IENG 4565 Lean Engineering | Final Report

Boat Production

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Group 8

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In the Define phase of Lean Six Sigma, the primary goal is to clearly define the problem, project scope, goals, and customer requirements. This phase involves:

- **Project Charter**: Creating a document that outlines the project's purpose, scope, objectives, team members, and expected outcomes.
- **Voice of the Customer (VOC) Analysis**: Gathering and analysing customer feedback and requirements to ensure that the project addresses their needs.
- Identification of **Critical to Quality (CTQ)** Characteristics: Determining the key factors that directly impact customer satisfaction and quality.
- **Stakeholder Analysis**: Identifying all stakeholders involved in the project and understanding their expectations and concerns.
- **Setting SMART Goals:** Establishing specific, measurable, achievable, relevant, and time-bound objectives for the project.
- **Risk Assessment**: Identifying potential risks and developing strategies to mitigate them.
- By the end of the Define phase, the project team should have a clear understanding of the problem to be addressed, the project scope, and the expected outcomes, laying the foundation for the subsequent phases of Measure, Analyse, Improve, and Control**.**

1.1 Problem Statement: The challenge is to determine the most efficient production method (batch or continuous) within a 20-minute timeframe for creating paper boats in the most profitable manner. Ensuring precision in dimensions, with a sail height of 10 ± 2 mm and a window diameter of 30 ± 2 mm, is crucial for meeting project objectives.

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PROJECT CHARTER

PROJECT NAME	Boat Production
PROJECT ID	Dal #8
PROJECT MANAGER	Rafath Banu
PROJECT SPONSOR	Dalhousie University

DATE	20th January, 2024

PROJECT DESCRIPTION

The primary goal of this project is to implement lean engineering principles to optimize the production of paper boats. The focus is on achieving the most profitable quantity of paper boats within a 20-minute production cycle while minimizing costs and maximizing profits.

SCOPE

IN SCOPE	Production Time Management (within 20 min cycle), Optimizing batch size, Cost Optimization, Quality Assurance, Dimensional Accuracy
OUT OF SCOPE	Selling the product, Market Expansion, Technology Implementation, Environmental Impact Assessment

OBJECTIVES

Optimize the paper boat production process through lean engineering principles to determine the most profitable quantity within a 20-minute cycle, achieving highest profits with minimal costs.

CTQs

Critical Need	Driver	CTQ
Best Boat	Cost-efficient	Reduce waste and optimize use of paper
	Time efficient	Maximize profit in 20 minutes
	Dimensions of boat	Sail height 10 +- 2 (mm)
		Window diameter' 30 +- 2(mm)

MILESTONES

Sr. No	Milestone	Target Start Date	Target End Date
1	Define	11th Jan	29th Jan
2	Measure	30th Jan	8th Feb
3	Analyze	9th Feb	7th March
4	Improve	8th March	21st March
5	Control	22nd March	28th March

ROLES & RESPONSIBILITIES

Name	Designation	Role Description
Rafath	Product Manager	Controlling time, managing production and delivering the product to the customer
Kavish	Quality Control Manager	Measuring product specifications
Jaysinh	Production Supervisor	Documenting and filming the processes
Jay	Worker - 1	Fold in half and then fold in half again
Siddharajsinh	Worker - 2	Fold in corners then fold up edges on both sides, then pull the sides out and flatten
Purbasha	Worker - 3	Fold front and back layers and pull sides apart and flatten
Vraj	Worker - 4	Pull top flaps outwards and pull the sides up to finally make the window

Figure 1.1: Project Charter

1.3 SIPOC FOR BOAT PRODUCTION

Supplier	Input	Process	Output	Customer
Prof Michael, Paper company, Dalhousie University	Paper, Pen, Eraser (stand), ruler, bottle cap (stamp), ink (for stamping)	1) Fold the paper in half. 2) Fold the paper in the other half to create a crease to work on. 3) Folding the corners. 4) Folding up the edges on both sides 5) Pulling the sides to flatten out the boat's structure. 6) Fold the front and the back layers towards the upward direction. 7) Pull the sides apart and flatten. 8) Pull top flaps outwards. 9) Squish the bottom and pull the sides up. 10) The boat is ready.	Paper boat	Craft shops

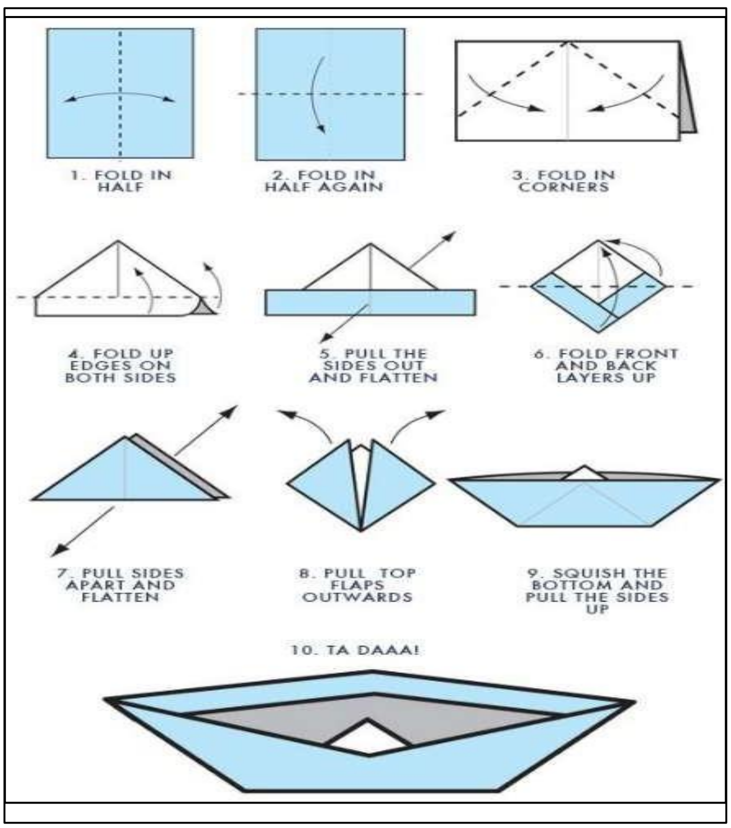

Figure 1.2: SIPOC

1.4 Voice of Customer

With a cost of $0.22 per sheet of paper and a sales price of $1 per paper boat, our aim is to achieve peak output while maintaining financial viability. We've got 20 minutes to dominate this paper boat challenge and maximize profits. We've got two strategies: single-product precision and batch production efficiency. Remember, our profit depends on hitting those specs: sail height 10±2 mm, window diameter Ø 30±2 mm.

1.5 Conclusion: The DEFINE phase provides a clear understanding of the project's objectives, target audience, desired features, evaluation criteria, and approach to feedback collection. With this foundation, the project can proceed confidently into subsequent phases, poised to address the challenge of optimizing paper boat production within a constrained timeframe while meeting specific dimensional requirements.

2.1 BASIC PROCESS MAPPING:

- Basic process mapping is a fundamental tool in lean engineering aimed at visualizing and understanding the flow of activities within a process. Its primary aim is to identify inefficiencies, bottlenecks, and areas for improvement within a workflow.

- In our boat production project, process 1 involves four workers performing specific tasks on a single piece of paper before passing it to the next station. This indicates a sequential process flow where each worker adds value to the boat before it moves forward. Additionally, the quality manager examines the boat to ensure it meets dimension specifications, ensuring quality control at the end of the process.

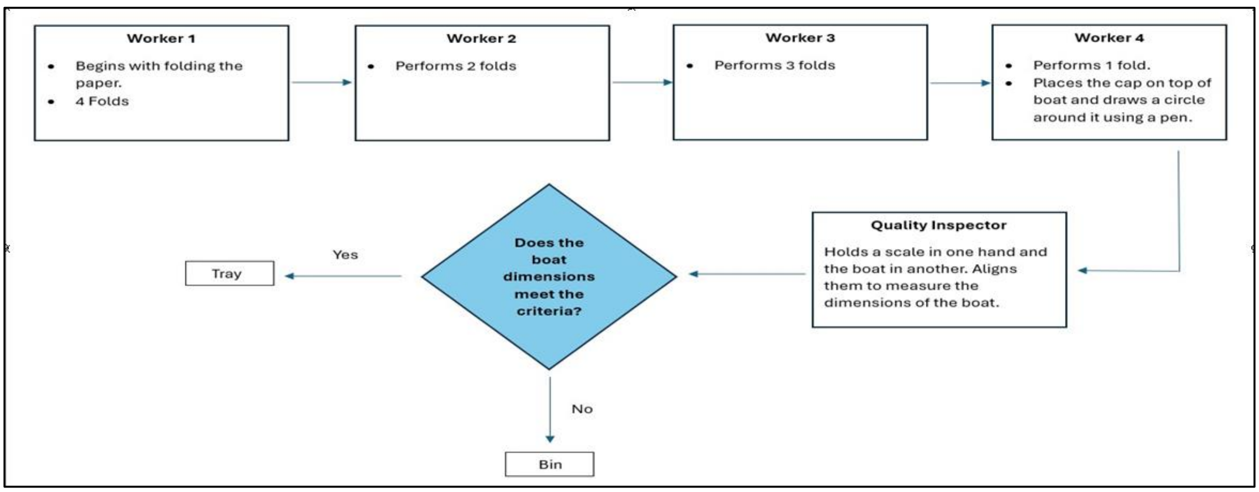

Figure 2.1: Basic Process Mapping Chart of the Production Area

- On the other hand, process 2 adopts a batch-oriented approach where each worker handles a set of 4 pieces of paper at a time before passing them to the next station. This implies a more parallel process flow where batches of work are processed simultaneously at each station.

By mapping out these processes, you can identify potential areas of waste, such as waiting times, excessive handling, or quality issues, allowing you to streamline operations, reduce lead times, and improve overall efficiency in boat production.

Process 1 steps:

1. Worker-1: Fold in half and then fold in half again.
    a. Average seconds: 27.85 seconds

2. Worker-2: Fold in corners then fold up edges on both sides, then pull the sides out and flatten.
    a. Average seconds: 22.15 seconds

3. Worker-3: Fold front and back layers and pull sides apart and flatten.
    a. Average seconds: 26.05 seconds

4. Worker-4: Fold front and back layers and pull sides apart and flatten.
    a. Average seconds: 17.95 seconds

5. Worker-5: Measuring product specifications.
    a. Average seconds: 7.2 seconds

- **Average time for process-1 is: *101.2 seconds*.**

Process 2 steps:

All the steps performed by the worker in Process-2 are identical to those in Process-1. The key distinction lies in Process-2, where the advancement to the next workstation is contingent upon the completion of work on four boats simultaneously.

1. Worker-1: Fold in half and then fold in half again.
    a. Average seconds: 102.56 seconds

2. Worker-2: Fold in corners then fold up edges on both sides, then pull the sides out and flatten.
    a. Average seconds: 50.67 seconds

3. Worker-3: Fold front and back layers and pull sides apart and flatten.
    a. Average seconds: 80.89 seconds

4. Worker-4: Fold front and back layers and pull sides apart and flatten.
    a. Average seconds: 93 seconds

5. Worker-5: Measuring product specifications.
    a. Average seconds: 23.89 seconds

- **Average time for process-1 is: *327.12 seconds*.**

2.2 QUANTITATIVE DATA:

Quality Standards meeting boat		
Sr. No	Window Diameter (in cm)	Sail height (in cm)
1	3.1	1
2	3.1	0.9
3	3.1	1.2
4	3.1	1
5	3.1	1.1
6	3.1	0.8
7	3.1	1
8	3.1	0.8
9	3.1	1
10	3.1	1
11	3.1	1.2
12	3.1	1
13	3.1	0.8
14	3.1	1.2
15	3.1	0.9
16	3.1	1.1
17	3.1	0.9
18	3.1	1
19	3.1	1.1
20	3.1	0.9
21	3.1	0.9
22	3.1	0.8
23	3.1	0.8
24	3.1	0.9
25	3.1	0.9
26	3.1	1
27	3.1	1
28	3.1	0.9
29	3.1	1.1
30	3.1	0.8
31	3.1	1
32	3.1	1

Defective Boats		
Sr. No	Window Diameter (in cm)	Sail height (in cm)
1	3.1	1.4
2	3.1	0.6
3	3.1	0.6
4	3.1	0.7
5	3.1	1.4
6	NA	0.9
7	3.1	0.3
8	NA	1

WIP	3

Table 2.1: Quantitative Data for Continuous Process

Batch	Worker - 1	Worker - 2	Worker - 3	Worker - 4	Quality Manager
1	30	18	26	17	8
2	33	30	26	17	8
3	40	25	25	18	7
4	26	15	25	19	9
5	32	22	28	20	10
6	31	20	27	16	6
7	28	21	26	17	9
8	32	19	25	19	8
9	31	23	28	20	7
10	30	17	26	16	6
11	27	23	25	18	7
12	27	25	30	19	10
13	30	23	25	18	6
14	27	25	27	19	7
15	26	23	30	19	6
16	30	19	27	18	10
17	27	23	25	17	6
18	26	25	26	17	6
19	27	23	26	18	7
20	26	25	25	19	7
21	32	25	25	20	6
22	36	23	28	16	7
23	32	25	27	17	6
24	30	23	26	19	7
25	20	18	25	20	10
26	18	25	28	16	7
27	26	19	26	16	6
28	25	23	26	16	7
29	30	25	25	17	10
30	31	18	28	17	6
31	32	25	26	18	6
32	28	25	29	19	7
33	20	23	32	20	7
34	27	25	30	16	7
35	21	23	25	17	6
36	26	18	24	19	6
37	25	19	23	20	7
38	24	25	22	16	6
39	23	17	19	19	7
40	22	18	20	19	7
Average	27.85	22.15	26.05	17.95	7.20

