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# Donaldson Single-Piece Flow

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**Problem Statement**

The client for this project is Donaldson Company. They have nearly 12,000 employees worldwide specializing in the production of filters and filter readers that are used in many industries. This project took place at Donaldson's Waterloo, Iowa facility.

The Capstone team has been tasked to update their oldest and least changed Mechanical Air production line from a batch process to a single-piece flow. The current line utilizes too much overtime to meet demand, and Donaldson would like us to solve that without the addition of more operators. Donaldson wants to consolidate space to make room for new product lines. They will use our changes made and consider it when updating other lines in the facility.

**Disciplines**

Bioresource and Agricultural Engineering | Industrial Technology

**Department of Agricultural and Biosystems Engineering (ABE)**

**TSM 416 Technology Capstone Project**

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## 1 Problem Statement

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**Business Case Statement**

The Mechanical Air product assembly line is inefficient. In the past employees carried batches of 100 subcomponents to the next station for further assembly. As of November 2018, the batch size was reduced to 50. This size allowed for a cushion for machine failure, the cap assembly press at station 3 fails weekly. Machine reliability is outside the project scope. Workstation repositioning will reduce batch sizes and motion waste significantly.

# 2 GOAL STATEMENT

Determining the root cause for the production line inefficiency was assessed first. It was a low priority for management to improve the current line function, as it had no major failures and a low scrap rate.

- **Main Deliverables**
  - Overall cycle time reduction
  - Reduce dwell time by 50%
  - Current and future state Value Stream Map
  - Yamazumi Chart

- **Secondary Deliverables**
  - Reduce ergonomic strain on employees
  - Workplace hazards assessment
  - Improve employee quality of life in working conditions

- **Main Objective(s) and Specific Objectives**
  - Take the current Mechanical Air product line from batch production to single-piece flow by reducing the number of workstations and motion waste.

- **Specific objectives include**:
  - Time observations of current and future line production.
  - Creating a current and future value stream maps.
  - Suggesting improvements to the process to create a single-piece flow up until the annealing oven and the processes for testing after the oven.

- **Rationale**
  - Space will be saved for future product lines or storage.
  - Optimization of employee labor time.
  - Become more predictable and consistent with production.

- **Project Scope**
  - The original project scope was limited to the Mechanical Air production line. The scope changed to include the adjacent T1 Snap line to creating a mixed-model line in a kaizen event (found in Appendix 8.6). These changes were driven by Donaldson as they sought out a lean consultant to do a facility-wide lean workshop.

- **Outside of the Project Scope**

- The annealing process that involves the ovens.
- Packaging after the product has been tested.
- Material handling in and out of the production line.
- Machine efficiency and reliability.

# 3 Project Plan/Outline

**A. Methods/Approach**

- **Data collection**:
  - AutoCAD layout of the facility was used to get approximate dimensions of tables and the area used for assembly.
  - Initial time studies were conducted to get baseline cycle times. After implementations were made, time studies were conducted for results.
- **Skills**:
  - TSM 440 lean manufacturing and value stream mapping knowledge was applied in this project.
  - TSM 444 knowledge to conduct a proper time study was used.
  - ABE 273 knowledge for creating an AutoCAD drawing for Donaldson.

**Solutions**:

  - Solutions were created by referencing the future state value stream map, time studies, and AutoCAD drawing.
  - Donaldson was looking for a reduction in the area used for the production line without decreasing the production times. A final AutoCAD drawing with the new assembly line was created.
  - A final time study of the new line changes was conducted.
  - The proposed solution creates a single-piece flow assembly line that reduces the total production area used.
- **Organization:**
  - Project responsibilities involved splitting the AutoCAD and Value stream map work between Miles and Ryan, and Michael focused on the safety and ergonomics.
  - Major milestones of the project were completing the initial time study done by the entire team and creating the current value stream map from that information.
  - The next milestone was the completion of the future value stream map and generating ideas for the improved line.
  - The final milestone will be implementing the proposed solutions and the entire team conducting a final time study.

# 4 Results

The completion of this project involves the Mechanical Air line being converted to a single-piece flow production without the use of additional operators and no overtime needed to meet the demands. We have met parts of this goal through the implementation of a new mixed-model layout.

Donaldson does not need to hire additional operators to run the line, but instead it uses all operators from both the Mechanical Air line and the T1 Snap production line to operate the mixed-model production line. Donaldson is still using consistent overtime with the current setup. There are several aspects that contribute to the continued use of overtime. Some of those reasons are inefficient changeovers and material presentation, some product lines do not use the standard processes for every station, and there was a large culture change with the switch from batch to single-piece flow. However, all of the issues can be attributed to the mixed-model production line being new, so we are confident these issues can be resolved in time with effort.

