current layout can be found.

Table 7--Material Movement and Footprint of Proposed Layouts

Layout	Material movement (ft.)	Footprint (sq. ft.)
Current	566	9662
Proposed 1	360	4120
Proposed 2	369	3944
Proposed 3	390	4016
Proposed 4	363	3944
Proposed 5	399	4024

The difference between the current layout and each of the proposed layouts was then taken for both material movement and footprint. The results of these steps can be seen in Table 8 below.

Table 8--Difference in Material Movement and Footprint from Current to Proposed

Layout	Difference in Material Movement (ft.)	Difference in Footprint Size (sq. ft.)
Proposed Layout 1	206	5542
Proposed Layout 2	197	5718
Proposed Layout 3	176	5646
Proposed Layout 4	203	5718
Proposed Layout 5	167	5638

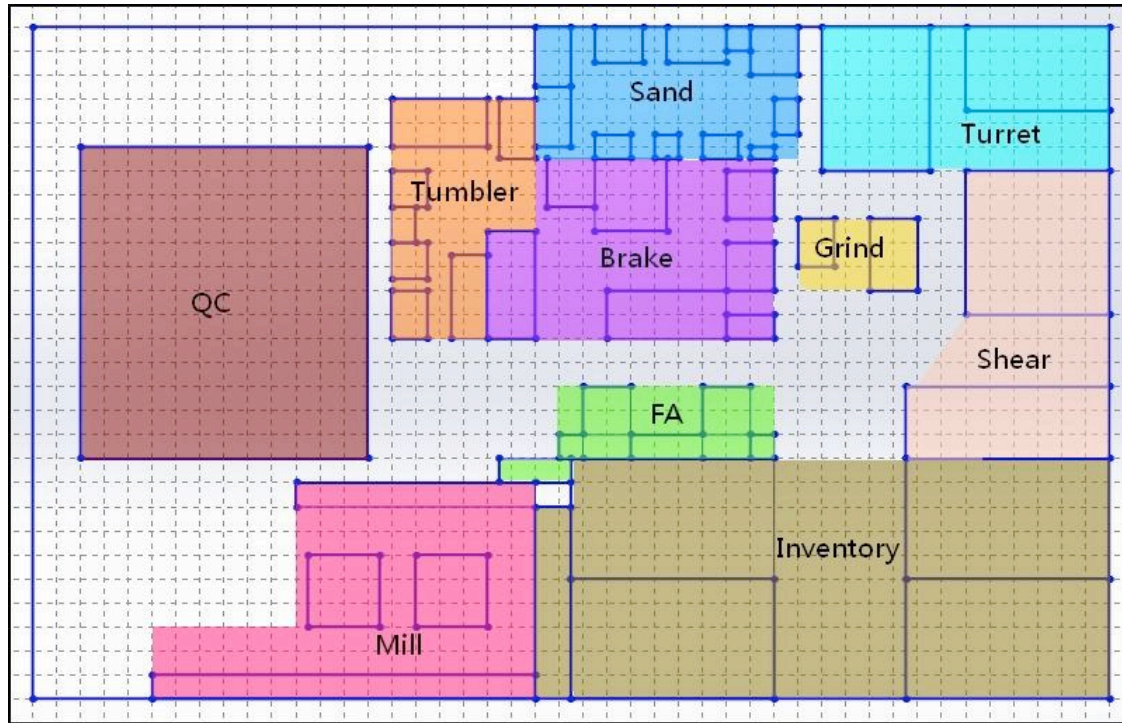
From these results, a ranking was created and can be seen in Table 9 below.

Table 9--Ranking of Proposed Layouts

Ranking	Layout
1	Proposed Layout 4
2	Proposed Layout 2
3	Proposed Layout 1
4	Proposed Layout 3
5	Proposed Layout 5

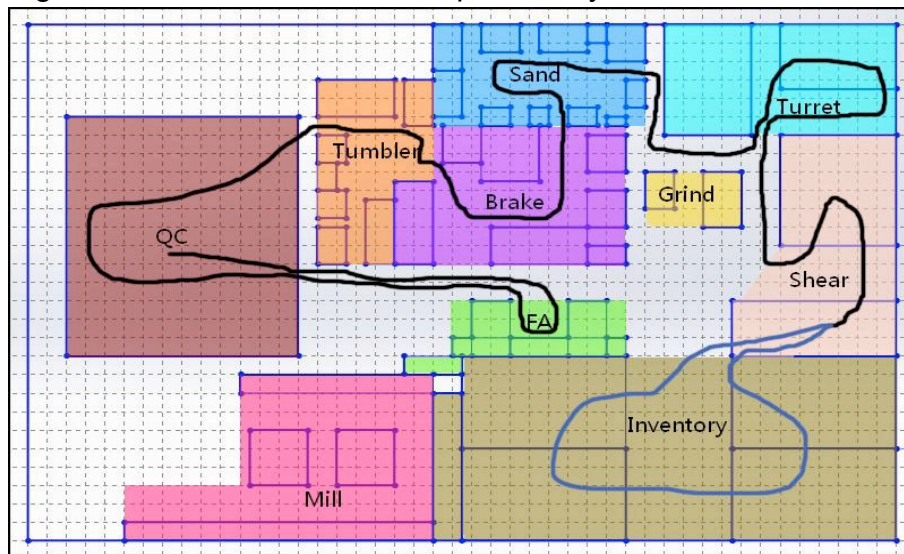
Beginning with ranking one and following until ranking 5, the machines were placed into each of the systematic layout positions. If the machines did not fit in the designated area due to size or orientation, the layout was slightly altered and material movements were recalculated. A final proposed layout was chosen from the new material movement and footprint sizes. Proposed layout 5 was selected. From this layout, worker flow was then calculated and the layout was made digital. Additionally, the layout was made into a physical model. A scaled layout can be seen below in Figure 10: Below that, Figure 11 shows the material flow throughout the layout.