Table 2.2A: Quantitative Data for Batch Process

Quality Standards meeting boat		
Sr. No	Window Diameter (in cm)	Sail height (in cm)
1	3.1	0.9
2	3.1	1.2
3	3.1	1
4	3.1	0.8
5	3.1	1
6	3.1	1
7	3.1	0.9
8	3.1	0.8
9	3.1	1
10	3.1	0.9
11	3.1	1
12	3.1	0.9
13	3.1	0.8
14	3.1	1
15	3.1	0.8
16	3.1	0.9
17	3.1	1
18	3.1	1
19	3.1	0.9
20	3.1	0.8
21	3.1	0.9
22	3.1	1
23	3.1	1
24	3.1	0.9
25	3.1	1
26	3.1	0.9
27	3.1	0.8
28	3.1	1

Defective Boats		
Sr. No	Window Diameter (in cm)	Sail height (in cm)
1	3.1	1.4
2	3.1	1.3
3	3.1	0.6
4	3.1	0.7
5	3.1	1.4
6	3.1	0.7
7	3.1	0.3
8	3.1	1.4

WIP	11

Batch	Worker - 1	Worker - 2	Worker - 3	Worker - 4	Quality Manager
1	103	54	83	87	35
2	98	65	67	97	25
3	117	42	80	110	21
4	102	45	79	94	22
5	109	39	73	107	27
6	78	45	93	66	20
7	111	56	85	89	24
8	100	60	78	100	20
9	105	50	90	87	21
Average	**102.56**	**50.67**	**80.89**	**93.00**	**23.89**

Table 2.2B: Quantitative Data for Batch Process

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2.3 QUALITATIVE DATA:

- **Employee Feedback**: Insights into perceptions, attitudes, and barriers toward lean initiatives.
- **Gemba Walks**: Observations of workflows, communication patterns, and inefficiencies.
- **Root Cause Analysis**: Uncovering underlying causes of process issues using techniques like the 5 Whys.
- **Customer Feedback**: Understanding needs, preferences, and pain points for product or service improvement.
- **Team Dynamics**: Assessing collaboration, communication, and problem-solving effectiveness.
- **Organizational Context**: Considering leadership support, structure, and readiness for change.

2.4 VALUE STREAM MAPPING:

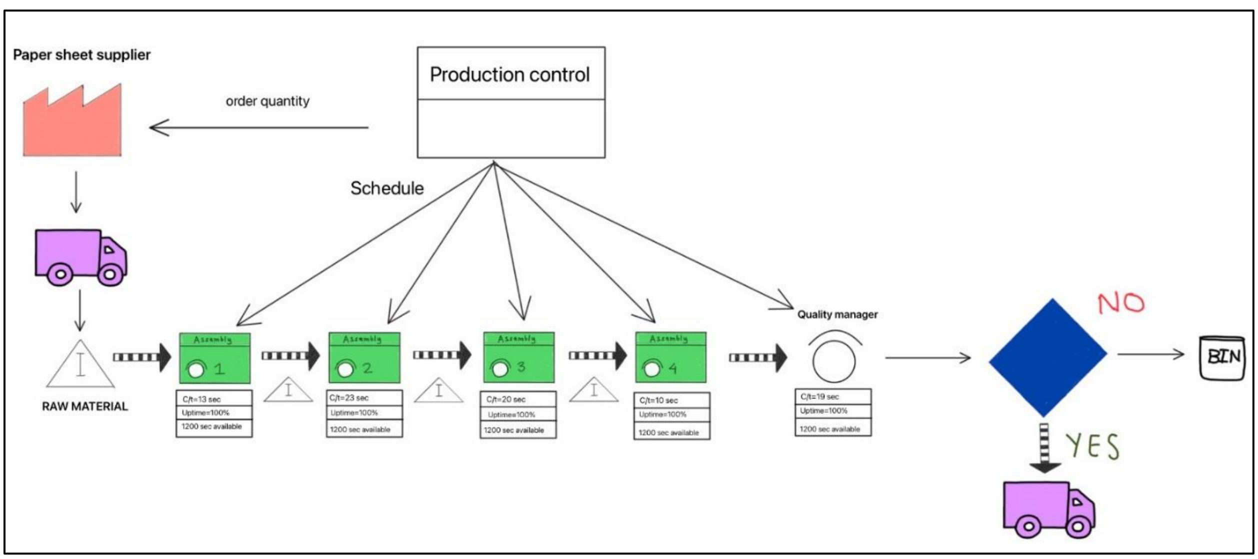

Figure 2.2: VSM

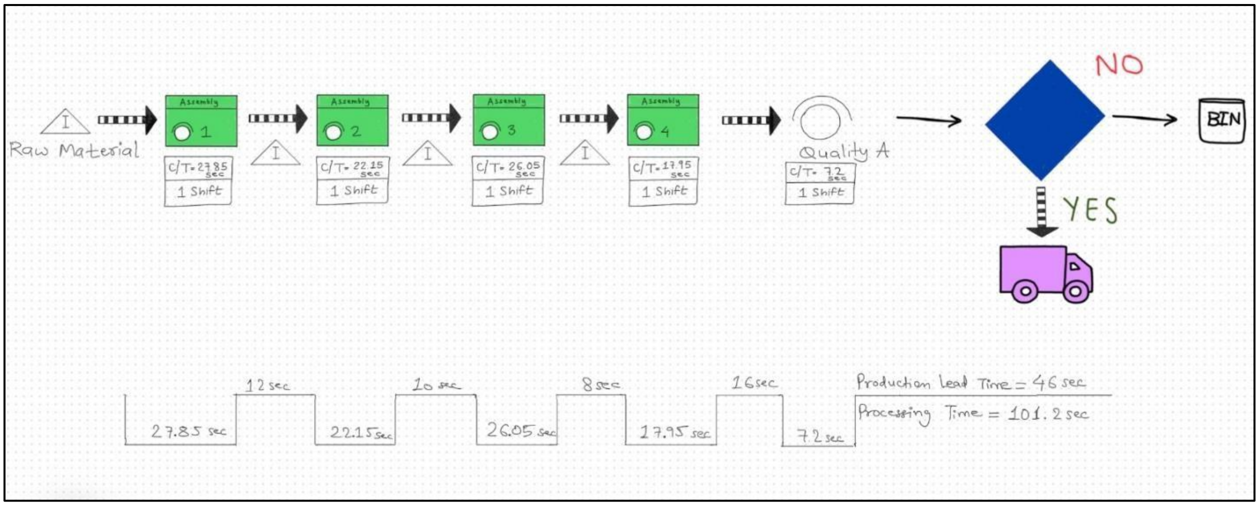

Figure 2.3: VSM of Continuous Production

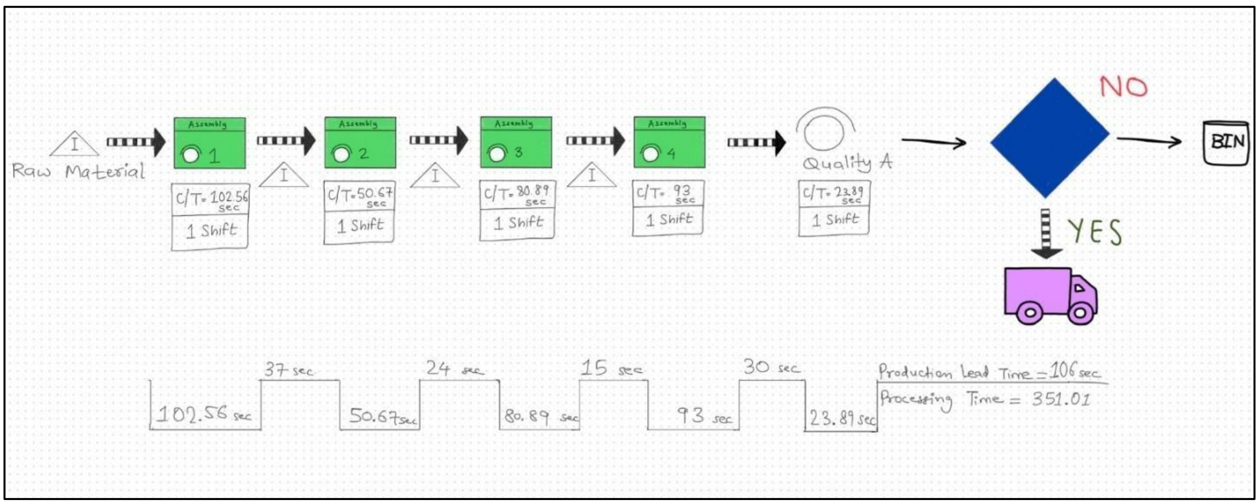

Figure 2.4: VSM of Batch Production

2.4 PERFORMANCE INDICATORS:

For the goal of maximizing the boat production and meeting all the critical aspect of quality, the following indicator should be taken into the consideration:

- From the measure of time taken by every worker to complete their part in the process we can compare both the processes.

- We can focus on the wasteful part of the process.
- The number of boats produce indicator simply give us the reflection of the efficient process.

Continuous Process		
Sr. No.	Process step	Availability
1	Worker 1	7.17%
2	Worker 2	26.17%
3	Worker 3	13.17%
4	Worker 4	40.17%
5	Quality Manger	76.00%

Batch Process :- 4 boats per batch		
Sr. No.	Process step	Availability
1	Worker 1	23.08%
2	Worker 2	62.00%
3	Worker 3	39.33%
4	Worker 4	30.25%
5	Quality Manger	82.08%

(Here, availability is meant as idle time of the workers)
Figure 2.5: Performance indicator 1

Continuous Process				
Sr. No.	Performance Indicator	As-is	UOM	Comment
1	Worker 1	27.85	Seconds	Time taken per boat made
2	Worker 2	22.15	Seconds	Time taken per boat made
3	Worker 3	26.05	Seconds	Time taken per boat made
4	Worker 4	17.95	Seconds	Time taken per boat made
5	Quality Manger	7.2	Seconds	Time taken per boat made
6	Total boat production	32	unit	-

Batch Process :- 4 boats per batch				
Sr. No.	Performance Indicator	As-is	UOM	Comment
1	Worker 1	25.64	Seconds	Time taken per boat made
2	Worker 2	12.67	Seconds	Time taken per boat made
3	Worker 3	20.22	Seconds	Time taken per boat made
4	Worker 4	23.25	Seconds	Time taken per boat made
5	Quality Manger	5.97	Seconds	Time taken per boat made
6	Total boat production	28	unit	-

Figure 2.6: Performance indicator 2

Quality Rate	Continuous - 80% Batch - 77.78%
WIP	Continuous - 3 Batch - 11
Total Profit	Continuous - $23.2 Batch - $20.08

Figure 2.7: Performance indicator 3, 4 and 5

Overall Quality rate for the continuous process is 80.00 % and for the Batch process 77.78 %.

After considering all the measures that are discussed in a class, we have provided the measures that are inappropriate for Boat production, which are listed below:

<u>Rolled Throughput Yield (RTY):</u>

- It represents the probability that a product will pass all the stages in a process without failures. It is computed by multiplying the first pass yields of the respective stages. RTY may be less directly applicable in paper boats production until there are various stages at which errors can come about such as cutting, folding, or sealing.

<u>Takt time:</u>

- It is the rate at which a product must be manufactured to satisfy client demand. It is determined by dividing the available production time by the consumer demand rate. Since we don't have any specific client demands apart from the required dimension as specified earlier, this measure can be used in later stages of company life cycle.

Overall Equipment Effectiveness (OEE):

- In paper boat manufacturing the OEE measure, is an overall measure of how well machines are utilised, how efficiently they run and the quality of the output they produce. Since we are not using any machines at this moment for paper boat production, this measure is of no use.

After considering all the measures that are discussed in a class, we have provided the measures that are appropriate for Boat production, which are listed below:

Gemba:

- It is a Japanese term meaning "the real place" or "the actual place." It refers to the concept of going to where the work is done to observe and understand processes, identify inefficiencies, and gather insights for improvement.

- In the context of paper boat production, we think that Gemba could involve physically visiting the production floor to observe the assembly process, material handling, and workflow.

- This hands-on approach allows site manager and team members to gain a deeper understanding of how the production process operates and to identify opportunities for optimization.

Availability:

- In paper boat production, availability could be relevant for ensuring that machines used in cutting, folding, or sealing paper are functioning when needed to avoid delays and minimize downtime. (Performance Indicator 1)

Cycle Time:

- The cycle time for paper boat production was measured by computing the time it takes for one paper boat to be produced from start to completion, which included cutting, folding, and assembly.

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Performance Efficiency:

- In the paper boat construction process, we could use performance efficiency indicators, for example worker productivity, machine utilization rates (if we use this), and overall equipment effectiveness.

Quality Rate

- It is the percentage of products that satisfies defined quality standard. Quality assurance entails checking for defects during the production of paper boats and ensuring that the final products not only meet but also exceed client expectations about correct folding, sealing, and overall aesthetics.

2.5 CONCLUSION:

The performance indicators shall be monitored and improved over time which will help us in appraising the processes of production entirely as a whole directing towards a continuous improving effort of future developments. The inference we have reached is that it highlights the fact that choosing the measurements should be in line with the project objectives and constraints. That means the resources should be directed toward improving the parts of the paper boat making process that results in the highest efficacy and quality, and minimum wastage.