**Deliverables**

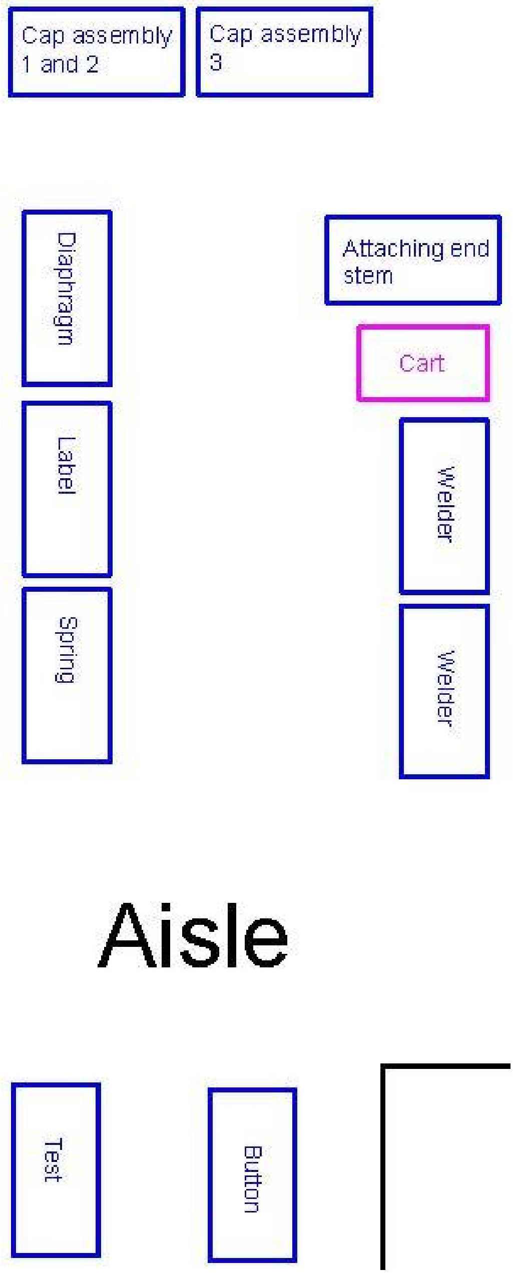
- Job safety analysis: Found in Appendix 8.1
- Time observations: Found in Appendix 8.2
- R and X-bar charts: Found in Appendix 8.2
- Yamazumi chart: Found in Appendix 8.3
- Current value stream map: Found in Appendix 8.4
- Future value stream map: Found in Appendix 8.4
- Further improvements: Found in Appendix 8.5
- Space reduction: Found in Appendix 8.7

# 5 BROADER OPPORTUNITY STATEMENT

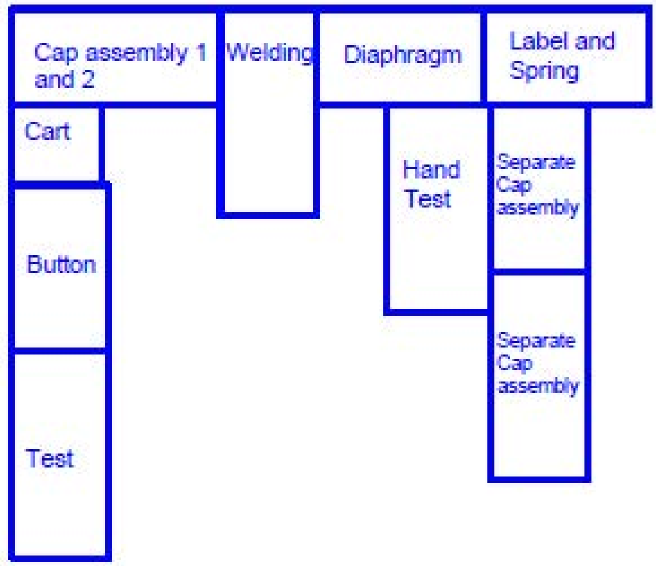
Our project, through and through was a lean manufacturing project. We believe that this project can appeal to anyone looking to take a lean approach to manufacture. Lean is a concept which is growing rapidly in the United States that can benefit all types of industries and not just the manufacturing industries. If more industries can adapt to lean manufacturing, we could see a boost in production around the world. There are endless possibilities to how much lean can affect everyone.

# 6 Graphical Abstract

Initial Facility Layout




Final Facility Layout




# 7 REFERENCES


- Stephens, M. P., & Meyers, F. E. (2013). *Manufacturing facilities design and material handling*. Upper Saddle River, NJ: Prentice Hall.

# 8 APPENDIXES

## 8.1 Job Safety Analysis

**Job Safety Analysis (JSA)**

| | | | |
|---|---|---|---|
| Activity/Work Task: **Mechanical Air Production Line** | | Overall Risk Assessment Code (RAC) | LOW |
| Project Location: **Donaldson Filter Minder, Waterloo, IA** | | | |
| Prepared by: **Michael Shultz** | | | |
| Date Prepared: **4/16/2019** | | | |
| PPE to be used: | Supervisor: **Allen Anderson** | | |
| 1) Ear Plugs<br>2) Safety Glasses<br>3)<br>4)<br>5)<br>6)<br>7)<br>8) | FILTER MINDER<br>The Filter Monitoring | | |

**RISK ASSESSMENT CODE (RAC) MATRIX**

| ***Frequency of Job*** | ***Severity of Incident*** | | | | |
|---|---|---|---|---|---|
| | **Minor** | **Moderate** | **Major** | **Critical** | **Catastrophic** |
| **Rare** | LOW | LOW | MED | MED | HIGH |
| **Minimal** | LOW | MED | MED | HIGH | HIGH |
| **Occasional** | MED | MED | HIGH | HIGH | EXTREME |
| **Likely** | MED | HIGH | HIGH | EXTREME | EXTREME |
| **Frequent** | HIGH | HIGH | EXTREME | EXTREME | EXTREME |

"**Frequency of job**"; how often does this job take place on your worksite?