Figure 10-- Scaled Model of Proposed Layout



C&D Sheet Metal Proposed Layout

Figure 11-- Material Flow in Proposed Layout



C&D Sheet Metal Proposed Layout

The material travel distance between each department for the final proposed layout 5 is summarized in the following tables:

Table 10- Sheet Metal Material Travel Distance

From	To	Distance Traveled (ft.)
Inventory	Shear	24.4
Shear	Turret	11.6
Turret	Grind	14.2
Grind	Sand	19.2
Sand	Brake	12.0
Brake	Tumble	16.1
Tumble	QC	21.2
QC	FA	37.8

Table 11-Metal Bars Material Travel Distance

From	To	Distance Traveled (feet)
Inventory	Mill	34.6
Mill	QC	57.6

The proposed layout will reduce the material flow by 167 feet and reduce the size of the shop floor by 5638 sqft. It will leave 20% (1016 sqft.) of the designated floor space (5040 sqft.) unused. The extra room can be used to expand the existing sheet metal line offering more room for the workers or additional machinery, or the floor space may be delegated to the Honda project. Recommendations have been presented and final conclusions can be made.

Conclusions

After being presented by C & D Zodiac with the challenge of finding a way to arrange their sheet metal department in their new building, a series of steps was taken to develop a solution that would provide a small footprint, an increased flow of material, and a decrease in worker travel and process time. In order to arrive at an optimal solution, first the current process and layout were mapped using process flow, layout maps, and time studies. Pareto charts, flow diagrams, flow process charts, and operations process charts also helped identify and target the major wastes within the process. Then, each process was thoroughly understood by interviewing machinists, managers, planners, and industrial engineers. From that understanding, relationship diagrams and workspace requirements were developed. These numbers were integrated into a systematic layout planning technique. Multiple proposed layouts were then evaluated in a weighted matrix for material travel distance, worker movement, and footprint size. A final layout selection was then made and mocked in Solidworks and in a physical model. The following conclusions were drawn from the results:

- 6 minutes of wasted time is consumed when the operator restocks the main inventory using the surplus inventory.
 - Delays increase from a varying 15 to 20 minutes when the work order calls for a special order sheet metal due to the use of a forklift on the vertical shelving.
- The strippet process is occasionally running at 50% efficiency because only one of two machines are being operated at a time.
- For the deburr process, 90 seconds of wasted motion is occupied per work order.
- 4 to 10 minutes of wasted time per work order is accumulated due insufficient space and limited accessibility for the brake process.
- The current layout is not aligned to promote a flow of material, which causes wasted time and money.

Based on the conclusions above,we recommend the following:

- Relocate the sheet metal inventory closer to the processes.
- Systemize the shelving system for the special order sheet metal inventory in a horizontal alignment rather than current vertical arrangement to eliminate the use of a forklift.
- Balance the use of the Strippet LVD turrets so that both machines are used equally to minimize takt time.
- Provide more clearance between the brake and holding racks so larger parts can be more accessible in the work station.

- Place storage rack closer to the tumbler to eliminate wasted time from unnecessary movement.
- Improve quality control for work orders coming from the warehouse to the assembly process.
- Organize and standardize the available hardware used for the assembly process.
- Upgrade computers used for inspection to eliminate delay time.
- Reorganize or upgrade shelving at the inspection process to suit larger boxes.
- Locate and organize the tools for the inspection process on or underneath the worktable to eliminate wasted time walking to lockers where tools are currently held.

Implementing these suggestions into the proposed layout will create a greater material flow within a smaller area saving the operation time and money.

REFERENCES

Richard Muther and Associates. "Overview of Systematic Layout Planning." *Hpcinc.com*. High Performance Concepts, Inc., 2005. Web. 2 Mar. 2013.

