First Pass Yield Scrap Reduction in Aluminum machining Components

Rajesh

ROADMAP

- Overview
- Define
- Measure
- Analyse
- Improve
- Control

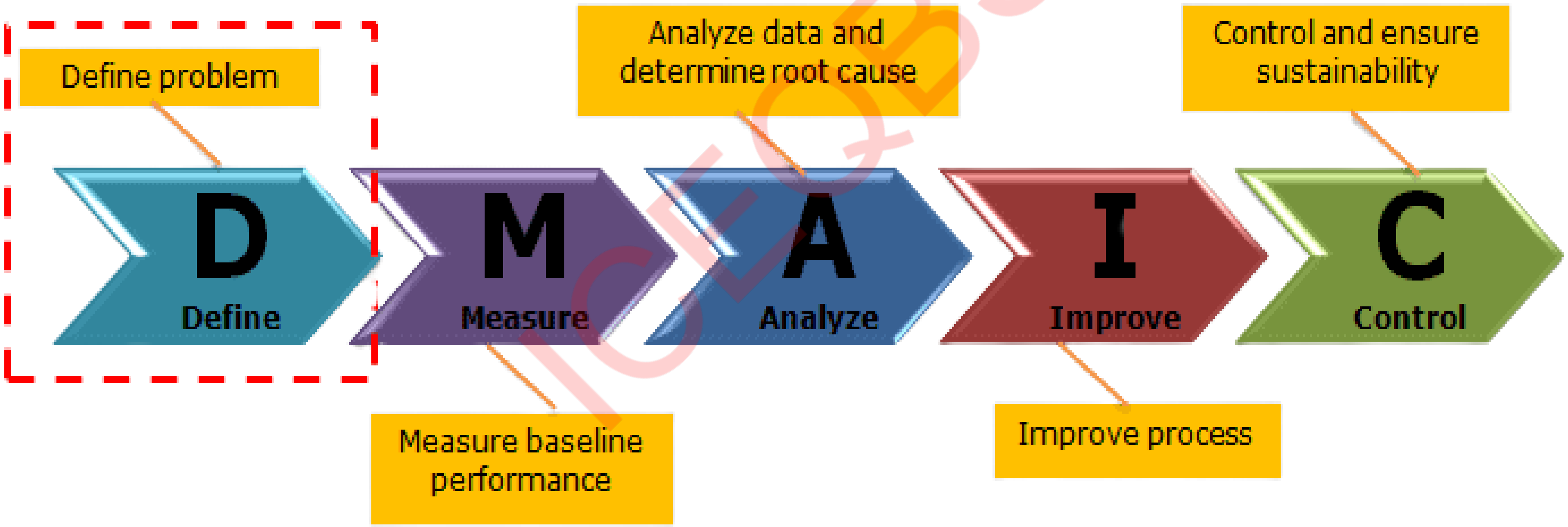
OVERVIEW

Background

The manufacturing line's First Part Yield (FPY) scrap rate has averaged 8% over the past nine months, with peaks reaching 10%, resulting in significant material losses, rework, and productivity inefficiencies. This level of scrap has led to an estimated annual financial impact of ₹3.2 Lakhs, directly affecting manufacturing costs and overall profitability.

High scrap levels also create capacity loss, increased handling and inspection effort, and inconsistent product quality, which can negatively influence customer satisfaction and delivery commitments. In addition, recurring rework and scrap reduce effective throughput and place unnecessary strain on manpower and equipment.