"**Severity**" is the outcome/degree if an incident, near miss, or accident did occur?

**NOTE: You should not operate machines without proper training.**

| **Job Steps** | **Hazards** | **Controls** | **RAC** |
|---|---|---|---|
| Moving batches, parts, or supplies between work stations | Tripping; Repetitive Motion Stress | Keep walkways clean and clear of equipment, boxes, etc.; Perform stretches throughout the work shift, sit/stand with good posture. | LOW |
| Operating presses, ultrasonic welder, or vacuum tester | Pinch; Cut; Abrasion; Repetitive Motion Stress | Only one person may operate a machine at one time; Only activate 2-handed sensing switches with your hands; Sit upright when operating machine, do not move your face up close to the work done. | LOW |

Safety Walkthrough findings relayed to management:

- No GFCI receptacle near a water source.
- Items stored on top of the electrical breaker box.
- Less than 3 feet of clearance on all sides of the electrical breaker box.
- Flexible cord in place of permanent wiring.

### 8.2 Time Study Data

Initial Time Study

The initial time studies were conducted when the production line was doing batches of 50. To simplify conducting the time study, we timed the operator doing a full batch three times per process. Per batch time, we divided that by 50 to get the average cycle time for one part. Due to this, the ranges for the assembly time study will not be completely accurate but show a general representation.

| Assembly | Cap 1 | Cap 2 | Cap 3 | Welder | Label | Spring | Diaphragm | Button | Test | Averages |
|---|---|---|---|---|---|---|---|---|---|---|
| Cycle Time (average, sec) | 2.4 | 3.14 | 3.83 | 5.64 | 4.56 | 1.41 | 3.71 | 2.87 | 6.67 | 7.51 |
| Max (sec) | 2.72 | 3.85 | 4.34 | 5.84 | 5.14 | 1.64 | 4.5 | 3.16 | 7.38 | 4.29 |
| Min (sec) | 2.16 | 2.65 | 3.44 | 5.52 | 4.22 | 1.31 | 3.3 | 2.5 | 6.26 | 4.48 |
| Range (sec) | 0.56 | 1.2 | 0.9 | 0.32 | 0.92 | 0.34 | 1.2 | 0.66 | 1.12 | 0.80 |

Dwell time is the time between steps in the process where the product is not doing any value added or non-value added processes. We used the First-In-First-Out (FIFO) methodology to get the dwell times. An example of how to use FIFO is when a batch at cap station one is starting, and the first piece of that batch is completed, the timer is the started. The timer continues to run until that same first piece starts the next process.

| Dwell | Cap 1-3 | Cap 2-3 | Cap 3-weld | Label to spring | Spring to weld | Diaphragm to weld | Button to test | Averages |
|---|---|---|---|---|---|---|---|---|
| Dwell Time (average, sec) | 459.67 | 173.67 | 853 | 11.83 | 23.66 | 690 | 1175 | 483.83 |
| Max (sec) | 703 | 269 | 630 | 20 | 28.07 | 813 | 1681 | 592.01 |
| Min (sec) | 303 | 39 | 1011 | 6.9 | 18.65 | 597 | 651 | 375.22 |
| Range (sec) | 400 | 230 | 381 | 13.1 | 9.42 | 216 | 1030 | 325.65 |

