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Independent Project

Lean Six Sigma Project – BX Oven
Section



Dissertation

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Declaration of Authenticity

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: C. P. [Signature]

Date: 17 May 2023

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Abstract

This thesis focuses on the implementation of a Lean Six Sigma DMAIC project aimed at reducing defects and eliminating waste in the BX oven section at Mono Equipment's manufacturing facility in Swansea. The project was initiated due to the dissatisfaction of a key strategic customer experiencing poor quality and under-delivery of machines, which resulted in many warranty calls.

The DMAIC methodology was chosen for this project, as it is a well-established framework for process improvement. The project team consisted of a cross-functional team from various departments. The team began by defining the problem, collecting data, and establishing the scope of the project.

After analysing the data, the team discovered the source of defects and waste in the BX oven section. It was determined that a combination of several factors led to inconsistent quality and increased waste. To address these issues, the team created a Value Stream Map for the entire operation, which helped identify areas for improvement through KAIZEN opportunities.

The results of the project were significant, with a 25.2% reduction in defects and a 21% increase in performance by eliminating lean wastes within the BX oven section.

The project utilizing Lean Six Sigma DMAIC proved to be successful in reducing defects and eliminating waste in the BX oven section. As a result, customer satisfaction improved, quality was enhanced, and manufacturing efficiency increased. The implementation of various lean six sigma tools and concepts contributed to achieving these goals.

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1 Introduction

In the last 24 months, the COVID-19 pandemic, global supply shortages of raw materials, semiconductors, and rising energy costs have created an economic crisis that forced Mono Equipment to make difficult decisions to meet customer demands.

These external factors forced Mono into a total redesigning of the BX oven range to accommodate a new controller as the current supplier was unable to supply the quantities required, as a consequence the ovens were rushed into production.

The BX Ovens section is crucial to Mono Equipment, representing over 60% of its total revenue.

The project was defined when a key strategic customer raised concerns surrounding the quality of the 'new style oven' Further to this Mono had significantly under delivered the desired quantity of ovens.

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1.1 Aims

This thesis focuses on the implementation of a lean Six Sigma DMAIC project aimed at reducing defects and eliminating waste in the BX oven section of Mono Equipment's manufacturing facility.

1.2 Objectives

The project was initiated due to the dissatisfaction of a key strategic customer who was experiencing poor quality and under delivery of machines, which resulted in a high number of warranty calls, using lean and 6 sigma principles to improve customer satisfaction by reducing defects and increase output.

2 Literature Review

2.1 LEAN

The concept of lean manufacturing was developed to maximise the resource utilisation through waste reduction. By introducing lean allows manufacturing companies to maintain a competitive edge against business competition.

As ever with a rapidly evolving environment organisations and businesses face challenges, success will depend of the company's ability to continuously respond to the changes while enhancing product value. (Sundar, 2014) Therefore to seek perfection a value adding process must be defined, and by definition implementation of lean strategies. (Summers, 2011)

Lean implementation seeks the ideal way, the ideal way can mean many things to different organisations, this is important to recognise that every step taken on the lean journey should move towards the ideal way. (Nicholas, 2011) This could be perfect quality, zero waste, perfect customer satisfaction.

The lean toolbox mentions the six rights as a fundamental philosophy. Right product, right place, right time, right quantity, right quality, and right cost. (Bicheno, 2009) To seek perfection on a lean journey involves finding the best way, there is after all the best way to do everything. To seek this requires a deep understanding of the customers and the participation of all employees. (Lane, 2007)

Lean can be a repetitive process, for example reduction in batch size moves us closer to the ideal, batch size may need further reduction in the future.

The Lean principles ensures the product value is defined as perceived by the customer. Then flow needs to be gathered in line with the customer pull whilst striving towards perfection through continuous improvement techniques and eliminating wastes by identification of value added and non-value-added steps. (Bicheno, 2009)

The main sources of non-value adding waste within manufacturing can be identified using the acronym DOWNTIME. This stands for defects, overproduction, waiting, non-utilisation of talent, transport, inventory, motion, extra processing. By eliminating these wastes is achieved successfully implementing lean strategies. (Lane, 2007)



Figure 1: LEAN Principles

2.2 Six Sigma - 6σ

It is essential that companies / organisations maintain a competitive edge. This should challenge leaders daily. Quality, productivity and cost these three words is what drives effective organisational leaders. (Summers, 2011) What do these words mean? Is it:

- Enhancing Customer Satisfaction
- Maintaining a safe, organised and clean workplace
- Using effective logistics
- Deploying facilities, raw material, and technology effectively
- Employing and motivating talented people.

All these fundamental principles create a better product and service that the customer expects. Six Sigma is a process optimisation tool which has the ability to improve the three metrics. It is said that 'The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost' (Summers, 2011).

Six Sigma Methodology is driven by results, reduce cost, improve quality, enhanced efficiency, customer satisfaction. It aims to reduce variation and focuses on doing the right things right. It uses customer knowledge combined with process optimisation.

In the 1970's Motorola, discovered the cost of poor quality the hard way, they were consistently beaten in the market until the large operational changes were made. Which ultimately created the

Six Sigma Methodology. (McCarthy, 2005) Bill Smith a reliability engineer at Motorola believed that increasing system complexities beyond what the customer desires ultimately increases the failure rate. To reduce the failure rate the components need to have a failure rate of zero. (Summers, 2011) This mentality led them to create the Six Sigma. This was described as a highly focused system of problem solving with a strategy to reduce defects to 3.4 defects per million units. (George, 2002).

Ultimately companies that realise driving new methods to cut production costs, improve quality, speed up assembly times and increase throughput are vital to staying competitive. By combining both lean and six sigma together enhances the effectiveness of both methods. In essence the message of working hard to keep things simple saves money. Six sigma concentrates on reducing process variation. Lean enhances company performance by reducing waste.

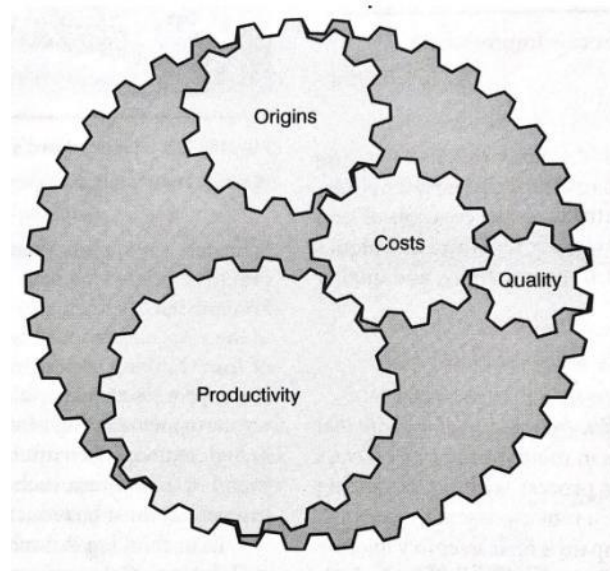


Figure 2: Six Sigma Process Optimisation (Summers, 2011)

2.3 Change Management

Change is often very difficult to implement within organisations, this is often because of culture rooted within. To introduce change is difficult as the results are often difficult to predict and this can be unsettling. (Carnall, 2014) Change is difficult as it is about people, therefore we need to understand human behaviour and feelings on the receiving end of change. (Burnes, 2014)

Given the current situation of global pandemic, supply chain issues, increasing cost of raw materials has forced many organisations into change. Ultimately the current economic climate can be described as a period of rapid continuous and simultaneous change. (Carnall, 2014)

Along with these effects globally Mono Equipment has also gone through a massive period of change with an aging workforce reaching retirement age and a local skill shortage to the wider area making it difficult to hire the right people. Coupled with an increase in variants has created a perfect storm.

3 DMAIC – Define

3.1 Voice of the Customer – External

As a customer of Mono Equipment's new range of ovens, Greggs experienced a rapid increase in failures and warranty callouts, this resulted in an increase in costs and placed pressure on the maintenance department. They received 420 ovens to date, out of which 135 required a warranty callout for repair, with 18% of ovens failures due to the new controller.

Greggs were also concerned that the number of ovens received fell short of what they had expected, affecting their ability to meet their growth plans.

The length of time it took to repair and replace the controller also caused a significant loss of revenue, with an average repair time of 20 days before the machine was back functioning.

3.2 Problem Statement

The new style ovens provided by Mono Equipment to Greggs since October 2021 have shown a significant increase in failures with 18% of the failures being linked to the new controller, compared to 5% with the old-style controller. This increase in failures was having an impact on Greggs ability to maintain operational effectiveness as the failures resulted in an increase downtime averaging 20 + days to replace / repair controllers.

Mono Equipment has failed to deliver 35% of the ovens expected by Greggs, resulting in a loss of revenue in the region of £455,700.00 to Mono.

The average repair and refurbishment time for the controllers is 20 days, leading to substantial revenue loss for the customer.

These challenges pose a threat to Greggs' ambitious growth plans and require urgent attention to identify and resolve the root cause of the failures and shortfall of ovens delivered and improve customer satisfaction..

3.3 Project Charter

A project charter was used to justify the project, highlight the major deliverables, objectives and forms the basis for future project decisions, it was used to communicate with stake holders and allow scope management as the project progressed.

BX Ovens – Project Charter			Version 1	001
Project Name	BX Ovens Improvement Project	Process Owner	Andrew Jones (MD)	
Project Start Date	28-Oct-2022	Project leaders	Craig Petherbridge (QM)	
Estimated Duration	28-April-2023 (6 Months)	Mentor	Andrew Williams (OM)	
Business Case: Unable to meet customer demands and excessive warranty calls have been observed, highlighting the controller as main concern.		Primary: Improve efficiency		
		Secondary: Reduce warranty callouts		
Business scenario: MONO Equipment has struggled to meet the demands of the customer, Gregg's PLC highlighted that they have only received 65% of their expected ovens. Greggs maintenance department has seen an increase in warranty call outs regarding their 'new style' ovens. The current production area is deemed to have inefficiencies due to a number of lean wastes. The reason identified is the rapid introduction of new machines into production. Production appears to be failing to hit KPI's. The last 10 months has increased the pressure on the section with both manpower and supply issues. This project will look to use a range of lean manufacturing tools to drive continuous improvement activities.				

Using the 5S and red tagging process for the removal and relocation of any end of life or obsolete items will alleviate the pressure and increase efficiencies. Obsolete items can be discarded, and important test equipment, jigs and fixtures stored safely.

A value stream map will highlight improvement opportunities.

Sales forecasts for 2023 is showing an increase in product demand for U.K. and U.S.A. markets for BX Ovens range.

Problem Characteristics & Statement:

- Failed to deliver 35% of ovens expected by Greggs.
- Poor quality concerns raised by the customer regarding their 'new style' ovens.
- Slow returns leading to downtime.
- Production line failing to hit targets.
- Increased demand putting pressure on new inexperienced workforce.
- Limited amount of space to sustain the increased demand.
- Identify manufacturing & Lean wastes.

Objectives:

- Increase output by 35% to meet the customers demands.
- Reduce warranty calls on controllers to below 5%
- Reduce all other warranty calls by use of Poke Yoke / RCA.
- Identify appropriate Subject Matter Experts (SME) to identify and label with red tags.
- SME will identify all applicable obsolete and end of life equipment.
- Storage areas (shelves, containers etc.) are to be fully labelled with standardised labels.
- Reduce manufacturing waste.

Metrics:

To measure the effectiveness of the project the total number of ovens manufactured daily will be recorded and measured before and after any improvements or kaizen activities. This will assess overall production capacity.

Greggs warranty data will be analysed from the first 6 months of new style ovens to assess overall performance, the data will be categorised and grouped. The most frequent issues will be assessed and using a combination of process and engineering changes will be made to reduce or eliminated the defects.

Project Scope:

- Inefficiencies will be eliminated using Lean.
- The warranty data will only be gathered from the year previous, to assess 'new style' ovens.
- Data will only include Greggs specific BX oven.

Key Points:

The project must not impact on current production demands, all improvements will be made outside of regular hours. Considerations will need to be made about increasing staff levels to balance production and help meet current demands.

Removal of obsolete equipment will improve space and layout issues.

Error proofing will be used to reduce defects to further combat excessive warranty callouts

Data/Information required:

- VSM data will include inventory levels and WIP
- Greggs Warranty Data to be used.
- Identification of appropriate SME with knowledge of end of life or obsolete equipment.
- Agreed standardised methods for equipment/ tooling
- Historical data can be used.
- Any investment required must have a CAPEX approval.

Table 1: Project Charter - Greggs Warranty Callouts

3.4 Project Team

After developing the project charter, it was essential to develop a diverse team of SME to be involved at the earliest stage of the project, thus giving ownership and detailing each individual's role within the project.

With the specific strategy set it is important that the project team members have the knowledge, skills, abilities, and personal attributes (KSAP) to successfully achieve the project objectives withing the timeframe. (Pyzdek, 2003)

Project Team			
DMAIC Project – BX Oven Improvement Project			
Project Co-ordinator: Craig Petherbridge (Quality Manager)			
Position	Name	Project Role	Time (h/week)
Managing Director	Andrew Jones	Project Sponsor	1
UWTSD Lecturer	Andrew Thorn	Project Sponsor	1
Operations Manager	Andrew Williams	Project Sponsor	5
Process Engineer	Darryl Evans	Project Leader	20
Production Planner	Helen James	Project Leader	5
Production Planner	Jonny Randell	Project Member	10
Section Supervisor	James Davies	Project Member	40
Electrician	John Dowsett	Project Member	20
Production Tech	Kevin Tucker	Project Member	40
Production Tech	Dylan Goddard	Project Member	40
Production Tech	Stuart Dalling	Project Member	40
Production Tech	Tony Fett	Project Member	40
Production Tech	Harry Dunn	Project Member	40
Production Tech	Robert Davies	Project Member	40

Table 2: Project Team

3.5 Stakeholder Analysis

The stakeholder analysis was written to inform project members of all stakeholders both internal and external to the company, this analysis defines their role, the importance, what is expected and how they are likely to benefit from the project.

Stakeholder Analysis					
DMAIC Project – BX Oven Improvement Project					
Project Co-ordinator: Craig Petherbridge (Quality Manager)					
Name	Interest	Support	Priority	Action	Gain
Andrew Jones	Project Sponsor	Financial	High	Weekly Meeting	Increased Profit
Andrew Thorn	Project Sponsor	Project Mentor	Medium	Monthly Meeting	Successful Project Delivery
Andrew Williams	Production Manager	Production Demands	High	Allocation of resource	Improved efficiency
Darryl Evans	Project Leader	SME	High	Support and advice	Improved efficiency
Neil Walters	Customer	Data	High	Monthly Performance Meeting	Reduced warranty calls
Simon Moon	Sales Director	Customer Support	High	Monthly Meeting	Improved customer satisfaction

Table 3: Stakeholder Analysis

3.6 SIPOC

The SIPOC diagram was created after the project teams brainstorming session in the initial project meeting, it was used to identify the critical information for the project, each step was analysed identifying suppliers, inputs, major process steps, outputs and the customers. It was important for the whole team to witness how each step interacts with another.

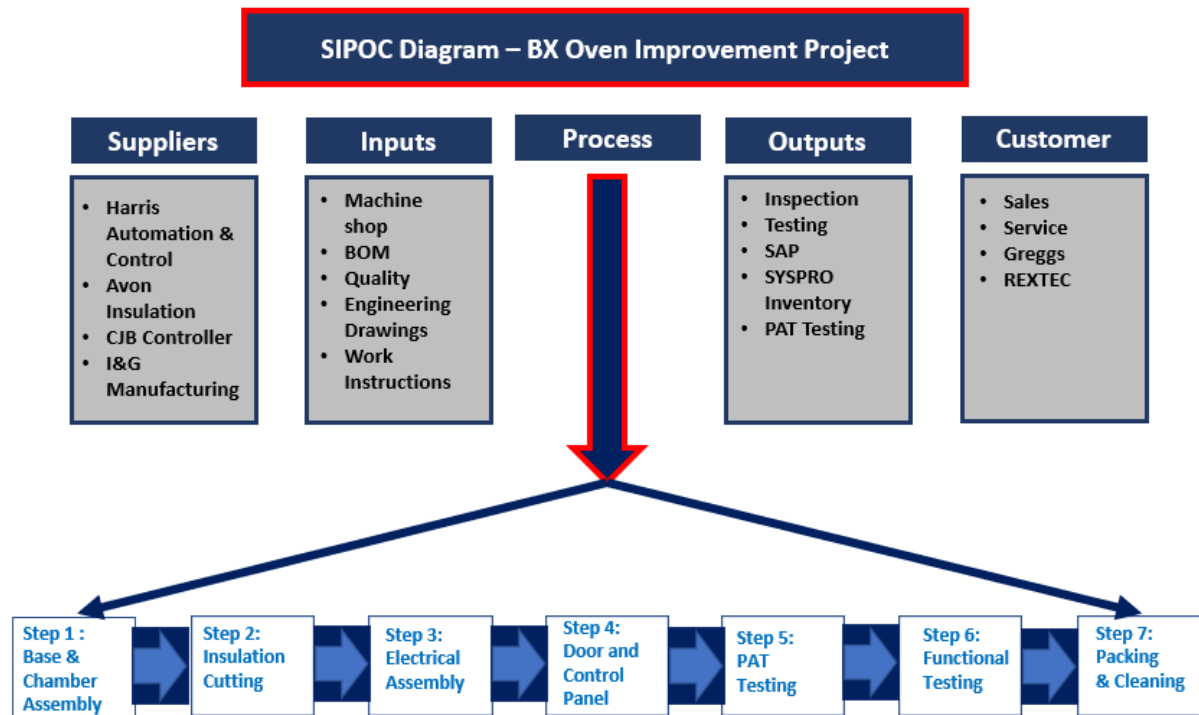


Table 4: SIPOC Diagram

3.7 Boundary Tool – Is / Is Not

The simple Boundary tool was used and displayed so the project team understood the basic metrics for the project, this saves confusion, and prevented additional issues being addressed.

3.7.1 Is

- Improve efficiencies.
- Reduce oven failures.

3.7.2 Is Not

- To effect current production.
- Change suppliers.

3.7.3 Problem Characteristics

- Failure to meet the demands of Greggs Plc.
- Excessive warranty callouts due to quality related issues.

3.7.4 Problem Statement

- Poor efficiencies resulted in Mono failing to meet the demands of a strategically important customer, Greggs is a leading food supplier in the UK. Greggs Plc is strategically important to Mono and is described as critical to business.

3.8 Project Timeline – Gantt Chart

The project timeline was created to ensure deadlines were respected and kept the project flowing, it was also used to identify if targets were going to be missed so additional resources could be allocated to the task.

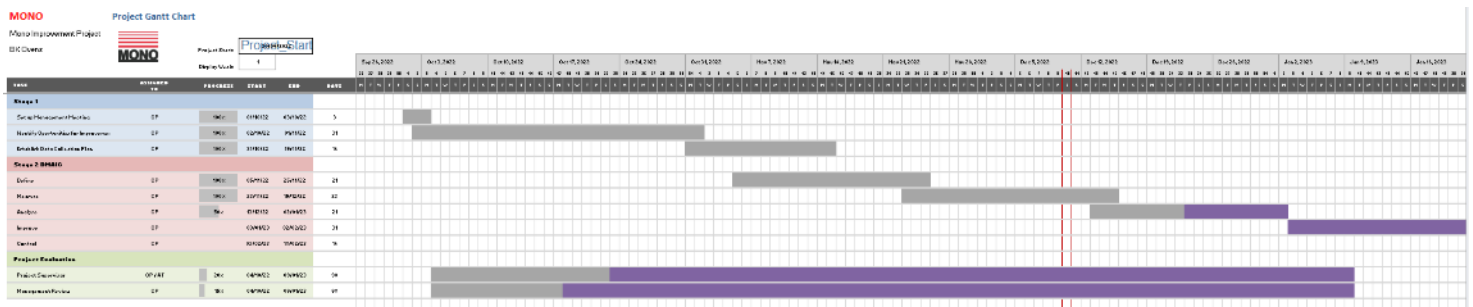


Table 6: Full Gantt Chart

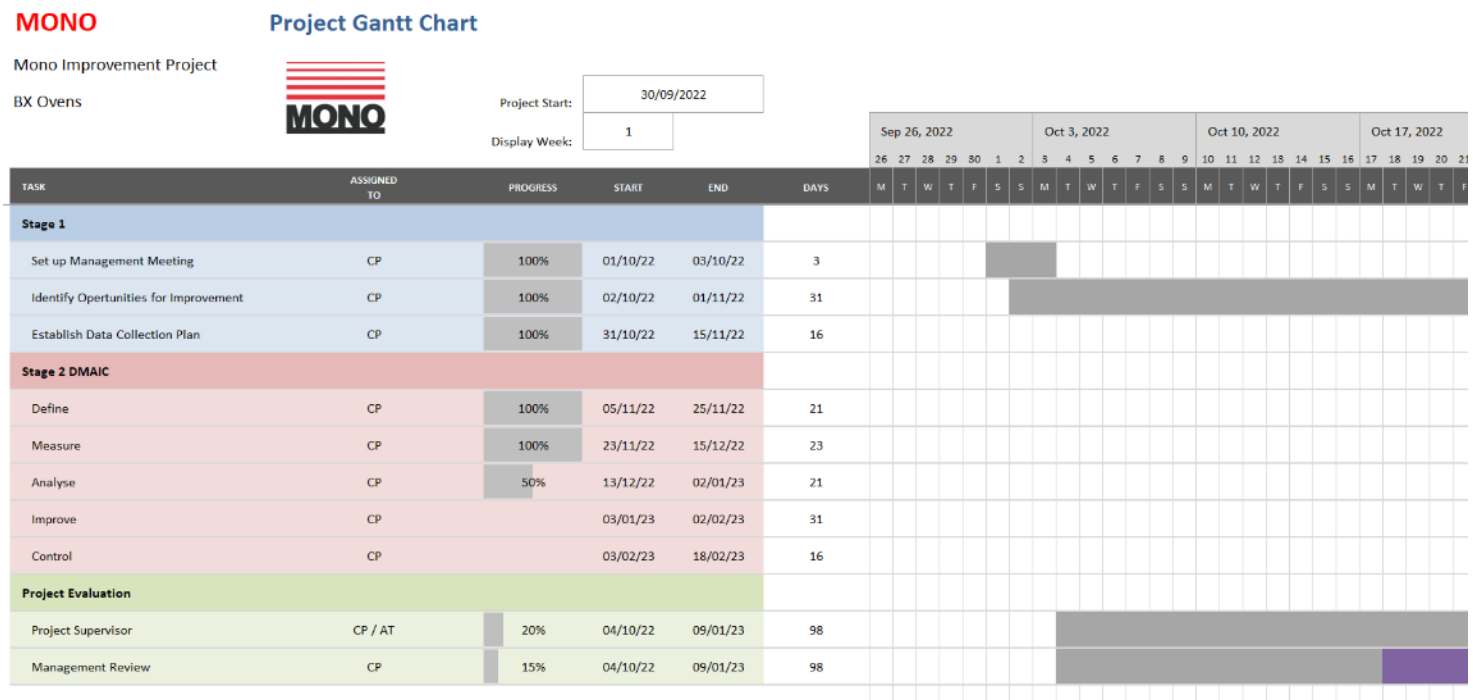


Table 5: Gantt Chart Zoomed

3.9 SMART Objectives

The SMART Objectives Poster was created to allow team members and stakeholders to track and monitor the goals set and eliminated confusion.

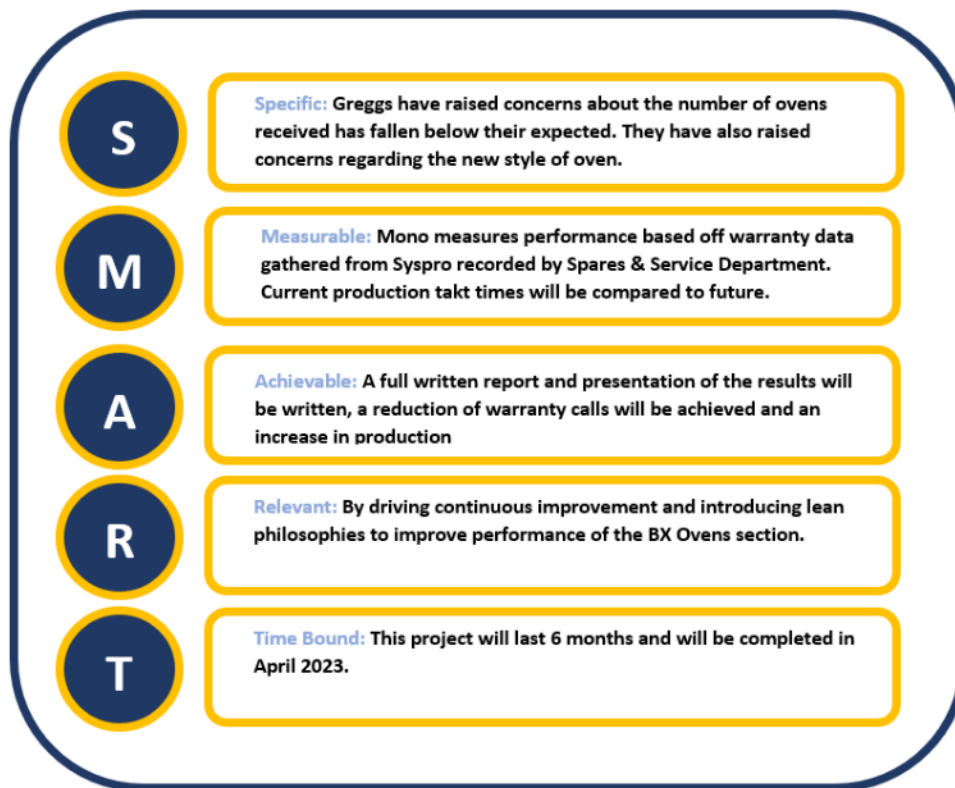


Figure 3: SMART Objectives Poster

3.10 High Level Process Map – Controller Returns

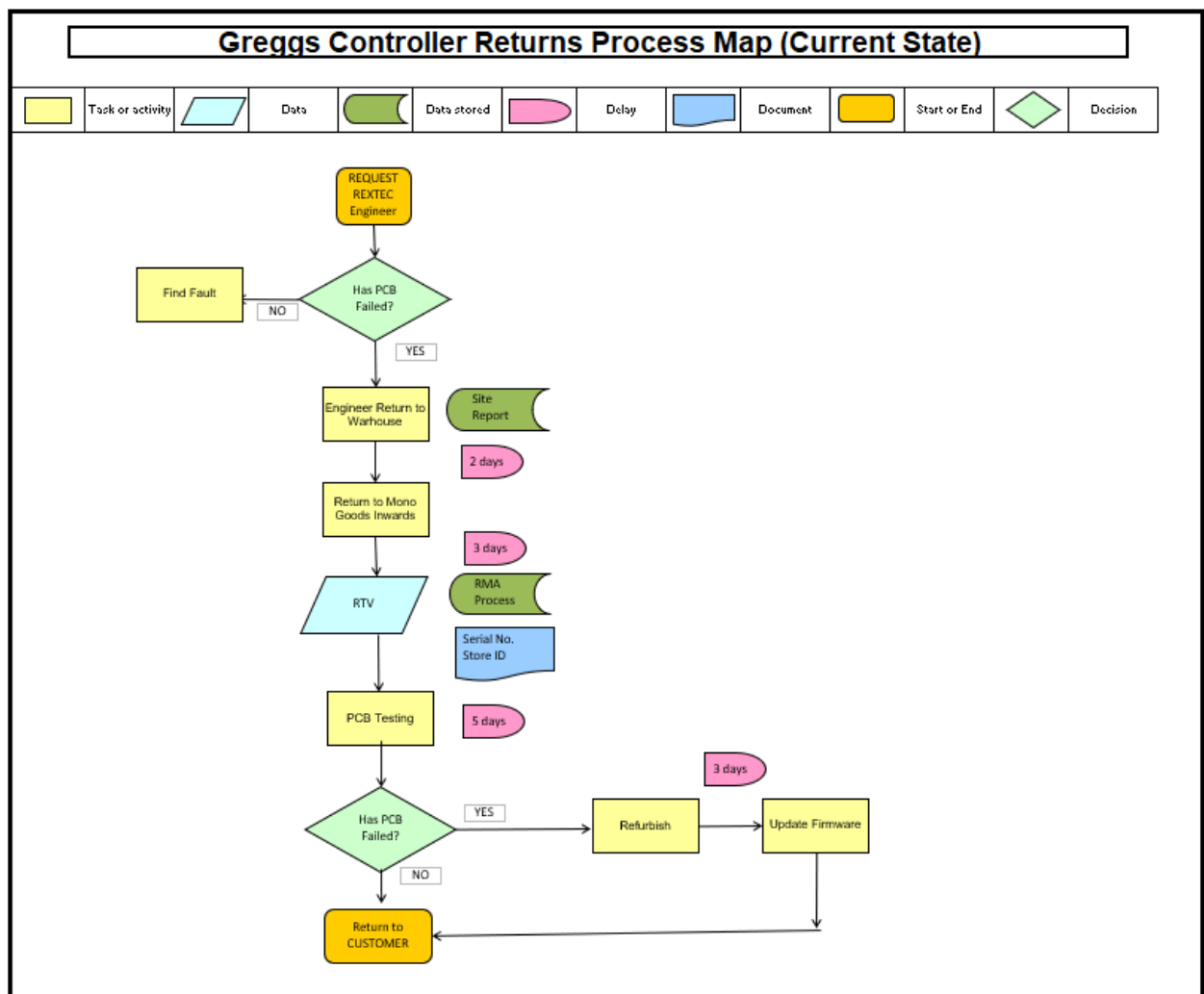


Table 7: High Level Process Map - Returns Process

A high-level process map / flow diagram was created to identify the bottlenecks within the returns process, the delays accounted for a lack of manpower and resources to deal with the level of returns.