Videos of two processes:

Video link for process 1: https://dalu-my.sharepoint.com/:v:/g/personal/kv226484_dal_ca/EdOSiBQxcOdJrrql6sr0ACUB-qd6UwAaICFJFxYD9aTOIg?e=L1ygtW

Video link for process 2: https://dalu-my.sharepoint.com/:v:/g/personal/kv226484_dal_ca/ERGaiBHRCWpIqpPg8KEUhqUB4JEh_2WmVkF7i_Vdt5GTmQ?e=O0HS4

Introduction:

The Analyze Phase in lean boat production marks a crucial stage where meticulous examination takes center stage. Here, the aim is to scrutinize every aspect of production with precision, identifying inefficiencies, bottlenecks, and areas ripe for improvement. Through methods like waste identification, root cause analysis, and value stream mapping, we delve deep into the intricacies of their operations. Data-driven insights drive decision-making, enabling us to uncover hidden opportunities and streamline workflows. Active engagement among cross-functional teams fosters a culture of continuous improvement, laying the groundwork for transformative enhancements in efficiency and productivity.

3.1 Pareto Analysis:

- Pareto analysis, also known as the 80/20 rule or the law of the vital few, is a decision-making technique used to prioritize tasks, resources, or issues based on the principle that roughly 80% of the effects come from 20% of the causes.

- In essence, Pareto analysis involves identifying and focusing on the most significant factors that contribute to a problem or outcome, allowing for more efficient allocation of resources and efforts. It helps in distinguishing between the "vital few" factors that have the most significant impact and the "trivial many" that have less impact.

Manual measurement
Uneven utilization of workers
Manual Circle Drawing
Size of the paper
Fatigue
Quality
SOP
Unstable Desk

Table 3.1: Causes in the production processes.

- In line with the Pareto analysis performed on both the processes, the Manual measurement and Uneven work distribution appeared to the significant factors that have an adverse impact on the continuous boat manufacturing.

- The batch process, on the other hand, was hindered by three major factors which are Manual measurement, Uneven work distribution and Manual Circle Drawing as indicated in Pareto analysis.

- Confronting with manual measurement and unbalanced work distribution can be a key challenge to enhancing both continuous and batch boat manufacturing processes and manually drawing circles especially within the batch process requires to be solved to promote the performance.

Continuous				
Causes	**Frequency**	**Cumulative**	**Percentage**	**Explanation**
Manual measurement	14	14	36.8%	Sometimes errors occurred when measuring the dimensions with a scale, as the boat was being held in hand and not stable on the table.
Uneven utilization of workers	13	27	71.1%	Work was not properly distributed amongst the workers, hence it created downtime
Manual Circle Drawing	3	30	78.9%	Did not got proper circle while revolving the pen around the cap
Size of the paper	2	32	84.2%	When building a boat with a paper size other than letter size, we obtained irregular measurements for the boat.
Fatigue	2	34	89.5%	After 15 minutes, the workers became tired of building the boat while standing
Quality	2	36	94.7%	The quality of the pen and paper was not up to the mark, leading to errors and misalignment in building the boat
SOP	1	37	97.4%	When attempting minor changes while folding the paper to innovatively construct the boat, we ended up with an improper boat.
Unstable Desk	1	38	100.0%	The desk was shaky, leading to errors during the construction of the boat
	38			

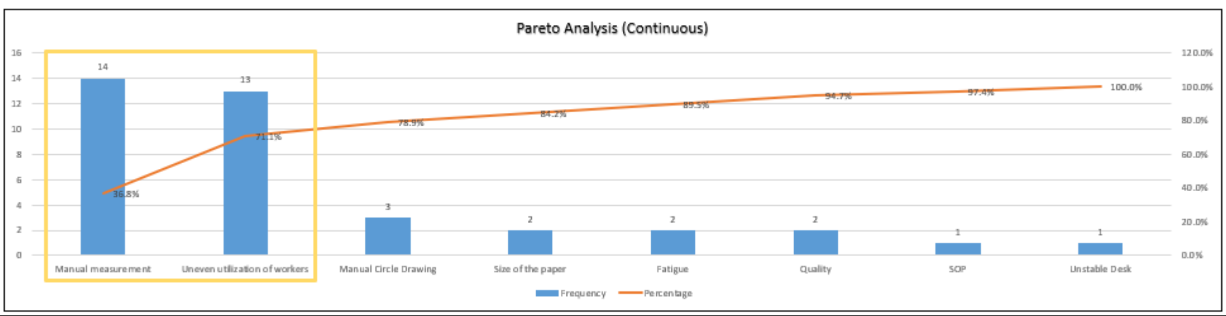

Figure 3.1. Pareto Analysis - Continuous Production

(The Yellow box indicates the vital few) || (Y-Axis represents frequency of the causes)

Batch				
Causes	**Frequency**	**Cumulative**	**Percentage**	**Explanation**
Uneven utilization of workers	20	20	33.3%	Work was not properly distributed amongst the workers, hence it created downtime
Fatigue	16	36	60.0%	After 15 minutes, the workers became tired of building the boat while standing
Manual measurement	12	48	80.0%	Sometimes errors occurred when measuring the dimensions with a scale, as the boat was being held in hand and not stable on the table.
Quality	4	52	86.7%	The quality of the pen and paper was not up to the mark, leading to errors and misalignment in building the boat
Size of the paper	3	55	91.7%	When building a boat with a paper size other than letter size, we obtained irregular measurements for the boat.
Manual Circle Drawing	2	57	95.0%	Did not got proper circle while revolving the pen around the cap
SOP	2	59	98.3%	When attempting minor changes while folding the paper to innovatively construct the boat, we ended up with an improper boat.
Unstable Desk	1	60	100.0%	The desk was shaky, leading to errors during the construction of the boat
	60			

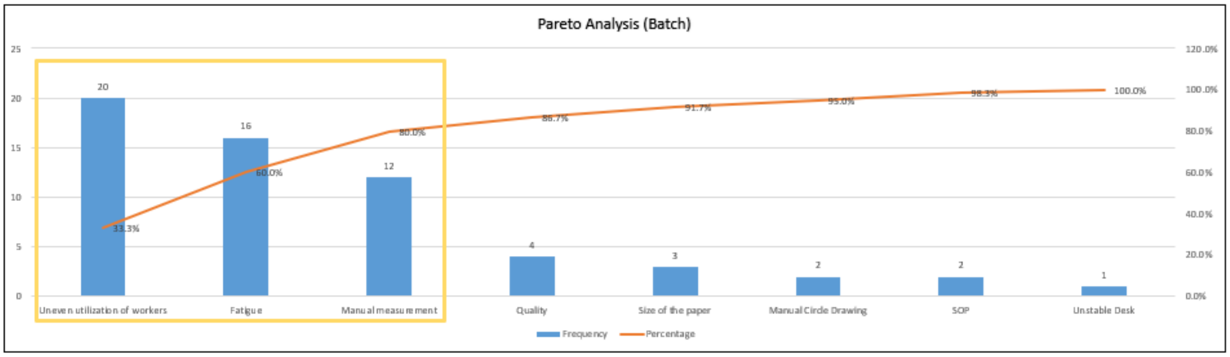

Figure 3.2: Pareto Analysis - Batch Production

3.2 Fishbone Diagram:

Fishbone diagram, also called Ishikawa diagram or cause-and effect diagram, is a visual tool for problem solving and detection of the main causes of a problem. It is called fishbone diagram due to having the appearance of a fish skeleton. The “head” is the problem statement or the effect with the spine comprising various causes that determine or influence the problem.

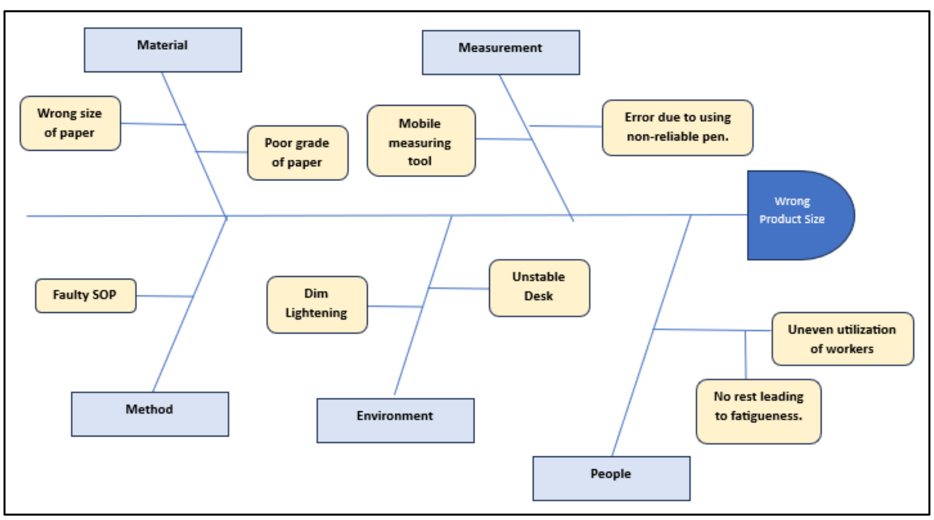

Figure 3.3 Fishbone Diagram – Wrong Product Size

- A fishbone diagram is used here as a pictorial manifestation of the significant problem detected that caused product failure, like the wrong product size for instance.

- This presents a well-organized way of looking into the many different variables pointing to this problem, which will help uncover the deeper underlying causes as we carry out root cause analysis. Distinguishing the factors which contribute to the problem leads us into gaining knowledge about the intricacies of the phenomenon and we can attempt problem-solving strategies which can be effective.

- The diagram eliminates all speculations of the issue's root causes, and equipped with the knowledge of which solutions or strategies will be able to minimize the recurrence, informed decision making, and implementation of the same has been possible.

3.3 FMEA:

- Failure Mode and Effects Analysis (FMEA) is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures.

- It is used to prioritize potential defects based on their severity, occurrence, and detectability. The goal of FMEA is to help design out or mitigate failures to enhance reliability and safety of the product or process.

- The Risk Priority Number (RPN) in Failure Mode and Effects Analysis (FMEA) is calculated by multiplying three factors:

    - **Frequency(F):** How frequently the failure is likely to occur, on a scale of 1 (very unlikely) to 5 (most frequent)
    - **Detection (D):** How likely it is that the failure will be detected before it becomes a problem, on a scale of 1 (most likely to detect) to 5 (least likely to detect)
    - **Severity (S):** How serious the consequences of the failure are, on a scale of 1 (least severe) to 5(most severe)

$$\boxed{\mathbf{RPN=F\times D\times S}}$$

Continuous						
Process Step	**FailureMode**	**Effect**	**Frequency**	**Detection**	**Severity**	**RPN**
Measurement of the boat dimensions	Inaccuracy in dimension measurement due to manual handling instability	Potential misclassification of conforming boats as defective leading to unnecessary waste	2	4	5	40
Manufacturing boat	Failure mode due to imbalanced task allocation among personnel	Elevated downtime resulting in reduced production efficiency and jeopardized customer trust due to delivery postponements	2	2	4	16

Figure 3.4: FMEA - Continuous Production

Batch						
Process Step	**FailureMode**	**Effect**	**Frequency**	**Detection**	**Severity**	**RPN**
Manufacturing boat	Failure mode due to imbalanced task allocation among personnel	Elevated downtime resulting in reduced production efficiency and jeopardized customer trust due to delivery postponements	2	2	4	16
Manufacturing boat	Failure mode due to worker fatigue from prolonged standing during boat assembly	Decreased production quality and increased risk of errors, potentially leading to higher defect rates	2	1	5	10
Measurement of the boat dimensions	Inaccuracy in dimension measurement due to manual handling instability	Potential misclassification of conforming boats as defective leading to unnecessary waste	1	4	5	20

Figure 3.5: FMEA - Batch Production

- The critical causes identified through Pareto Analysis have been subjected to an FMEA, focusing on the "vital few" causes. Manual measurement emerged as the leading cause of high RPN in both continuous and batch production methods. Following closely is the uneven utilization of labor. Therefore, corrective actions must be implemented to mitigate these failures.

- The detection and severity ratings are given according to company standards. The frequency rating is given according to the percentage of that step failure occurring when compared to others.

3.4 Scatter Diagram:

Plotting the data points in a graph will create a scatter plot which tells about the relationship between two variables in a visual way.

The causes identified as “vital few” in Pareto analysis are plotted against the serial number of boats for both continuous and batch production.