Final Time Study

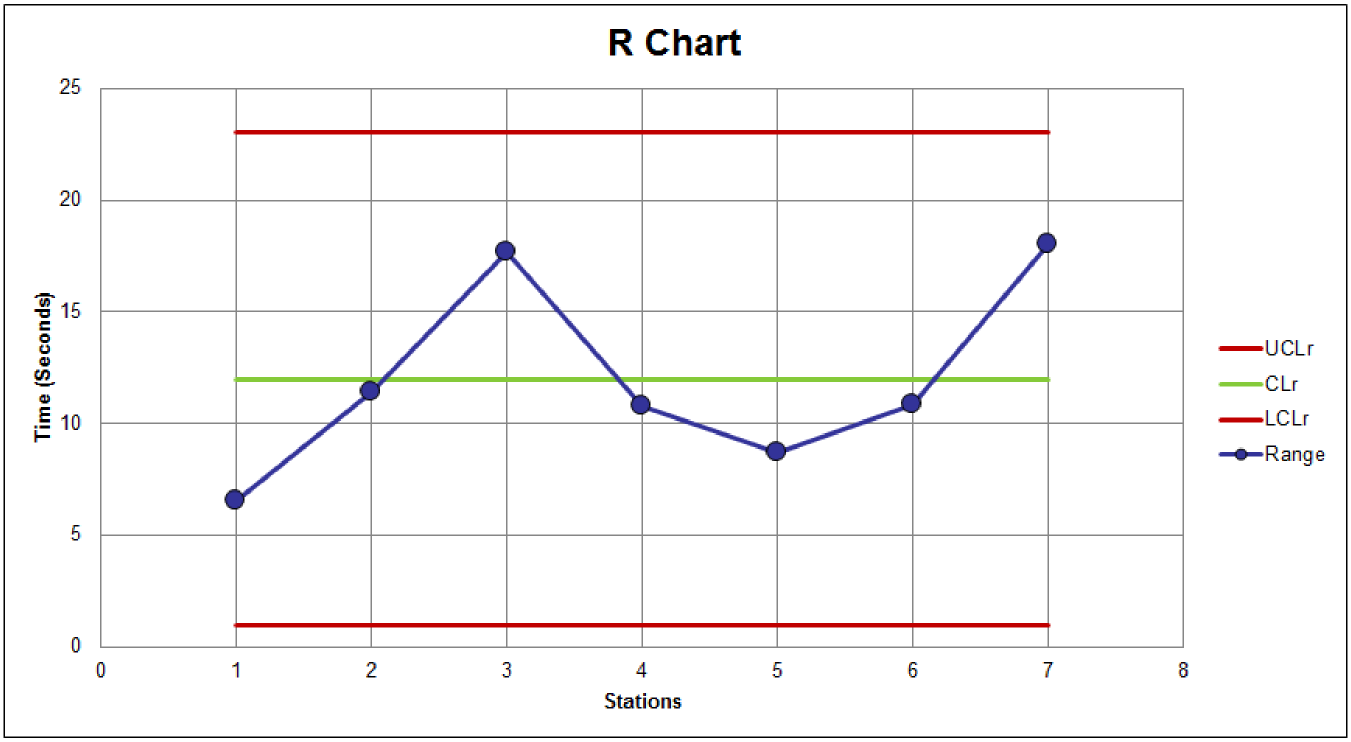
For the final time study, the production line was operating in single-piece flow. To get statistical significance for our data, we took 120-time samples of single pieces going through the stations.

| Assembly | Cap 1 | Cap 2 | Welder | Label and Spring | Diaphragm | Button | Test | Averages |
|---|---|---|---|---|---|---|---|---|
| Cycle Time (average, sec) | 4.87 | 9.23 | 9.52 | 7.22 | 7.36 | 4.54 | 9.86 | 7.51 |
| Max (sec) | 8.1 | 12.4 | 22.92 | 10.76 | 12.75 | 13.18 | 22.24 | 14.62 |
| Min (sec) | 1.6 | 1 | 5.26 | 0.16 | 4.1 | 2.34 | 4.24 | 2.67 |
| Range (sec) | 6.5 | 11.4 | 17.66 | 10.76 | 8.65 | 10.84 | 18 | 11.97 |

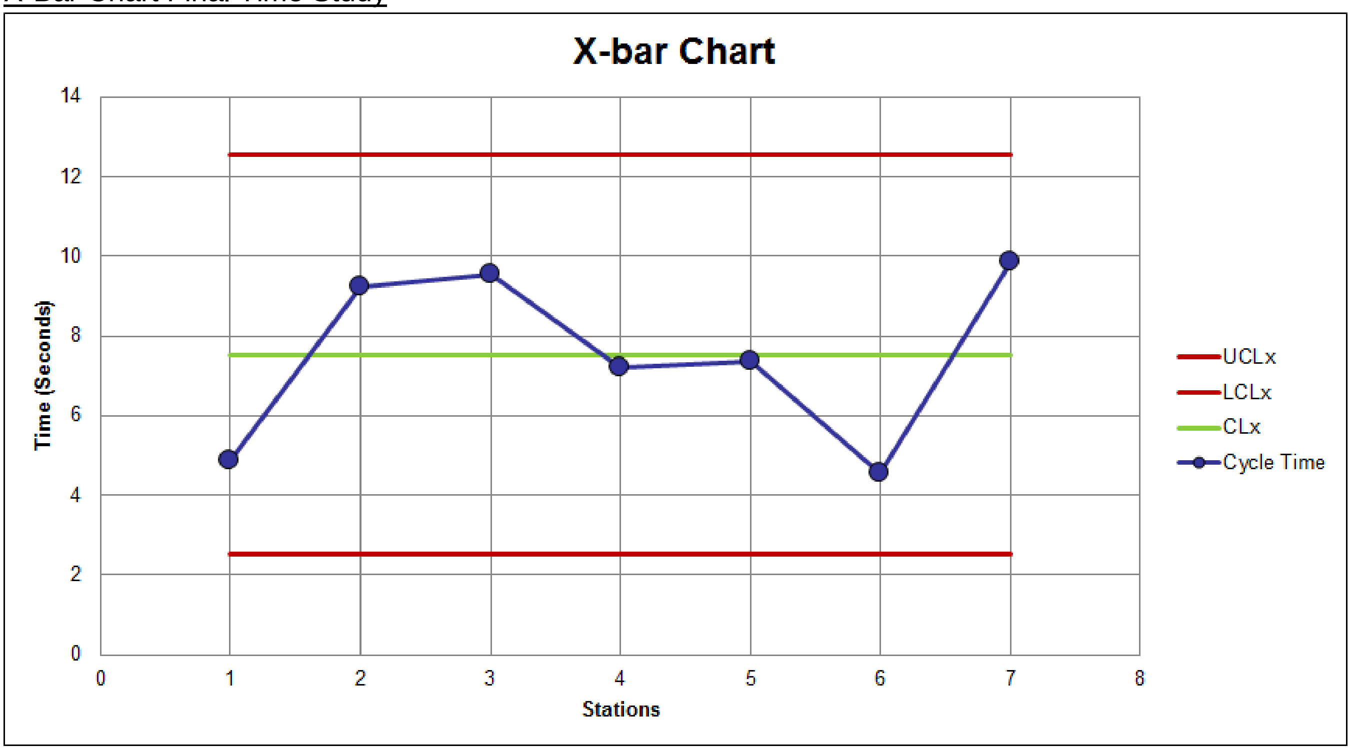
| Dwell | Cap 1-2 | Cap2 - Welder | Label and Spring - Diaphragm | Diaphragm - Welder | Button - Test | Averages |
|---|---|---|---|---|---|---|
| Dwell Time (average, sec) | 2.22 | 2.91 | 1.08 | 2.91 | 6.36 | 3.10 |
| Max (sec) | 4.4 | 6.6 | 3.07 | 6.23 | 11.8 | 6.42 |
| Min (sec) | 1.5 | 0.3 | 0 | 0 | 3.53 | 1.07 |
| Range (sec) | 2.9 | 6.3 | 3.07 | 6.23 | 8.27 | 5.35 |