APPENDICES

Appendix A--Flow Diagram of Current Processes

Appendix B--Time Studies for Current Processes

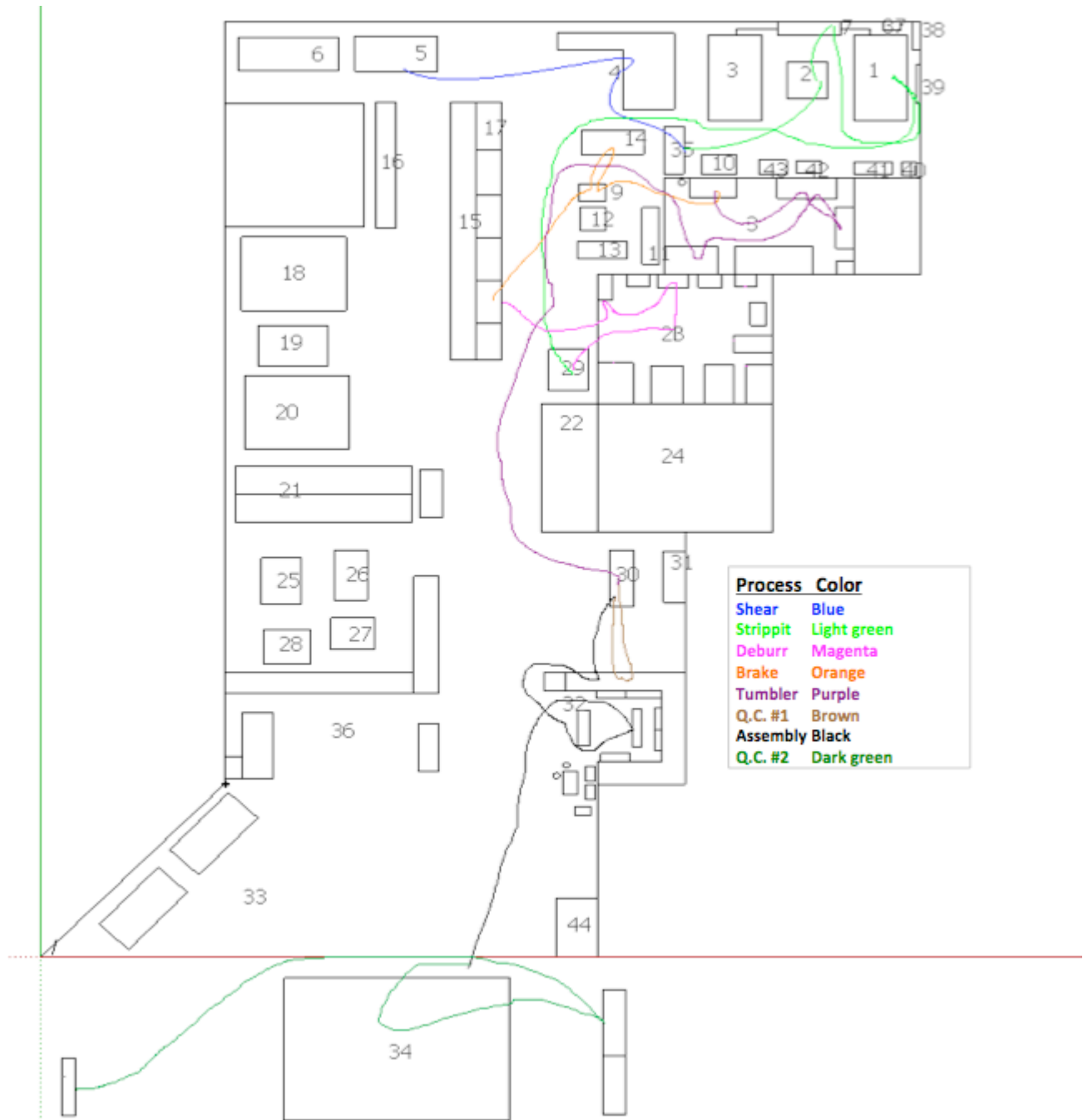
Appendix C--Operations Process Chart for Current Processes

Appendix D--Flow Process Charts

Appendix E--Proposed Layouts

Appendix F--Current Layout and Data

Appendix A--Flow Diagram of Current Process:



Appendix B--Time Studies

Shear (no waste):

	Walk to Sheet Metal Storage			Load shear		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	11.8	11.8	100	9.5	9.5
2	100	12	12	100	10	10
3	100	13	13	100	14	14
Avg	100	12.266667	12.266667	100	11.166667	11.166667
Allowances			0.11			0.15
ST (as listed)			13.616			12.84167

Shear setup			Shear 1			shear 2		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	20	20	100	11.2	11.2	100	9.7	9.7
100	22	22	100	10	10	100	15	15
100	19	19	100	13	13	100	11	11
100	20.333333	20.333333	100	11.4	11.4	100	11.9	11.9
		0.11			0.11			0.11
		22.57			12.654			13.209

Pick up metal and get work order			Fill out work order			Walk to strippet storage		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	30	30	100	57.5	57.5	100	12.8	12.8
100	28	28	100	62.3	62.3	100	13	13
100	32	32	100	57.8	57.8	100	12.4	12.4
100	30	30	100	59.2	59.2	100	12.733333	12.733333
		0.16			0.13			0.15
		34.8			66.896			14.64333

Total ST	191.23
Total OT #1	169
Time/Work Element	9.10619

Shear (waste):

	Walk to Sheet Metal Storage			Load Dolly		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	69	69	100	179	179
2	100	75	75	100	138	138
3	100	67	67	100	160	160
Avg	100	70.333333	70.333333	100	159	159
Allowances			0.11			0.16
ST (as listed)			78.07			184.44

Walk Back to Shear			Load shear			Shear setup		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	59.5	59.5	100	9	9	100	18	18
100	61	61	100	10	10	100	23	23
100	68	68	100	13	13	100	20	20
100	62.833333	62.833333	100	10.666667	10.666667	100	20.333333	20.333333
		0.15			0.15			0.11
		72.25833			12.26667			22.57

Walk Back to Shear			Load shear			Shear setup		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	59.5	59.5	100	9	9	100	18	18
100	61	61	100	10	10	100	23	23
100	68	68	100	13	13	100	20	20
100	62.833333	62.833333	100	10.666667	10.666667	100	20.333333	20.333333
		0.15			0.15			0.11
		72.25833			12.26667			22.57