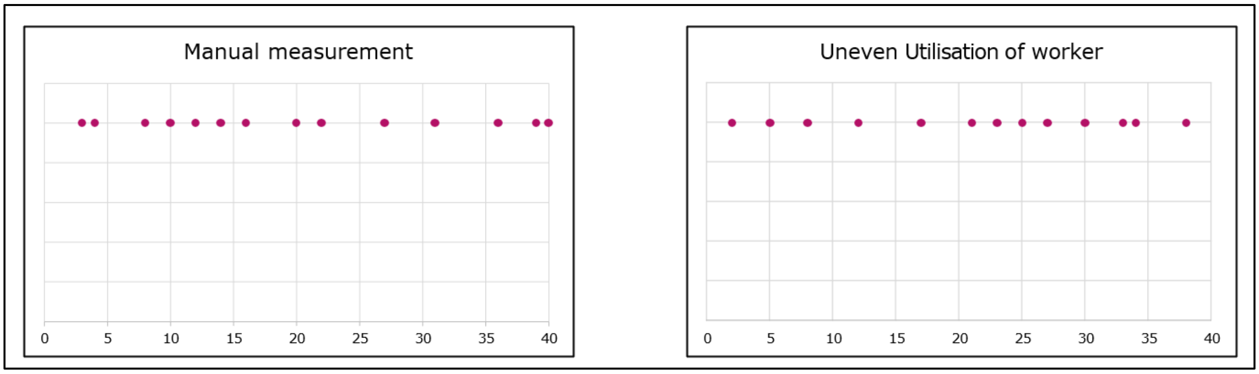

Figure 3.6: Scatter Diagram - Continuous Production

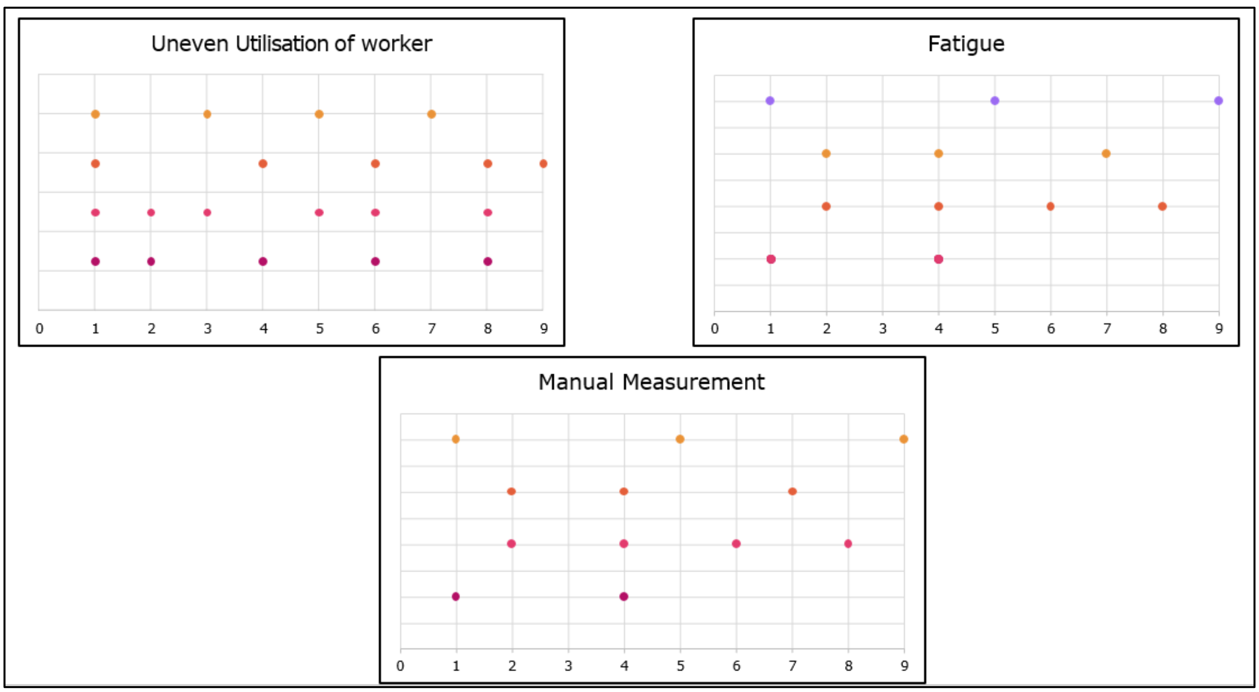

Figure 3.7: Scatter Diagram - Batch Production

3.5 5 Why's:

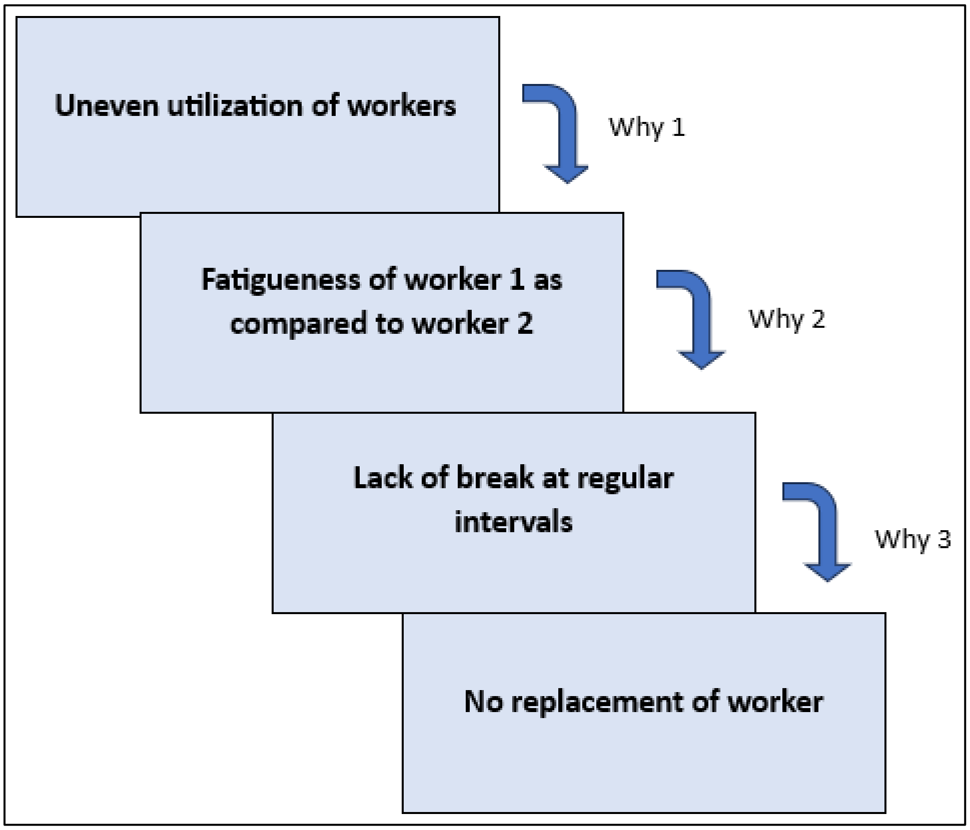

Figure 3.8: 5 Why (1) - Continuous Production

Errors have been observed in boat dimensions when measured.

- *Asking 'why' the first time, it was found that the dimensions marked by worker 4 were uneven and varied a lot, resulting in the rejection of the final product.*
- *Asking 'why' for the second time, the unnecessary movement of worker 4's arms required lots of time and effort with poor output.*

- *'Why' for the third time, the reason was found to be the usage of a method that required a non-reliable marker.*

- *Further asking 'why' the last time, it was concluded that the marking method needed to be modified by replacing the marker with an inked circular stamp.*

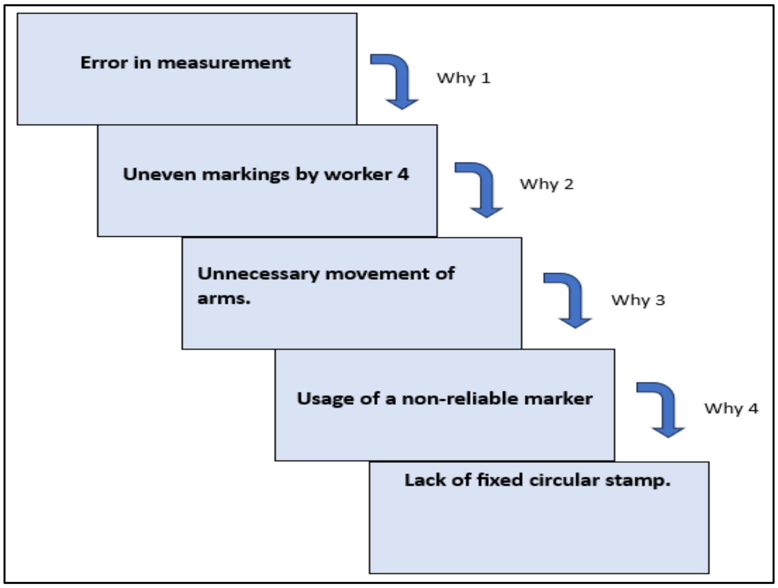

Figure 3.9: 5 Why (2) - Continuous Production

When the worker's efficiency during the process was observed, it was concluded that the workers had been unevenly utilized.

- Asking 'why' the first time, it came to notice that worker 1's efficiency was 1.38 times less when compared to the average efficiency of all the workers combined.
- Asking 'why' the second time, the reason for this occurrence was the absence of break/rest at regular intervals.
- Asking 'why' the third time, it was concluded that the production required an extra worker who could replace the previous worker during the break.

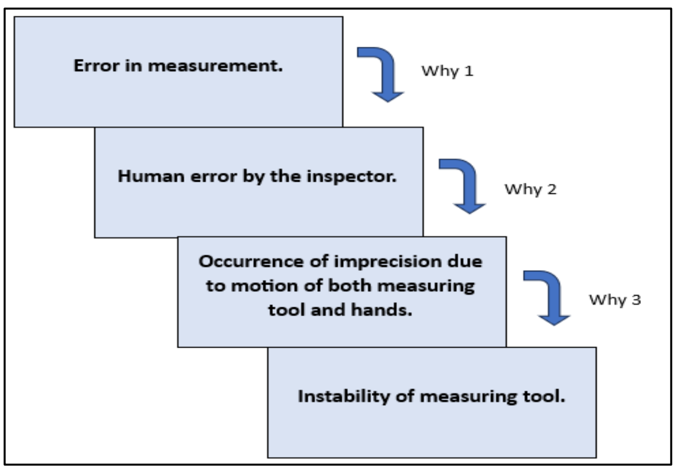

Figure 3.10: 5 Why - Batch Production

Errors have been observed in boat dimensions when measured.

- Asking 'why' the first time, it was found that the measurements taken had scope of inefficiencies, resulting in the rejection of the final product.

- Asking 'why' for the second time, the unnecessary movement of inspector's arms as well as the movement of measuring tool resulted in imprecise readings.

- Asking 'why' for the third time, the reason was found to be the unstable/mobile measuring tool that required the inspector to move the align the product and the tool manually in a non-efficient manner.

- Thus, it is required to be modified by fixing it to the table to avoid unnecessary movement as well as providing a contrasting background making the inspection efficient.

3.6 Process Balance Chart:

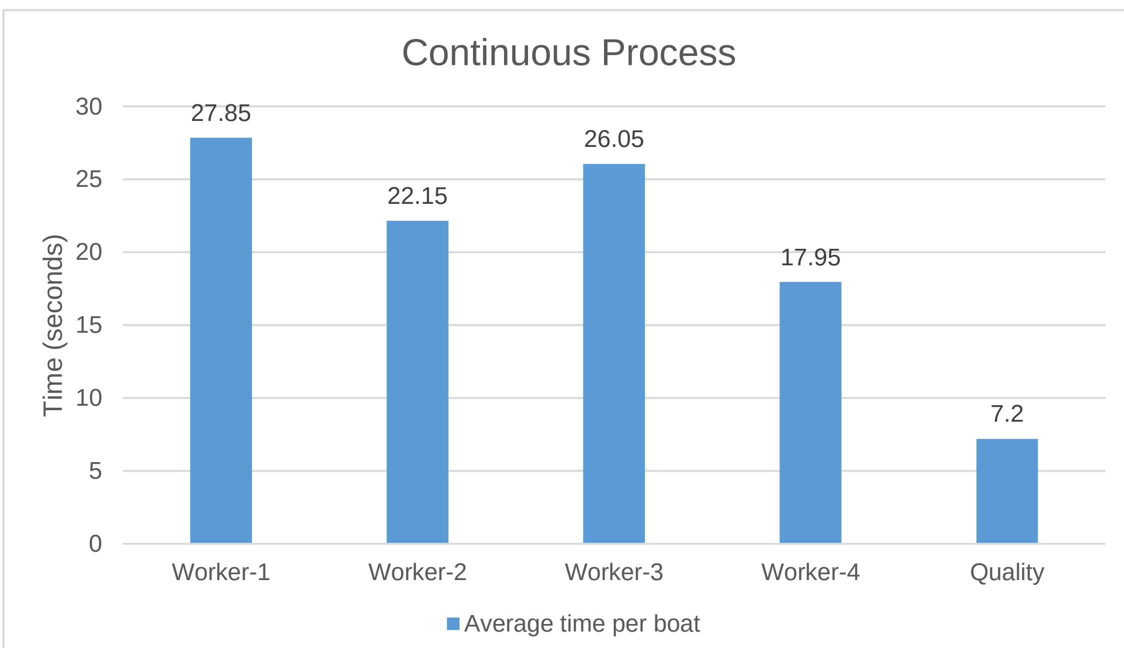

Figure 3.11: Continuous Process Balance Chart

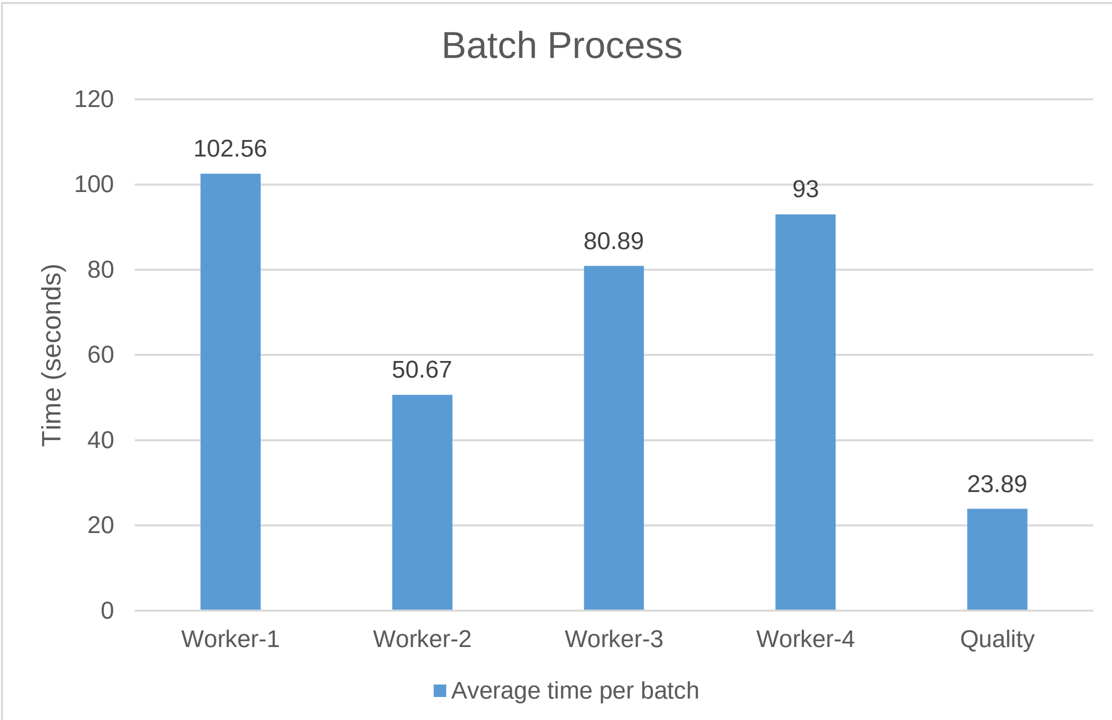

Figure 3.12: Batch Process Balance Chart

Here, we can observe that even though the average time per boat is less for batch production when compared to continuous there are many other factors which are better for continuous production, The number of boats produced, profit obtained, quality rate is higher for continuous production. We also observed that the WIP in the case of batch production is very high compared to continuous which leads to more cost and less profit. So, the preferable process out of these two is continuous production.