3.10.1 Delay No.1

The first delay was recorded as 2-day hold time by the service provider (Rextec), this delay is inherited by returning defective parts in bulk as appose to individual items.

3.10.2 Delay No.2

The second delay was of 3 days and because of slow RMA processing requiring recording and inputting, manpower issues result in delays and the highest priority items get processed first.

3.10.3 Delay No.3

The third delay is as a result of PCB testing, the testing is conducted by Maintenance Engineer Steve Lok, Steve's job requires him to be away from site for many days sometimes even weeks at a time. This causes further delays.

3.10.4 Delay No.4

Is a result from the requirement of programming, this involves the storeman to collect the board and take it to the test bay for the firmware to be updated, witnessed as 3 days, the 3 days was a result of no communication to establish the controller had been refurbished.

3.10.5 Customer Impact

The table below displays and calculates the total impact on the store should their oven controller fail and the time to repair is 20 days. The aim was to reduce downtime by 70% totalling 6 days to return, process and dispatch back to store. If this is achieved the customer (Greggs) will see an estimated saving of £34,776 per unit by reducing the turnaround time.

Average days Lost due to controller failure	20 days
0500 – 1400 Operating Time (9 hours)	9 hours
Total Machine Hours Lost	$9 \times 20 = 180$ hours
Average Bake Time	25 minutes
Bakes in an Hour	$60 / 25 = 2.4$
Number of Units / Tray	$4 \times 6 = 24$
Average Number of Trays / Bake	4
Average Number of Units / Bake	$24 \times 4 = 96$
Average price / unit (£)	1.2
Cost / Bake (£)	$96 \times 1.2 = 115$
Total Cost Impact to Customer	$(115 \times 2.4) \times 180 = \text{£}49,680$
Estimated Improvement	Reduce downtime by 70%
Estimated Saving	$49680 \times 0.70 = \text{£}34,776$
Target Time to Improve	3 Weeks

Table 8: Quantifying Impact to Customer - PCB Returns

By quantifying the impact to the customer in the define stage highlights the need to act and with what urgency, this gives every team member an understanding of the importance to act. (Martic, 2020) If the target is achieved the customer (Greggs) will see an estimated saving of £34,776 per unit by reducing the turnaround time.

3.11 Manufacturing Process Map

The process map below was created for the oven manufacturing process, this visual display shows every step created from customer request, through to dispatch. This focusses on the assembly lines with the BX ovens section, with production planning and line feeding are integrated.

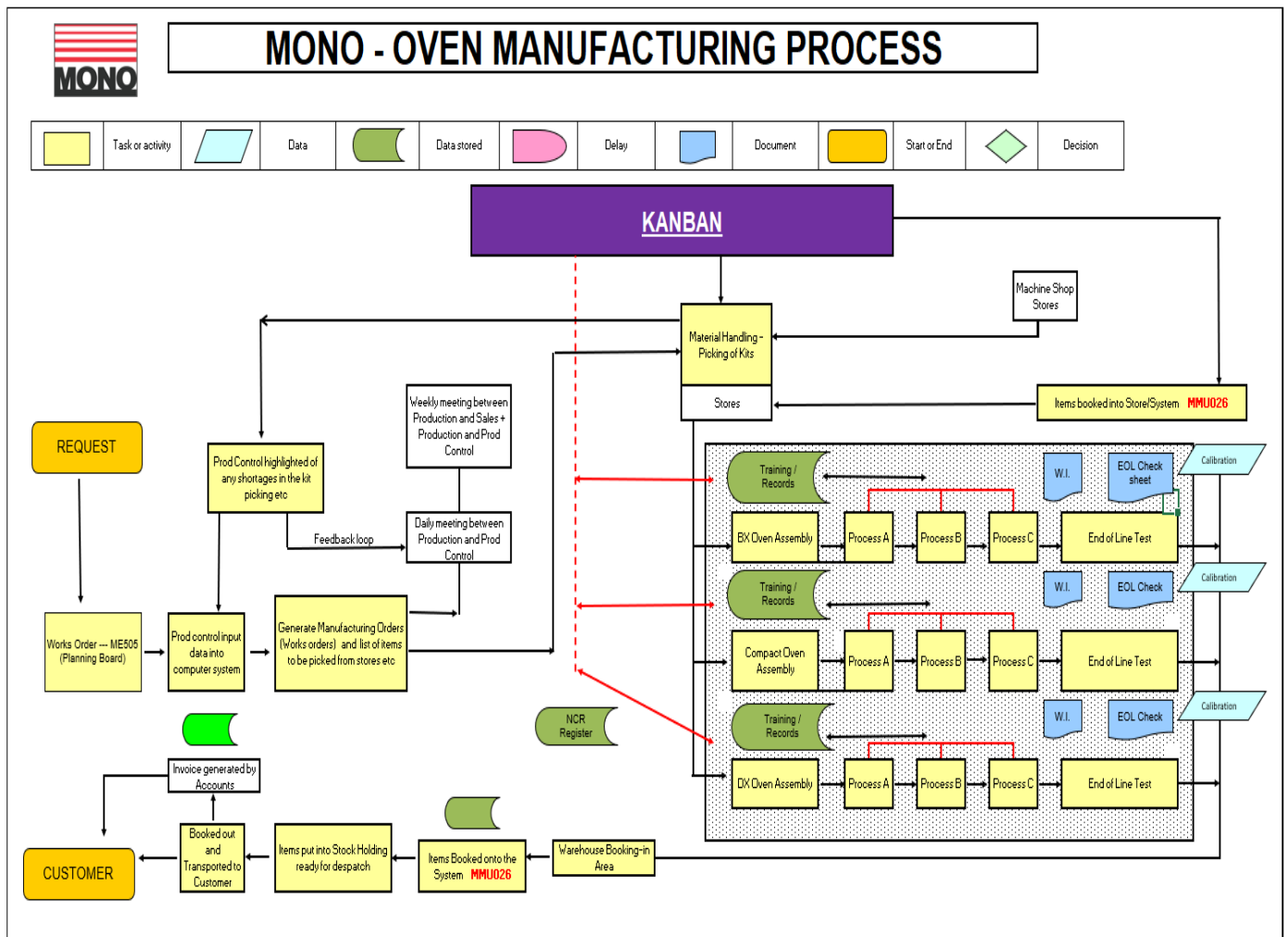


Table 9: Oven Manufacturing Process Map

4 Measure

4.1 Greggs Warranty Data

Table 10 and 11 was issued by Neil Walters National Contracts Manager at Greggs, table 10 details overall faults, and specifically focuses on controller failures compared with their previous model, typically 5% of failures related to old eco ovens compared to 18% on new BX ovens.

Information	
Pairs of Eco ovens in the Greggs estate (420 assets)	210
Faults logged to Eco ovens	371
Faults logged to Eco oven that fall under warranty work	135
Average time to return a PCB and receive back	17 days
Average time oven is Out of Order (faulty PCB only)	20 days
Nov 21 - Nov 22	
Percentage of Eco ovens with PCB faults	5.20%
Percentage of BX ovens with PCB faults	18.10%

Table 10: Greggs Warranty Data Supplied

Count of Fault	
Fault	Total
Condenser fan on hood	1
damaged led lighting wiring	10
door catch loose	54
door handle loose	1
door handle snapped	1
faulty overload	1
Faulty PCB	19
Faulty PCB	1
faulty PSU	2
faulty thermocouple	1
flue leaks onto elements	1
flue not tightened	1
flue too close to element	
connection	1
fuse on pcb	14
Hinge snapped	1
led lights	1
Led strip light faulty	3
loose door	1
loose internal connection	11
loose screws	4
Main fan motor faulty	1

Door Issues: 56

PCB Issues: 38

Table 11: Greggs Warranty Data Supplied

Greggs provided Mono Equipment with the warranty data which had been collected through service department. This was in spreadsheet format with only a brief description of the fault. The team began by utilising the VLOOKUP function and adding the invoice date taken from Mono Equipment's MRP System SYSPRO, by adding the invoice date the number of days to failure could be calculated from the fault logged date in the spreadsheet. This information provided us with a number of benefits including assessing the accuracy of the data Provided, on analysing the data the number of days to failure was too great to be considered, this excluded a total of 9 defects which were added in error and confirmed by serial number. It is essential to verify the given data especially from third party source.

Table 12: Greggs Data Analysed

4.3 Pareto Analysis

The data spreadsheet was grouped using a pivot table to establish categories to account for each failure. The pareto analysis highlighted that 30% of ovens had failed under warranty.

Total Number of Ovens	420	%
Total Faults 1 st 6 Months	126	30.0

Table 13: Totals Ovens Built & Faults

Fault Type 1 st 6 Months	Freq	Freq %	Cum Freq	Cum Freq %	Fault %
Oven Temp	35	27.8	35	27.8	8.3
PCB Failures	32	25.4	97	77.0	7.6
Door Issues	30	23.8	65	51.6	7.1
Oven Not Working	17	13.5	114	90.5	4.0
LED	7	5.6	121	96.1	1.7
Other Electrical	5	4.0	126	100.0	1.2

Table 14: Pareto of Faults from Data

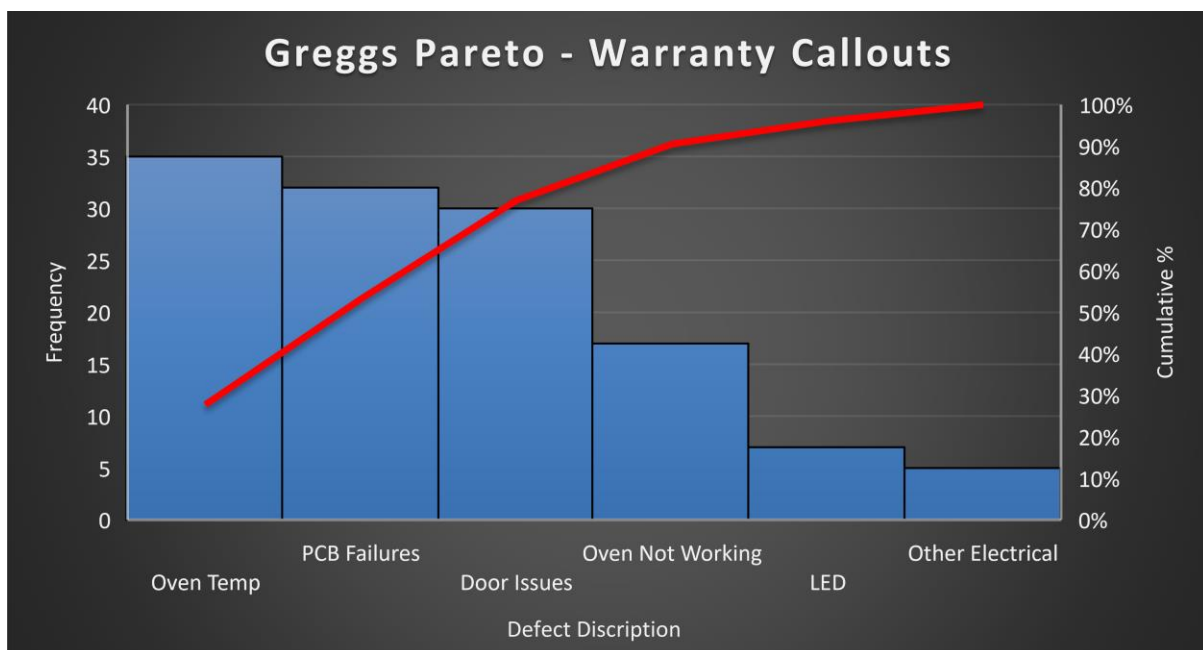


Table 15: Greggs Warranty Pareto Chart

4.4 Current State Floor Plan

The current state of the BX ovens section was created to analyse the performance of the section and give an overview of the current performance. The section consists of three production lines with different ovens produced on each line, the 4-man 4 stage line is currently where the Greggs style oven is produced. 4 men have a target of 14 ovens / day with a 35-minute takt time. there is another line in the middle of the section which is used to build compact ovens and a three-stage line used to build the larger 10 tray ovens. The section also has a door section where the doors are assembled for each production line and a test bay where all ovens are pat tested and undergo a functional test. Once passed functional test it is passed through to cleaning and packing where the ovens are stacked and boxed before being transferred to warehouse.

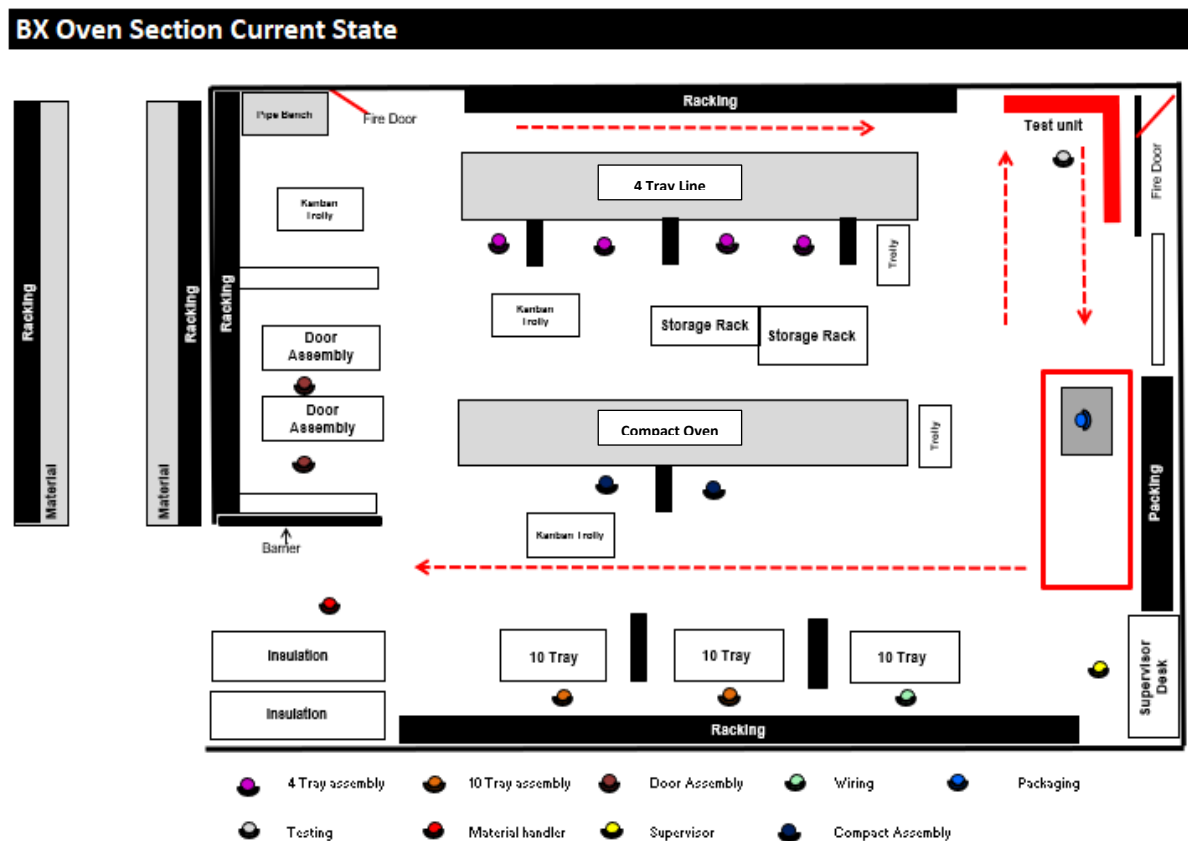


Figure 4: BX Oven Section Layout

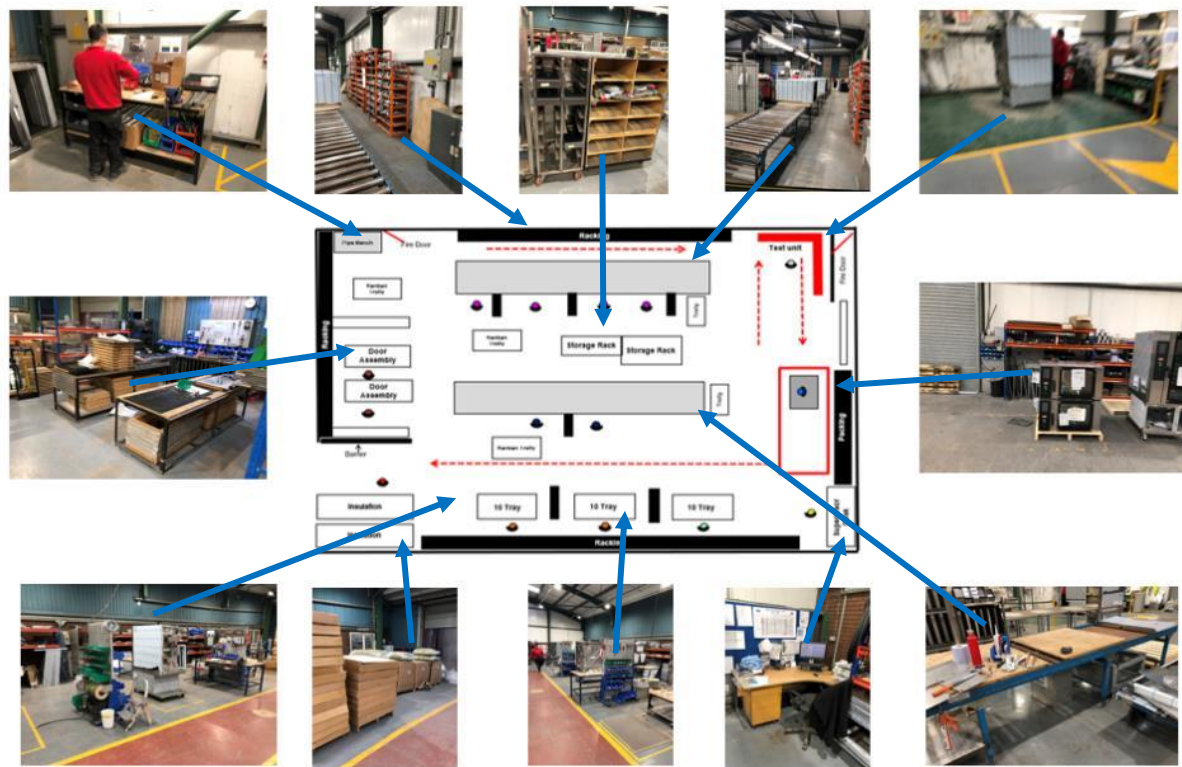


Figure 5: BX Oven Section Current State

4.5 Cumulative Sum Control Chart (CUSUM)

To understand how the BX oven section is performing a CUSUM control chart was created to analyse the deviation from the target over a period of time. the BX Oven 5 tray line consists of 4 stages with each stage having 35 minutes / build. The target for a 4-stage line is 14 ovens / day during standard working day (7.5hrs).

Team Member	Stage
Rob	Stage 1
Dylan	Stage 2
Scott	Stage 3
Tony	Stage 4

Table 16: 4 Stage Team Members

Day	Target	Lower	Actual	Deviation	Mean
1	14	13	10	-4	11
2	14	13	11	-3	11
3	14	13	11	-3	11
4	14	13	11	-3	11
5	14	13	10	-4	11
6	14	13	12	-2	11
7	14	13	11	-3	11
8	14	13	10	-4	11
9	14	13	11	-3	11
10	14	13	12	-2	11
11	14	13	11	-3	11
12	14	13	12	-2	11
13	14	13	12	-2	11
14	14	13	10	-4	11
15	14	13	11	-3	11
16	14	13	12	-2	11
17	14	13	10	-4	11
18	14	13	11	-3	11
19	14	13	11	-3	11
20	14	13	11	-3	11
Total	280	260	220	-60	

Table 17: CUSUM Analysis

Standard deviation	0.725476
Mean	11
Percentage from target	-21.4286

Table 18: CUSUM Analysis

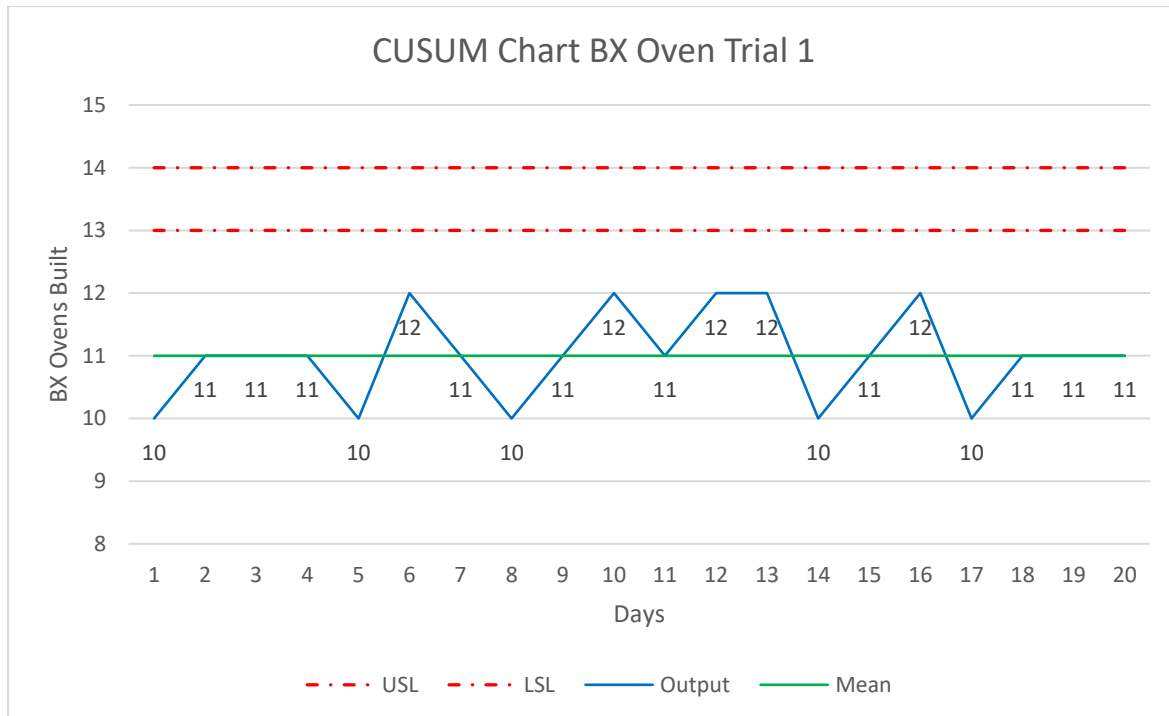


Table 19: CUSUM Chart

During this trial of 4 weeks there was a deviation from the target creating a shortfall of 60 ovens, Greggs purchase the ovens at £3,100.00/ oven. This accounted for a significant loss in revenue which amounted to $60 \times 3100 = £186,000.00$, production inefficiencies were having a huge impact on production.

4.6 Value Stream Map – Initial

The Value Stream Map (VSM) was created to allow a visual representation of the entire operation based at Mono, it defines every step from the customer order through to delivery while integrating the communication channels.

The first stage in developing this VSM involved interviewing each department while sketching the map. It started with the national and key accounts manager Jack Jones, Jack described his role and what happens at the customer order stage through to order processing. Each stage lead to the next and eventually the full picture was mapped. This initial mapping was hand written piecing together each interaction. Kaizens opportunities were marked with a blue zig zag, communication links were added, with inventory locations and WIP marked with an I.