DEFINE PHASE

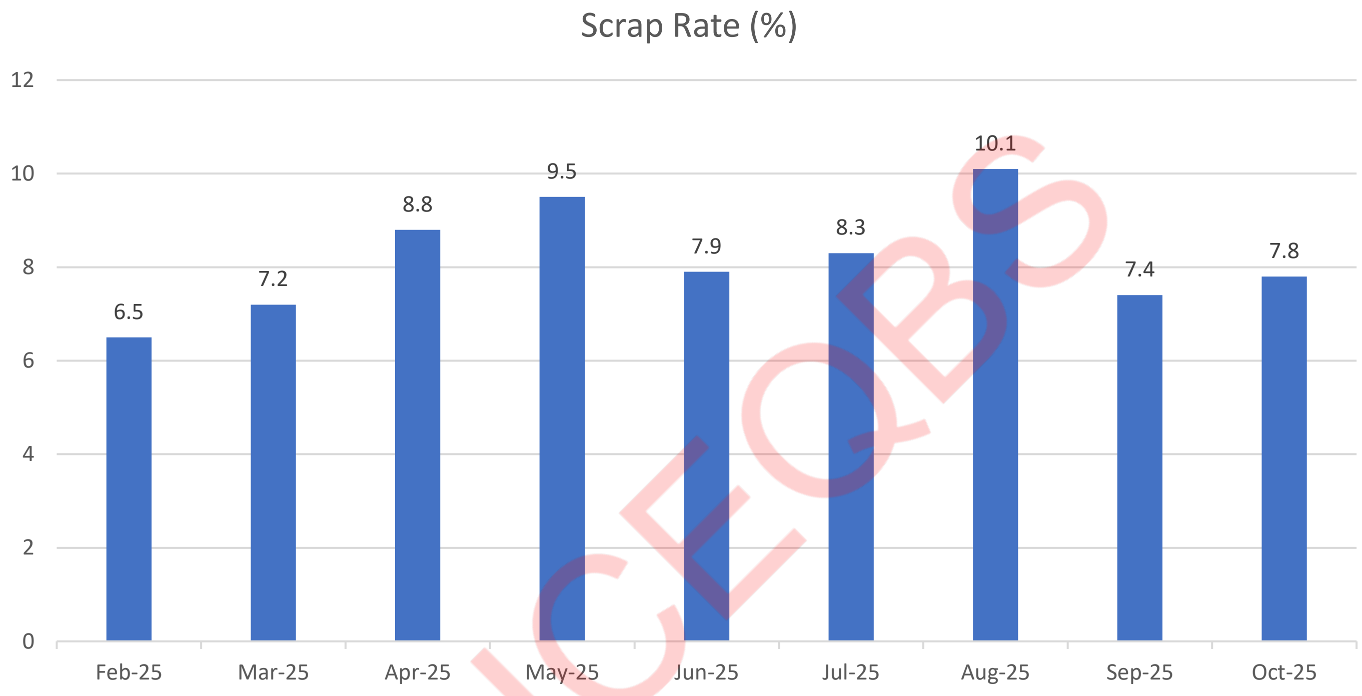


VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
Defect-free, dimensionally accurate, on-time delivered machined parts	CTC – accuracy	**Primary Metric -** Y = Scrap Rate (%) **Secondary Metric -** Productivity

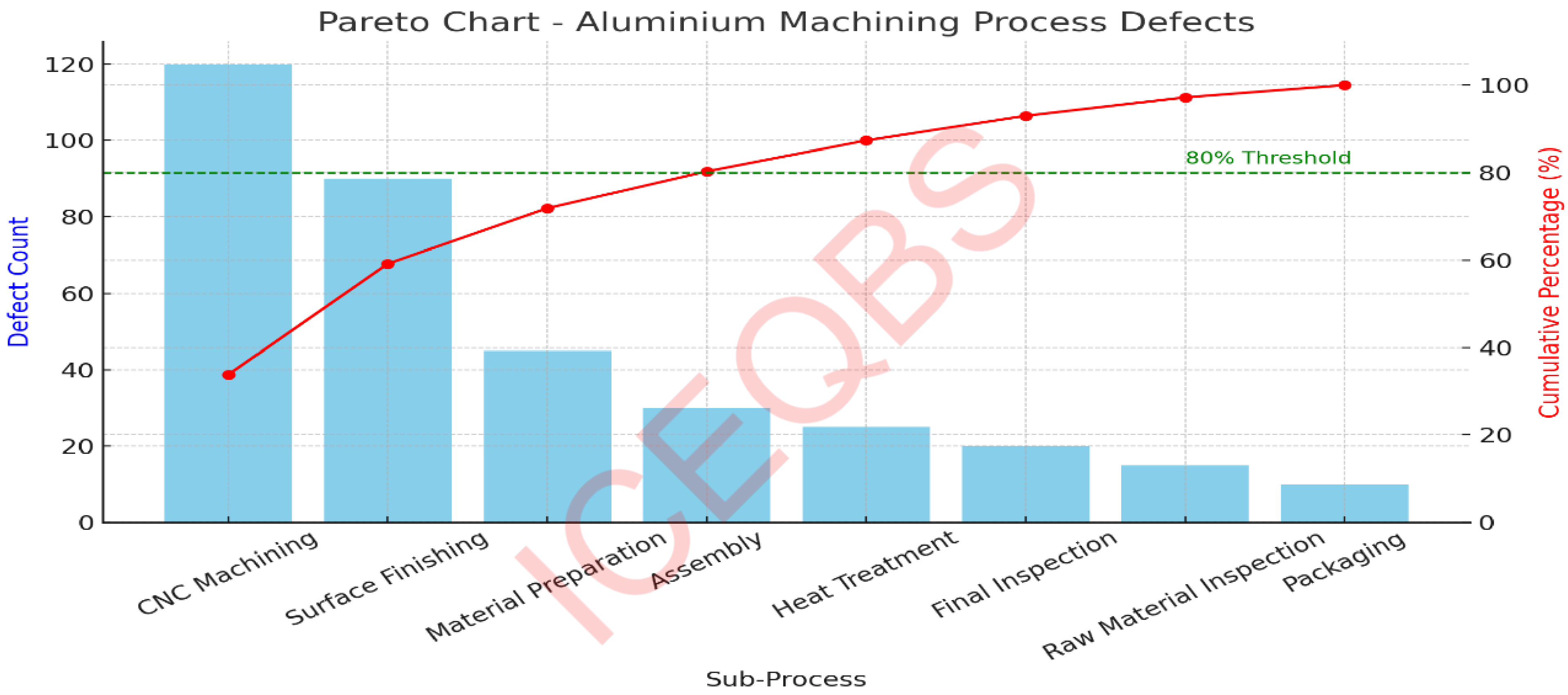
Baseline Performance of Primary Metric (9 months data)