3.7 Waste Workshop:

- A waste workshop is a concentrated, hands-on learning experience created to identify, analyze, and eliminate various forms of waste in organizational operations. The goal of the program is to impart lean thinking concepts to participants and in addition to providing them with appropriate tools and techniques to minimize inefficiencies, reduce costs, and optimize workflows.

- It is possible to eliminate or reduce waste across the value chain by applying unique lean concepts to each kind of waste. A lean program that is successful must result in notable process enhancements. Managers striving to implement lean manufacturing principles can begin by reviewing the following list of waste.

1. *Waiting*
   - Inventory that is idle, whether it be in between production lines or finished goods that are kept on shelves or in warehouses until they are needed, is known as waiting waste. The main principle is to eliminate any wait times for material, people, or equipment within or between operations. Ensure flows are balanced.
   - After the project was reviewed, it was discovered that poor production flow management had led to worker idle times, which in turn had increased the time that customers had to wait for finished goods.

2. *Extra processing*
   - The basic notion is to eliminate non-value-added process steps.
   - Upon analyzing this project, it was discovered that during production, some workers were investing excessive time in creating the proper shape of the crease to prevent rejection in the final product.
   - Because of the unequal allocation of this process among employees, bottlenecks developed, and workers wasted time refining the shape of the crease.

3. *Overproduction*
   - The underlying principle is to reduce excess work-in-process and finished goods inventory. The analysis of this project revealed that batch production tends to generate more unfinished products.
   - It is crucial for all frontline workers to possess knowledge about demand and inventory, enabling their active involvement in collecting production data. Providing guidance and instruction on lean concepts, methods, and instruments can successfully detect or eradicate overproduction.
   - Employees that are empowered are better able to make judgments, act, and implement changes within their specific areas of expertise.

4. *Defects*
   - The principle of defects is to Eliminate all defects along the process flow and work toward “perfect” product quality.
   - Defective products often result from inappropriate folding, manual measurement, and imperfectly executed edges during the production process.

- Empowering frontline workers can be achieved by offering tailored courses designed to impart the necessary knowledge and skills, thereby enabling them to initiate or revitalize lean efforts within the facility.

3.8 Conclusion:

Summing up, after conducting the boat manufacturing processes analysis using several Lean engineering tools, we came up with the following points which should be further reviewed and optimized.

- The **Pareto Analysis** pointed out the most important factors, which were manual measurement, uneven work distribution, and manual circle drawing. These were the key contributors in causing production inefficiencies.

- The **Fishbone Diagram** further elucidated the complexities surrounding product failures, particularly concerning the wrong product size. By systematically examining various contributing factors, we gained a deeper understanding of the underlying causes, enabling informed decision-making and the development of effective problem-solving strategies.

- Additionally, the **Failure Mode and Effects Analysis (FMEA)** highlighted critical causes and prioritized potential defects based on severity, occurrence, and detectability. This systematic approach allows for targeted corrective actions to mitigate failures and improve reliability and safety.

- The **Scatter Diagrams** provided visual representations demonstrating any correlation between the cause and time. The **Process Balance Chart** demonstrated the preferable process out of continuous and batch production.

- Lastly, the **Waste Workshop** identified key areas of waste, such as waiting, extra processing, overproduction, and defects, offering opportunities for process optimization and efficiency gains.

In summary, our comprehensive analysis underscores the value of Lean engineering methodologies in identifying inefficiencies, optimizing processes, and driving continuous improvement in boat production. By addressing root causes, prioritizing corrective actions, and fostering a culture of continuous improvement, organizations can enhance productivity, quality, and customer satisfaction in the boat manufacturing industry.

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4.1 PDCA:

The PDCA cycle, standing for Plan-Do-Check-Act, is a continuous loop of planning, implementing, assessing, and adjusting.

It's a dynamic method used to achieve continuous improvement in business processes, allowing teams to test solutions on a small scale, assess results, and refine before full-scale implementation.

This iterative approach is especially valuable in environments like boat manufacturing, where precision, quality, and efficiency are paramount, facilitating systematic improvements and fostering a culture of quality and innovation.

Plan

Problem: Identification of the problem

The initial step involved acknowledging the presence of inefficiencies within the boat production line, leading to reduced quality output and increased waste.

Observation: Recognition of problem characteristics

Through meticulous examination and data collection, we identified that manual procedures were the primary source of inaccuracies and inefficiencies, negatively impacting productivity and quality standards.

Analysis: Discovering the main causes

Utilizing analytical tools such as Pareto charts, the 5 Whys technique, and FMEA, we pinpointed manual measurements, disproportionate worker utilization, and worker fatigue as the fundamental issues requiring intervention as identified in the Analyze Phase.

Action Plan: Countermeasures to root causes.

We strategized to introduce stamped tools for standardized circle drawing, fixed scale for accurate measurements on the table, and conduct comprehensive training for equitable workload distribution and process efficiency.

DO

Execution: Acting in accordance with the “Action Plan”

Implement training sessions focusing on process efficiency and workload management. Introduce stamped tools for drawing circles to ensure uniformity. Redistribution of work to the workers so that all of them have equal workload. Install scale on table to eliminate inaccurate manual measurements.

CHECK

Verification: Confirmation of the effectiveness of the action

The effectiveness of these interventions was assessed through comparative analysis of performance metrics before and after implementation, focusing on production timing, quality improvement, and worker satisfaction levels. This involved a detailed examination of the ratio of perfect to defective boats produced.

ACT

Standardization: Definitive elimination of causes

With verified improvements, we can move to institutionalize these practices across all production operations, updating operational guides and training materials accordingly. Although creating a comprehensive SOP was beyond our immediate scope, it's identified as a future objective.

Conclusion: Review of activities and planning for future work

The cycle concluded with a reflective discussion on the enacted improvements and strategizing for the next PDCA cycle, emphasizing the commitment to perpetual enhancement of the production process. By applying PDCA, we can systematically identify inefficiencies, implement targeted improvements, and ensure that changes lead to measurable enhancements in productivity, quality, and worker satisfaction.

4.2 Potential Enhancements:

Based on the findings from our Analyse phase, we pinpointed three potential improvements for the process:

1. Introduction of Stamped Tools for Standardized Circle Drawing:
- Implement stamped tools specifically designed for drawing circles(window) to ensure uniformity and precision in circle sizes across various tasks. This method standardizes circle drawing, significantly reducing variability and enhancing the quality and consistency of the outputs.

2. Fixing a Scale on the Table to Minimize Manual Measurement Errors:
- Instead of relying on handheld measuring tools that can vary in precision and user handling, a scale is permanently affixed to the worktable. This allows for immediate and accurate measurements directly on the work surface, significantly reducing the likelihood of manual measurement errors. This setup streamlines the measurement process,

ensuring that all dimensions (window diameter and sail height) are precise and consistent, which is crucial in our process.

Figure 4.1: Potential Enhancements

3. *Conducting Comprehensive Training for Equitable Workload Distribution and Process Efficiency:*
- Focus on delivering extensive training to all team members to ensure they are proficient in using the new tools and understand the updated processes. This includes training on the optimal use of the stamped tools for circle drawing, how to effectively utilize the fixed table scale for measurements, and best practices for maintaining efficiency. The goal is to ensure an equitable distribution of workload, where all team members are equally capable and efficient, leading to enhanced process efficiency and productivity.

These refined strategies emphasize the importance of precise tools and measurements, alongside skilled personnel, to enhance process efficiency, accuracy, and the quality of outputs.

4.3 Poka-Yoke:

Poka-Yoke is a Japanese term that means "mistake-proofing." It refers to any mechanism in a lean manufacturing process that helps an equipment operator avoid (yokeru) mistakes (poka). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. Poka-Yoke can be implemented in any process where something can go wrong or an error can be made, aiming to make it virtually impossible to make mistakes in order to improve quality and reliability in the manufacturing process.

- *Pre-cut Paper with Fold Lines:* Use pre-cut paper that includes clearly marked fold lines or tabs that align precisely when folded correctly. This prevents incorrect folds and ensures that each boat has the same size and shape.

- *Color-Coded Sections:* Implement color-coded sections on the paper that correspond to different parts of the boat. This visually guides the assembler through the folding process, reducing the chance of incorrect folds.

- *Templates and Jigs for Folding:* Create physical templates or jigs that the paper can be placed into, which guide the folding process. These tools can ensure that folds are made at the correct angles and positions, leading to a uniform final product.

4.4 5S:

The 5S methodology is a system derived from five Japanese words: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). It's designed to organize the workplace, keep it clean, maintain discipline, and improve efficiency and safety. The goal is to reduce waste, optimize productivity, and foster a sense of ownership and satisfaction among employees by ensuring a well-organized, clutter-free, and systematic working environment. Each "S" represents a step towards maintaining an orderly environment where employees can perform optimally.

Sort (Seiri) - Eliminate unnecessary steps or tools identified in the process mapping, particularly those not contributing to efficiency or quality in both continuous and batch processes. In our case, replacing drawing the circles with stamps.

Set in Order (Seiton) - Optimize workspace layouts to facilitate smoother transitions between folding and measuring activities, ensuring tools and materials are within arm's reach. This optimization includes well-defined zones for storing raw materials, segregating finished goods from defective ones, and maintaining an efficient flow from one stage to the next.

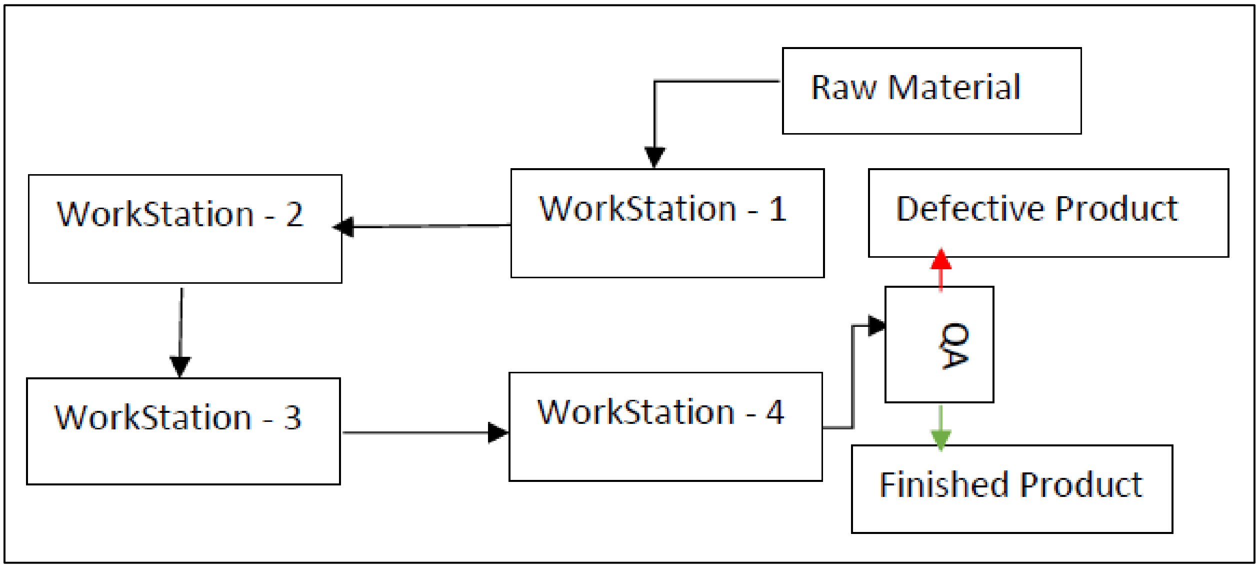

Figure 4.2: Process Flow Representation

Shine (Seiso) - Implement a cleaning schedule for workspaces to maintain a clutter-free environment, ensuring tools like scales and stamped tools are always in good condition and ready for use. We ensure to remove the boats, work in process inventory, waste before we head onto the next process.

Standardize (Seiketsu) - Develop standard operating procedures for both processes, incorporating best practices for folding techniques, tool usage, and workstation maintenance. This includes standardized training for all workers to ensure consistency.