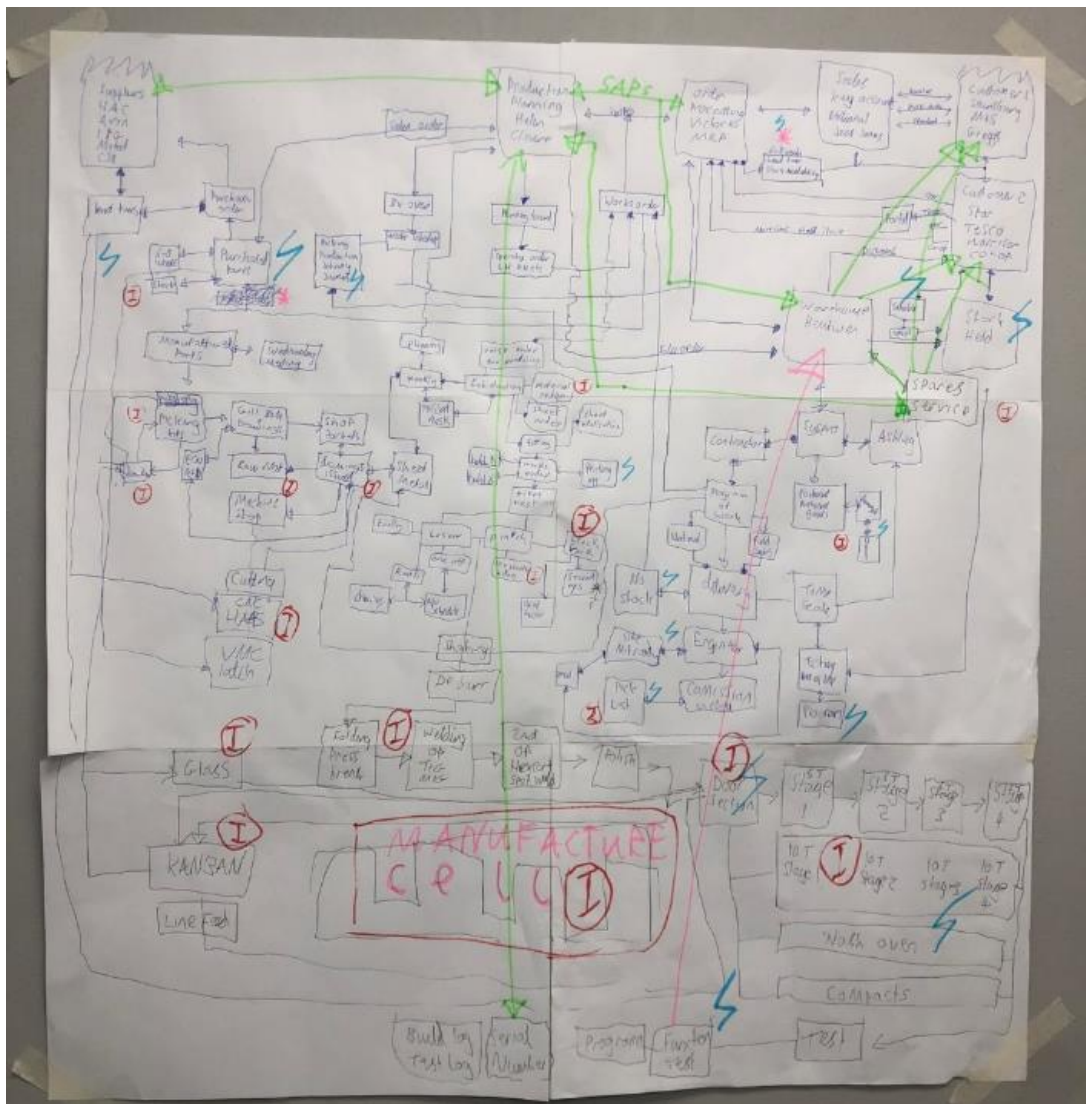


Figure 6:VSM Initial Map - Hand Drawn

The value stream map of the current state was transferred into excel creating a simplified visual display using mapping icons in sequential order. Each process step was indicated including the number of operators used to complete the task. Timings were set for current batch quantity of 16 ovens. Data boxes were included showing cycle time, change over time, uptime, first pass yield. Kaizen and improvement opportunities were marked with Kaizen bursts.

4.6.1 VSM – Current State

The value stream map was based on the current state, an scenario used was based on Greggs ordering BX oven using the current method derived from a fixed batch quantity of 16. Detailing the cycle time of each process step, it was then possible to calculate the current lead time, this is currently 10 days or 2 working weeks from raw material to finished goods. Opportunities to improve the process were marked with kaizen bursts.

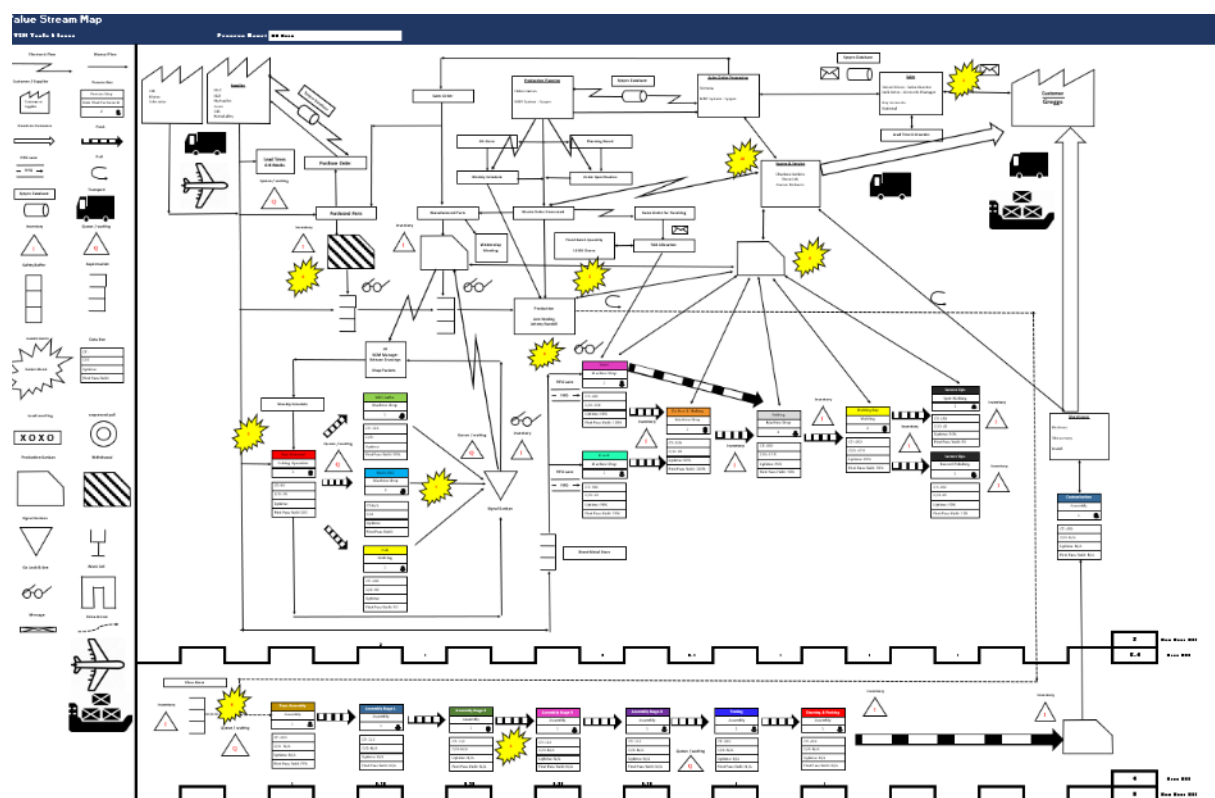


Figure 7: VSM Current State

5 DMAIC – Analyse

5.1 Value Stream Map – Kaizen Ideas

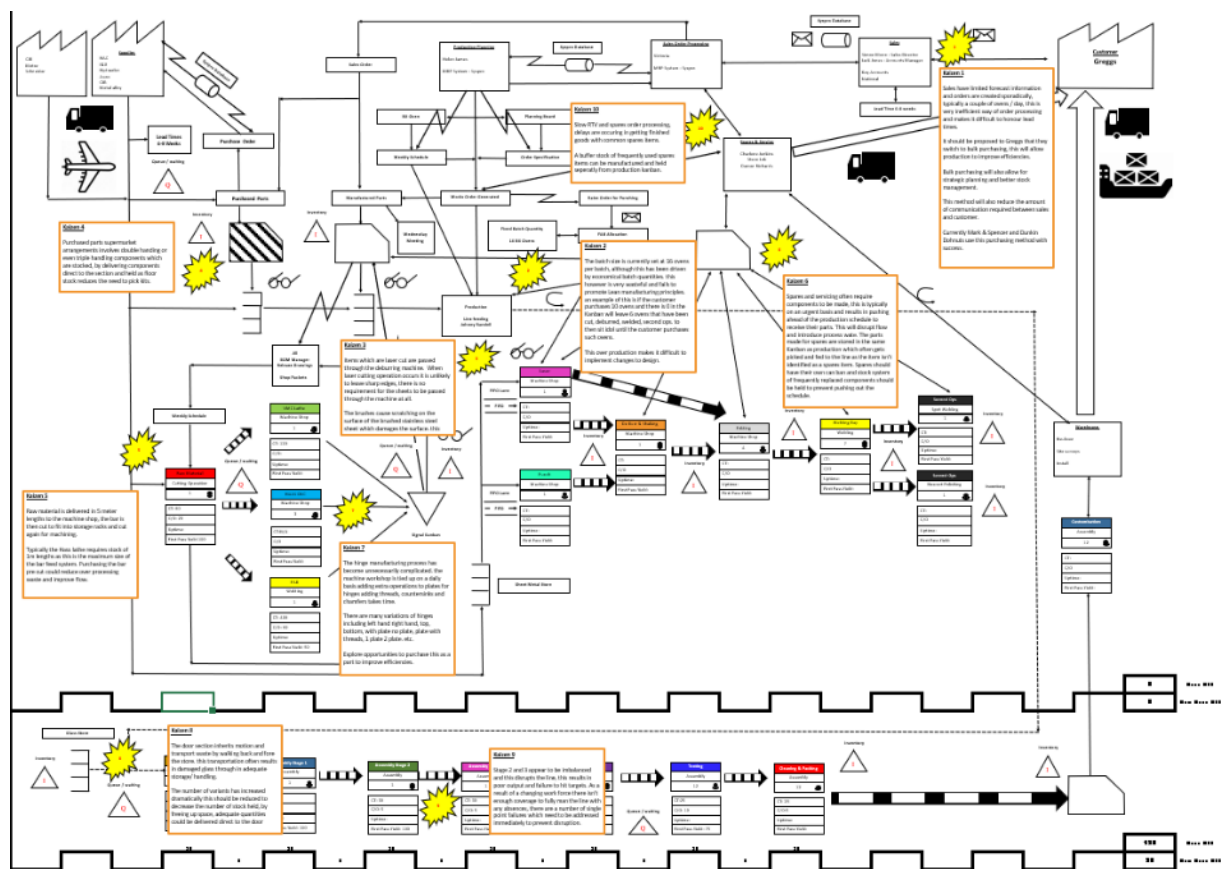


Figure 8: VSM With KAIZEN's Added

Kaizen Ideas were added to the VSM to document how the process could be improved. Below is a list of the Kaizens:

5.1.1 Kaizen 1

Sales have limited forecast information and orders are created sporadically, typically a couple of ovens / day, this is very inefficient way of order processing and makes it difficult to honour lead times.

It should be proposed to Greggs that they switch to bulk purchasing, this will allow production to improve efficiencies.

Bulk purchasing will also allow for strategic planning and better stock management. This method will also reduce the amount of communication required between sales and customer. Currently Mark & Spencer and Dunkin Donuts use this purchasing method with success.

5.1.2 Kaizen 2

The batch size is currently set at 16 ovens per batch, although this has been driven by economical batch quantities. this however is very wasteful and fails to promote Lean manufacturing principles. An example of this is if the customer purchases 10 ovens and there is 0 in the Kanban will leave 6 ovens that have been cut, deburred, welded, second ops. To then sit idle until the customer purchases such ovens.

This over production makes it difficult to implement changes to design.

5.1.3 Kaizen 3

Items which are laser cut are passed through the deburring machine. When laser cutting operation occurs it is unlikely to leave sharp edges, there is no requirement for the sheets to be passed through the machine at all.

The brushes cause scratching on the surface of the brushed stainless steel sheet which damages the surface. this limits what face the folders can use.

5.1.4 Kaizen 4

Purchased parts supermarket arrangements involves double handing or even triple handling components which are stocked, by delivering components direct to the section and held as floor stock reduces the need to pick kits.

5.1.5 Kaizen 5

Raw material is delivered in 5 meter lengths to the machine shop, the bar is then cut to fit into storage racks and cut again for machining.

The Hass lathe requires stock of 1m lengths as this is the maximum size of the bar feed system. Purchasing the bar pre-cut could reduce over processing waste and improve flow.

5.1.6 Kaizen 6

Spares and servicing often require components to be made, this is typically on an urgent basis and results in pushing ahead of the production schedule to receive their parts. This will disrupt flow and introduce process waste. The parts made for spares are stored in the same Kanban as production which often gets picked and fed to the line as the item isn't identified as a spares item. Spares should have their own kanban and stock system of frequently replaced components should be held to prevent pushing out the schedule.

5.1.7 Kaizen 7

The hinge manufacturing process has become unnecessarily complicated. the machine workshop is tied up on a daily basis adding extra operations to plates for hinges adding threads, countersinks and chamfers takes time.

There are many variations of hinges including left hand right hand, top, bottom, with plate no plate, plate with threads, 1 plate 2 plate. etc.

Explore opportunities to purchase this as a part to improve efficiencies.

5.1.8 Kaizen 8

The door section inherits motion and transport waste by walking back and fore the store. this transportation often results in damaged glass through in adequate storage/ handling.

The number of variants has increased dramatically this should be reduced to decrease the number of stock held, by freeing up space, adequate quantities could be delivered direct to the door section removing transport waste and preventing defects.

5.1.9 Kaizen 9

Production line is imbalanced and this disrupts the line, this results in poor output and failure to hit targets. As a result of new ovens the tool arrangement is poor, 5S should be used to resolve. There are a number of single point failures which need to be addressed immediately to prevent disruption. The lean wastes result in poor process control.

5.1.10 Kaizen 10

Slow RTV and spares order processing, delays are occurring in getting finished goods with common spares items.

A buffer stock of frequently used spares items can be manufactured and held separately from production Kanban.

5.2 Fishbone Diagram – Brainstorming

The fishbone diagram was created during a team brainstorming exercise to help identify possible causes for the increase in oven failures. This cause-and-effect style approach uses the 6M titles they stand for Material, Machine, Measurement, Manpower, Mother nature (switched to environment) and Method. These titles lead a structured approach to the problem solving conducted during this project. The team responded well to the exercise and the diagram below was created to reflect the input from the team.

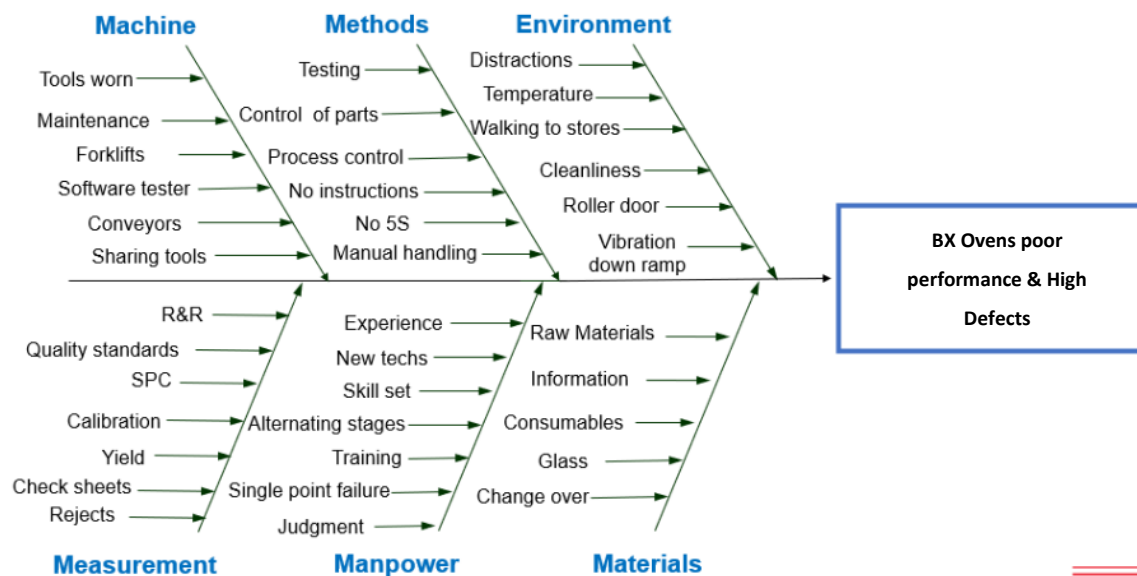


Figure 9: Fishbone Diagram

PCB Failures	• Steam Damaging PCB • High humidity • Poor ventilation • Unsuitable protective cover on PCB	• Damper pipe leaking steam. • Door opening releasing steam into the controller. • Chamber internally leaking steam • Software upgrades to identify faults
Door Locking Issues	• Operator error on new style lock. • Handle slipping on door. • Door dropping over time. • Door being slammed shut	• Additional checks to door catch. • Remove slotted holes on handle to prevent dropping. • Introduce a new door handle.
Oven Not Working & / Other Electrical	• Loose Connection • Fuse Falling Out • Crimp Failure	• Brace Electrical Panel to prevent excessive movement. • Lockable fuse carrier to prevent fuse falling out. • Tug testing cables on electrical panel • Improve storage of panels to prevent damage.
LED Lighting Issue	• Poor handling process of LED • Wires being trapped on assembly.	• Review handling procedure, ensure earth straps and insulated mats are used correctly.

		• Poke Yoke the wiring routing to prevent entrapment. • Training delivered to all relevant staff members.
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Table 20: RCA Meeting Findings

5.3.1 Controller Failure Type

On analysing the data controller failures were grouped into 8 specific categories, by categorising the fault by type measures can be taken to eliminate these faults. The table below shows the fault as recorded by type.

Fault type	Freq	Cum Freq	%	Cum %
PCB FUSE	16	16	24.62	24.62
PCB FAULT	13	41	20.00	63.08
PCB SCREEN BLANK	12	28	18.46	43.08
PCB SCREEN CALIBRATION	9	50	13.85	76.92
PCB SD CARD	6	56	9.23	86.15
PCB LOOSE CONNECTION	4	60	6.15	92.31
PCB SOUND ISSUE	3	63	4.62	96.92
PCB CRACKED SCREEN	2	65	3.08	100.00

Table 21: Pareto Analysis of PCB Failure

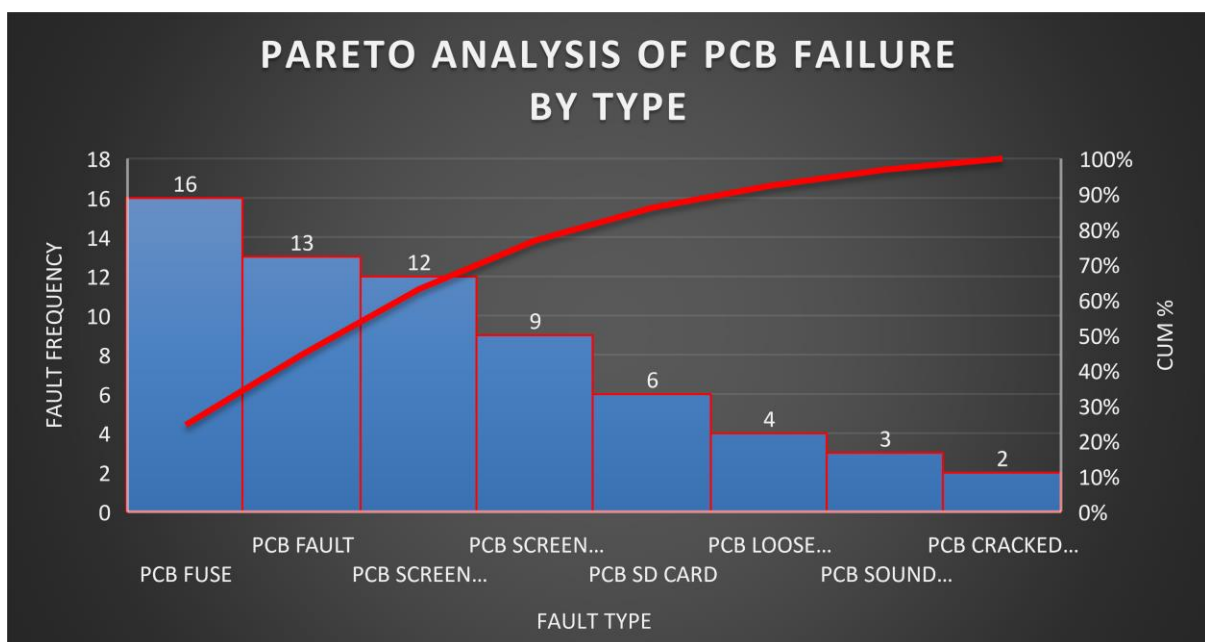


Table 22: Pareto Chart of PCB Failures

5.3.2 FMEA – Controller Improvements

An FMEA was used during the analyse phase to identify the root cause of the controller failures, using this tool helped understand the current control measures used and how these could be improved to reduce the severity occurrence and detection. Improvements were identified and the risk analysed before implementing.

FMEA

Item Name: CIB Controllers		FMEA Team: Process		Prepared by: Craig Petherbridge											
				FMEA Date (Orig):22-Dec-2022								Revision #: 1A			
Process Step or Variable or Key Input	Potential Failure Mode	Potential Effect on Customer Because of Defect	S E V	Potential Causes	O C C	Current Process Controls	D E T	R P N	Actions Recommended	Resp.& Target Date	Actions Taken	S E V	O C C	D E T	Future RPN
usb card falling out over time	Corruption	Slow responsive screen & oven fails to operate	8	Loose card holder, corrosion and humidity	7	Observations of boot time should be < 20 seconds and updates within a minute	9	504	PCB Cover to protect against humidity, additional check to be carried out prior to programming	Alex Davies / Darryl Evans 10/01/2023	PCB Cover to protect against humidity, additional check to be carried out prior to programming	8	2	1	16
	Controller fails to boot	Oven failure no operation	8	Loose card holder, corrosion and humidity	7	Observations of boot time should be < 20 seconds and updates within a minute	9	504				8	2	1	16
Fuse falling out	Controller fails to boot	Oven failure no operation	8	Fuse not secure	6	Glue is used to secure the fuse	9	432	Fuse to be hard soldered to PCB	Craig Petherbridge/ Angela Thomas/ Saaid Ostad 12/02/2023	Fuse to be hard soldered to the PCB	8	1	1	8
	Corruption	Slow responsive screen & oven fails to operate	8	Fuse not secure	6	Glue is used to secure the fuse	9	432	Replace fuse holder			8	1	1	8
Screen Issues	Poor calibration/ sensitivity	Slow responsive screen & oven fails to operate	8	Moisture/ humidity	6	None	9	432	Calibration function to recalibrate screen issues	Craig Petherbridge/ Alex Davies/ Saaid Ostad 12/02/2023	Recalibration of screen function incorporated	8	1	3	24
	Blank Screen	Oven failure no operation	8	Moisture/ humidity	6	None	9	432	New PCB Cover for protection	Craig Petherbridge/ Alex Davies/ Saaid Ostad 12/02/2024	New PCB Cover	8	2	1	16

Table 23: FMEA Controller Improvements

5.3.3 Steam Investigation

To fully understand why the controllers were failing an investigation was conducted to find the root cause of the failures. An oven was put on test and 20 seconds of steam was injected into the chamber with an oven temperature of 200°C.



Figure 11: Steam Investigation

Steam escaped the chamber and formed water droplets around the metal work. After repeating this multiple times it is possible for steam to get into the control panel. The example in *figure 12* was observed in a store. It shows moisture built up between the overlay and controller.



Figure 12: Steam Investigation

To fully understand the operating environment a oven was pulled from goods returned area, after removing the panel of an old style controller there was evidence of moisture and grease ingress. In this example the oven had a different pcb cover which offered good protection against the steam.



Figure 13: PCB Operating Environment - High Humidity

The current controller cover in comparison had limited protection of the screen as it was surface mounted to the PCB leaving the screen exposed to any escaping moisture.



Figure 14: Current PCB Cover

5.4 LEAN Wastes – DOWNTIME

5.4.1 Defects

Defects had been observed within production, currently defects are passed along to the next stage until it is too late to rectify. Every defect that is passed along the problem magnifies and becomes more difficult to resolve. In the case below the welder has damaged the thread on the latch post stiffener. The technician then snapped a screw in the part and once the screw had been removed the tapping tool also snapped. Almost 2 hours was lost during this episode causing disruption to the production line.

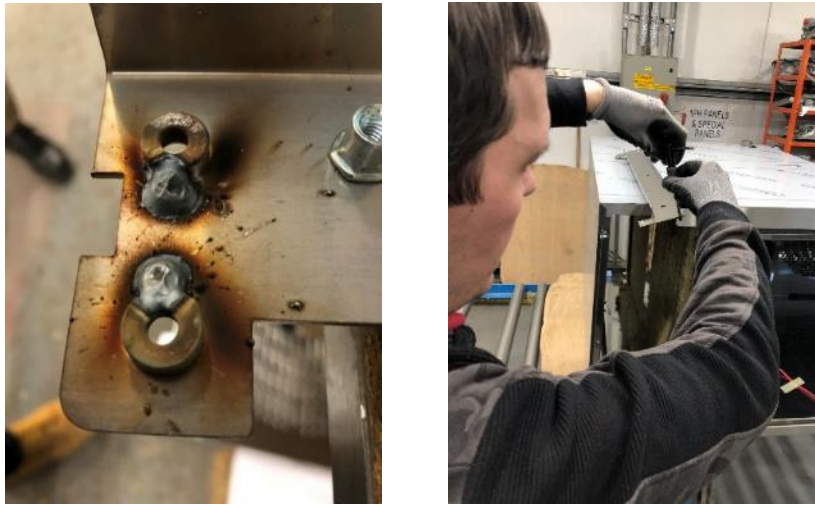


Figure 15: Defects

5.4.2 Overproduction

Overproduction is evident across the production facility and the effects of this lean waste were clear to see. There were many items produced as a result of fixed batch quantities driven by economical batch quantities (EBQ). However, this has resulted in many additional parts being stored and becoming obsolete, this is because parts were produced that were not required or paid for by the customer. The examples below show control panels that are not currently used. These panels are costed at £60.23 per unit there are a total of 102 units sat on a shelf collecting dust and have no use due to becoming obsolete.

Total Cost on this one shelf $60.23 \times 102 = \text{£}6143.46$

The next example is of oven chambers being produced these chambers are halogen light variants which are no longer produced. These chambers will sit here as WIP until a decision is made to build the ovens out and sell at a reduced cost to independent bakeries.



Figure 16: Overproduction

5.4.3 Waiting

Waiting on components was seen to disrupt the production process, as simple as technicians waiting on fixings would cause delays to production. The door section ran out of nylon spacers this resulted in a massive disruption. By not having these spacers resulted in doors being produced and fitted with incorrect spacers which needed to be replaced at a later date. A total of 28 ovens were backed up. It was then impossible for these to be tested as there was no time in the schedule to add an additional 28 ovens through the test bay. There was wider disruption to the machine shop also as these components needed to be urgently pushed through delaying the schedule in other areas.



Figure 17: Waiting

5.4.4 Non- Utilisation of Talent

Non utilisation of talent was impacting production. By creating a section skills matrix highlighted a number of single point failures. During periods of sickness and holiday periods resulted in the line being reduced to 2 stage – 2 man producing only 50% of the intended target. The production board highlights that a target of 7/day instead of the 14/day as required see figure 18.