Shear 1			shear 2			Pick up metal and get work order		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	13	13	100	11	11	100	25	25
100	12	12	100	10	10	100	24	24
100	14	14	100	13	13	100	27	27
100	13	13	100	11.333333	11.333333	100	25.333333	25.333333
		0.11			0.11			0.16
		14.43			12.58			29.38667

Total ST	520.7783					
Total OT #1	456.5					
Time/Work Element	24.79897					

Notes: Wasted motion and time due to inventory being on the other side of the facility

Strippit:

	Pick up from storage			Load Platform		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	10	10	100	32.7	32.7
2	100	22.9	22.9	100	25	25
3	100	10	10	100	12	12
Avg	100	14.3	14.3	100	23.23333	23.23333
Allowances			0.16			0.16
ST (as listed)			16.588			26.9507

Machine Prep/Maintenance			Check Countersinks			Program Computer		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	141	141	100	192	192	100	53.5	53.5
100	256	256	100	0	0	100	83	83
100	180	180	100	0	0	100	56	56
100	192.3333	192.3333	100	64	64	100	64.16667	64.16667
		0.11			0.11			0.11
		213.49			71.04			71.225

Machine Work			Unload/Wipe off			Fill out work order		
	min	min		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	6.5	6.5	100	20	20	100	55	55
100	15.1	15.1	100	20	20	100	60	60
100	16.5	16.5	100	51.7	51.7	100	135	135
100	12.7	12.7	100	30.56667	30.56667	100	83.33333	83.33333
		0.16			0.11			0.11
		14.732			33.929			92.5

Total ST	1363.233
Total OT #1	914.9
Time/Part	64.91587

Notes: Strippit Machine - 21 parts - 0.063 thickness

Sand/Deburr:

	Grab Parts from shelf			Setup Tool		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	25	25	100	30	30
2	100	30	30	100	45	45
Avg	100	27.5	27.5	100	37.5	37.5
Allowances			0.11			0.11
ST (as listed)			30.525			41.625

Sand per part			Organize into Pile			Fill out work order		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	203.6	203.6	100	41.7	41.7	100	74	74
100	216	216	100	35	35	100	82	82
100	209.8	209.8	100	38.35	38.35	100	78	78
		0.17			0.11			0.14
		245.466			42.5685			88.92

Move to storage shelf			Computer Input paperwork			Walk back		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	10.4	10.4	100	37.7	37.7	100	23.2	23.2
100	15	15	100	30	30	100	20	20
100	12.7	12.7	100	33.85	33.85	100	21.6	21.6
		0.11			0.14			0.11
		14.097			38.589			23.976

Move to Tumbler storage		
	sec	sec
R	OT	NT
100	26.1	26.1
100	27	27
100	26.55	26.55
		0.11
		29.4705

Total ST	895.9065		
Total OT	816.55		
Time/Part #1	23.57649		

Notes: Sand/Deburr Station - 38 parts *Long walk times from station --> storage --> computer ---> storage --> tumbler

Brake:

	Grab Parts from shelf			Check work order			Setup computer		
		sec	sec		min	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT	R	OT	NT
1	100	13	13	100	6	6	100	120	120
2	100	14	14	100	5.4	5.4	100	128	128
Avg	100	13.5	13.5	100	5.7	5.7	100	124	124
Allowances			0.11			0.17			0.17
ST (as listed)			14.985			6.669			145.08

Load machine			Run break			Check reference		
	min	min		min	min		min	min
R	OT	NT	R	OT	NT	R	OT	NT
100	7	7	100	17.4	17.4	100	6.3	6.3
100	6.8	6.8	100	16.9	16.9	100	6.5	6.5
100	6.9	6.9	100	17.15	17.15	100	6.4	6.4
		0.11			0.17			0.11
		7.659			20.0655			7.104

Count pieces			Fill out work order			Walk to tumbler shelf		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	213	213	100	68	68	100	12	12
100	223	223	100	70	70	100	14	14
100	218	218	100	69	69	100	13	13
		0.14			0.11			0.14
		248.52			76.59			14.82

Total ST	2989.845	
Total OT #1	2606.5	
Time/Part #1	19.9323	
Notes: Brake station - 150 parts		

Tumbler:

	Pick up from storage			Place parts into tumbler		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	9	9	100	74	74
2	100	12	12	100	68	68
Avg	100	10.5	10.5	100	71	71
Allowances			0.16			0.16
ST (as listed)			12.18			82.36

Run Tumbler Machine			Remove parts from tumbler			Air Compressor Clean		
	min	min		sec	sec		min	min
R	OT	NT	R	OT	NT	R	OT	NT
100	30	30	100	87	87	100	6.5	6.5
100	30	30	100	80	80	100	6	6
100	30	30	100	83.5	83.5	100	6.25	6.25
		0.11			0.11			0.11
		33.3			92.685			6.9375

Pile into groupings of 25			Tape together			Walk to QC storage		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	100	100	100	25	25	100	27	27
100	95	95	100	27	27	100	29	29
100	97.5	97.5	100	26	26	100	28	28
		0.16			0.11			0.11
		113.1			28.86			31.08

Total ST	2774.515
Total OT #1	2491.5
Time/Part	55.4903
Notes: Tumbler - 50 parts	

Inspection:

	Pick up from shelf			Remove from bag		
		sec	sec		sec	sec
Cycle	R	OT	NT	R	OT	NT
1	100	5	5	100	44	44
2	100	5	5	100	34	34
3	100	4	4	100	40	40
Avg	100	4.666667	4.666667	100	39.333333	39.333333
Allowances			0.11			0.1
ST (as listed)			5.18			43.2667

Layout on table			Review paper work			Inspect units		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	130	130	100	20	20	100	155	155
100	34	34	100	20	20	100	85	85
100	56	56	100	19	19	100	137	137
100	73.333333	73.333333	100	19.666667	19.666667	100	125.6667	125.6667
		0.11			0.11			0.16
		81.4			21.83			145.773

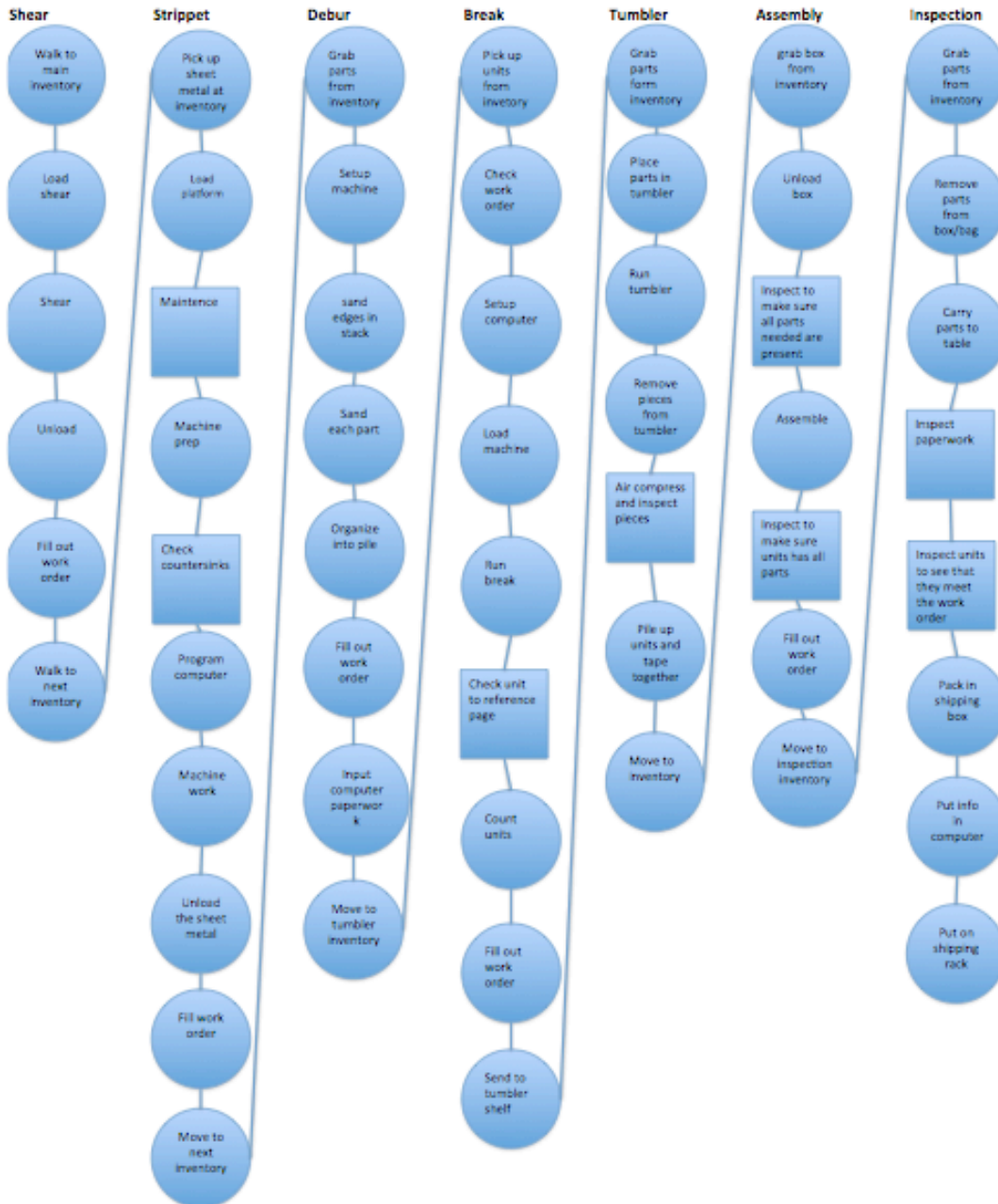
Pack in shipping box			Put on shipping rack			Put info into computer		
	sec	sec		sec	sec		sec	sec
R	OT	NT	R	OT	NT	R	OT	NT
100	185	185	100	20	20	100	78	78
100	92	92	100	12	12	100	100	100
100	113	113	100	18	18	100	87	87
100	130	130	100	16.666667	16.666667	100	88.333333	88.333333
		0.11			0.11			0.12
		144.3			18.5			98.9333

Total ST	559.1833				
Total OT #1	497.6667				

Time/Work Element	55.91833				
Notes: Cycle 1- 9 pieces, Cycle 2- 10 pieces, Cycle 3- 10 pieces					