Sustain (Shitsuke) - Establish a culture of continuous improvement, encouraging feedback on the process and adapting as necessary. Regularly review process efficiency and quality metrics to ensure the 5S principles are being maintained.
This 5S plan aims to address the identified inefficiencies and manual errors by organizing the workspace, streamlining processes, and maintaining high standards of cleanliness and order, thereby improving overall productivity and quality in boat production.

4.5 Kaizen:

In implementing our process improvements, we've actively applied the Kaizen philosophy of continuous and incremental improvement.

- For instance, by introducing stamped tools and fixed scales, we aimed at reducing manual errors and enhancing precision in our boat manufacturing process.

•   We also reorganized our workstations for better workflow efficiency and minimized unnecessary movements, embodying Kaizen's principles.

•   Moreover, establishing a routine for workspace cleanliness and maintenance, along with standardizing our operational procedures, reflects our commitment to constant betterment.

•   Encouraging regular feedback and adapting our methods accordingly, we've ensured that our approach to improvement is both systematic and sustainable.

4.6 Why not PDSA?

Our decision to favor PDCA over PDSA is deeply rooted in our specific need for a highly structured and iterative approach to continuous improvement. The "**Check**" phase in PDCA is critical for us because it involves a thorough evaluation of the implemented changes against our initial objectives. This step allows us to pause and analyze the data collected during the **"Do"** phase, ensuring that our actions are based on solid evidence and lead to verifiable improvements. In contrast, the "Study" phase in PDSA, while similar, suggests a broader reflection that may not always culminate in immediate action. For our processes, the direct transition from **"Check" to "Act"** in PDCA offers a clear pathway for implementing adjustments or improvements, making it a more suitable model for our goal-oriented and data-driven improvement strategy. This alignment with our operational ethos and the clarity it brings to our improvement initiatives explains our preference for PDCA.

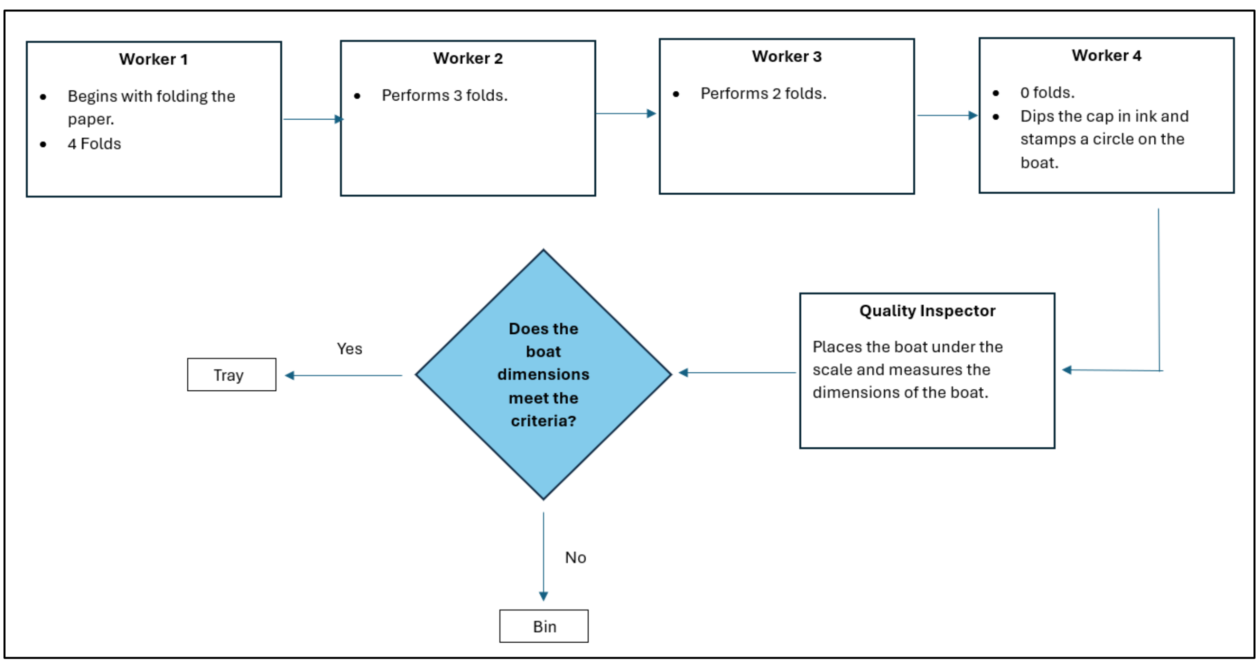

Figure 4.3: Future State Process Map

- The current state mapping was performed, and it was discovered that worker 4's procedure might be improved because it required him to take many steps to mark a circle on the boat. Furthermore, the procedure used by the quality inspector was determined to be ineffective since it involved superfluous hand motions.
- Thus, in the future state map, worker 4 was given an ink stamp to increase the circle's uniformity. Furthermore, anchoring the scale to the table has minimised the quality inspector's hand motions.
- Utilising these improvements, a value stream map has been created as shown below.

4.7 VSM:

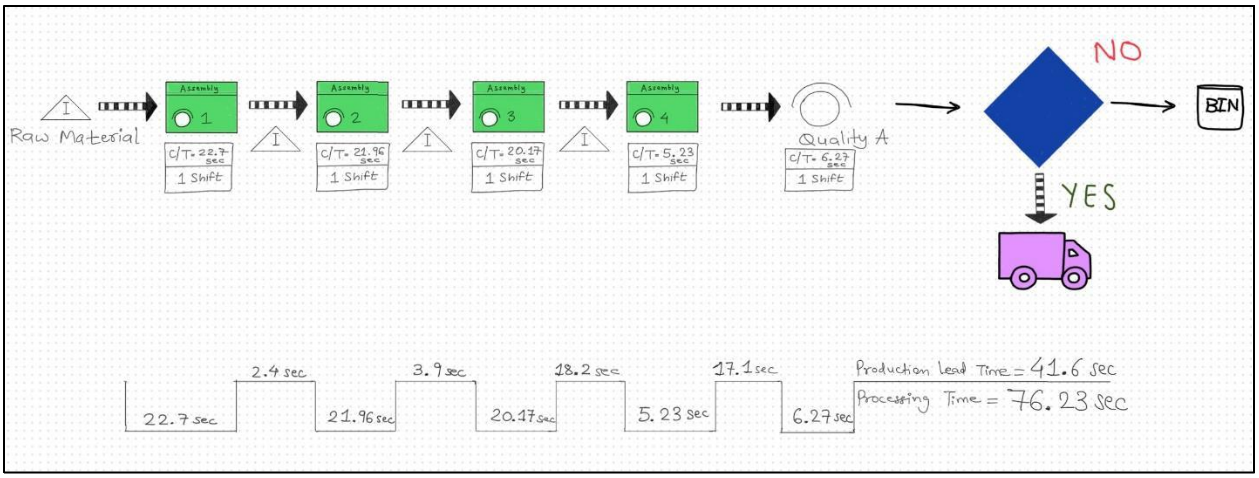

Figure 4.4: VSM of Continuous Production

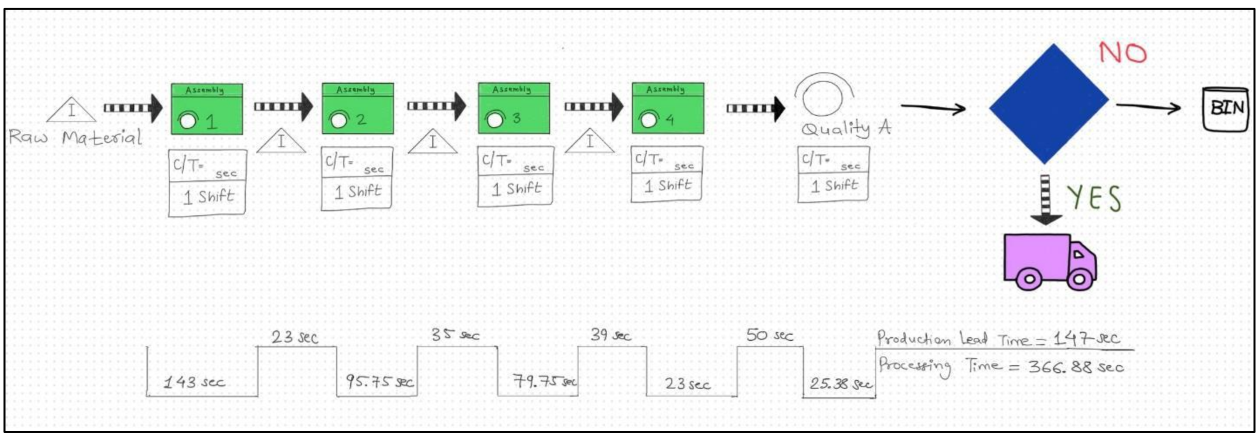

Figure 4.5: VSM of Batch Production

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4.8 Performance Indicators:

The first performance indicator as highlighted in the Measure Phase is the availability of the workers so that we can check if the work was distributed properly. We can observe that there is significant reduction in availability of workers 1,2 and 3 because of the redistribution of work among them.

Batch Production		
Sr. No.	**Process Step**	**Availability**
1	Worker 1	4.67%
2	Worker 2	36.17%
3	Worker 3	46.83%
4	Worker 4	84.67%
5	Quality Manager	73.75%

Continuous Process		
Sr. No.	**Process Step**	**Availability**
1	Worker 1	1.50%
2	Worker 2	4.83%
3	Worker 3	12.58%
4	Worker 4	77.33%
5	Quality Manager	72.83%

Fig 4.6: Performance Indicator 1

The second performance indicator was the average time taken to make each boat and the total number of boats made. We can observe a drastic reduction in time taken by worker 4 because of the improvement made by replacing drawing with a stamp. Also, there has been reduction in number of defective boats due to efficient process. The continuous process has seen a 53.13% rise in boat production, indicating substantial enhancements resulting from the implemented changes. In contrast, the batch process experienced minimal growth, potentially attributed to worker fatigue.

The overall quality rate observed was 94.23% for the continuous process and 90.625% for the batch process, demonstrating increased efficiency due to the interventions.

Continuous Process				
Sr. No.	Performance Indicator	As-is	UOM	Comment
1	Worker 1	22.73076923	Seconds	Time taken per boat made
2	Worker 2	21.96153846	Seconds	Time taken per boat made
3	Worker 3	20.17307692	Seconds	Time taken per boat made
4	Worker 4	5.230769231	Seconds	Time taken per boat made
5	Quality Manager	6.269230769	Seconds	Time taken per boat made
6	Total Boat Production	49	unit	

Batch Process				
Sr. No.	Performance Indicator	As-is	UOM	Comment
1	Worker 1	35.75	Seconds	Time taken per boat made
2	Worker 2	23.9375	Seconds	Time taken per boat made
3	Worker 3	19.9375	Seconds	Time taken per boat made
4	Worker 4	5.75	Seconds	Time taken per boat made
5	Quality Manager	6.345	Seconds	Time taken per boat made
6	Total Boat Production	29	unit	

Fig 4.7: Performance Indicator 2

Quality Rate	Continuous – 94.23% Batch – 90.625%
WIP	Continuous – 2 Batch – 5
Total Profit	Continuous - $37.56 Batch - $21.96

Fig 4.8: Performance Indicators

Conclusion:

The implementation of DMAIC's Improve phase in our project has led to substantial advancements in our boat manufacturing efficiency and productivity. By deploying targeted solutions, such as optimizing layout and integrating precision tools, alongside fostering a culture of continuous training, we've observed a marked improvement in our operational metrics. These efforts have not only validated the impact of our strategic interventions but also laid a robust groundwork for ongoing improvement and excellence in our operations, propelling us towards future enhancements with a solid evidence-based approach.

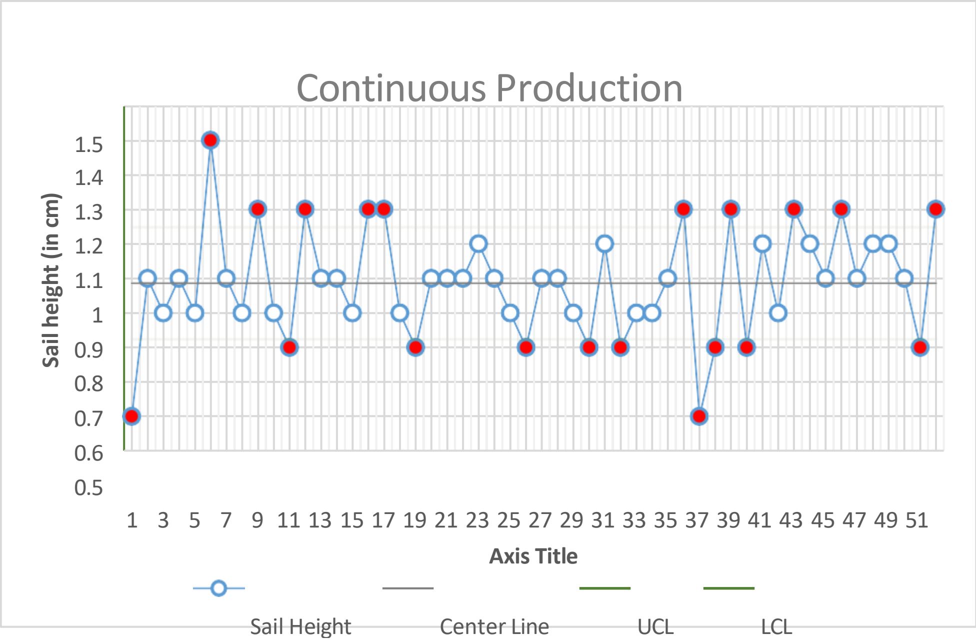
Introduction:

The Control section of our DMAIC route covering paper boat production is where we implement rigorous procedures to guarantee the sustenance of process stability and quality of the product. Using control charts, dashboards, and data visualisation tools we keep up a constant watch on all parameters defined to err on the side of caution and handle any variations from preset standards immediately. Process accountability is achieved through the clear development of the roles and duties of the individuals, while making use of the well-structured Control Plan and the effective SOPs to be able to follow and strictly abide by the implementation of the best practices. In addition to the process and quality reviews, which, by themselves, already improve the efficiency and the working environment of the organisation, there is the utilisation of the lean manufacturing methodology known as 5S. The efforts have resulted in observable outcomes in the process flow, defect reduction as well as the consistency in the production process which is corroborated by the fact that we are a quality-oriented paper boat manufacturer.