MONO EQUIPMENT
QUEENSWAY
SWANSEA WEST IND PARK
SWANSEA
SA5 4EB

WORK SKILLS MATRIX

SMALL OVENS

5/5 LEAN Manufacturing	First Aid Trained	Use of basic hand tools	Ability to pack boxes	Job Description	4/5 Tray Oven Stage 1	4/5 Tray Oven Stage 2	4/5 Tray Oven Stage 3 (electrical)	4/5 Tray Oven Stage 4	4/5 Tray Wash Oven Stage 1	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray 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3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 1	3 Tray Compact Oven Stage 2	3 Tray Compact Oven Stage 3	3 Tray Compact Oven Stage 4	3 Tray Compact Oven Stage 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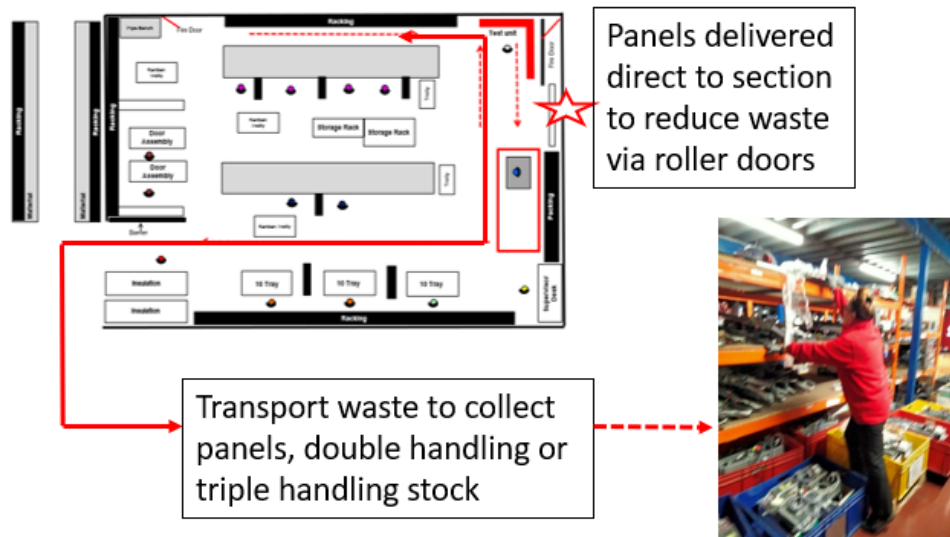
Table 24: Skills Matrix

5 TRAY	10 TRAY	WASH	COMP	DOORS	ISSUES & CONCERNS
7711	21	-	17.13		SHOULD BE REPAIRING
7720	22	-	17.13		SHOULD BE REPAIRING
7732	11	30	17.14		SHOULD BE REPAIRING
6632	-	33	17.9		SHOULD BE REPAIRING
21		3			SHOULD BE REPAIRING

Figure 18: Line Reduced to 7/Day - Staff Unable to Cover

5.4.5 Transportation

Excessive transportation of components can be seen. Mono equipment complex layout often results in excessive transportation. This has been overcome using bespoke trolly's and dedicate material handlers. These is still excessive transportation of individual parts. The example below is of electrical panels being delivered to stores and the production technician required to walk and collect the panels individually. Identifying these could be delivered directly to the section.



Section	Location	Reason	No. Steps	No. Journeys	M/Step	Meters	Yearly Meters	Av. Pace (M/s)	Time Taken	No. Ovens
10Tray S3	Stores	Electrical Panel	520	4	0.76	395.2	411008	1.2	137.003	38.056

Figure 19: Transportation

5.4.6 Inventory

Excessive inventory has been built up as a result of many factors which could impact supply including Brexit, Covid-19 pandemic and also the war in Ukraine. These factors have driven manufacturing sectors into making bold decisions to hold more stock to avoid price rises and disruption to lead times of components.

There are still many dangers associated to excessive inventory including the danger of parts becoming obsolete and no longer required. It also complicates activities such as stock take.

The examples below highlights a few issues with holding excessive inventory, these are electrical panels with the old style connections for controllers which are no longer required.

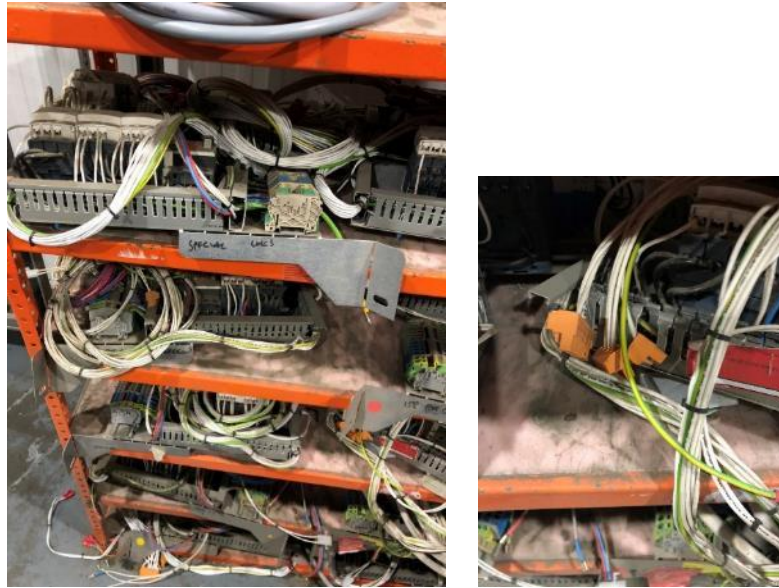


Figure 20: Inventory Build Up Electrical Panels

Excessive amounts of glass being stored taking up walkways with stillages, this excessive glass is difficult to track, when damaged it is typically thrown into the skip with no accountability.



Figure 21: Inventory Build Up Glass

5.4.7 Motion

Motion waste like transportation waste is evident due to the complex layout at Mono equipment. The below example shows some of the motion waste generated by the door section when going to collect glass. This motion waste may seem insignificant to the production technician but over a period of time the waste mounts up to a considerable amount of waste.



Section	Location	Reason	No. Steps	No. Journeys	M/Step	Meters	YearlyMeters	Av. Pace (M/s)	Time Taken	No. Ovens
Doors	Stores	Glass	420	5	0.76	319.2	414960	1.2	138.320	38.422

Figure 22: Motion

5.4.8 Extra- Processing

Extra processing has been generated by a combination of design issues, waiting for components and defect. By inheriting these issues results in time taken to rectify these issues. The example below shows the door assembler having to replace the parts that were used temporarily, the technician then had to replace the temporary spacer with the correct part, this time is not accounted for and the customer does not pay for this additional work. This puts pressure on production and results in quality issues.



Figure 23: Extra Processing

Another example of extra processing is the documented below, this example resulted in the production technician filling the oven base to fit the electrical cable. Again an example of extra work which the customer doesn't pay for.

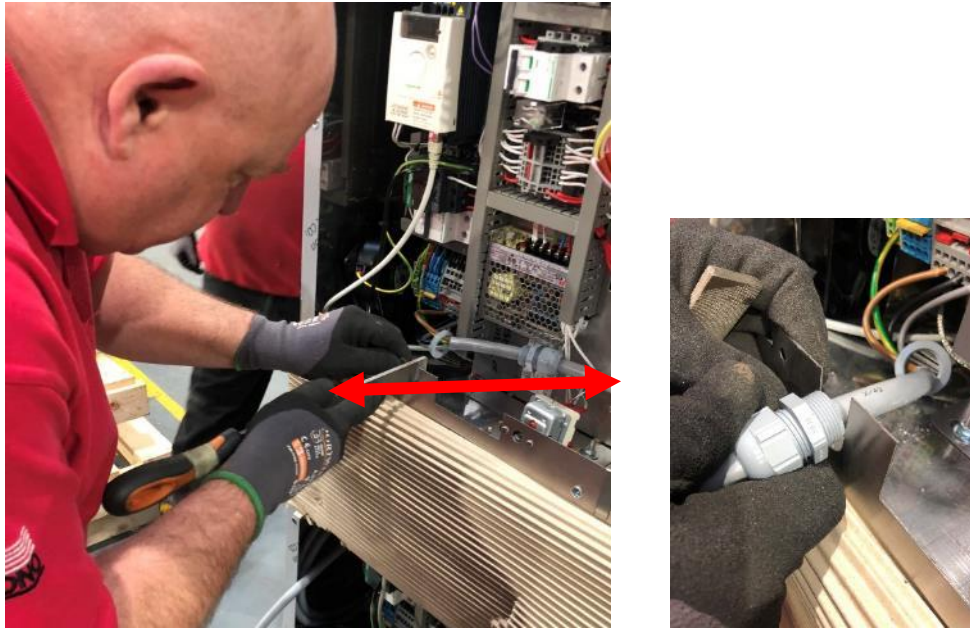


Figure 24: Extra Processing

5.5 Spaghetti Diagram – Tools

During a production meeting, production operatives raised significant concerns relating to the tools within the BX oven section. Upon further investigation it became clear that there were various issues including, tool sharing, missing tools, poor tool organisation with tool boards that were inadequate for the tools being stored. Having no designated place for tools or accountability resulted in several lean wastes. The section required a system to manage the tools in an efficient way.



Figure 25: Tool Storage - Current State 5 Tray Line

Figure 25 show that the tool boards are inadequately laid out with limited space for the tools, the production technicians use component storage bins to hold the tools over using the tool boards. Another observation made is that there is no space for power tools used such as impact drivers, wrenches and cordless drills have no defined location.

The example in figure 26 is an image taken from the 10 tray line tool board. In this example there are several pegs welded to a board this layout draws confusion as no designate space is created for tools, many duplicates are stored.



Figure 26: Tool Storage Current State - 10 Tray Line

To fully understand the impact this can have on the section a spaghetti diagram was created to give a boarder picture of the loss in efficiencies. In the example set in figure 27 each operator travels from one stage to another to share a tool. The examples given are all scenarios which were observed. The steps were counted between each stage and converted to meters by using an average of 0.76m/ step. This was calculated daily then weekly (based on a 5 day week) and finally yearly to determine distance travelled. A average walking pace of 1.2m/s was used to calculate the time lost in hours. Considering it takes 3.6 hours to build an oven the final calculation determined the potential number lost ovens due to lean wastes.

The average price of an oven is £3100 so the total loss in revenue is calculated to be £161,080.59.

Spaghetti Diagram - Motion Waste - Missing / Sharing Tools

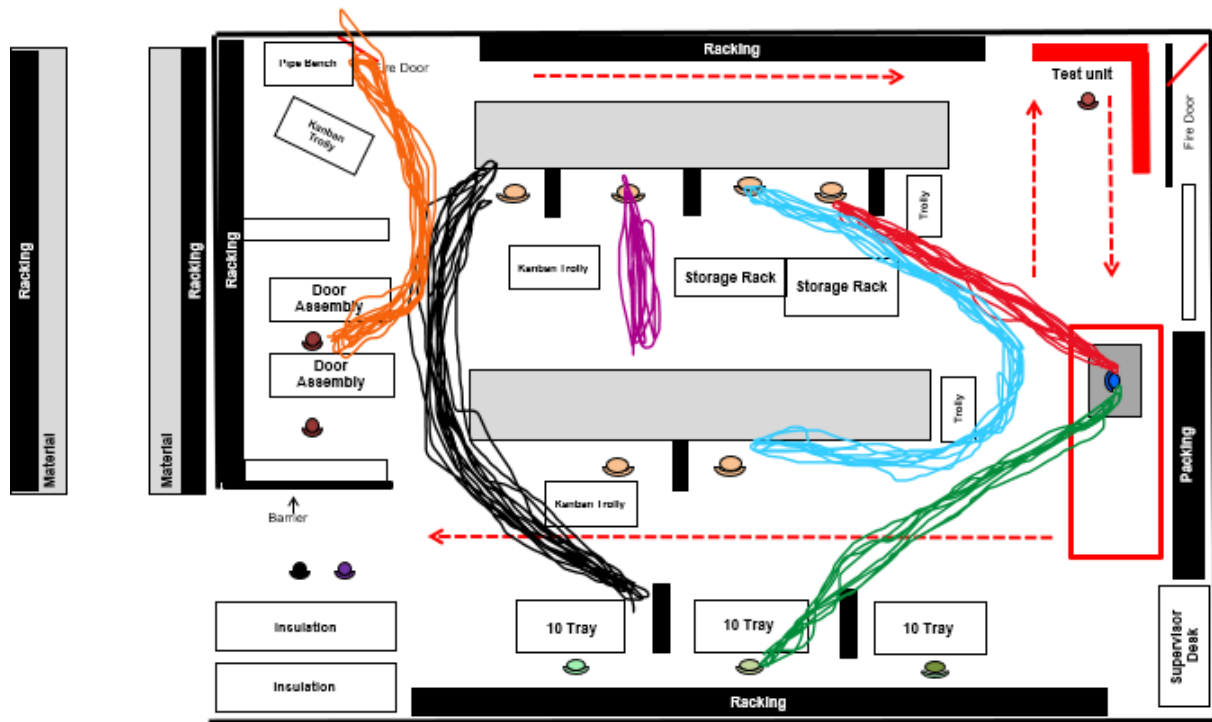


Figure 27: Spaghetti Diagram BX Oven Section

Section	Operator	Location	Reason	Steps	Journeys	M/Step	Meters	Daily (M)	Yearly (M)	Pace M/s	Time h	Ovens
Doors	A	Pipe Bench	Reaming/vice	35	20	0.76	26.6	532	138320	1.2	46.107	12.807
10Tray S1	B	5Tray S1	Impact	50	15	0.76	38	570	148200	1.2	49.400	13.722
5Tray S3	C	Compact S2	Drill	40	15	0.76	30.4	456	118560	1.2	39.520	10.978
5Tray S4	D	Packing	Tapping	25	10	0.76	19	190	49400	1.2	16.467	4.574
Packing	E	10Tray S2	Knife	30	10	0.76	22.8	228	59280	1.2	19.760	5.489
5Tray S2	F	Compact S1	10mm Spanner	12	20	0.76	9.12	182.4	47424	1.2	15.808	4.391

Total Ovens	51.961
Price/Oven (£)	3100
Total Loss (£)	161080.59
Total Lost Time (h)	187.06
Total Days Lost	24.94

Table 25: Spaghetti Diagram Analysis

5.6 Line Performance / Balance

To fully understand why the section was under performing and failing to meet its targets a detailed analysis was conducted into the timings of the oven build process. On the 4-stage production line, each operative has 35 minutes to complete the stage.

5.6.1 Flow Process Chart Stage 1 – 4

FLOW PROCESS CHART		MAN / MATERIAL / MACHINE TYPE							
Date :	10/11/2022	○	= OPERATION						
Edition :	1	□	= INSPECTION						
Author :	Craig & Rob	⇨	= TRANSPORTATION						
Process :	158 Bottom	D	= DELAY						
Location :	Stage 1	▽	= STORAGE						
DESCRIPTION	○	□	⇨	D	▽	Time (min)	Qty	Dist Metre	Comments
1 Load build platform			20					2	
2 Collect / sort chamber kit			57					2	Trolley 1
3 Collect insulation			25					10	Pallet
4 Set insulation	103								
5 Dispense waste insulation			10					2	Bin
6 Collect chamber			7					2	Trolley 1
7 Collect bracket			8					2	trolley 1
8 Remove protective tape	31								
9 Collect bracket fixings (nuts, bolts, washer & shaker)			37					4	Rack 1
10 Fit brackets	102								
11 Fit locators	124								
12 Tighten locators	33								
13 Fit chamber to base	16								
14 Collect chamber fixing			36					4	Rack 1
15 Insert chamber fixings	85								
16 Tighten chamber fixings	41								
17 Adjust trim	13								
18 Collect fixing (strengthen motor & heat shield)			17					4	Rack 1
19 Fit & tighten fixing (heat shield motor)	183								
20 Bulkhead assembly (subline area)			7					3	Table
21 Measure pipe	10								
22 Cut pipe	12								
23 Straighten pipe	9								
24 Fit coupling to pipe	29								
25 Return to chamber assembly			7					4	
26 Fit bulkhead coupling to chamber	70								
27 Collect thermostat / coupling			16					4	Rack 1
28 Fit thermostat / coupling	166								
29 Fit rear heat shield	106								
30 Collect earth strap			24						Rack 1
31 Assemble earth strap	57								
32 Assemble clinch studs	52								
33 Fit motor shaft alignment jig	9								
34 Collect motor fixing			28					4	
35 Fit motor fixings	55								
36 File light aperture	14								
37 Collect light Fittings			14					4	
38 Collect light cable			15					4	
39 Fit cable to light	9								
40 Collect light insulation			8					2	
41 Cut light insulation	21								
42 Fit insulation & light units	111								
43 Bracket / solenoid assembly area			14					4	
44 Assemble bracket / solenoid	119								
45 Return to chamber assembly			9					4	
46 Collect damper unit			5					2	
47 Silicon damper unit	27								
48 Collect fixings for damper unit			31					2	
49 Fix damper unit to chamber	57								
50 Silicon damper unit to chamber	15								
51 Collect stop end			14					2	
52 Fit stop end	100								
53 Fit Solenoid Assembly	152								
TOTAL seconds	1931	0	389	0	0	0	0	69	2320
TOTAL minutes	32.2	0.0	6.5	0.0	0.0	0.0	0.0		38.7

FLOW PROCESS CHART		MAN / MATERIAL / MACHINE TYPE							
Date :	10/11/2022	○	= OPERATION						
Edition :	1	□	= INSPECTION						
Author :	Craig & Dylan	⇨	= TRANSPORTATION						
Process :	158	D	= DELAY						
Location :	Stage 2	▽	= STORAGE						
DESCRIPTION	○	□	⇨	D	▽	Time (min)	Qty	Dist Metre	Comments
1 Collect element			13					4	
2 Collect element fixing			14					2	
3 Fit element	74								
4 Collect fan			12					4	
5 Collect fixing			12					2	
6 Isotite fixing	12								
7 Align & tighten element	38								
8 Collect fixing & blanking plate			18					1	
9 Remove protective seal				76					
10 Fit blanking plate	26								
11 Insert fan guard	28							1	
12 Collect fan guard fixing			10						
13 Fit fan guard fixing	45								
14 Water pipe assembly			16					6	
15 Measure copper pipe	19								
16 Cut Pipe	13								
17 Measure copper pipe	9								
18 Cut Pipe (inside)	20								
19 Straighten Pipe	30								
20 Bend Pipe	19								
21 Fit coupling	54								
22 Return to chamber assembly			16					6	
23 Fit inside pipe	94								
24 Collect fixing for back of element			31					2	
25 Fit fixing on back of element (probe)	192								
26 Collect insulation			51					6	
27 Fit back insulation	15								
28 Fit back Pipe	30								
29 Collect fixing for thermostat			15					2	
30 Fit thermostat / coupling	154								
31 Remove protective seal				49					
32 Fit retainer / motor	99								
33 Fit insulation	380								
34 Remove protective seal on heat shield				61					
35 Collect heat shield fixing	23								
36 Fit heat shield	150							2	
TOTAL seconds	1524	0	208	186	0	0	0	38	1918
TOTAL minutes	25.4	0.0	3.5	3.1	0.0	0.0	0.0		32.0

Table 26: Flow Process Chart - Stage 1 & Stage 2

FLOW PROCESS CHART		MAN / MATERIAL / MACHINE TYPE							
Date :	15/11/2022	○	= OPERATION						
Edition :	1	□	= INSPECTION						
Author :	Craig & Scott	⇨	= TRANSPORTATION						
Process :	158	D	= DELAY						
Location :	Stage 3 Wiring	▽	= STORAGE						
DESCRIPTION	○	□	⇨	D	▽	Time (min)	Qty	Dist Metre	Comments
1	Fit element links	46							
2	Un coil solenoid cable	7							
3	Fit terminal to solenoid cable	21							
4	Insert terminal into connector	37							
5	Reposition probe cable	15							
6	Collect water inlet		11					4	
7	Fit water inlet to unit	88							
8	Position thermostat	10							
9	Fit spacer & thermostat to unit	17							
10	Prepare motor for assembly	71							
11	Prepare circuit board studs	72							
12	Collect circuit board		31					20	
13	Prepare board and fit earth strap	87							
14	Fit circuit board to unit	286							
15	Wire up board (back of unit)	1020							
TOTAL seconds		1777	0	42	0	0	0	24	1819
TOTAL minutes		29.6	0.0	0.7	0.0	0.0	0.0	0.0	30.3

FLOW PROCESS CHART		MAN / MATERIAL / MACHINE TYPE							
Date :	10/11/2022	○	= OPERATION						
Edition :	1	□	= INSPECTION						
Author :	Craig & Tony	⇨	= TRANSPORTATION						
Process :	158	D	= DELAY						
Location :	Stage 4	▽	= STORAGE						
DESCRIPTION	○	□	⇨	D	▽	Time (min)	Qty	Dist Metre	Comments
1	Trim off insulation	30							
2	Collect surround		21					1	
3	Remove protective seal	28							
4	Fit surround to unit	24							
5	collect fixing		8					2	
6	Fit fixing (surround to unit)	116							
7	Collect front panel		7					2	
8	Remove protective seal (front panel)	35							
9	Collect fixing		15					2	
10	Fit fixing (front panel)	75							
11	Adjust trim	19							
12	Collect latch post		4					2	
13	Remove protective seal	55							
14	Collect fixing		8					2	
15	Fit fixing (latch post)	99							
16	Fit door seal	254							
17	Collect light assembly parts		13					2	
18	Collect light fitting		24					2	
19	Silicon light fitting	42						2	
20	Assemble light fitting	50							
21	Fit Light assembly	90							
22	Collect door latch		15					2	
23	File door latch (subline)		15					15	
24	File door latch (vice)	28							
25	Return to chamber assembly		12					15	
26	Fit latch	42							
27	Fit blanking screws	80							
28	Collect door switch		10					2	
29	Assemble & fit door switch	95							
30	Fit panel bracket	56							
31	Collect door hinge fitting		12					2	
32	Fit bottom door hinge	100							
33	Collect tray runner		8					2	
34	Fit tray runner	30							
35	Collect door		26					20	
36	Fit door & top hinge	76							
37	Connect wiring	49							
38	Collect insulation		15					10	
39	Fit insulation (light area)	33							
40	Collect insulation panel & fixing		11					2	
41	Fit insulation panel	87							
42	Collect panel & fixing		20					2	
43	Fit and align panel & door	490							
TOTAL seconds		2083	0	244	0	0	0	89	2327
TOTAL minutes		34.7	0.0	4.1	0.0	0.0	0.0	0.0	38.8

Table 27: Flow Process Chart - Stage 3 & Stage 4

The timings of the flow process analysis highlighted an imbalance between the stages, Stage 1 and 4 were both outside the allocated time to complete the stage whilst 2 & 3 were both below the target of 35 minutes.

5.7 Statistical Process Capability Study

To understand the performance of the 4-tray production line a capability study was carried out. A sample size of 100 timings were recorded, the Upper Specified Limit (USL) and Lower Specified Limit (LSL) were defined by the internal customer and the business needs. The mean, standard deviation, upper control limit, and lower control limit were calculated and added to the charts for each section.

To calculate the UCL & LCL the following equations were used:

- *Mean* = μ
- *Standard Deviation* = *Sigma* σ
- $UCL = (\mu + 3) \times \sigma$
- $LCL = (\mu - 3) \times \sigma$
- *USL* = *Defined by Customer / organisation*
- *LSL* = *Defined by Customer / organisation*

5.7.1 Stage 1

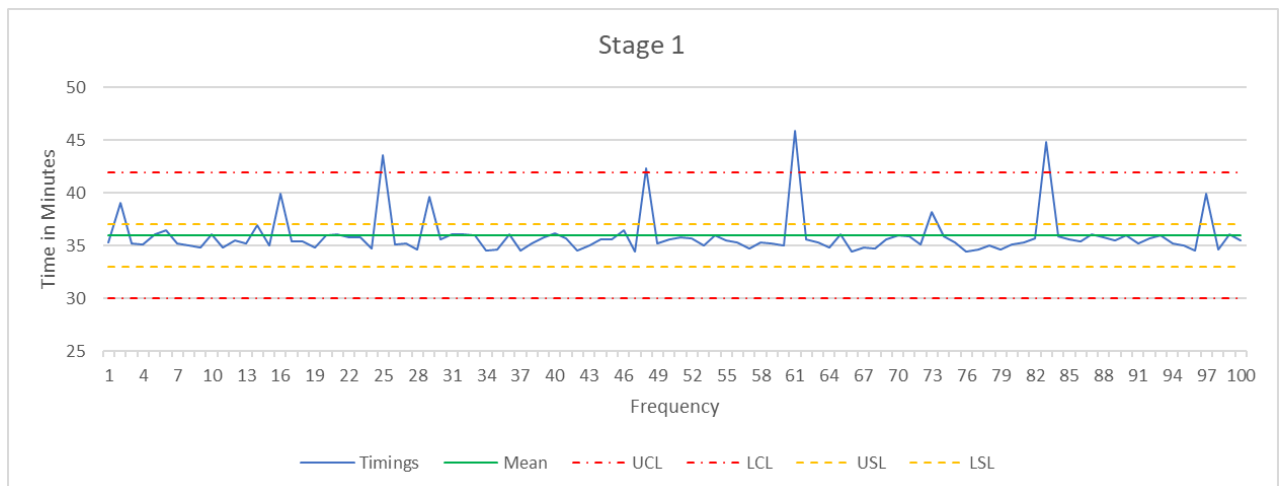


Table 28: SPC - Stage 1

	Mean	STD DEV	UCL	LCL	USL	LSL
STAGE 1	35.9233	1.988092358	41.88757707	29.95902293	37	33

Table 29: S1 SPC Calculations

Stage 1 SPC resulted in a high standard deviation, standard deviation result >1 is considered to be high, and an indication the process is out of control (Oakland E. S., 1999). the UCL & LCL are calculated using the standard deviation, this SPC has wide control limits due to the high standard deviation. The spikes within the data were caused by lean wastes including looking for tools, waiting for parts and fettling defects.

5.7.2 Stage 2

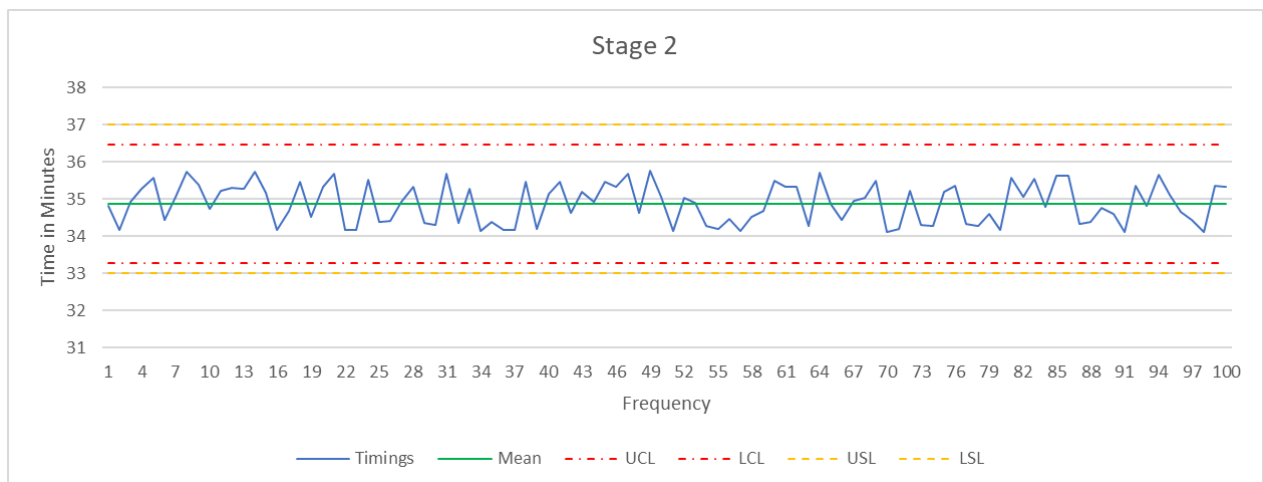


Table 30: SPC - Stage 2

	Mean	STD DEV	UCL	LCL	USL	LSL
STAGE 2	34.8853	0.532665216	36.48329565	33.28730435		37

Table 31 S2 SPC Calculations

Stage 2 appeared to perform the best of all, the timings were in control, this is because there was no deviation outside the control or specified limits and a low standard deviation <1 . This is a good example of the process control.