Appendix C-Operations Process Chart

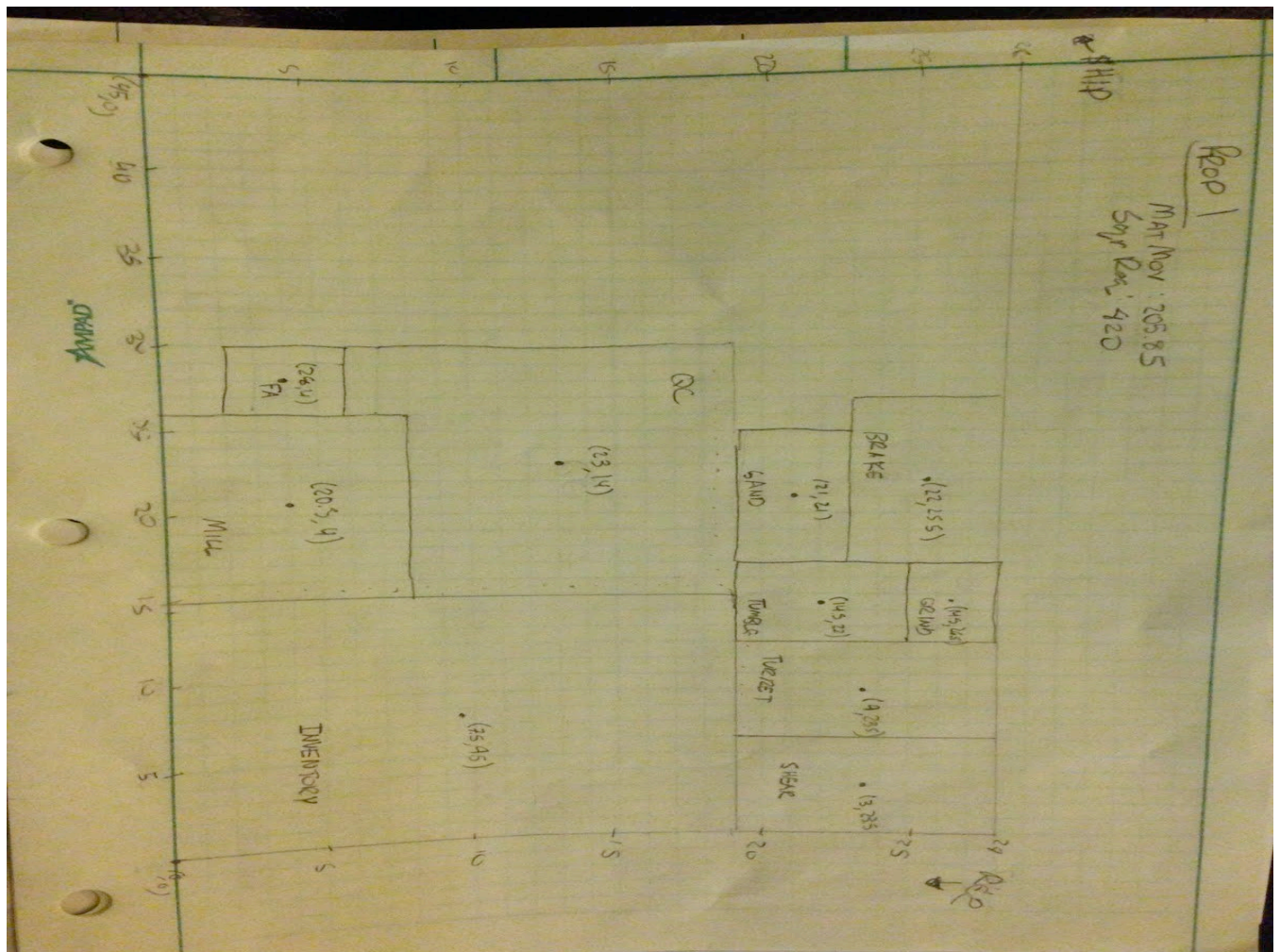
Operation Process Chart

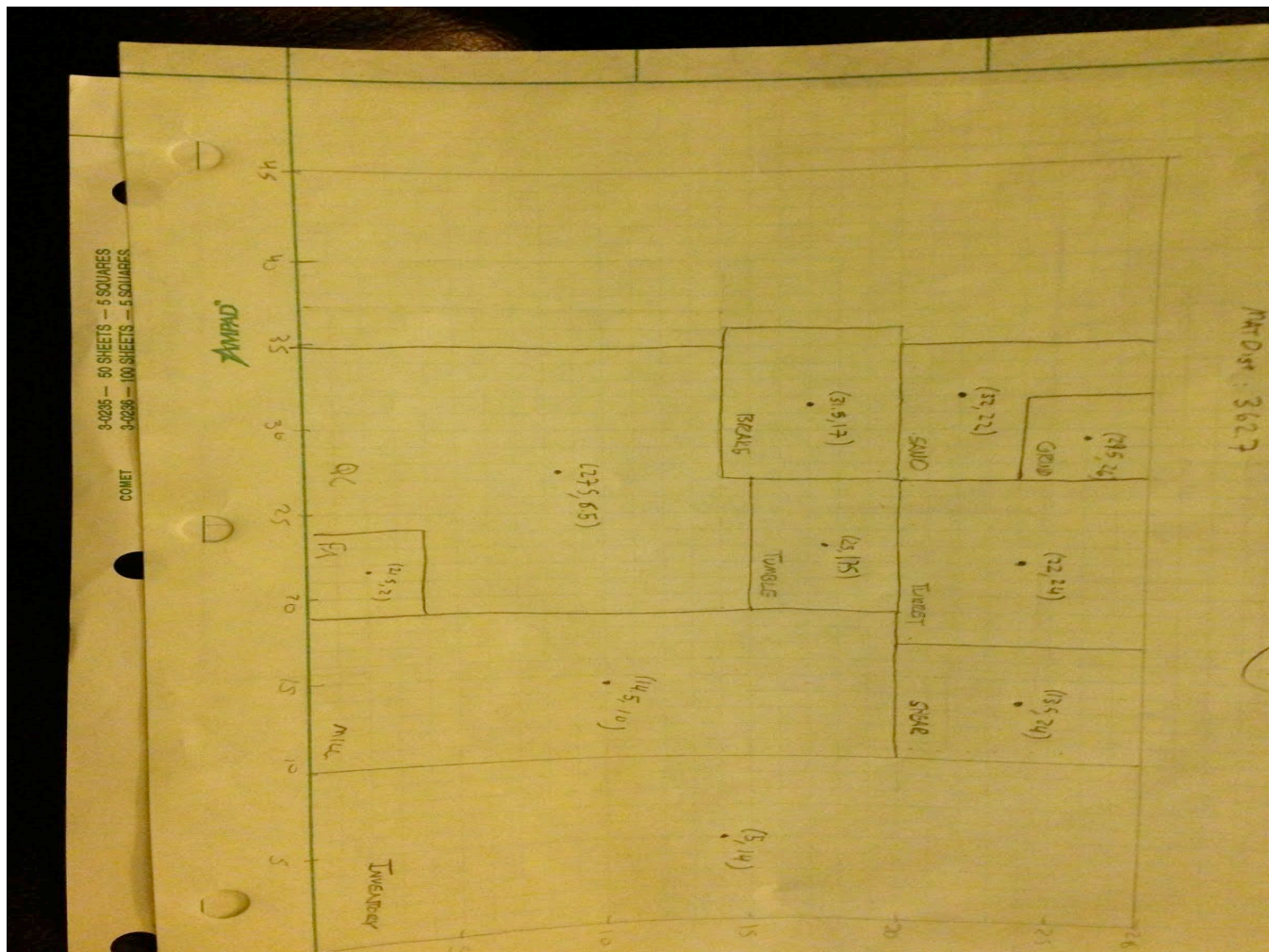


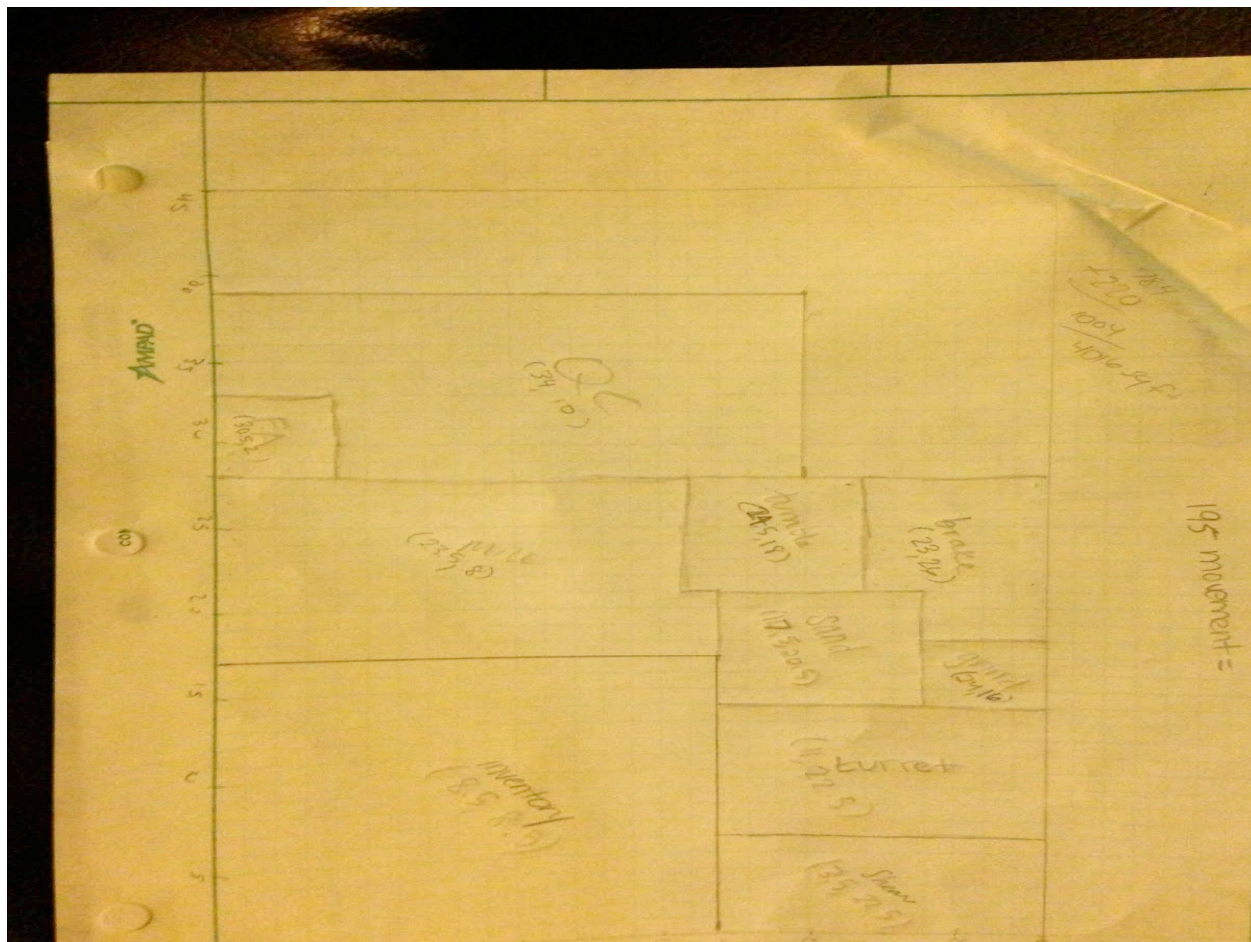
Appendix D--Flow Process Charts

Appendix									
Flow Process Chart									
Location: ZKD Zodiac					Summary				
Activity: Entire Process					Event	Present	Proposed	Savings	
Date: 3/8/13					Operations	279.1	111	168.1	
Operator: Employee					Transport	423.6	318	105.6	
Analyst: Jon, Alex					Delay	0	0	0	
Circle Appropriate Method and Type					Inspection	14.6	10	4.6	
Method: Present Proposed					Storage	0	0	0	
Type: Worker Material Machine					Time (sec)	9645.7	n/a		
Remarks:					Distance (ft)	806.2	413	393.2	
					Cost	\$129.00 @ \$9/hr	n/a	n/a	
Event Description					Time (sec)	Present Dist (ft)	Proposed Dist (ft)	Notes/Method Recommendation	
Get blank from inventory	○	→	○	□	13	1	8		
Load Shear	●	→	○	□	14	37.4	8		
Shear with machine	●	→	○	□	22	0	0		
Unload	●	→	○	□	28	0	0		
Fill out paper work	●	→	○	□	94.3	0	0		
Load stripped storage	○	→	○	□	13	16.1	44		