With the data collected from the final time study, we were able to make X-bar and R charts. These are control charts which are used to measure process control and determine the stability of the process being evaluated. The Upper Control Limit (UCL) and Lower Control Limit (LCL) show the limits for the process to be within. If the process goes outside of these bounds, then it is considered out of control. The data collected from the final time study shows that the mixed-model line is in control.

R Chart Final Time Study

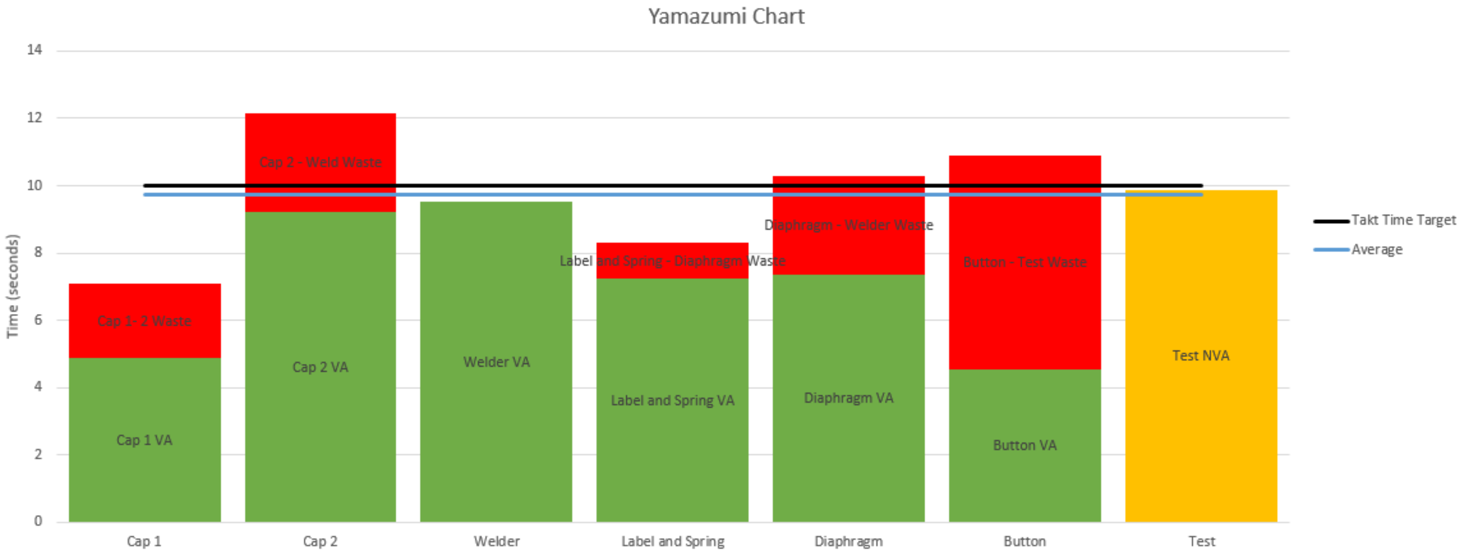



X-Bar Chart Final Time Study