5.7.3 Stage 3

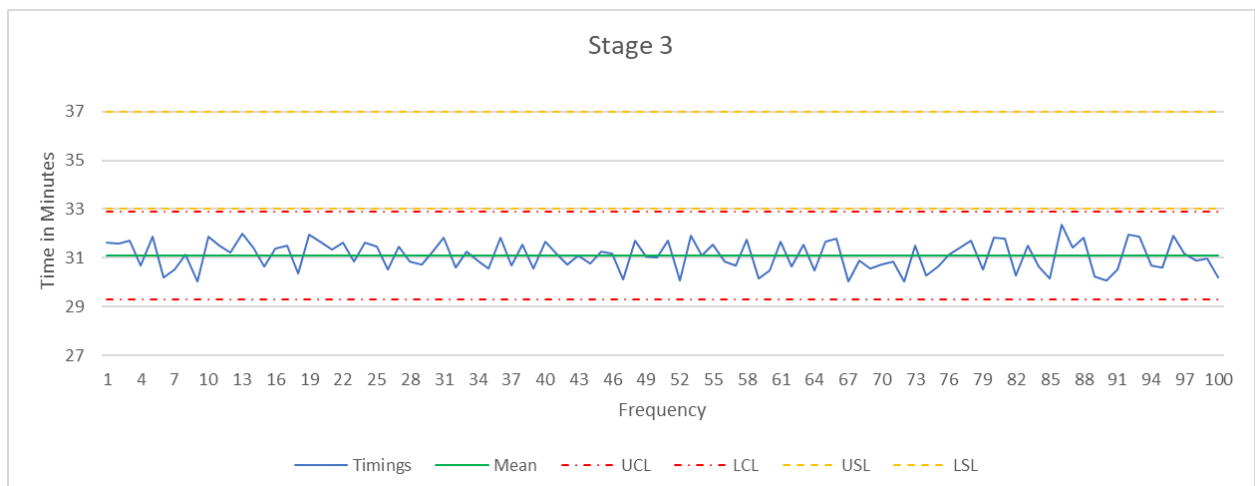


Table 32: SPC - Stage 3

	Mean	STD DEV	UCL	LCL	USL	LSL
STAGE 3	31.0947	0.594582368	32.8784471	29.3109529		37

Table 33: S3 SPC Calculations

Stage 3 performance had all the markings of a good stage, there was low standard deviation and the chart plotted within the control limits, however these results were completely outside the specified control, this indicates that there is a large imbalance within production.

5.7.4 Stage 4

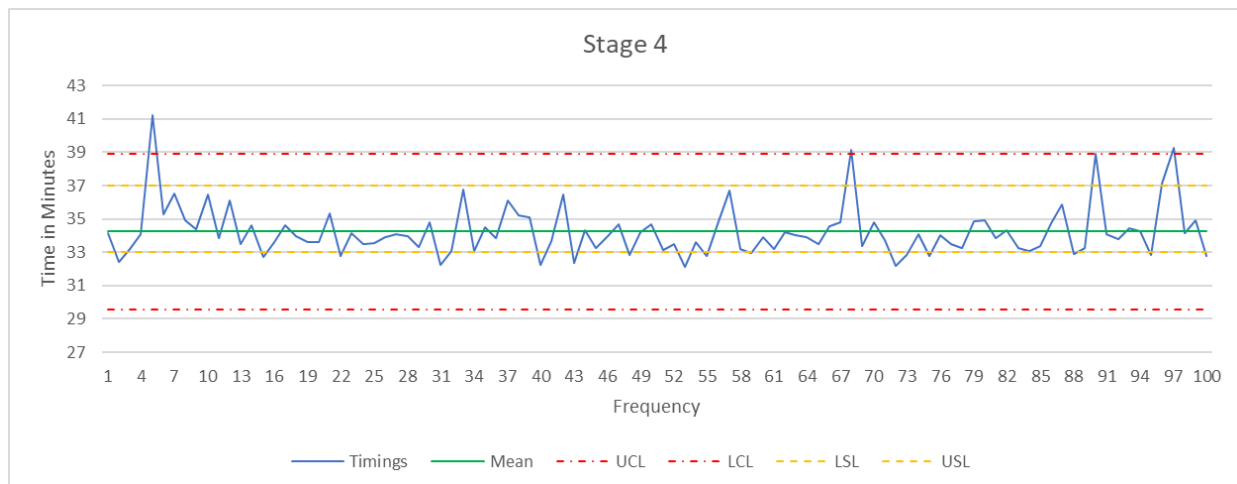


Table 34: SPC - Stage 4

	Mean	STD DEV	UCL	LCL	USL	LSL	
STAGE 4	34.2417	1.555989441	38.90966832	29.57373168		37	33

Table 35 S4 SPC Calculations

The timing of Stage 4 was comparable to that of Stage 1 with high standard deviation generated by peaks and troughs, the high standard deviation meant that the control limits were broad, and the specified limits were breached several times, these spikes were caused by additional processing due to lean wastes.

	Mean	STD DEV	UCL	LCL	USL	LSL	
STAGE 1	35.9233	1.988092358	41.88757707	29.95902293		37	33
STAGE 2	34.8853	0.532665216	36.48329565	33.28730435		37	33
STAGE 3	31.0947	0.594582368	32.8784471	29.3109529		37	33
STAGE 4	34.2417	1.555989441	38.90966832	29.57373168		37	33

Table 36: Calculations

5.8 Current Process Capability

After conducting the SPC the process capability was analysed, the findings backed up the findings from the SPC. This analysis of stage 1,2, &3 (table 37, 39, & 40) gave a visual representation of poor control where many samples fell out of spec and represents a low cp, cpk value, this is because there is a high probability that the sample will fall out of spec.

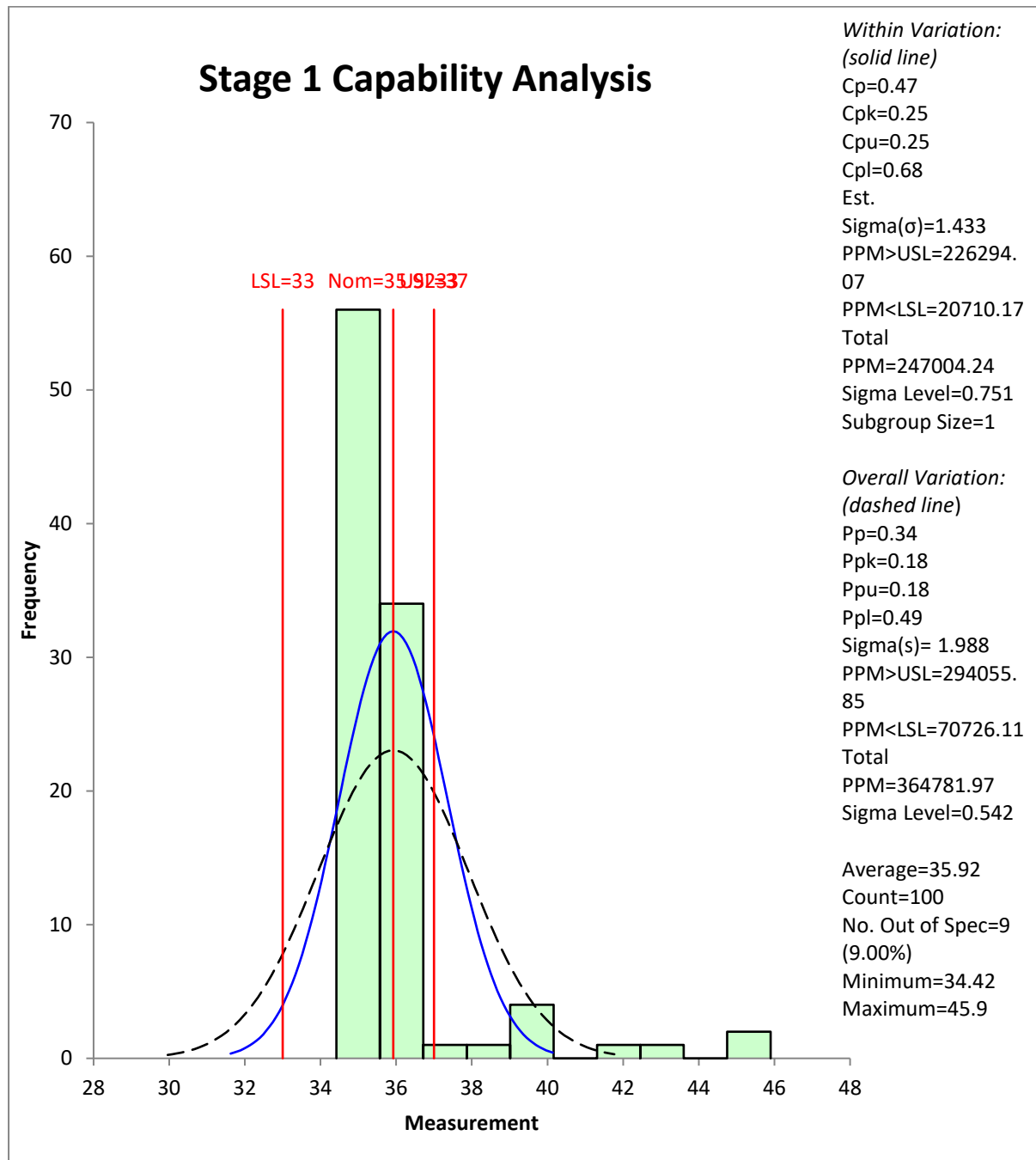


Table 37: Stage 1 Cpk

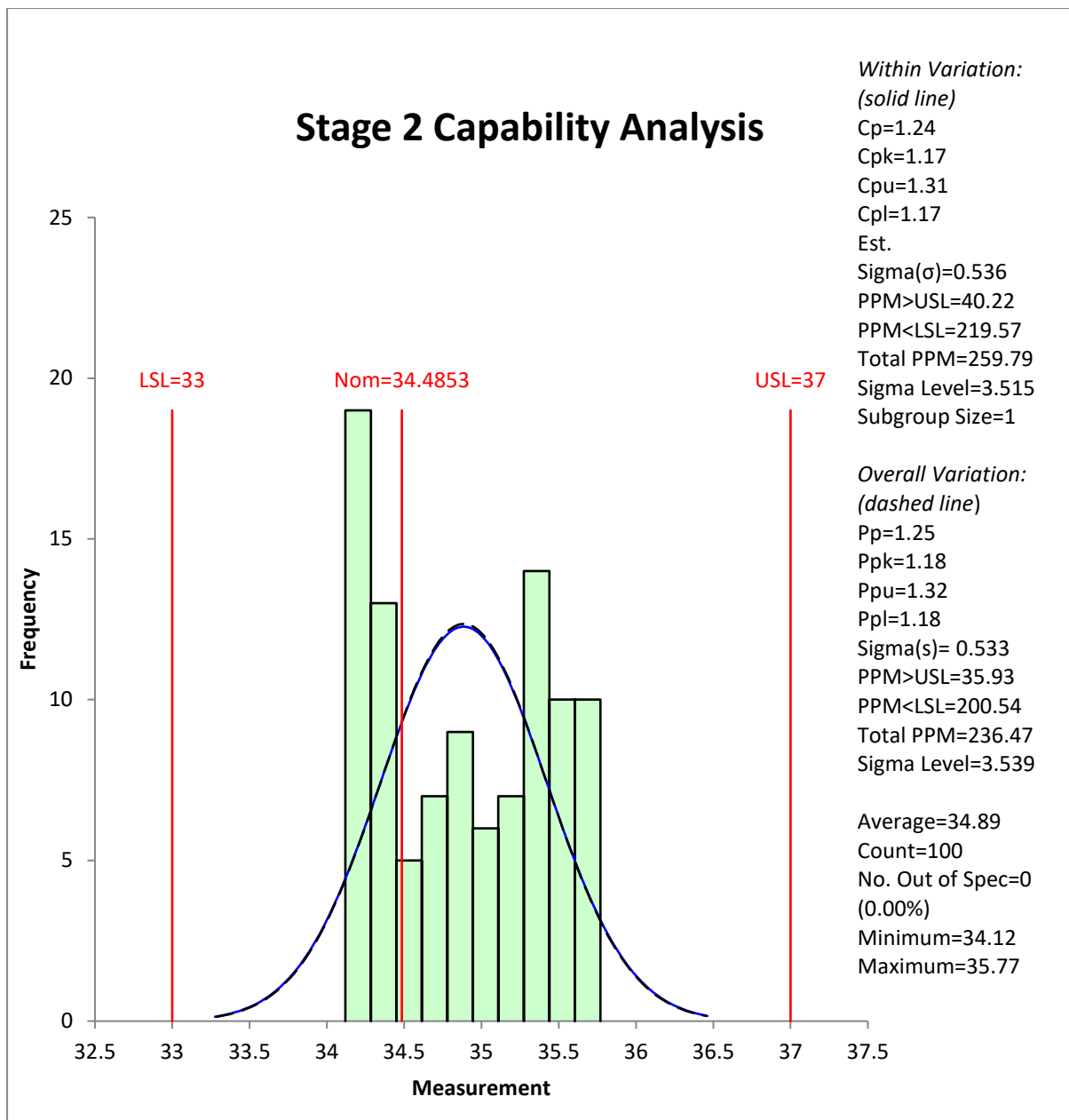


Table 38: Stage 2 Cpk

Stage 2 showed signs of good control as the samples fall well between the specified limits forming a long narrow bell curve with good margin between the specified limits. Another positive sign is a higher cp, cpk value which is an indication of good control.

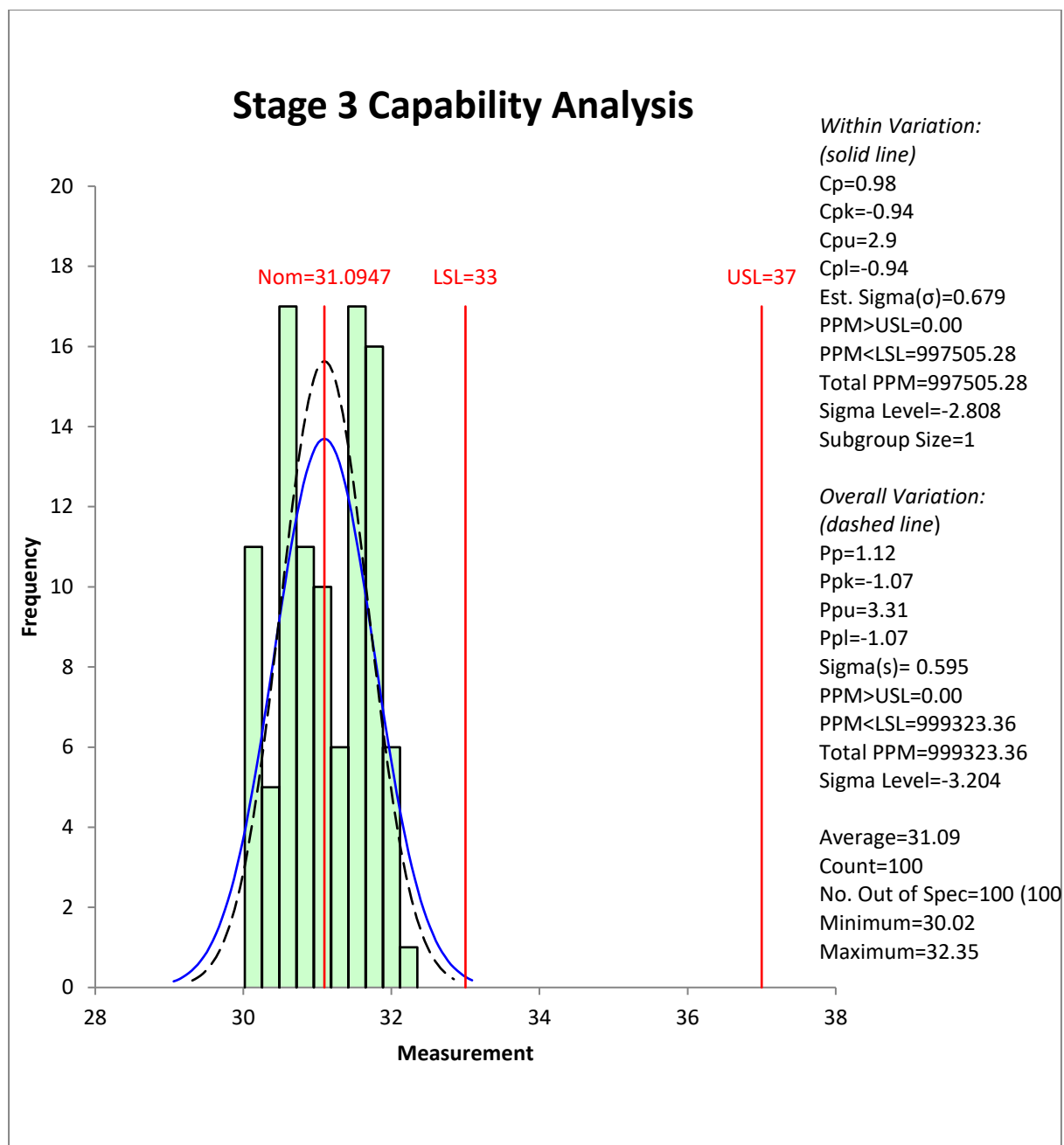


Table 39: Stage 3 Cpk

Stage 3 (table 39), the results were unusual as every sample fell out of the specification, however there is a tight grouping of results forming a long narrow bell curve symptomatic of good control.

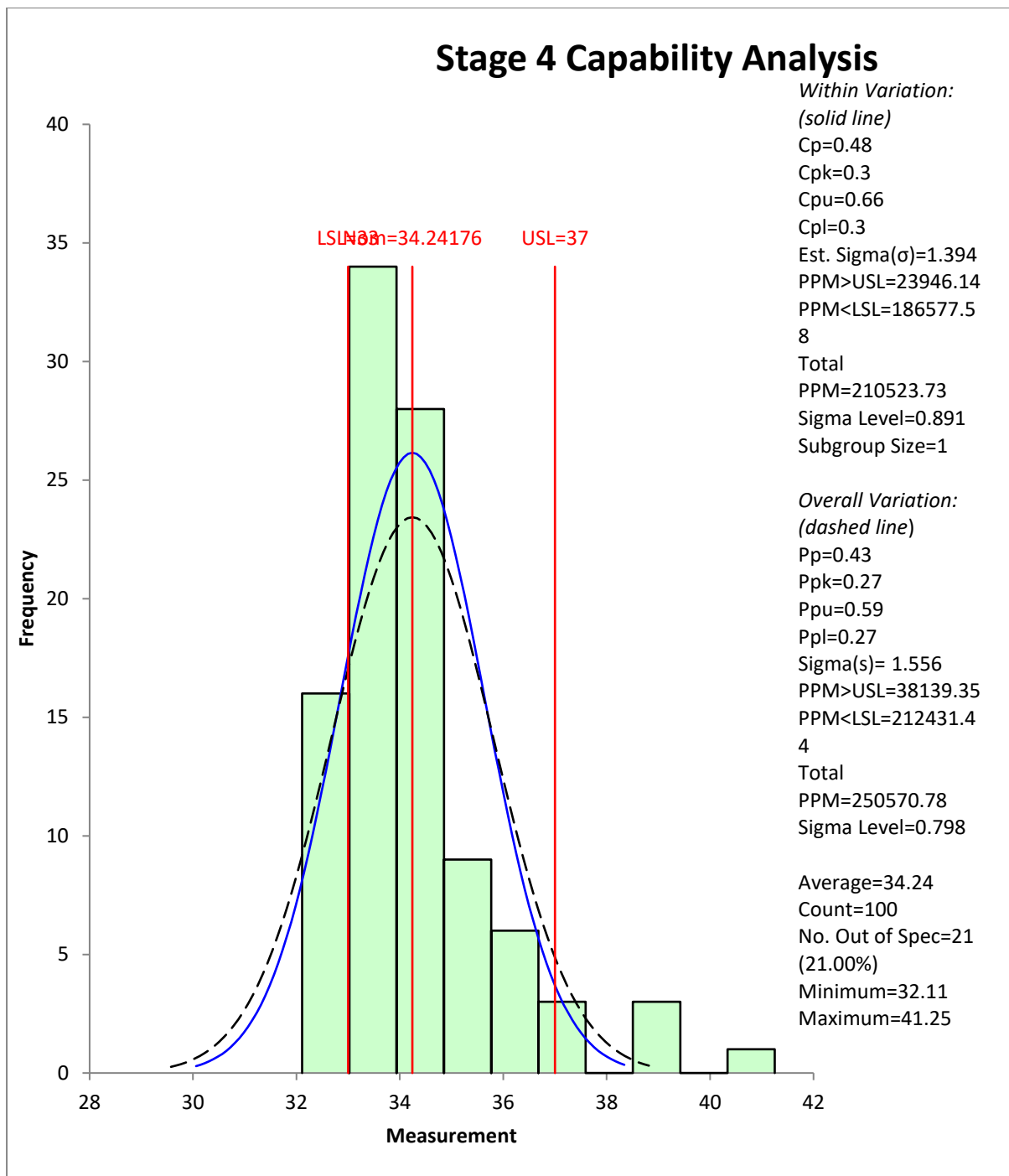


Table 40: Stage 4 Cpk

Stage 4 shows a huge variation between the max and minimum values with 21% falling outside of the limits, poor control and high variation, this is not a good example of process control.

6 DMAIC – Improve

6.1 Greggs PCB Returns Process

One of the first improvements made was to reduce the time taken to return and refurbish the defective controllers. A decision was made to create a buffer stock of controllers ready for dispatch, once the RMA process was raised the buffer stock was used to return the PCB immediately, reducing any impact on the customers operation.

The returns process was prioritised as it could be implemented with immediate effect and significantly reduce the impact on the customer. Using the previous calculations used in the define stage to measure the overall impact.

- Average cost to customer with each PCB defect & 20-day downtime = £49,680.00.
- Number of boards returned during the 6-month period = 25
- Potential loss of revenue due to controller failures = $49,680 \times 25 = \text{£1,242,000.00}$



Figure 28: Returns Buffer Stock of PCB

6.2 Engineering Changes – Defect Reduction / Poke Yoke

To reduce the number of defects occurring Mono introduced several engineering changes. These changes were driven by the earlier cause and effect exercise and the root cause analysis (RCA) meeting held.

6.2.1 Oven Not Heating & Electrical – Defect Reduction

During the RCA meeting it was discovered that the electrical panel had too much movement, which potentially causes the wiring to come loose during transportation to the customer. A recommendation was made to brace the electrical panel preventing movement. The change was implemented and the design can be seen in figure 29 & 30.

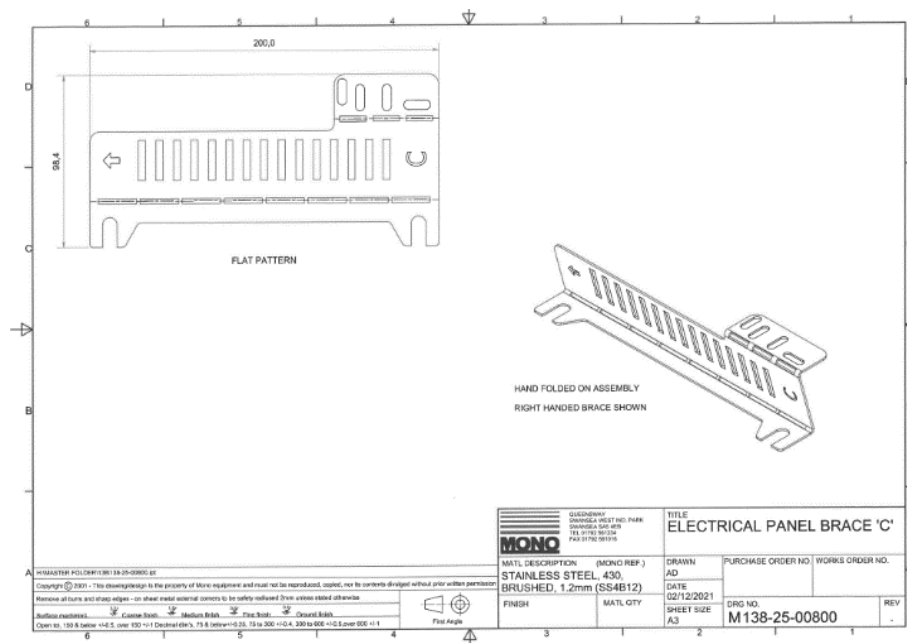


Figure 29: Electrical Panel Brace



Figure 30: Electrical Panel Brace

To reduce electrical faults a new fuse carrier was sourced which has a locking mechanism to prevent the fuse falling out post-delivery. The figure 31 details the change of fuse carrier.

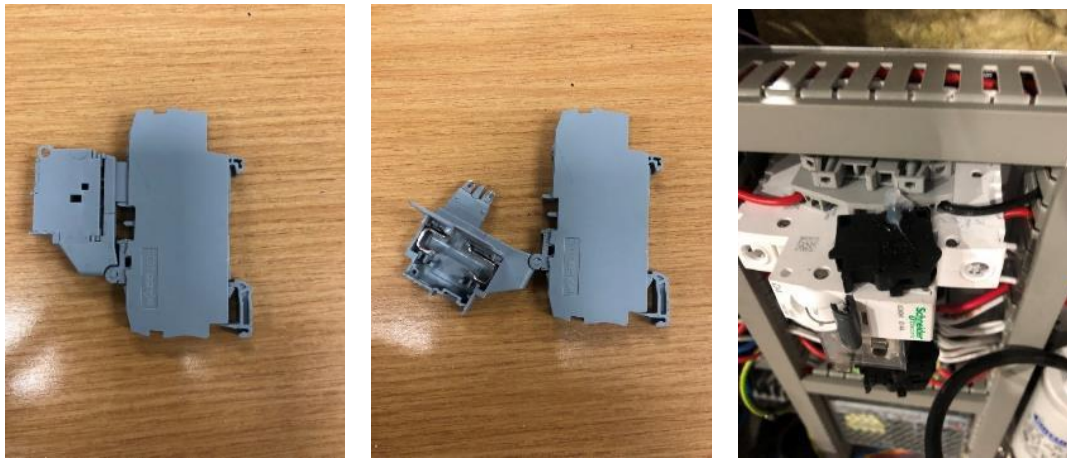


Figure 31: New & Old Fuse Carrier

6.2.2 PCB Failure - Defect Reduction

This was noted as the most significant failure due to the impact it had on the customer and the cost to replace a damaged high value item such as a controller. The controller cover was unable to cope with the high humidity and operating environment. A new cover was designed and produced which secured to alternative fixing points. Extension bars were added creating the platform to hold the new protective cover the PCB was further protected by a foam gasket, encasing the PCB and protecting against the high humidity.

6.2.2.1 New PCB Cover

A trial was conducted on the new cover to prove its effectiveness against steam, the trial was successful in protecting the screen and PCB.