Get sheet metal from storage	○	→	○	□	22.9	37.4	10		
Load platform	●	→	○	□	32.7	37.4	10		
Maintenance	●	→	○	□	141	0	0		
Machine prep.	●	→	○	□	256	0	0		
Program computer	●	→	○	□	83	5	4		
Check countersink	●	→	○	□	192	0	0	Occasional occurrence	
Machine work	●	→	○	□	1020	0	0		
Unload the sheet metal	●	→	○	□	51	0	0		
Fill out order	●	→	○	□	135	0	0		
Move to next storage	○	→	○	□	22	77.8	42		
Get units from storage	○	→	○	□	30	13.2	12		
Setup machine	●	→	○	□	45	16.1	12		
Sand edges in stack	●	→	○	□	75	0	0		
Sand each unit	●	→	○	□	448	0	0		
Organize into pile	●	→	○	□	41.7	0	0		
Fill out work order	●	→	○	□	82	0	0		
Input computer paperwork	●	→	○	□	38	81.8	15		
Move to brake storage	○	→	○	□	60	62.2	18		
Pick up units from inventory	○	→	○	□	13.5	31.7	24		
Check work order	●	→	○	□	342	0	0		
Setup computer	●	→	○	□	124	3	4		
Load machine	●	→	○	□	414	3	4		
Run brake	●	→	○	□	2029	0	0		
Check unit to reference page	●	→	○	□	384	4.6	4	Done every 20-30 units made	
Count units	●	→	○	□	218	4.6	4		
Fill out work order	●	→	○	□	69	0	0		
Send to tumbler shelf	○	→	○	□	13	14.9	20		