Control Chart:

Continuous Production:

- The control chart indicates that the production process is generally stable, as most data points fall within the control limits.
- Outliers in Sample 1 and Sample 4 warrant further investigation to identify potential causes of variation. Continuous monitoring and periodic analysis of the control chart will help maintain consistent sail height quality and identify any deviations from the expected standards.
- The control chart provides valuable insights into the sail height variation of paper boats during continuous production.
- By monitoring and addressing outliers, the production process can maintain quality standards and ensure customer satisfaction.



Sr No.	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1	0.6	0.8	1	1.1	1.1
2	1	1.2	1	0.8	0.9
3	0.9	1	1.1	0.9	1.2
4	1	1	1	0.9	1.1
5	0.9	0.9	0.9	1	1
6	1.4	1.2	0.8	1.2	1.2
7	1	1.2	1	0.6	1
8	0.9	0.9	1	0.8	1.1
9	1.2	0.8	0.9	1.2	1.1
10	0.9	1	0.8	0.8	1
Mean(x̄)	0.98	1	0.95	0.93	1.07
Max	1.4	1.2	1.1	1.2	1.2
Min	0.6	0.8	0.8	0.6	0.9
Range(R)	0.8	0.4	0.3	0.6	0.3

Average (x̄m)	0.986	Standard Deviation of x̄	0.0541295	UCL of x̄	1.148388423	LCL of x̄	0.823612

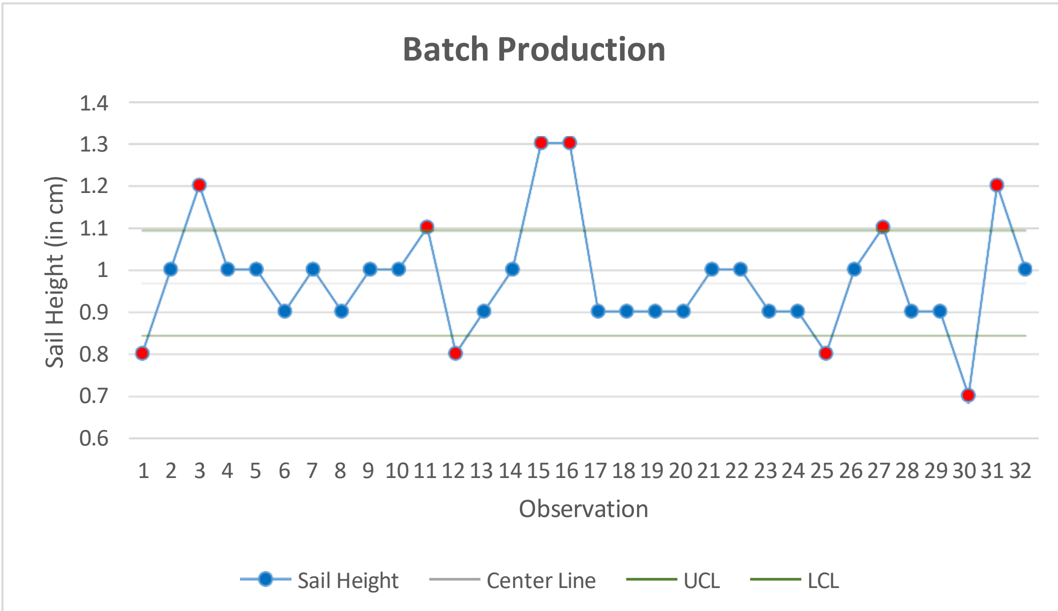
Batch Production:

- ➢ The control chart indicates that the production process is generally stable, as most data points fall. Within the control limits, the production process demonstrates stability, with most data points falling within the established limits.
- ➢ However, outliers observed in Sample 2 and Sample 3 suggest potential variations that require thorough investigation to pinpoint their underlying causes.
- ➢ Continuous monitoring and periodic analysis of the control chart remain essential practices to uphold consistent sail height quality and promptly identify any deviations from the expected standards.
- ➢ This proactive approach ensures that the production process maintains stringent quality standards, thereby guaranteeing customer satisfaction and adherence to quality benchmarks.

Sr No.	Sample 1	Sample 2	Sample 3
1	0.8	1.1	1
2	1	0.8	1
3	1.2	0.9	0.9
4	1	1	0.9
5	1	1.3	0.8
6	0.9	1.3	1
7	1	0.9	1.1
8	0.9	0.9	0.9
9	1	0.9	0.9
10	1	0.9	0.7

Mean(x̄)	0.98	1	0.92
Max	1.2	1.3	1.1
Min	0.8	0.8	0.7
Range(R)	0.4	0.5	0.4

Average (x̄m)	0.967	Standard Deviation of x̄	0.041633	UCL of x̄	1.091567	LCL of x̄	0.841767



Process Accountability:

A Product Manager, Quality Control Manager, and Production Supervisor are all involved in the production of paper boats. Their process accountability may be defined as follows:

Process Accountability:

- From receiving the product from vendors to auditing the boat quality, the complete paper boat production process will be led by the Product Manager.
- The process will work like a choreographed performance ensuring a smooth workflow.

Reporting Accountability:

- The Quality Control Manager is the one to operate and put into reports all the information prototyping prices and average cycle time of workers, and finishes and shipments results, analysing them to make an important informed decision making and process improvement.

Change Accountability:

- The Production supervisor is subordinate to the production principle. Correspondingly, in the case of problems like production rate fluctuations variability or worker efficiency they should give different recommendations and introduce changes where possible to make the production process efficient and effective.

Control Plan:

The Control Plan Lean Manufacturing Strategy for Boat Production tries to apply lean engineering principles that will increase paper boat production efficiency and profits.

- Critical quality parameters include paper usage reduction to <1%, a margin >70% and a production cycle, as well as a sail height stability (10 ± 2 mm) and a window diameter within 30 ± 2 mm ranges.
- Reporting is executed only once at the end of each cycle. It is a responsibility of Product Manager to reduce waste and maximise the profits, while Quality Control Manager has to make sure that sail height and window diameter comply with particular standards.
- Through this plan, we can maintain quality and performance regularly, setting realistic targets and reducing waste in the manufacture of paper boats.

Name of process **:** Boat Production
Purpose **:** Implement lean engineering principles to optimize the production of paper boats and maximizing profits.
Process Owner **:** Group - 8
Date: 10th March, 2024

Critical to Quality	Target	Reporting frequency	Who is Responsible
Reduce waste and optimize use of paper	<1%	Once per production cycle	Product manager
Maximize profit in 20 minutes	Margin >70%	Once per production cycle	Product manager
Sail height: 10 +- 2 [mm]	Mean = 1 mm	Once per production cycle	Quality Control manager
Window diameter" 30 +- 2[mm]	Mean = 30 mm	Once per production cycle	Quality Control manager

Dashboards and Data Visualisation:

These are always real-time metrics and analytics for paper boats like wastage, profit, and dimensional accuracy. These visual representations provide stakeholders with a check that can clearly detect the direction of change, deviations, and performance. One of the advantages of VSM is visualisation of the key performance indicators that is used by the managers to make the informed decisions to maximise the production process improvement, minimise the streams of waste, and increase the profitability in paper boat production.

- This Dashboard for Boat Production includes 6 KPI for the process.
- First four KPIs named “Worker 1”, “Worker 2”, “Worker 3” and “Worker 4” is the time taken by each worker to made boat.
- “UOM” (Unit of measurement) as the abbreviation suggest it tells the units in which KPI is measured.
- “Target”: - This column gives the target value for KPIs. Target for “Total boat production” is taken as third quartile (75^{th} percentile) of historical data, all the remaining targets are the first quartile value (25^{th} percentile) of the historical data.

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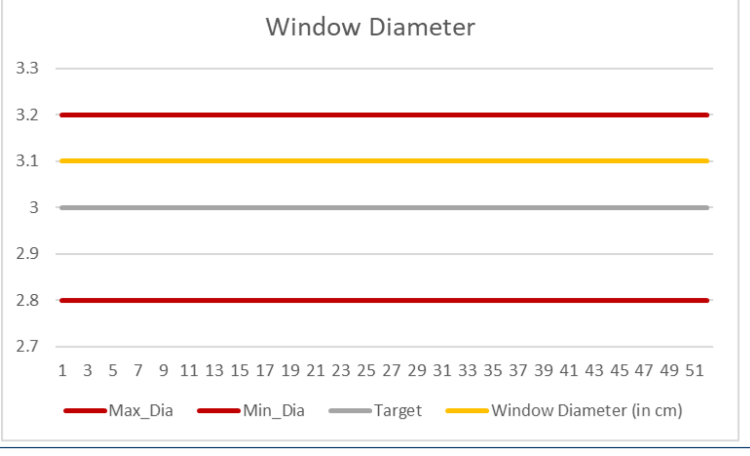
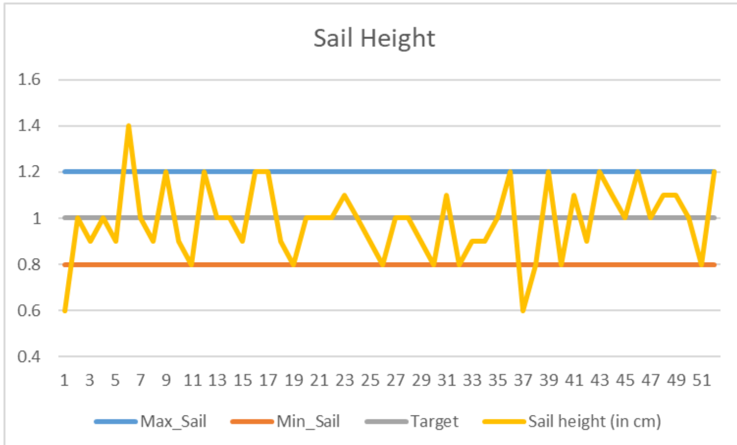
- “As-is”: - This column gives the current data of the process. The dashboard is dynamic and generates the new status after every cycle (20 mins).
- “Status”: - This column gives Red, Amber, or green sign depending on the as-is value and the target of the KPI.
- For first five KPIs, If the Value of as-is is Higher than 20% of Target then it will show **Red**, if it is between 1.2 times of the target and target value then it will show **Amber** and if the as-is is less than or equal to target then it will show **Green**.
- For “Total boat production” KPI, If the value of as-is is more than or equal to target then it will show **Green,** if the as-is value is between 20% less than target and target value then it will show **Amber,** otherwise it will show **Red**.





- For Quality KPI, we have two control limit charts, which will make sure that the process is in the control and gives us the information like how much is the process is near to the target value (Shown in **Grey** line in both charts).
- These charts are dynamic in nature, after every boat made Quality Manager will update this chart and make sure that the process is in control.
- While doing so, we can also focus on Target value for both parameters. Thus, this graphical representation is a handful tool for controlling the process.

<u>Results:</u>

Efficiency Improvements:

- ➢ The application of lean manufacturing principles and process optimization techniques would have resulted in significant efficiency increments evident at a paper boat production stage.
- ➢ This capability can be seen through various operational processes such as fastened cycle times and improved coordination that leads to greater efficiency and productivity.

Defect Reduction:

- ➢ This is accomplished through ensuring strict quality control measures are in place and that all processes adhere to standardised procedures. It is due to that fact that there has been a remarkable decrease in defects within the production process.
- ➢ This can also be seen in the detail that is given to the quality assurance of the paper boats and the uniformity that each customer gets, thus, raising customer satisfaction.

Cost Savings:

- ➢ Through effective functionality of recycling paper and efficient use of resources, the organisation has gained consistent savings in paper expense and operating costs. Such a result led to the strengthening of the items of own needs which corresponded with the aim of maximising the profit in the shipbuilding sector.

Consistency in Production:

- An organised approach to controlling production processes leading to paper boat manufacturing more paralleled with what is anticipated Consistency of sail height and window diameter measurement, along with the quality controls and manufacturing processes in place, all portray a well-established and reliable production framework.

Quality Assurance:

- Quality assurance is the main concentrate of the field where companies use strict criteria as a basis for process and quality reviews, hence guaranteeing quality after production of the boats.
- The company has made its image better by showing a picture about it being a manufacturer who is results oriented.

Continuous Improvement Culture:

- The control stage outcomes confirm a willingness of the organisation to practise the life-long learning process.
- The team, using data-driven information and proactive issue solutions, now has a working environment that has established the base for continuous optimization and excellence in lightboat making.

Process and Quality Review:

Regular Evaluation:

- Also, a key factor for a successful production of paper boats is an establishment of a solid production process and quality review mechanism that are constantly going through an improvement.
- For systematic monitoring of policy implementation results, it is important to carry out regular evaluation to track effectiveness and identify areas of improvement.