Figure 32: New PCB Cover Trial

6.2.2.1.1 New PCB Cover Design

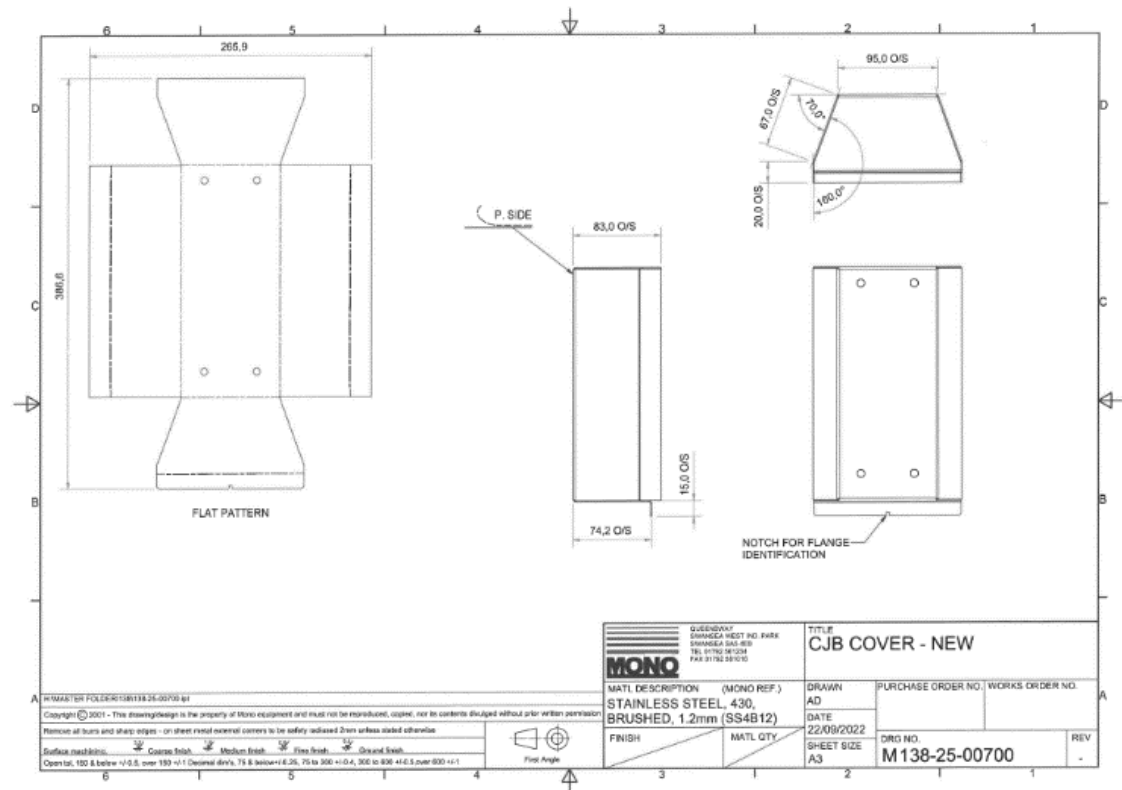


Figure 33: PCB Cover Design

6.2.2.1.2 Old PCB Cover Design

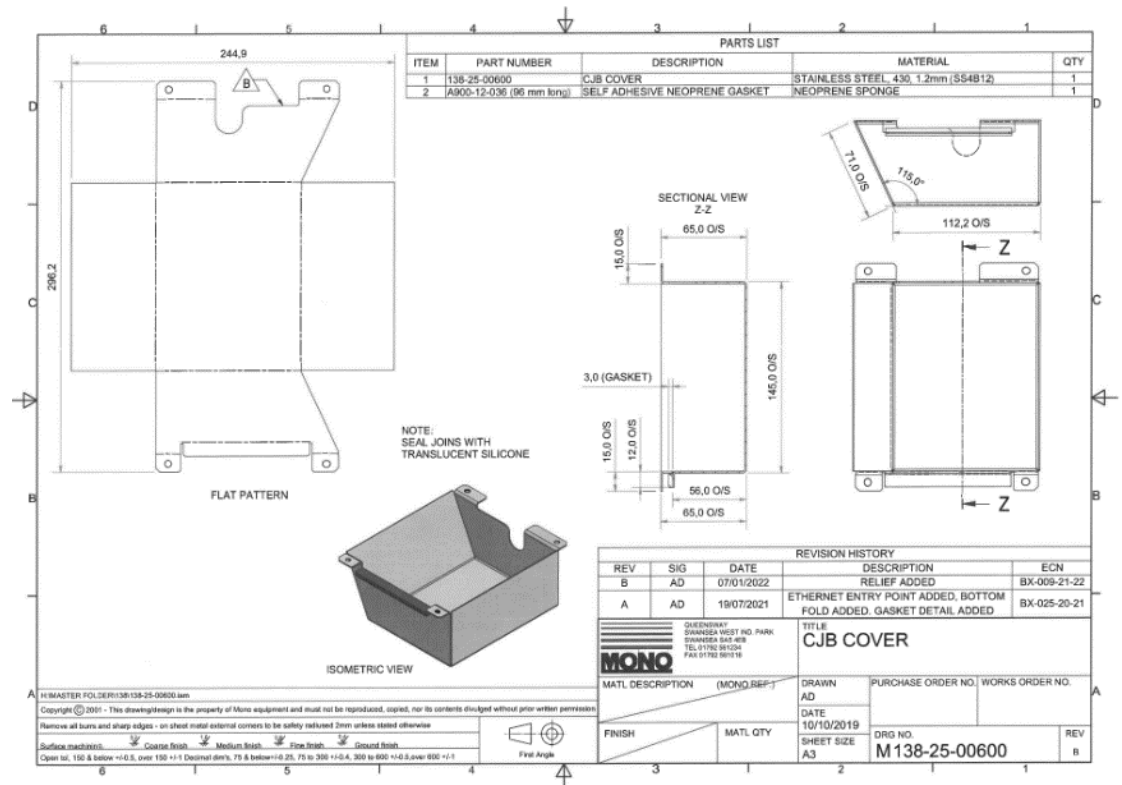


Figure 34: Old PCB Cover Design

6.2.2.2 PCB Fuse

The highest occurring fault was discovered to be the fuse falling out, the most practical suggestion was to hard solder the fuse in place as a permanent feature and eliminating the fault. In the unlikely event of a fuse failing the board would need to be replaced.

6.2.2.3 PCB Blank Screen

Blank screen is a difficult fault to diagnose, the screen may have failed due to moisture and humidity, the new PCB cover will protect against this and will reduce screen failures.

6.2.2.4 PCB Screen Calibration

Several issues relating to calibration of screen and poor touch response can be addressed with the new recalibration function, this is easily used by inserting the USB stick into the USB drive and powering up the machine, the user is asked to touch a series of points to realign screen. This was distributed to Greggs maintenance team to be used before replacing the PCB with an unresponsive screen.

A number of important functions are located on the edge of the screen if the screen is out of calibration the user will lose important functions.

Humidity can cause the calibration to drift due to the resistive touch response and water being a conductor, Mono intends of moving to PCAP screen which will offer good protection against this, the new screen can have redesigned metal work to protect against steam.

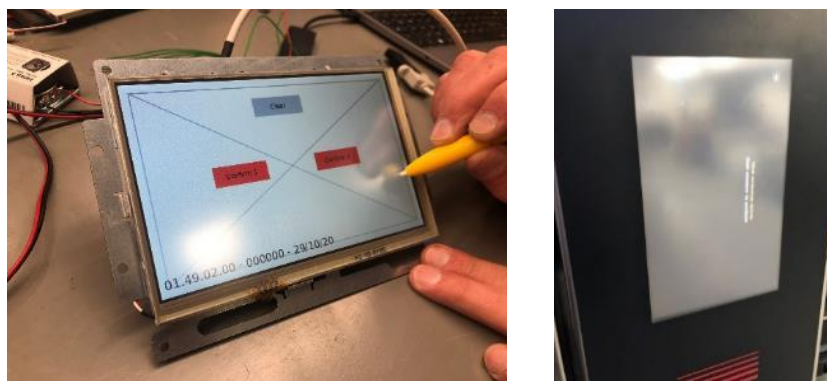


Figure 35: Screen Calibration Function Introduced

6.2.2.5 PCB μ SD Card

The PCB corruption failure was confirmed on several boards tested, these boards either failed to boot, slow response time and blank screen. To overcome the corruption issues Mono intends on upgrading the μ SD card with higher performance and better environmental protection making in more reliable as recommended by the supplier.

6.2.2.6 PCB Loose Connection

Loose connections are difficult to detect, Mono is looking at options to introduce new phoenix connectors to prevent thermocouples falling out and improve reliability.

6.2.2.7 PCB Sounder Issue

This has been resolved with the firmware update installed on all ovens.

6.2.3 Oven Door - Defect Reduction

The door failure was the most challenging issue to diagnose and rectify as there was limited information and multiple factors, the door seal failing due to degradation was one failure mode. Another issue discovered relating to the inner door resulting from the redesign, this meant the door could fold in on itself preventing the operator from being able to separate the doors. A change was made to extend the inner door metal work by 3mm to remove this defect.



Figure 36:Oven Door Catching Issue

6.3 Bulk Purchasing – KAIZEN No.1

Bulk purchasing was identified from the VSM exercise (Kaizen No.1). This method had already been adopted by other customers who purchase high volume of ovens. The benefit to Mono equipment lies with better forecasting, improved efficiencies and better stock management. Bulk purchasing requires the customer to agree to purchase a fixed amount per month, these ovens are produced in bulk, in doing so ensures reliable & efficient delivery.

The current method involves a high amount of communication between customer and sales, and low volume ovens being purchased in a sporadic way.

In a meeting between customer and Mono bulk purchasing method was suggested and later agreed. Gregg's forecast suggests batches of 31 double stacked ovens total 62 ovens/ month. A brief analysis of the current sheet utilisation mono can expect to reduce the number of sheets required and further improve efficiencies by reducing set up times.

- Old batch quantity of 14 ovens – total number of sheet metal 62 ovens = 325.5 sheets
- Re-nesting for 62 ovens EBQ = 302.8 sheets
- Current price of stainless-steel sheet = £36.20
- Cost of old batch @ 62 ovens:
 - $36.2 \times 325.5 = £11,783.10$
- Cost after re-nesting for 62 ovens:
 - $36.2 \times 302.8 = 10,961.36$
- Total saving in sheet metal = **£821.74**
- Reduction in sheet metal $\frac{|325.5 - 302.8|}{325.5} \therefore \left(\frac{22.7}{325.5} \right) \times 100 = 6.97\%$
- Sheet metal saving over 12-month period: $12 \times 821.74 = \text{£}9,860.88 \text{ PA}$

A considerable amount of cost reduction was created by introducing this new purchasing method. Mono will also reduce setup times on folding operations by 25% promoting more efficiencies. This method is a true definition of lean where production only manufactures what has been purchased and eliminates any form of overproduction.

By nesting in fixed batches of 14 generates a great deal on confusion through tracking inventory to over production putting unnecessary strain on the flow. to eliminate this Mono could adopt fixed nests of 1's, 2's and 5's and create multiples of to produce only what has been purchased, the high variation of oven types leads to many challenges and adopting this approach will improve flow, efficiencies and reduce cost as proven in this exercise.

6.4 Steam Reduction

An upgrade to the steam ducting was proposed to reduce the amount of steam escaping the chamber and subsequently damaging the controller. This improvement was going to see an increase in cost and required justification.

On investigation the current pipe showed signs of breaking down, becoming brittle, and developing holes, it was thought that the aluminium pipe became brittle due to a combination of thermal fatigue and galvanic corrosion. Galvanic corrosion occurs when there is a transfer of electrons from a metal acting as an anode to another metal as a cathode, in the presence of an electrode, the aluminium pipe in this case is the anode and is attacked by the stainless steel while the electrode is steam resulting in significant damage occurring.



Figure 37:Aluminium Ducting

Current Ducting

Semi Rigid Aluminium Ducting

Temperature Max/ Min: +300°C / - 30°C

Price / Meter : £5.58



Figure 38:New Proposed Ducting

New Proposed Ducting

Silicone Air Ducting

Temperature Max/ Min: +310°C / - 60°C

Price / Meter : £12.19

6.4.1 Advantages

1. Non-conductive material
2. Forms a better seal on jubilee clip
3. Reduced maintenance / durability
4. Reduced steam
5. Higher temperature resistance
6. Improved customer satisfaction

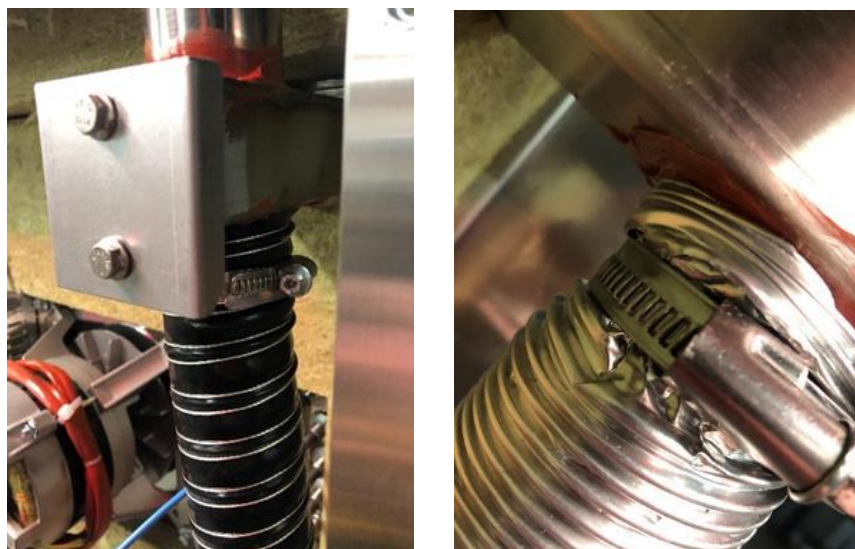


Figure 39: New Ducting Advantages

6.4.2 Cost Analysis Steam Ducting

All 5 tray ovens bar FG138 require 500mm. FG 138 ovens have a taller chamber and requires 600mm of ducting. These were all stackable ovens sold by type between 28/11/21 to 27/11/22.

Oven Type	No. Ovens	Pipe Length
FG138	599	600mm
FG153	57	500mm
FG158	187	500mm
FG159	26	500mm
	869	

Table 41: Number of Stackable Ovens Built

Current Ducting Value Analysis	
Total Number of double stacked @ 500mm	$(57+187+26+599)/2 = 434.5$
Price / meter semi ridged aluminium duct	£5.58/ meter
Price / 500mm	$5.58/2 = £2.79$
Total cost in this period	$2.79 \times 448 = £1,212.26$

Table 42: Current ducting value analysis

Silicone Ducting Value Analysis	
Total Number of double stacked @ 500mm	$(57+187+26)/2 = 135$
Total Number of double stacked @ 600mm	$(599)/2 = 299.5$
Price / meter silicone duct	£12.19/meter
Price / 500mm	$12.19 \times 0.5 = £6.01$
Price / 600mm	$12.19 \times 0.6 = £7.32$
500mm cost in this period	$135 \times 6.01 = £811.35$
600mm cost in this period	$299.5 \times 7.32 = £2,192.34$
Total cost in this period	$2192.34 + 811.35 = £3003.69$

Table 43: Value Analysis - Silicone Ducting

Price Difference	
Total cost aluminium pipe	£1,212.26
Total cost silicone duct	£3003.69
Price difference	$£3003.69 - £1,212.26 = 1,791.43$ Increase
% price difference	$((3003.69 - £1,212.26)/3003.69) \times 100 = 59.64\%$

Table 44: Price Difference

If this is calculated based on the forecast from Greggs based on 31 double stacked ovens / month Mono can expect to see an increase of:

£7.32 / Double stack

$31 \times 7.32 = £226.92$ / month on Gregg's ovens only

$226.92 \times 12 = 2,723.04$ PA

Price increased by: $(2723.04 \times 0.5964) = £1624.02$ PA

It will be beneficial to negotiate the cost of the silicone ducting. This calculation has not accounted for any potential reduction.

6.5 5S Implementation

5S is a Lean methodology for creating an organised and productive workplace by carrying out the following 5S strategies defined as; sorting, straightening, shining, standardising, and sustaining. Many companies implement 5S with the aim of improving productivity, reducing waste, enhanced safety, increased employee satisfaction, improved customer satisfaction, cost reduction and improved quality. (Lane, 2007)

At Mono it was identified that a lot of motion waste was observed for missing tools. This was having a significant impact on the moral of employees who were fed up of sharing tools and searching for equipment. The impact to Mono was analysed and it was estimated at a loss equivalent to 52 ovens per annum equating to £161,000.00. The result of this analysis prompted the introduction of 5S. To build understanding of these principles 5S training was delivered to all section workers and supervisors. This improved the chances of success.

The analyse phase highlighted that tools had no location and tool boards were badly laid out which made for inefficient working methods. A new tool storage system was created using storage shelves which we used for holding parts. This freed up space and provided an ergonomic working platform, the shelf was filled with foam and tools used cut out to help identify any missing tools and the location of each tool. A 5S audit was conducted on 4 tray production line.

A red tag area was introduced creating an area dedicated to removing items from the work space which are no longer required and support the 5s activity.



Figure 40: Red Tag Area

After the training employees were encouraged to undertake small 5S project, a team identified the pipe cutting area as a potential area for improvements. The audit allowed them to build understanding of the concept of 5S and how this could benefit them. The minor project was a great success results can be seen below.

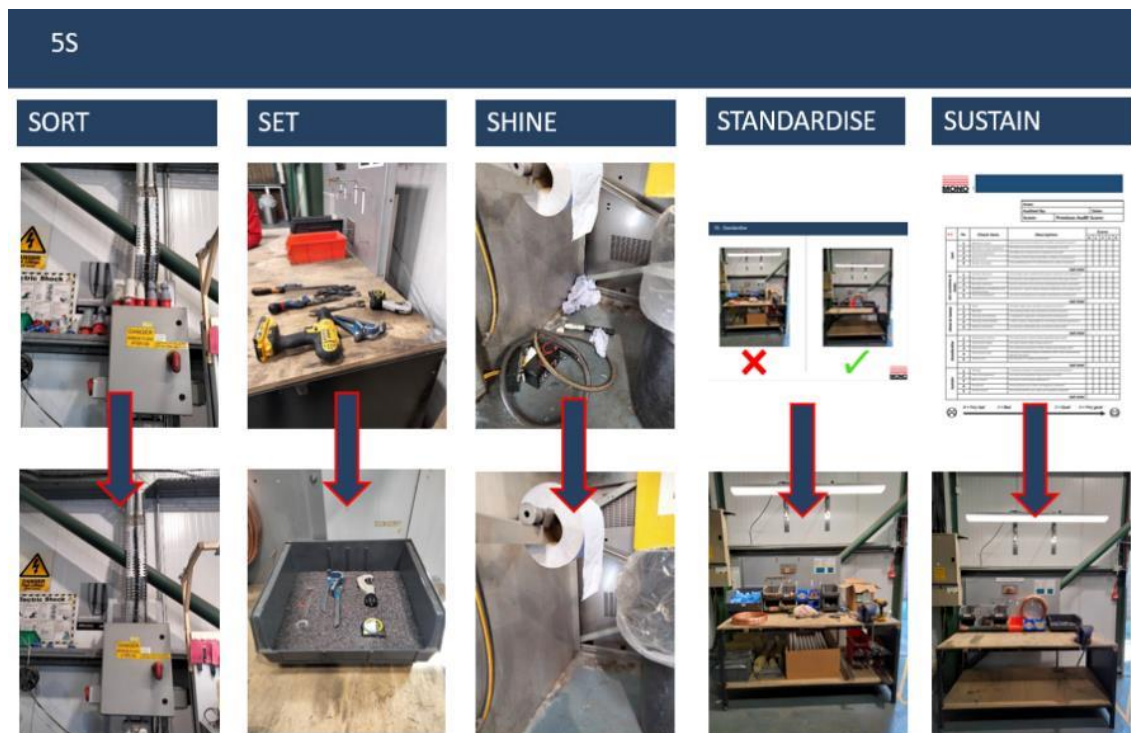


Figure 41:Pipe Bench 5S Project

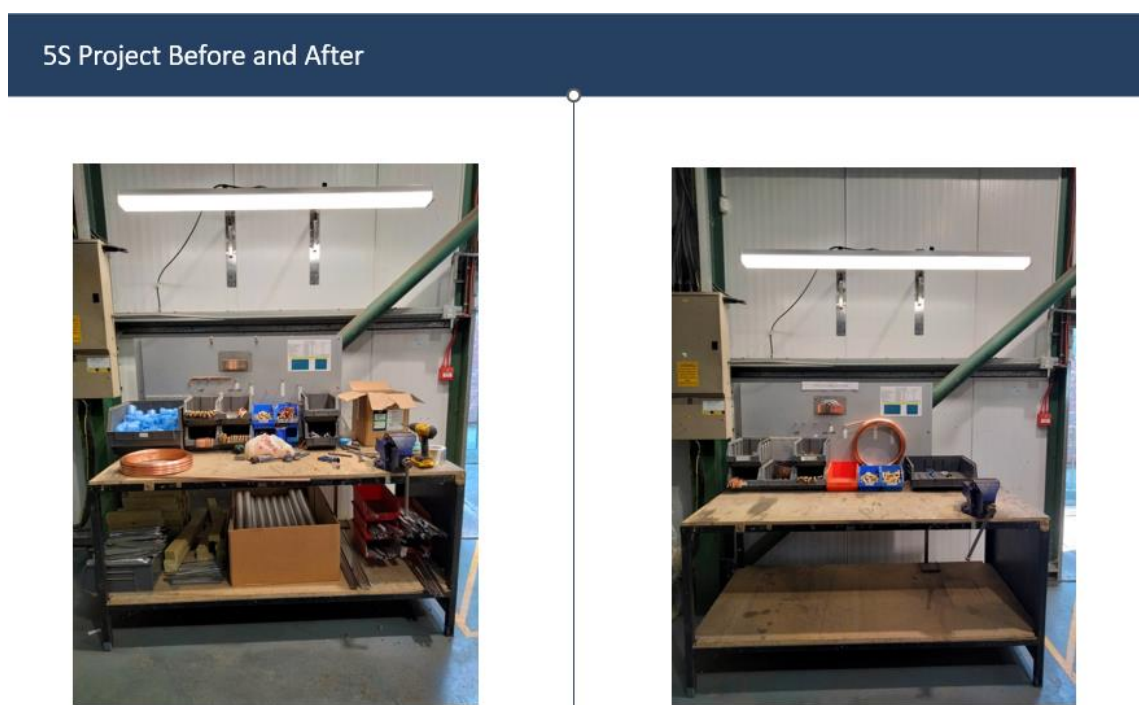


Figure 42:5S Pipe Bench Project Before & After

Once the team-built confidence and understanding of the 5S principles a larger project was undertaken with the aim of eliminating the motion waste associated to the tool situation. This section was set up as a trial with the aim of convincing senior management to invest and implement to all sections.

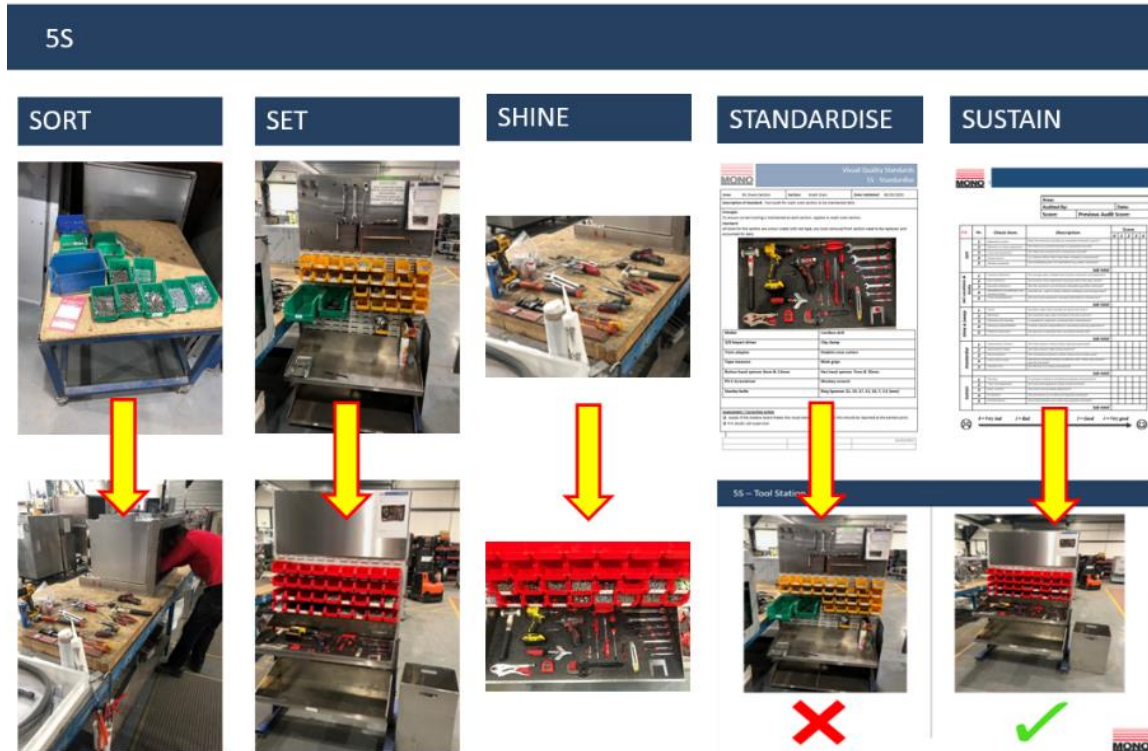


Figure 43:5S Project - Tool Station

5S – Tool Station



Figure 44:5S Project Tool Station

Our team was able to create a tool station with increased capacity for all tools, including power tools, thanks to the 5s activity. The space has been improved to provide a comfortable platform to work from, the foam cut outs added provide a shadow to easily identify tool location, the foam, fixing bins and tools were colour coded red for identification, making it unique to this section helps identify tool location should any go missing. By removing the old tool board and adding a new plain sheet created a space for information and feedback such as standardise and sustain audit sheets, the space can be used to communicate any process changes or quality issues using visual quality standards.

This system not only reduces motion waste but also offers a way of tracking tools in the most efficient way, operatives can identify any missing tools quickly and replacements can be ordered if needed, it gives ownership to each section and increases performance. The team were really pleased with the results improving employee satisfaction.



Figure 45: Tool Storage Layout

6.6 Waiting - Two Bin System

Another lean wasted observed was related to waiting, the door section ran out of nylon spacers which resulted in many other forms of lean waste, from waiting to over processing through to additional motion and transport waste.

Firstly, to keep production lines running temporary spacers were fitted, which required replacing once the spacers were produced. The nylon spacers should never get to the point of running out, for this to occur there were multiple systematic failures.

As a result of the redesign the usage increased significantly, the bulk ordering system is not tracked via MRP, this was because the components were being fed to the line without being booked into stock. Table 38 below looks at the current usage levels and identifies approximately how long the current batch lasted.

Batch Quantity Review	
Number / door	4
Number of doors manufactured daily	18
Number of spacers required daily	$4 \times 18 = 72$
Current batch quantity	400
Total number of days usage	$400/72 = 5.6$

Table 45:Batch Quantity Review - Nylon Spacer for Doors

The first improvement made was to increase the batch quantity by doubling it, and as a one off this was doubled again totalling 1600 units. These were machined on the lathe during a night run with automated bar feed system to reduce impact to the schedule.

The batch was split into two and an area created in the Kanban area to maintain the stock. This two-bin system enabled the team to maintain stock levels. The door assembly team ensured they had set a two-bin system in the production area. Once the top bins depleted, they draw more from the kanban. This buffer stock ensures no waste occurs, it puts ownership on the team to draw more once it has reached a level, reducing the impact on the machine shop.



Figure 46: Two Bin System

Table 39 below details the extra processing analysis based on a 2 day wait which occurred during the project and the overall impact this had on the section, based on the 2 hours over time a day it will take the section 24.5 days to recover as there is no additional time in the schedule to complete these tasks.