Grab units from storage	○	→	○	□	10.5	14.9	10		
Place in tumbler	●	→	○	□	71	0	14		
Run tumbler	●	→	○	□	1800	0	0		
Remove units from tumbler	●	→	○	□	83.5	0	0		
Air compress and inspect units	●	→	○	□	375	5	6		
Pile units in stacks and tape	●	→	○	□	123.5	17.3	12		
Bring to assembly storage	○	→	○	□	27.1	81.2	20		
Grab units from storage	○	→	○	□	n/a	21.8	14		
Unload box	○	→	○	□	n/a	36.3	0		
Inspect to make sure all parts are present	○	→	○	□	n/a	0	0		
Assemble	●	→	○	□	n/a	0	0		
Inspect for correct assembly	○	→	○	□	n/a	0	0		
Fill out work order	●	→	○	□	n/a	0	0		
Move to inspection storage	○	→	○	□	n/a	69.7	40		
Get units from storage	○	→	○	□	5	8.4	12		
Remove parts from box/bag	○	→	○	□	44	0	0		
Carry parts to table	○	→	○	□	130	4	6		
Review paperwork	○	→	○	□	20	5	0		
Inspect units	○	→	○	□	85	0	0		
Pack in shipping box	○	→	○	□	185	16.7	6		
Put information into computer	○	→	○	□	20	15.5	12		
Put on shipping rack	○	→	○	□	100	63.2	18		
Total =					9645.7	806.2	413		

Appendix E--Proposed Layouts







Appendix F--Current Layout