### 8.3 Yamazumi Chart

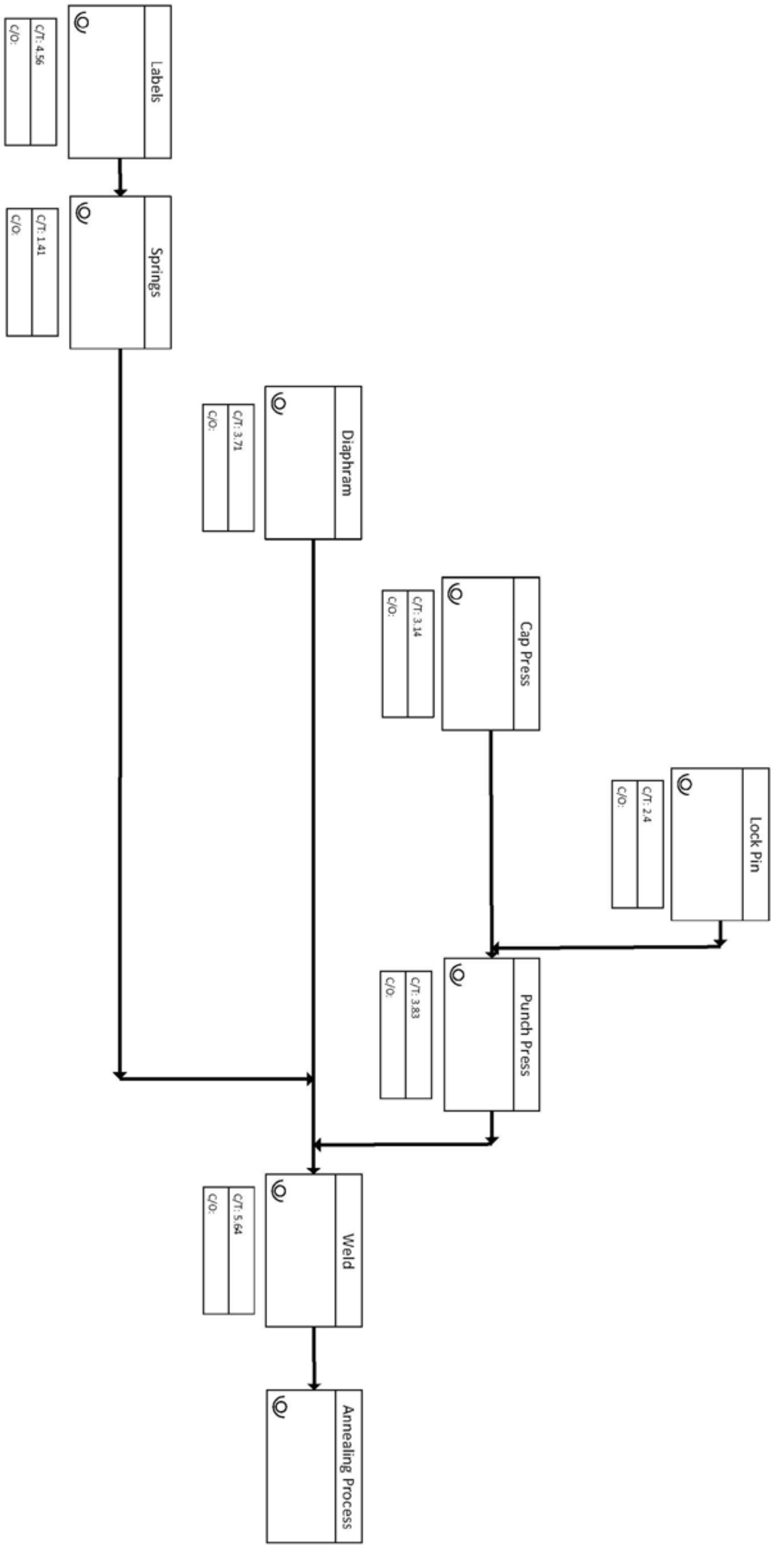
A Yamazumi chart is a stacked bar chart that shows value added, non-value added and waste in each process step. A process is value added is when a process does something to the product to change or improve it. Waste is when the product is doing nothing at that time, like dwell time. A process is non-value added when it does not do anything to change or add value to the product, such as testing the product.



### 8.4 Value Stream Maps (VSM)

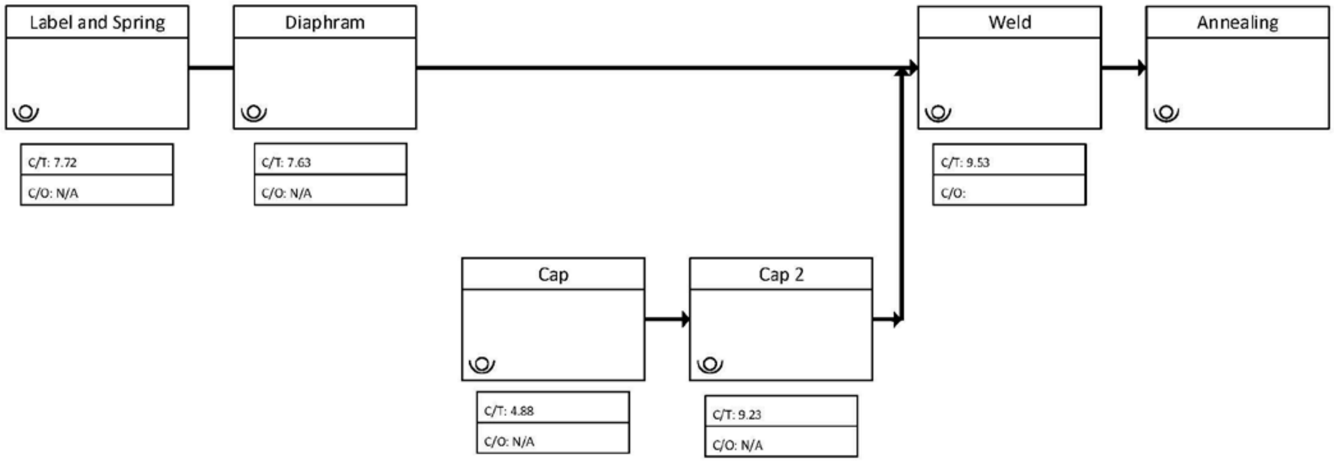
<u>Current VSM</u>

Condensed to fit report, button and test not included for space purposes.