Extra Processing Analysis	
Number of days without spacers	2 days
Number of ovens built in 2 days	28 oven doors
Minutes taken to fit temporary spacers / door	25 minutes
Total minutes taken to fit temporary spacers	$25 \times 28 = 700$ minutes
Total minutes to remove and replace spacers	$50 \times 28 = 1400$ minutes
Total Time wasted in Hours	$(700 + 1400) / 60 = 35$ hours
Testing time allocation	30 minutes
Additional time testing 28 Ovens	$(28 \times 30) / 60 = 14$ hours
Overtime Pay Rate (time & a half)	$11 \times 1.5 = \text{£}16.5/\text{hour}$
Total cost to replace these at overtime rate	$(35 + 14) \times 16.5 = \text{£}808.50$ overtime wages
Time Taken to clear backlog 2hrs/day	$(35 + 14) / 2 = 24.5$ working days

Table 46: Waiting / Extra Processing Analysis



Figure 47: Extra Processing Due to Using Incorrect Parts

6.7 Line Balance

The SPC detailed that there was an imbalance between the stages, it was noted that stage 3 was below the specified control limit which effected line balance. To generate better flow the line was balanced, on the process flow chart, line 16, stage 4 the operative required 254 seconds to secure the door seal, this was then added to stage 3 process to help balance the line.

16	Fit door seal	254								
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Figure 48: Line 16 Stage 4 flow process chart

Type	Stage 1	Stage 2	Stage 3	Stage 4
189	Elements & bolts	Damper & bracket	Door seals	Door seals
158,159, 138,153	Damper & bracket	Elements & bolts Make pipes	Make pipes	

Figure 49: Line balance

7 DMAIC – Control

The aim of the control phase is to ensure that the changes implemented are maintained, the new owners have the tools and resources to prevent the work and improvements for being undone.

Validation of the result is considered a critical element of the control phase. Many take the opportunity during this phase to celebrate the success between the project team and recognise the work contributed.

7.1 Results Validation

7.1.1 Pareto Analysis Post Improvements

The data of the second six-month period was analysed and during the second period post improvements was a significant reduction in failures observed. The pareto displayed less than 1% failure rate across all bar PCB failures which amounted to 1.29%. this is a significant reduction in failures compared to the original pareto which accounted for over 7% failures rate.

Total Number of Ovens	622	%			
Total Faults 2 nd 6 Months	30	4.8			
Fault Type	Freq	Freq %	Cum Freq	Cum Freq %	Total %
PCB + Fuse	7	26.7	8	26.7	1.29
Temperature / Fan Motor	6	20.0	14	46.7	0.96
Electrical	5	16.7	19	63.4	0.80
LED	4	13.3	23	76.7	0.64
Other	4	13.3	27	90.0	0.64
Door	3	10.0	30	100.0	0.48

Table 47: Pareto analysis table

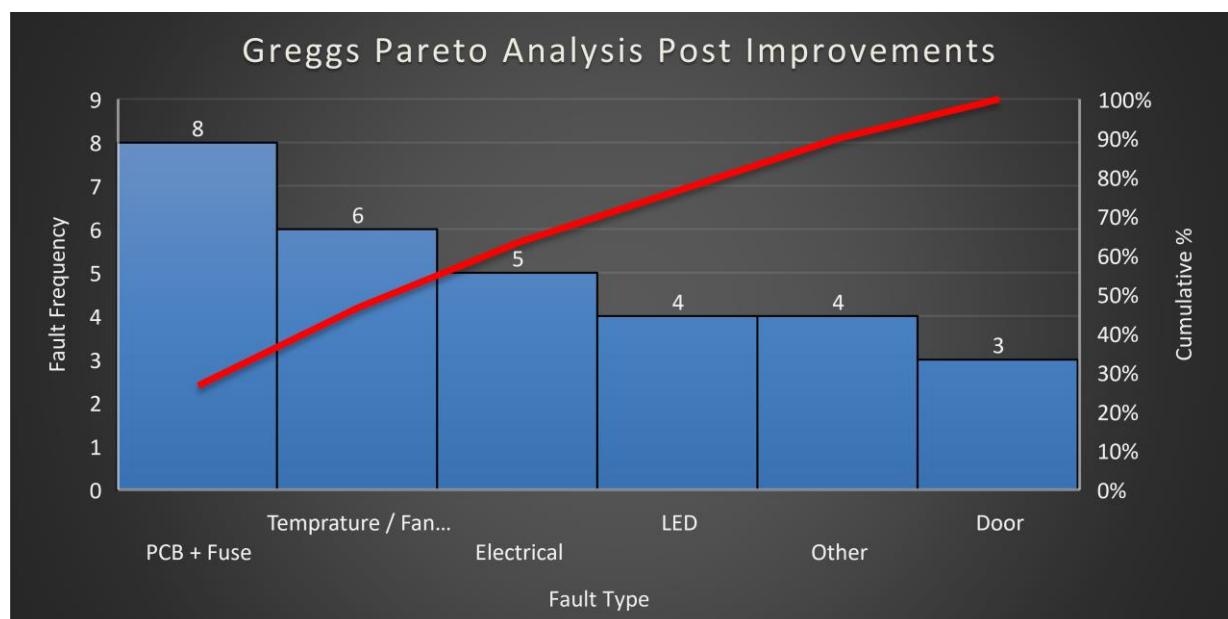


Table 48: Pareto chart post improvements

From the pareto analysis we can see a rapid decline of failure resulting in a reduction of callouts, this is a positive step in improving customer satisfaction and regaining the trust of a key customer like Gregg's. The improvements introduced have ensured the target set has been achieved. The number of ovens failing has reduced significantly whilst the number of ovens supplied has increased.

- Total fault period 1 = 126
- Total faults period 2 = 30
- Reduction in faults = $(30 / 126) \times 100 = 23.81\%$

7.1.2 Efficiency analysis

The efficiency of the section has increased significantly over the past 6 months, Mono has seen an increase in numbers produced (blue bar) and a reduction in faults (red bar) recorded during test.

Table 49 details the number of ovens built per month compared to faults recorded during test. Table 50 quantifies to performance and seen a significant boost to revenue generated as a result.

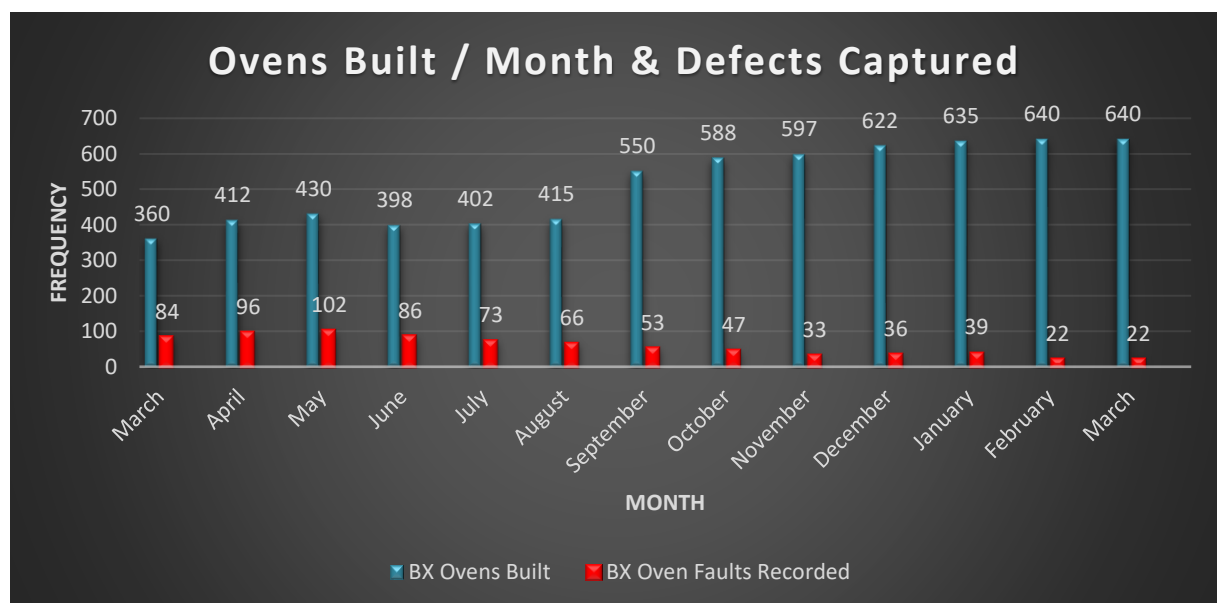


Table 49: Efficiencies Bar Chart

Performance Analysis	
Average number of ovens built / month pre improvements:	402.83 Ovens
Average number of ovens built / month post improvements:	610.29 Ovens
Difference	207.46
Monthly increase in revenue (Average)	207.46 x 3100 = £643,126.00

Table 50: Performance Analysis

7.2 Cumulative Sum Control Chart – Post Improvements

To validate the success of implementing lean strategies withing the BX ovens section another trial was conducted to see the effectiveness of the lean improvements, the CUSUM chart in table 52 & 53 shows that the production line is consistently reaching the daily target and within the control limits.

Team Member	Stage
Rob	Stage 1
Dylan	Stage 2
Scott	Stage 3
Tony	Stage 4

Table 51: Team

Day	Target	Lower	Actual	Deviation	Mean
1	14	12	14	0	13.85
2	14	12	14	0	13.85
3	14	12	14	0	13.85
4	14	12	14	0	13.85
5	14	12	14	0	13.85
6	14	12	14	0	13.85
7	14	12	14	0	13.85
8	14	12	14	0	13.85
9	14	12	14	0	13.85
10	14	12	14	0	13.85
11	14	12	14	0	13.85
12	14	12	14	0	13.85
13	14	12	14	0	13.85
14	14	12	13	-1	13.85
15	14	12	13	-1	13.85
16	14	12	14	0	13.85
17	14	12	14	0	13.85
18	14	12	13	-1	13.85
19	14	12	14	0	13.85
20	14	12	14	0	13.85
Total	280	240	277	-3	

Table 52: CUSUM Analysis

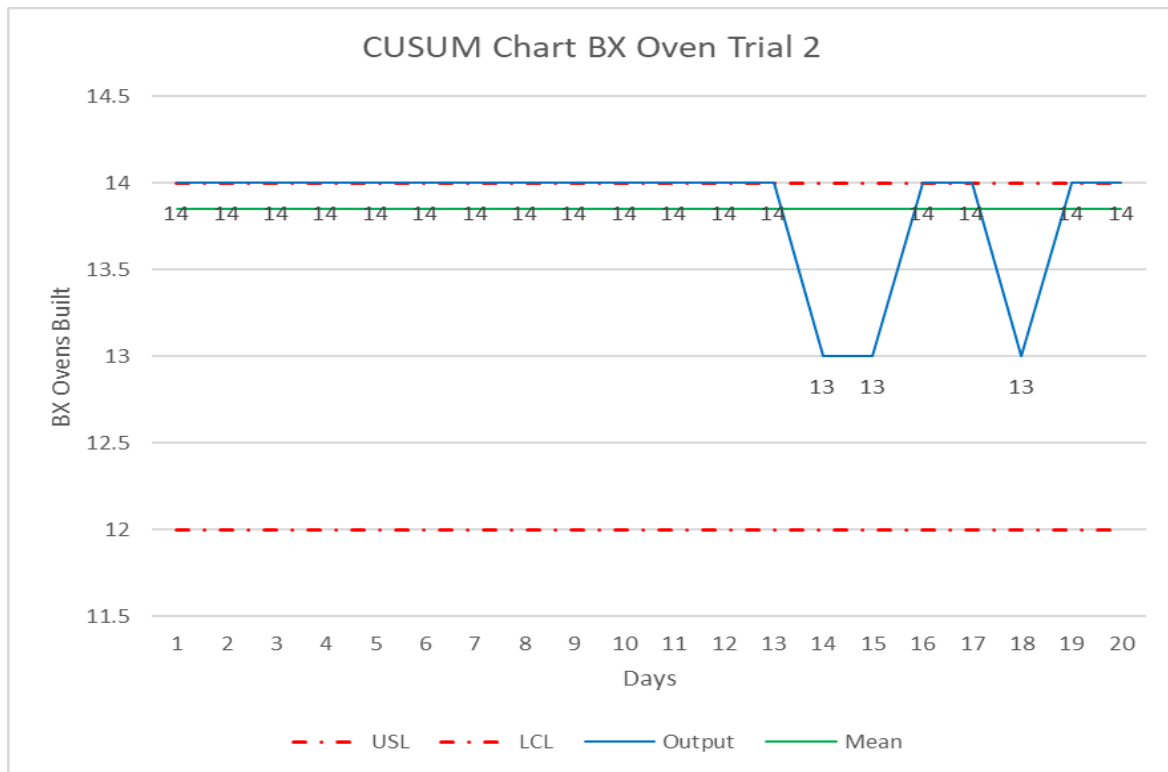


Table 53: CUSUM Chart Post Analysis

The second analysis detailed a deviation of -3 ovens over a 4-week period this compared to the -60 ovens built over the first 4-week CUSUM analysis.

$$3/280 \times 100 = 1.01\% \text{ from target } 2^{\text{nd}} \text{ trail}$$

$$60/280 \times 100 = 21.43\% \text{ from first trial}$$

7.3 Statistical Process Control – Post Improvements

The SPC allowed the team to analyse the behaviour of the production line over time, post improvements it was expected that there would be an improved performance compared to the initial analyse phase SPC.

The team reported there was an increased amount of control, the measurements now sit between the specified and control limits, there is also a standard deviation <1 on each stage this is another indication that the process is in control. (Oakland E. S., 1999) this can be seen in Table 54 and 55



Table 54: SPC Stage 1-4 Post Improvements

	Mean	STD DEV	UCL	LCL	USL	LSL
STAGE 1	35.2992	0.631252851	37.19295855	33.40544145	37	33
STAGE 2	34.8853	0.532665216	36.48329565	33.28730435	37	33
STAGE 3	35.016	0.835897872	37.52369362	32.50830638	37	33
STAGE 4	34.0287	0.998817134	37.0251514	31.0322486	37	33

Table 55: SPC Calculations Stage 1-4 Post Improvements

7.4 Process Capability Post Improvements

The process capability has detailed an interesting pattern where despite the good process control and the improvements made the process capability has marginally increased but still considered low. This is a result of tight specification limits and the variation of data, which means the chart has a high probability of falling outside the control limits. It is said that the higher the cp value the less chance of passing the control limits. (Oakland J. , 2008) This will need to be monitored to prevent such occurrences. The cp value is particularly low on table 56, 58, & 59 the team should not be concerned by this, the charts have a high probability of passing the Lower Specification Limit as the ovens are being produced quicker, this is a positive sign that the line is more efficient if the lower specified control limit was reduced, we would then see an increase to cp value.

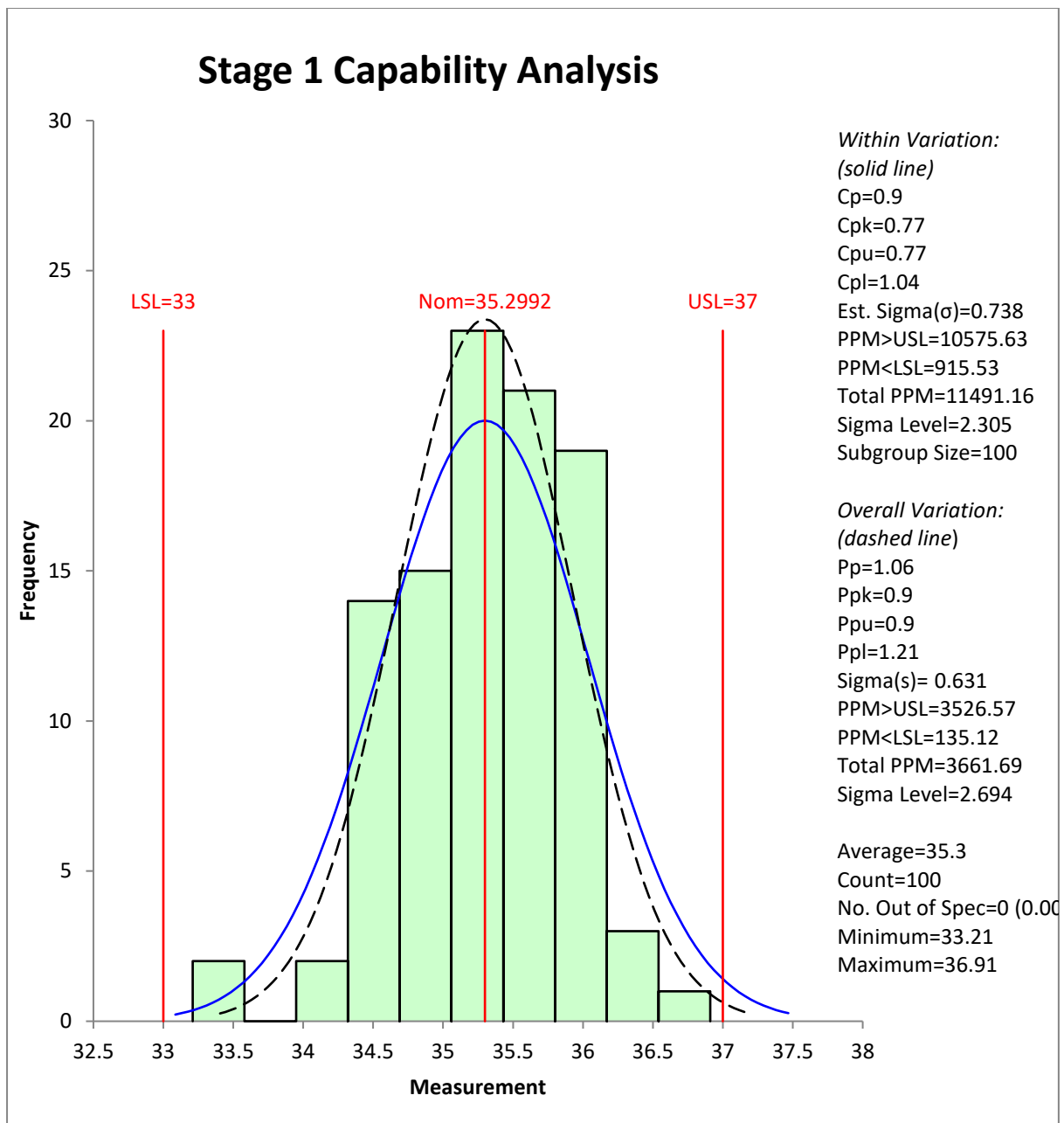


Table 56: Stage 1 Cpk Post Improve

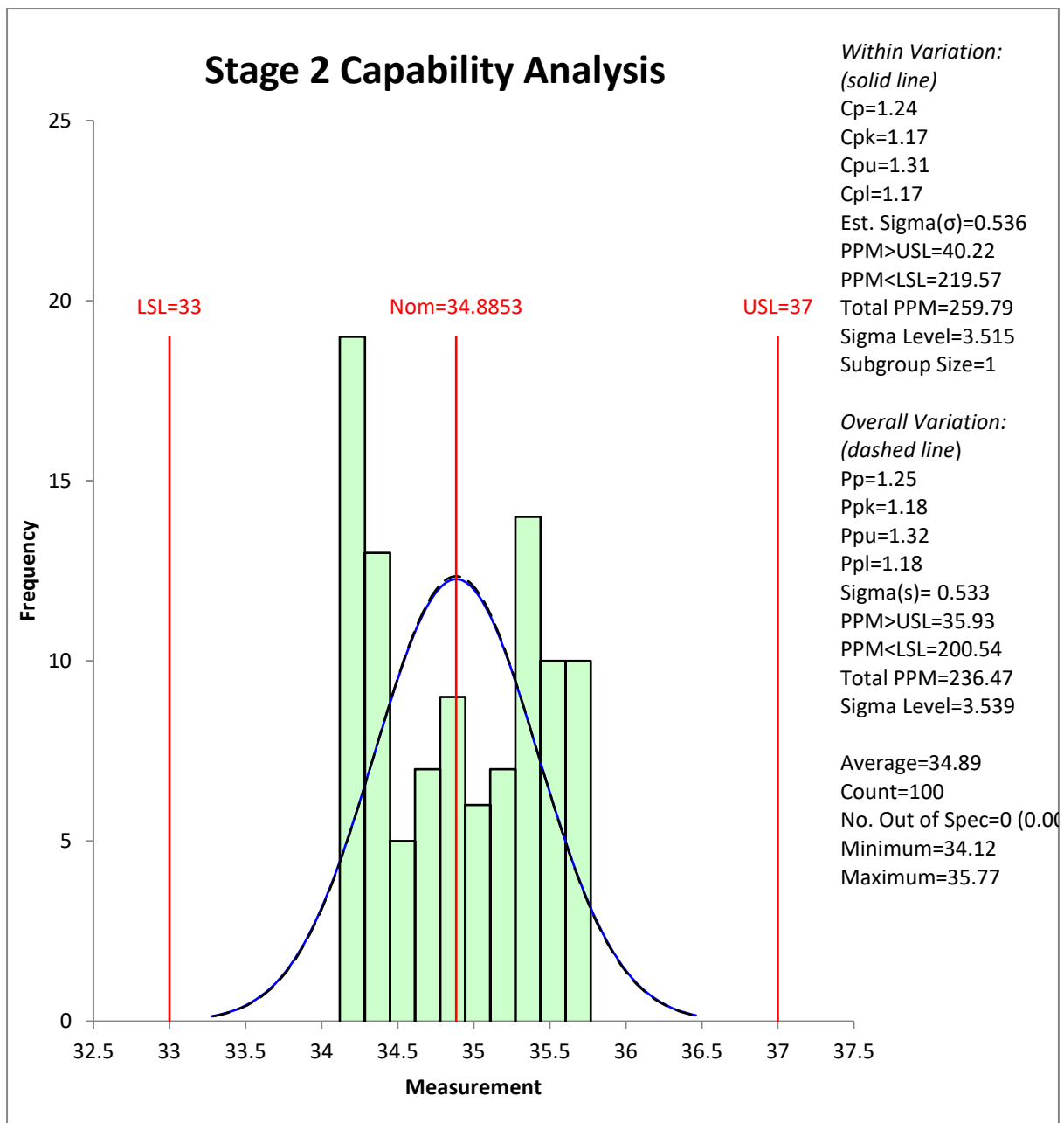


Table 57: Stage 2 Cpk Post Improve

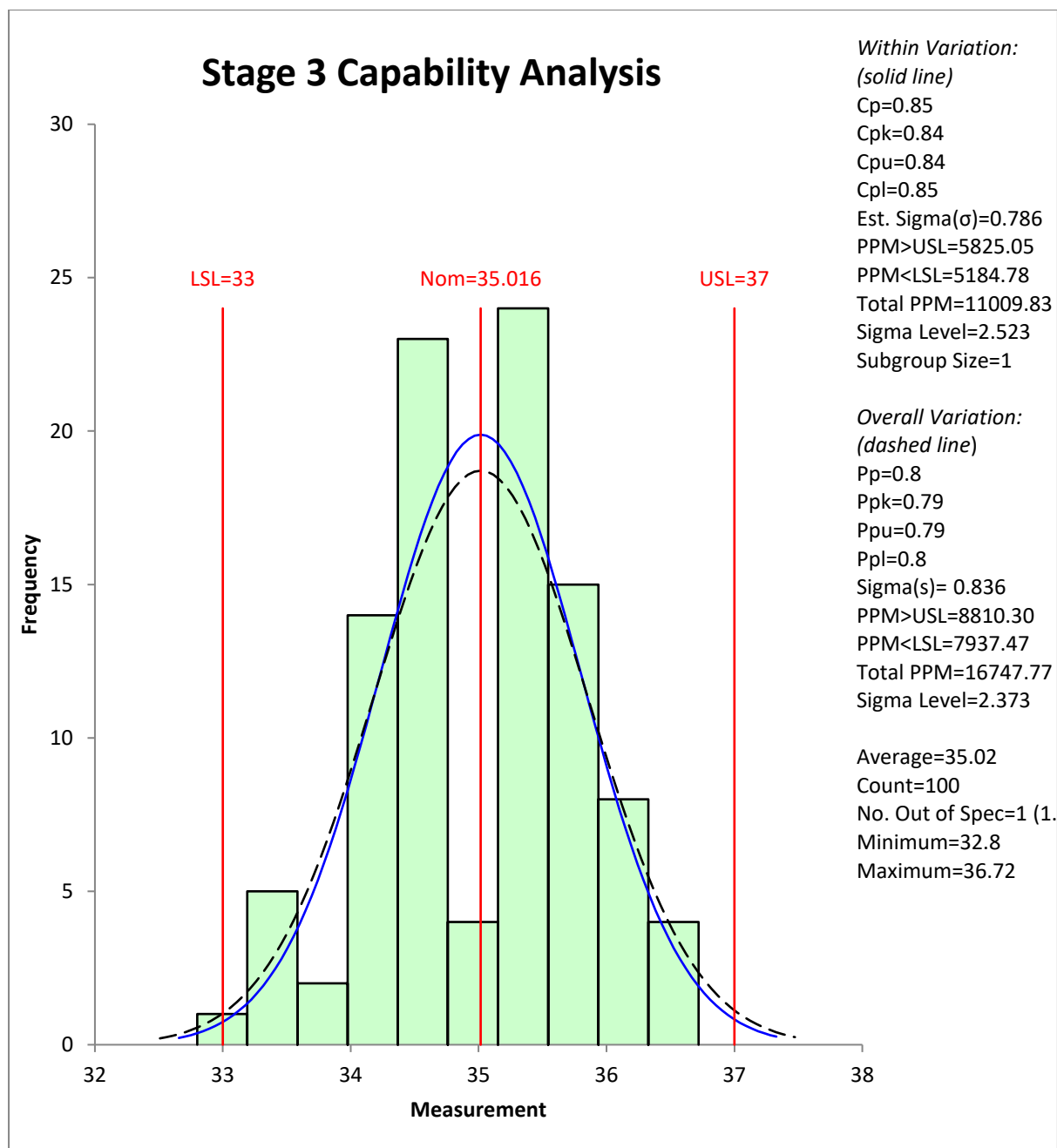


Table 58: Stage 3 Cpk Post Improve

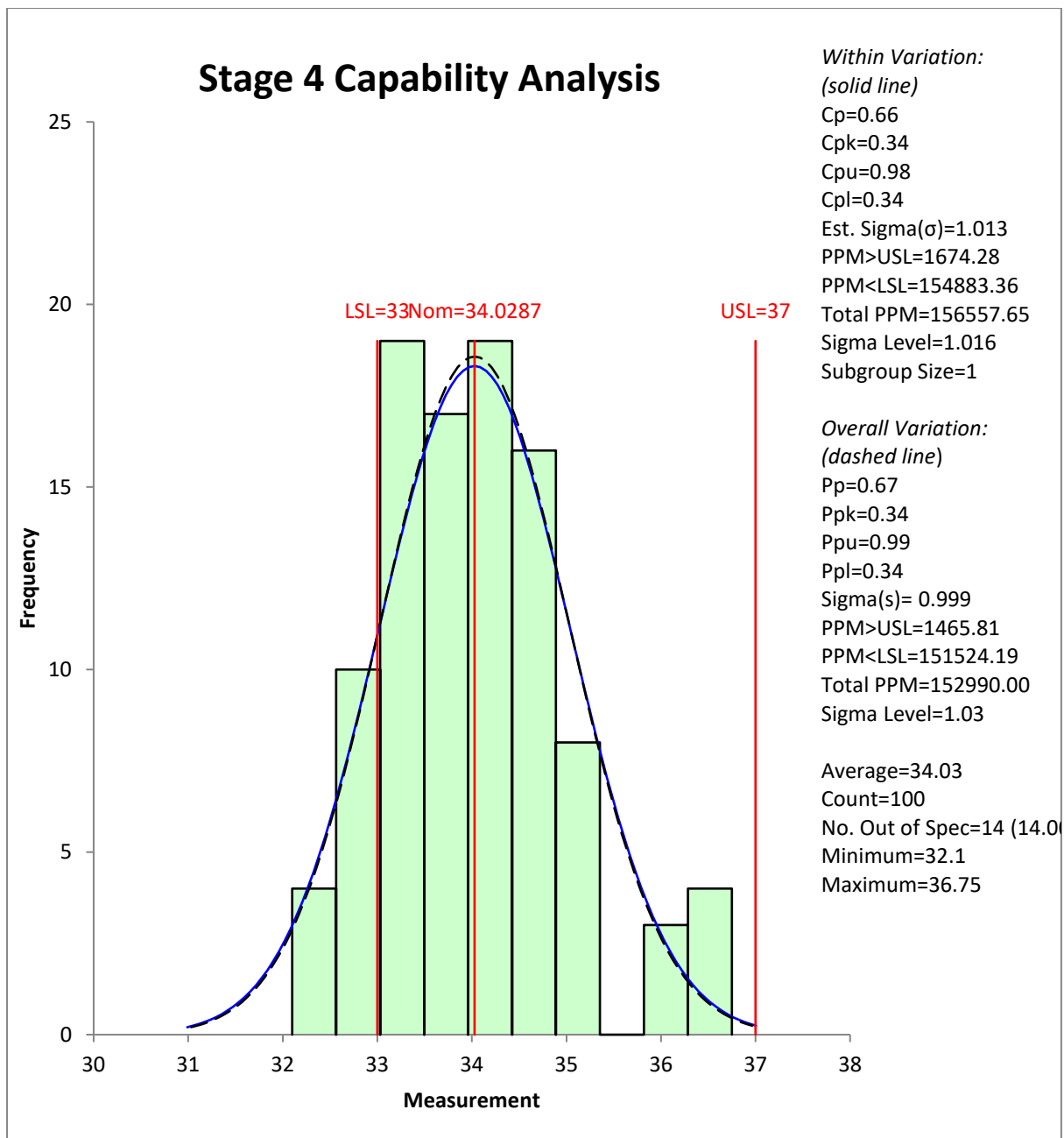


Table 59: Stage 4 Cpk Post Improve

7.5 Reduction in Warranty Calls – Cost

One of the main objectives of the assignment was to reduce warranty callouts, typically the cost of an average callout is set at £300.00 not including the cost of additional parts, components, or materials. In the first 6-month Greggs engineers were called out to 126 faults with a failure rate totalling 30%, an unacceptably high figure. The table below details the estimated cost of the callouts.