Study and Act Phases of PDSA:

- The cycle of Plan-Do-Study-Act (PDSA), which includes Study and Act phases, should be merged with the review process.
- It requires conducting comprehensive analysis of the consequences of process improvements, and it calls for taking pre-emptive measures when taking the findings into account, all this to improve the best practices.

Scheduled Reviews:

- Designate specific periods for the process-quality checks. Similarly, the established processes may be not less frequently reviewed, the terms of reference may be 2-3 years, while the emergence processes should be reviewed every 2-3 weeks.

- The review taken should be obtained directly from the company, and it should be based on the specific needs of the process.

Methods for Review:

- Using people who are not associated with the project team, for instance, external parties or customers, in the review process is also an option.
- Their reports contribute to the appreciation of effectiveness by looking at the things from different viewpoints of the production. Besides, try to integrate process department employees in the review process. They are well acquainted with process highlights and stumbling blocks.

5S:

The 5S methodology is a system derived from five Japanese words: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). It's designed to organize the workplace, keep it clean, maintain discipline, and improve efficiency and safety. The goal is to reduce waste, optimize productivity, and foster a sense of ownership and satisfaction among employees by ensuring a well-organized, clutter-free, and systematic working environment. Each "S" represents a step towards maintaining an orderly environment where employees can perform optimally.

- **Sort (Seiri)** - Eliminate unnecessary steps or tools identified in the process mapping, particularly those not contributing to efficiency or quality in both continuous and batch processes. In our case, replacing drawing the circles with stamps.

- **Set in Order (Seiton)** - Optimize workspace layouts to facilitate smoother transitions between folding and measuring activities, ensuring tools and materials are within arm's reach. This optimization includes well-defined zones for storing raw materials, segregating finished goods from defective ones, and maintaining an efficient flow from one stage to the next.

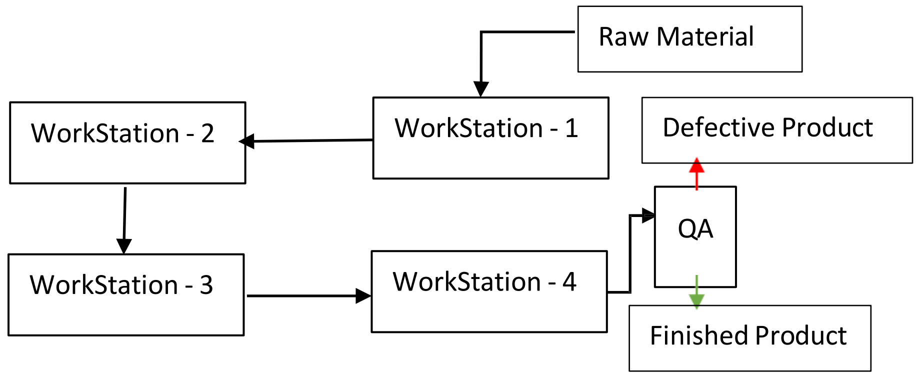


Fig 2. Process Flow Representation

- **Shine (Seiso)** - Implement a cleaning schedule for workspaces to maintain a clutter-free environment, ensuring tools like scales and stamped tools are always in good condition and ready for use. We ensure to remove the boats, work in process inventory, waste before we head onto the next process.

- **Standardize (Seiketsu)** - Develop standard operating procedures for both processes, incorporating best practices for folding techniques, tool usage, and workstation maintenance. This includes standardized training for all workers to ensure consistency.

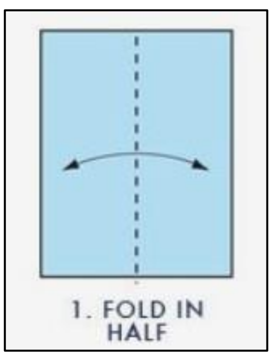
- **Sustain (Shitsuke)** - Establish a culture of continuous improvement, encouraging feedback on the process and adapting as necessary. Regularly review process efficiency and quality metrics to ensure the 5S principles are being maintained.

This 5S plan aims to address the identified inefficiencies and manual errors by organizing the workspace, streamlining processes, and maintaining high standards of cleanliness and order, thereby improving overall productivity and quality in boat production.

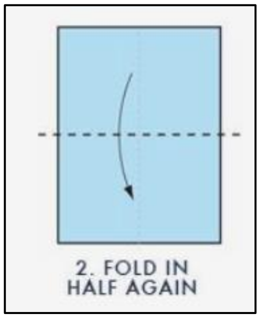
SOP (Standard Operating Procedures) for Improved Process:

- For both batch and continuous production of boats, we have implemented the following improved Standard Operating Procedure (SOP) to maximize efficiency, minimize waste, and reduce the overall production time.

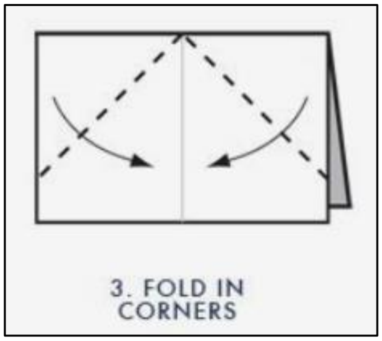
- SOP:



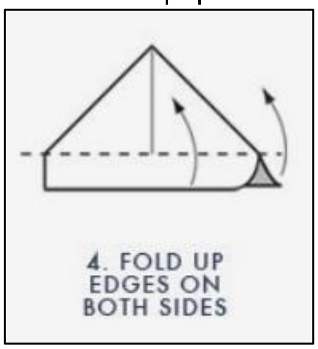
  - Fold the paper in half to create a center line.



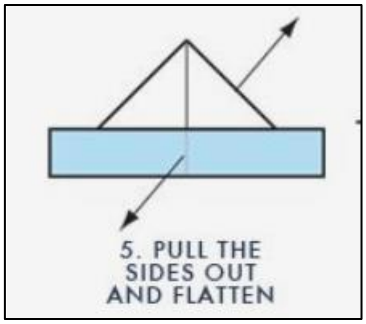
- Open the paper and fold the paper in half again but in opposite direction to get the center line crease.



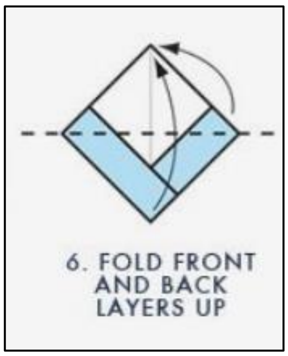
- Fold the paper's corners to get a triangular like structure.



- Fold up the edges on both the sides.

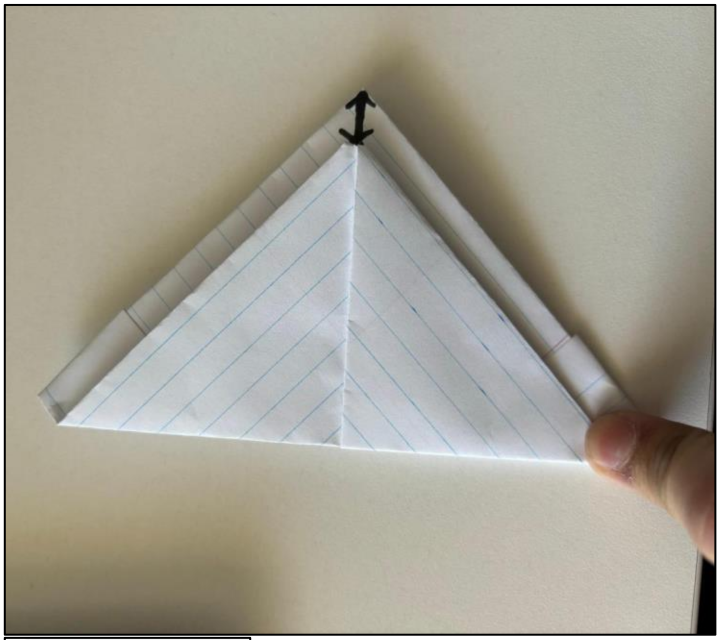


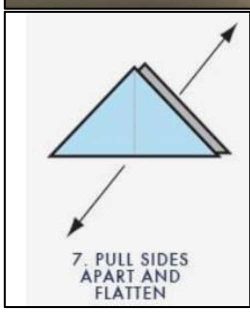
- Flatten the boat by pulling the sides of the paper.



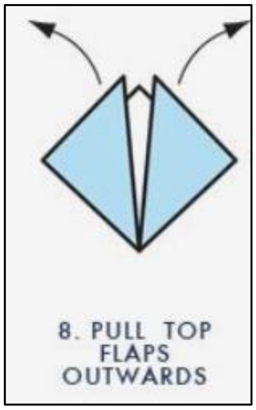
- This is where we made changes to consistently achieve accurate dimensions for the boat. Instead of folding the front and back layers directly to the corners (periphery) of the paper, we kept the folding at a distance from the corner to ensure that the sail height remains near

1 cm consistently.

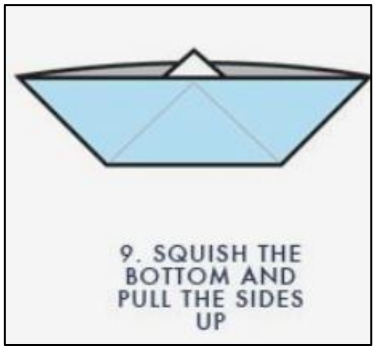




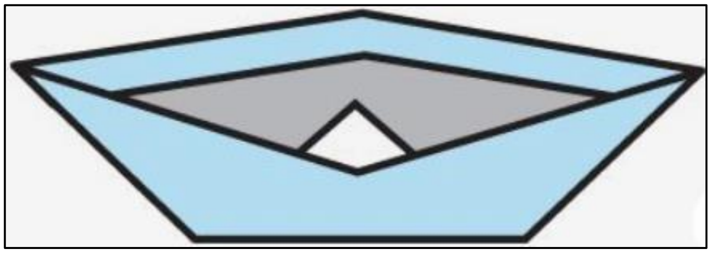
- Pull the sides apart and flatten again.



- Pull the top flap outwards.



- Squish the bottom and pull the sides up to get the perfect sail height dimensional boat.



- TA DAA!

- Finally, after creating the boat, instead of drawing the circle with pen and paper, we utilized a bottle cap with a perfect 3 cm diameter and used it as a stamping die. We simply dipped the bottle cap in the chosen color and printed it onto the paper boat to achieve a perfectly circular 3 cm window diameter.

Purpose:

The aim of this Standard Operating Procedure (SOP) is to delineate the standardized protocol for manufacturing paper boats, with the goal of maintaining uniformity, excellence, and productivity throughout the production process.

Scope:

This SOP applies to all the individuals involved in the paper boat production process, including workers, quality inspectors, and production managers.

Prerequisites:

- Availability of necessary tools such as ruler, eraser, tape, paint, bottle cap.
- Appropriate supply of papers
- Clean and organized workspace

Responsibilities:

1. Workers:

- Follow the usual steps to fold origami paper according to standardized procedures.
- Make sure you fold it accurately and neatly to meet quality rules.
- Work together with your team to keep things running smoothly.

2. Quality Inspector:

- Check paper boats for any problems and if they meet quality rules.
- Write down what you find and tell the production team about any issues.
- Work with workers to fix any quality worries.

3. Production Manager:

- Watch over the whole production process and make sure everyone follows the
- standard steps.
- Help workers and the quality inspector if they need it.
- Keep an eye on how much we're making and find ways to do better.

4. Video Maker:

- Properly create the video in such a way that every process is shown clearly.
- Edit the video so that it is not monotonous for the viewers.

Procedure

Step 1: Getting Ready

- Collect all the things you need to make paper boats.

- Make sure your workspace is tidy and clear.
- Check that you're handling tools safely.

Step 2: Folding Paper

- Everyone picks a piece of origami paper.
- Follow the folding instructions to make a paper boat.
- Fold carefully to make sure each boat looks the same.
- Finish folding on time to keep things moving smoothly.

Step 3: Checking Quality

- Once folded, give the paper boats to the quality inspector.
- They'll look at each boat for any problems, like folds that aren't even or tears.
- Write down any issues and set aside the faulty boats.
- Tell the production manager and workers about any problems so they can fix them.

Step 4: Cleaning Up

- Tidy up your workspace, putting tools and materials back where they belong.
- Dispose of any waste correctly.
- Check one last time to make sure everything is clean and neat.

Conclusion:

As a result, the implementation of lean engineering principles and systematic control measures in the paper boat manufacturing process would increase the performance in efficiency, quality, and cost-effectiveness. Through a comprehensive use of control charts, process accountability frameworks, control plans, dashboards, and data visualisation tools, the team has been successful in holding process stability, monitoring key performance indicators, and fixing deviations from standards in the timely manner.

Implementation of 5S methodology has promoted workplace cleanliness, organisation, and efficiency thus, creating a culture of continuous improvement with sustained production of quality products. Through the development and implementation of the evolving Standard Operating Procedures (SOPs) all production processes have been streamlined and waste minimised as well as quality standardised across both batching and continuous production processes.Additionally, the process and quality review mechanisms have made it possible to implement systematic assessment of production processes on regular bases with the purpose of constant optimization and staying relevant to the current customer preferences and feedback. This is in addition to the consolidation of the group activities with the Plan-Do-Study-Act (PDSA) strategy, which is the yardstick that measures effectiveness, through the continuous Drive for the progress and idealism in paper boat manufacturing.

All in all, the achievement of measurable quality through that stage of the DMAIC model confirms the strategy of the company which strives to achieve high standards of craftsmanship while maintaining the required efficiency of manufacturing, cutting costs and enjoyable experience for customers. Moving ahead we will remain fanatical to these standards all the while working continuously to make new and improvements in the production processes.