Future VSM

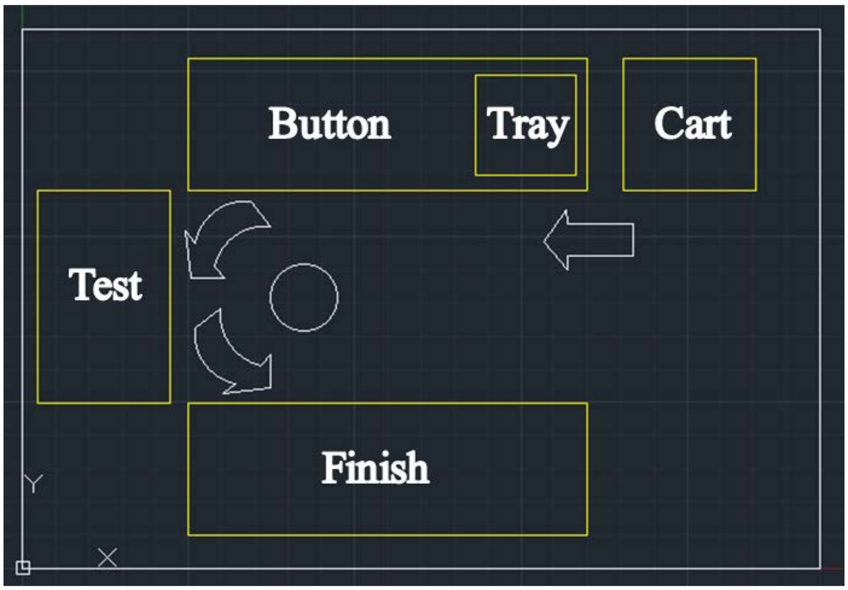
Condensed to fit report, button, and test not included for space purposes. In the future VSM of the final layout, the label and spring operations have been combined into one workstation. The capping process has also been changed from having three stations to now only two stations.



### 8.5 Further Improvements

For further improvements to the mixed-model line we believe the next step to take is improving the cap process. According to the Yamazumi chart and the future VSM, the Cap 2 process has the longest cycle times and is the current bottleneck. One potential solution to the bottleneck is having two operators doing a full cap assembly instead of breaking the process into two different steps. This will still utilize the same amount of operators, but potentially reduce the overall cycle times of the cap process.

Another improvement, which we believe will reduce the motion waste and save space, would be to move the button and test cell closer to the oven and have a single operator running the cell at all times. Below is an example of what that cell could look like.



### 8.6 Kaizen Event

Donaldson did a facility wide lean workshop that was out of the scope of our project, but from that workshop they decided to do a kaizen event for the Mechanical Air line, which fell into our scope. The events purpose was to combine our Mechanical Air line with the adjacent T1 Snap line and create a mixed-model line producing many different products. Our scope changed to include the T1 Snap line. A kaizen event is a 3 to 5 day brainstorming, waste identification, resource allocation and implementation tool. From this event we were able to calculate the resource allocation needed for each process. Resource allocation is the amount of workers needed for a certain process step. Resource allocation is calculated by finding the actual time weighed and dividing that by the takt time target as shown below.

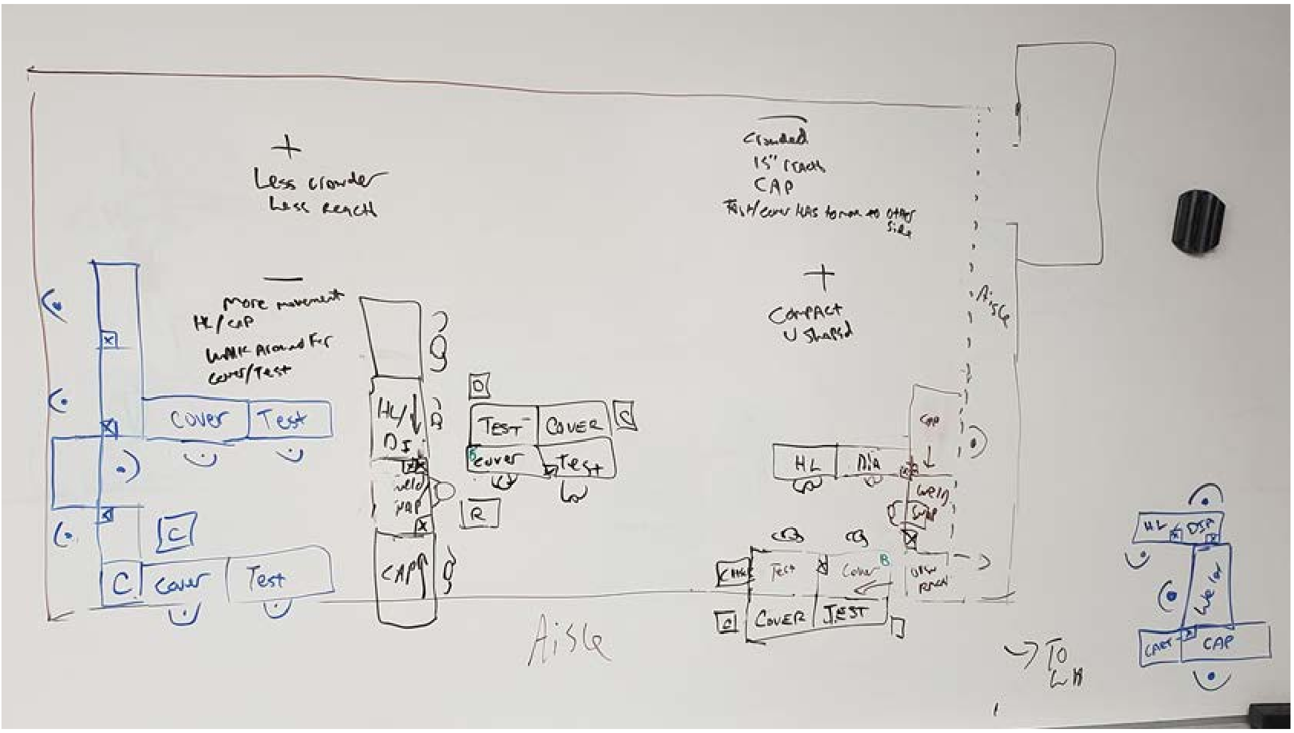
Actual Time Weighted (ATW)