Cost of callout	£300.00
Number of callouts 1st 6 month	126
Total estimated cost during 1st period	£37,000.00
Number of callouts 2nd 6 month	30
Total estimated cost during 2nd period	9,000.00
Total saving in warranty callouts	£26,000
% reduction in cost	$(9000/37000) \times 100 = 24.32\%$

Table 60: Warranty callout cost reduction

7.6 Troubleshooting - Controller Fault Diagnostics

To control the current situation of controller failures it was agreed at a meeting between Mono and Gregg's that the engineers would require additional training to better diagnose and control failure of the new controller. A casualty operating procedure was written and distributed to Gregg's engineering department. This was to prevent faults being incorrectly identified as a controller failure. Any issue on the 24-volt system could affect the controller but may not be a controller failure.

 Casualty Operating Procedure Guide Notes for Eco Ovens CJB	
PROCEDURE OVERVIEW	INSTRUCTIONS & EXPLANATION
Firmware Check & Diagnostics Screen	To check the firmware version – use the diagnostic screen as shown below On an Eco controller - press "settings", enter 3142 and select "service settings" then "Service" then "diagnostics" The software version is shown at the bottom of the screen as shown below (Red Arrow).  Note - In the pic above, chamber temp is reading 0°C (Green arrow) which means the thermocouple signal is not being received by the controller. Left like this, the oven will eventually trip it's overheat thermostat. To correct it check the thermocouple connections.
	CJB controller error codes (V2.21 onward - Sept 2022). 101 – Pre Heating Timeout - If the oven is left waiting in "ready" state without pressing "start" for more than 2 hours, the recipe program will stop and this alarm is shown. 102 - Board too hot - Controller board temperature detector has exceeded factory settings parameter 101 (usually set to 90°C board warning temp). Temperature is read from thermocouple cold junction. 106 – PLC Not Connected - PLC program crashed/hailed. Board will automatically reboot.
CP-02-01	Page 1 of 9 20/10/2022
Document Owner: D Evans	Issue A Approved By: C. Petherbridge

Figure 50: Casualty Operating Procedure Guide Notes for Eco Ovens

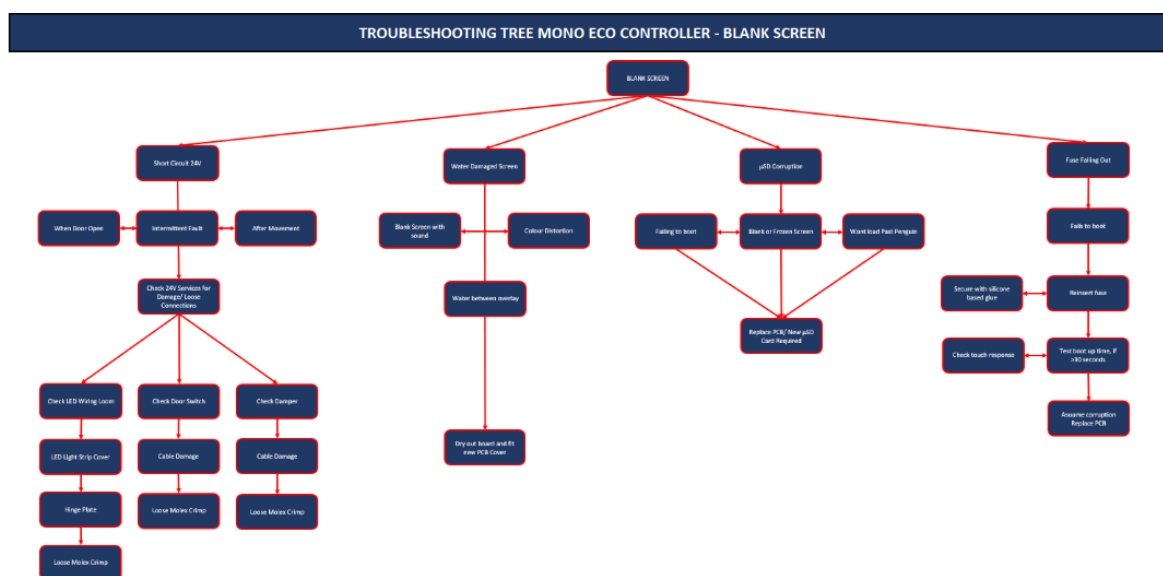


Figure 51: Troubleshooting Tree PCB Failures

7.7 New Proposed Layout

A layout was proposed to senior management, this was to ensure the section operated with efficiency, the 8 Wastes analysis highlighted a number of motion and transport wastes, to counter these issues, a proposal to move the section from its current location was made. This bold move would also increase the current capacity to prepare for future growth with expanding markets. it will allow greater flexibility.

Figure 48 details the requirements for the daily output of the BX Oven Section.

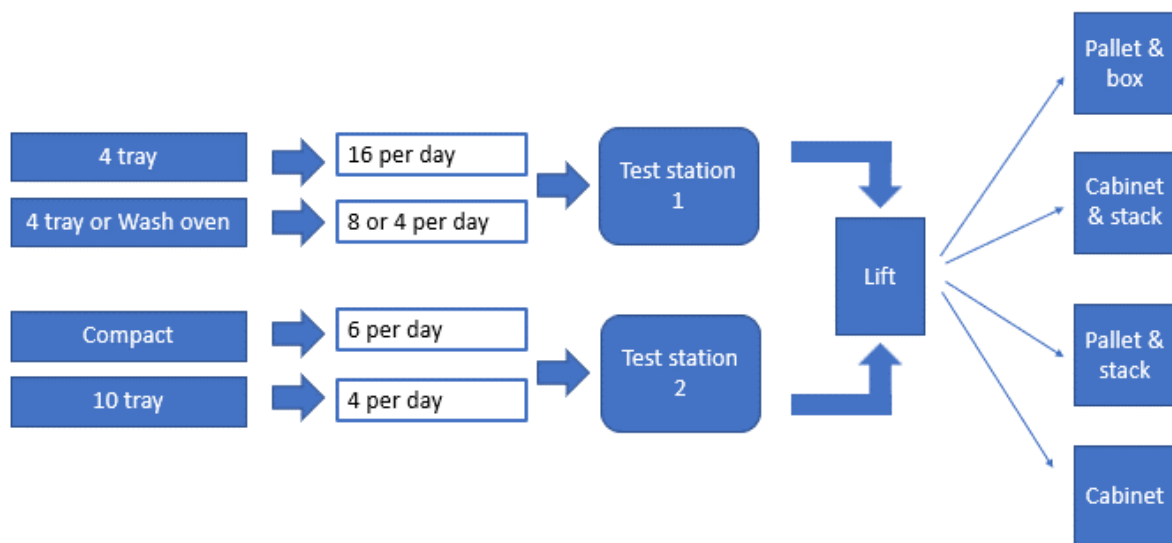


Figure 52: Daily Output Requirements

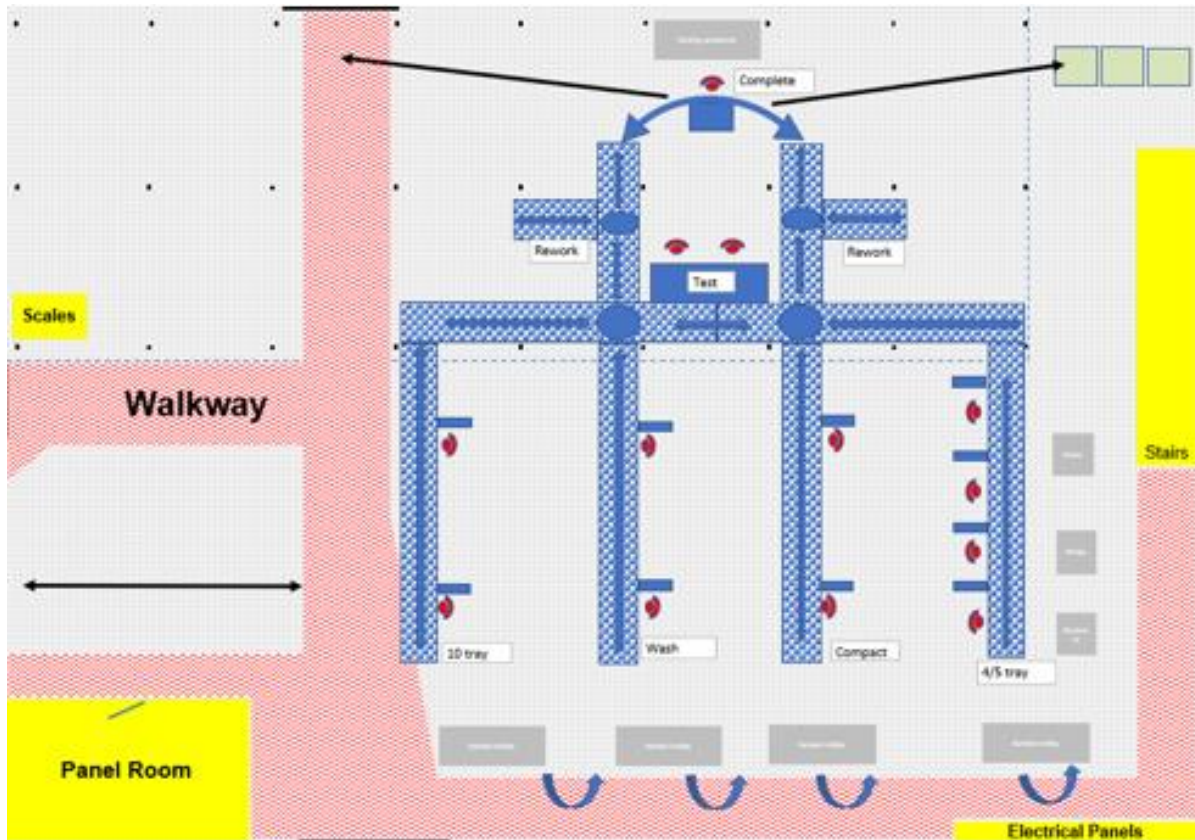


Figure 53: Proposed Layout BX Oven Section

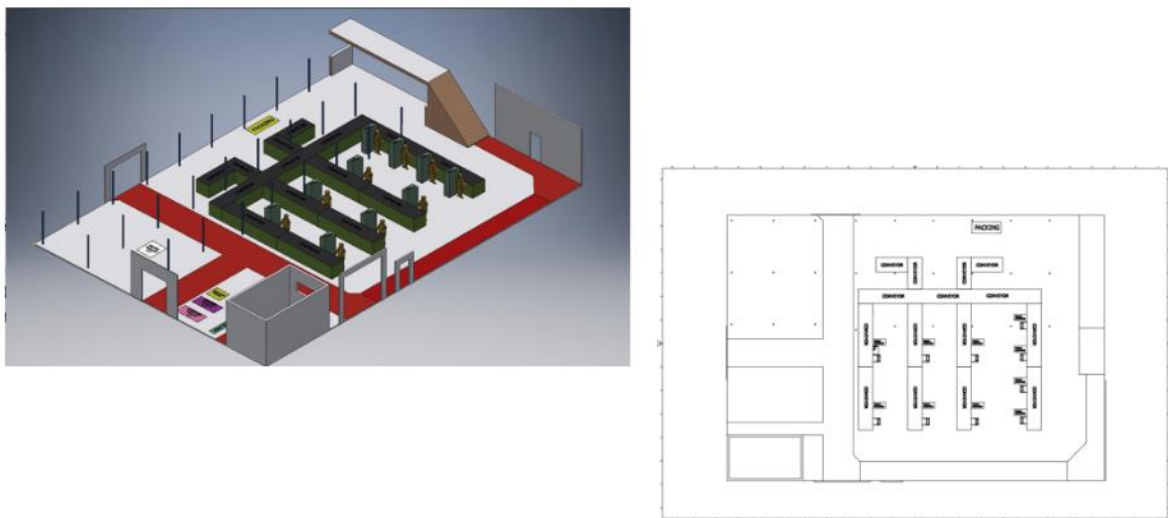


Figure 54: Inventor Model of Proposed Layout

This proposed layout will increase the capabilities of the section, by adding an additional line and test bay will promote flow. the location will significantly reduce transport & motion waste occurring.

7.8 Retrofit Action Planning

Despite the success of reducing the failures there were still many ovens with poorly protected controllers with the old-style PCB cover. A decision was made to retrospectively fit the new PCB cover to any oven without this protection to reduce warrant calls and controller failures.

A map was drawn up with the location of all known ovens and letters were distributed to stores notifying them of a pending visit to upgrade the PCB cover.



Figure 55: Retro fit planning

8 Future Developments

8.1 PCB Cover Redesign

The new PCB was introduced urgently to react to the concerning situation surrounding controller failures, this enabled Mono to reduce failures and improve customer satisfaction. However, there were still several issues with the initial design.

One of the main concerns was the production volume required, as it would lead to increased manufacturing time and resource allocation. Specifically, there was a need to produce and fit around 4,000 to 5,000 units on a yearly basis.

Another issue was the cost of using stainless steel which is an expensive material for an item which is not seen. Additionally there were several components required to fit the cover to the PCB incurring additional cost.

Thirdly there was additional time required to fit the controller cover, this was the most significant driving factor. As the retrofit process would need to be negotiated with Gregg's, if the time to fit the PCB cover was reduced this would give Mono better negotiating power reducing the impact and cost associated to this evolution.

These factors drove Mono Equipment to seek alternative manufacturing methods. It was decided that the upgraded PCB would be manufactured using injection moulded plastic. Despite the additional cost of the initial outlay for tooling to set up the injection moulding process. The use of plastic as a material was expected to significantly reduce costs compared to the stainless steel.

By changing the material and manufacturing methods the design was optimised to better fit and seal the unit. And initial meeting was arranged with local plastic moulding company DB Mouldings to discuss the feasibility of the project. From the meeting a value analysis was conducted in table 61.

Plastic Injection Moulding Feasibility Value Analysis	
Cost of new PCB cover (Stainless Steel)	£16 / unit
Cost of upgraded PCB cover (Plastic)	£3.10 / unit
Cost of Injection Moulding Tooling	£8100.00
Number of units produced annually	4000
Cost of producing stainless steel box	$4000 \times 16 = £64,000.00$
Cost of producing plastic box	$4000 \times 3.10 = £12,400.00$
Cost of plastic box with tooling	$12400 + 8100 = £20,500.00$
Injection moulded tool life	10 years or 50,000 units
Saving over the life of the tooling	$(64000 \times 10) - ((12400 \times 10) + 8100) = £507,900.00$

Table 61: Plastic Injection Moulding Feasibility Value Analysis

From the value analysis conducted in table 61 Mono will save up to £507,900.00 over the 10-year life span of the tooling. This helped senior management to understand the need to invest in the initial outlay for the tooling.

By introducing the plastic cover would reduce the number of errors occurring during installation by ensuring a quality seal. This is because the injection moulded box can incorporate a seal meaning the operator will not need to cut the seal avoiding potential gaps.

This cover will help reduce the number of interactions with the controller, this will inherently reduce the number of errors due to accidental damage. The controller will not need to be removed, simplifying the instal compared to the stainless-steel version.

Another change by optimising the design and maximising the benefits of injection moulding the controller will be secured to the original fixing points removing the requirement for extension pillars. There are 8 pillars required per unit, the pillars are £0.13 per pillar with 4000 produced every year. This will save $(8 \times 0.13) \times 4000 = £4160.00$ / annum by removing the need for pillars.

By incorporating all these features will reduce the time taken to fit the box. the current design (stainless steel) has many additional steps such as removal of controller to fit pillars, cutting and securing foam seal, and sealing the corners of the box with sealant. None of these steps will be required with the upgraded plastic box. to understand the potential time savings the time taken to install the stainless-steel cover was measured and compared to the time taken to fit the new plastic cover.

Table 62 presents a significant time saving the equivalent of 222.2 days of a full-time operative totalling 1666.67 hours.

Installation Time Analysis – Plastic PCB	
Time taken to fit stainless steel box	40 minutes
Time taken to fit plastic box	15 minutes
Time saved per installation	$40 - 15 = 25$ minutes
Time saved per year	$25 \times 4000 = 100,000$ minutes
Time saved per year in hours	$100,000 / 60 = 1666.67$ Hours
Number of working days lost for one operative	$1666.67 / 7.5 = 222.2$ days

Table 62: Installation Time Analysis - Plastic PCB

9 Conclusions

In conclusion, this Lean Six Sigma project has proven to be successful in achieving its intended goal of reducing warranty calls, improving efficiencies & subsequently improving customer satisfaction. Adopting a lean six sigma approach has not only resulted in a 21% increase in output but has also generated significant additional revenue for Mono. The results demonstrate that lean principles can successfully be applied with 6 sigma philosophy to benefit manufacturing, leading to improved quality, reduced waste, and increased profitability. Mono equipment should continue to embrace these principles, by continuously improving its process will maintain its competitive advantage in an ever-evolving market.

The project highlighted the many challenges faced with work-based projects, there were many unexpected challenges along the way. Specifically, significant resistance to the idea of adopting lean principles to the BX oven section came from members of the management team, to overcome this several techniques surrounding change management was used, to progress the changes everything was quantified to show the impact or potential impact the inefficiencies were having, by assigning a value in either time, ovens, or loss in revenue helped understand the need.

This project is an example of the difficulties faced reversing poor quality, by rushing ovens into production mistakes were ultimately made. This project only accounted for newly built ovens between two, six-month periods and successfully reduced defects occurring, in reality there were older ovens still failing, the data didn't consider this. To combat this a strategic decision was made to retrospectively fitting new PCB covers to all ovens, essentially a product recall scenario. To counter the additional cost associated with this the PCB cover was redesigned so it could optimise performance and significantly reduce time taken to fit cover. By switching to plastic meant that batches of 1000 units could be produced rapidly. It is estimated that this change will reduce the fitting time by 37.5% from 40 minutes to 15 minutes, it will improve quality by reducing interactions with the controller and increased moisture protection and is expected save over £507,900.00 during the 10-year lifespan of the tooling inclusive of tooling set up costs.

As with many DMAIC projects they continue to develop and grow, at this stage the DMAIC methodology would revert to the define stage and the cycle would continue over again. The Value Stream Map was an excellent tool used with good effect in this project, there could be many projects driven alone by the VSM exercise, and it led to the introduction of bulk purchasing of materials which improved efficiencies and reduced material cost by promoting smart nesting and eliminating any form of waste. It prevented fixed batch quantities and reduced the number of ovens being pushed through the factory and developed a true pull system focussing on value-added.

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11 ANNEX A

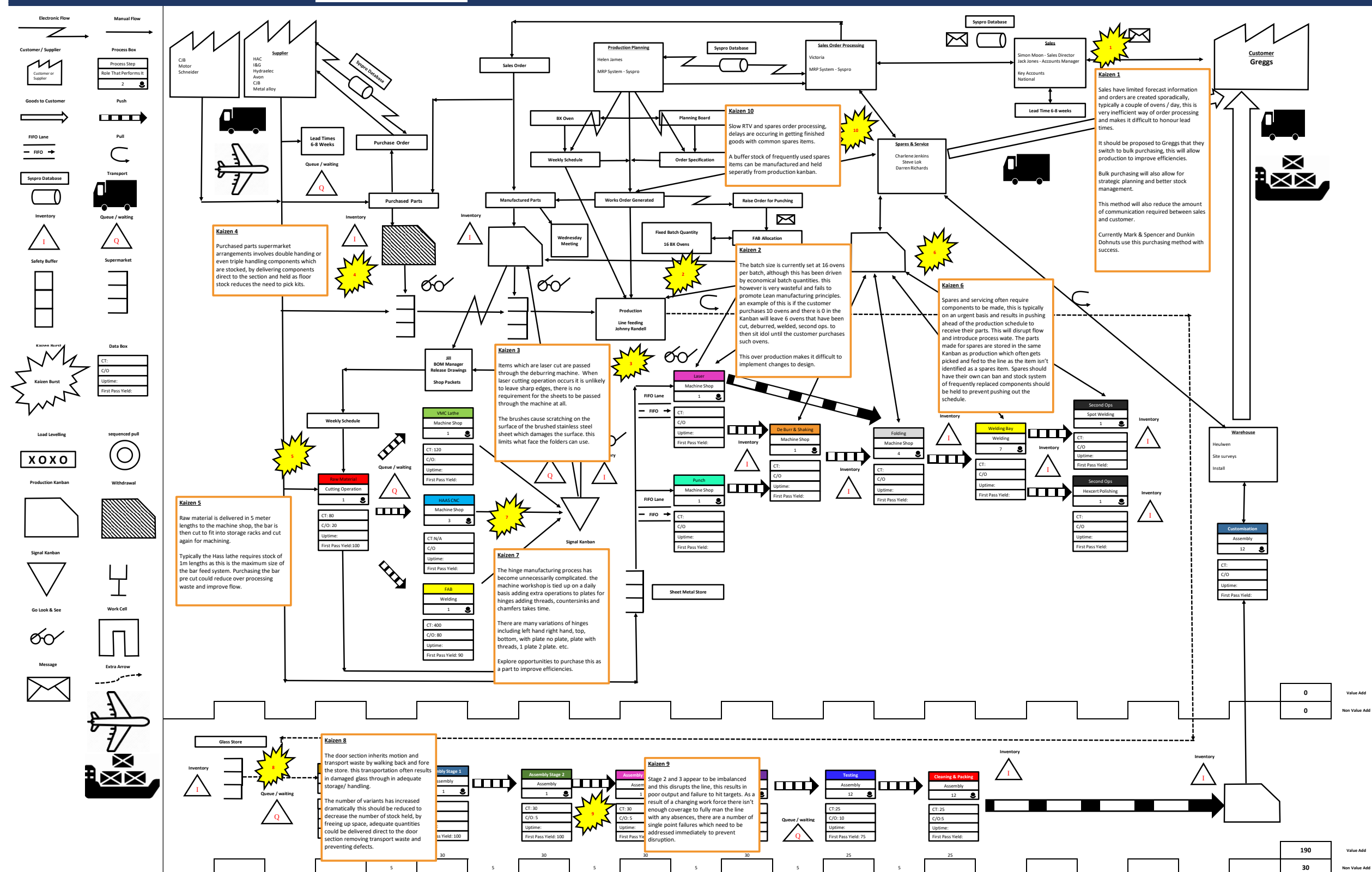


12 ANNEX B

Value Stream Map

VSM Tools & Icons

Process Name: BX Oven



FMEA

Item Name: CJB Controllers			FMEA Team: Process			Prepared by: Craig Petherbridge									
						FMEA Date (Orig):22-Dec-2022				Revision #: 1A					
Process Step or Variable or Key Input	Potential Failure Mode	Potential Effect on Customer Because of Defect	S E V	Potential Causes	O C C	Current Process Controls	D E T	R P N	Actions Recommended	Resp.& Target Date	Actions Taken	S E V	O C C	D E T	Future RPN
µsd card falling out over time	Corruption	Slow responsive screen & or oven fails to operate	8	Loose card holder, corrosion and humidity	7	Observations of boot time should be < 20 seconds and updates within a minute	9	504	PCB Cover to protect against humidity, additional check to be carried out prior to programming	Alex Davies / Darryl Evans 10/01/2023	PCB Cover to protect against humidity, additional check to be carried out prior to programming	8	2	1	16
	Controller fails to boot	Oven failure no operation	8	Loose card holder, corrosion and humidity	7	Observations of boot time should be < 20 seconds and updates within a minute	9	504				8	2	1	16
Fuse falling out	Controller fails to boot	Oven failure no operation	8	Fuse not secure	6	Glue is used to secure the fuse	9	432	Fuse to be hard soldered to PCB	Craig Petherbridge/ Angela Thomas/ Saaïd Ostad 12/02/2023	Fuse to be hard soldered to the PCB	8	1	1	8
	Corruption	Slow responsive screen & or oven fails to operate	8	Fuse not secure	6	Glue is used to secure the fuse	9	432	Replace fuse holder			8	1	1	8
Screen Issues	Poor calibration/ sensitivity	Slow responsive screen & or oven fails to operate	8	Moisture/ humidity	6	None	9	432	Calibration function to recalibrate screen issues	Craig Petherbridge/ Alex Davies/ Saaïd Ostad 12/02/2023	Recalibration of screen function incorporated	8	1	3	24
	Blank Screen	Oven failure no operation	8	Moisture/ humidity	6	None	9	432	New PCB Cover for protection	Craig Petherbridge/ Alex Davies/ Saaïd Ostad 12/02/2024	New PCB Cover	8	2	1	16