$$ATW = \frac{DailyDemand}{ActualTime}$$

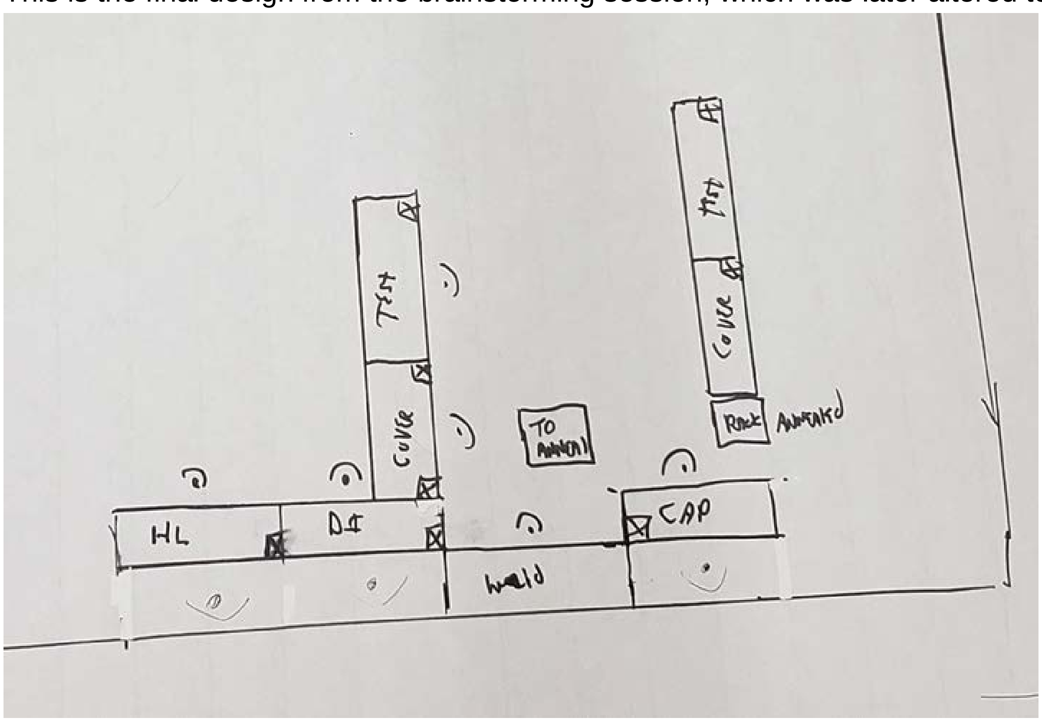
$$Resources = \frac{ATW}{TaktTimeTarget}$$

The kaizen event started with creating a layout of the initial flow of production. This was laid out on sticky notes with information such as the process name, resources needed and equipment needed.

After the initial flow of production is created a brainstorming session is done creating different layouts of the process while referencing the sticky notes to ensure no steps are missed or out of order.




This is the final design from the brainstorming session, which was later altered to improve performance.



### 8.7 Area Reduction Calculations

| | Old (sq ft) | New (sq ft) | Area reduction |
|---|---|---|---|
| Area | 531.50 | 421.167 | 20.8% |

The old area calculation takes into account the area of the two lines used in the new mixed-model line. The new area calculation takes into account the area of the new line, the additional space needed for the movable welder stations and the additional line needed for the products with the long cycle time and lower quantity.

When first implementing the new mixed-model production line, there were some products that were causing the line to operate at a takt time of roughly 15 seconds when the target is 10 seconds. Due to this, the decision was made to split off the product lines that were causing an increase in takt time. This line is nearby to the mixed-model production line which is only operated when needed. This allowed for the mixed-model production line to operate at the times shown in the final time study.