Inference :

- Last 9 months scrap percentage data shows a significant variation and hence ideal problem to be taken up as a Six Sigma Project.

Pareto chart



Inference :

- CNC Machining Process contributes substantially for the scrap and included in the scope of the project

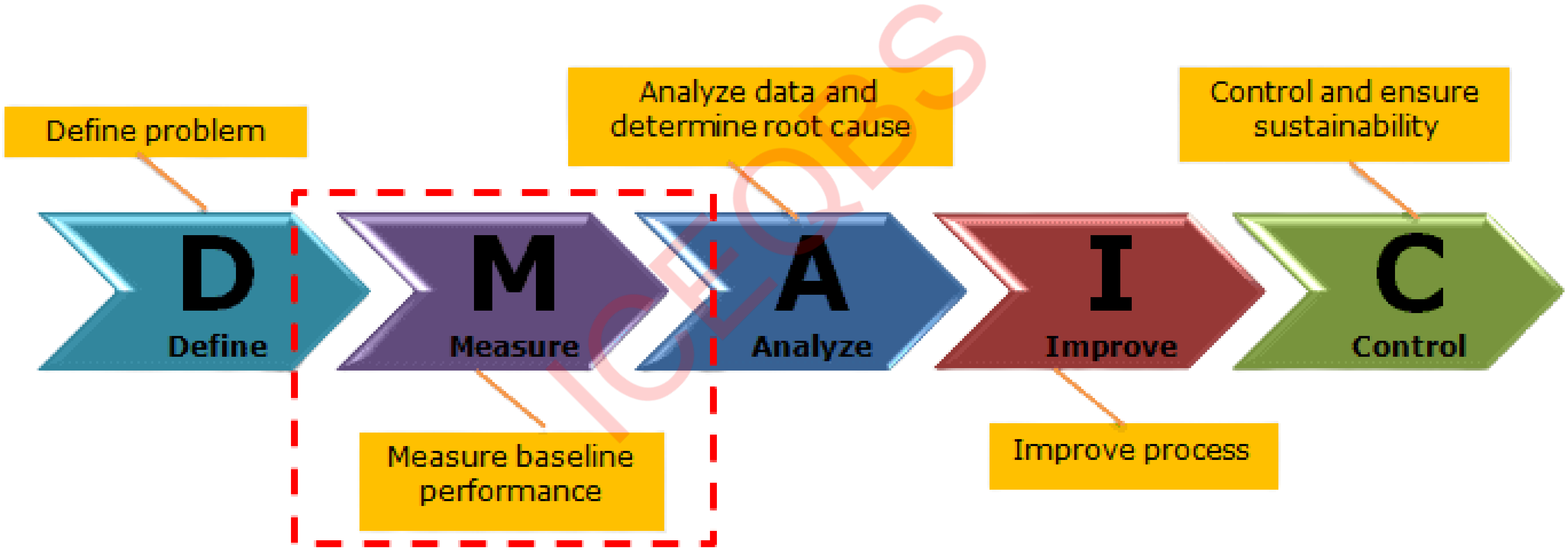
Project Charter

Project Title:	Reduction of Scrap% in Machining process
Project Leader	**Project Team Members:**
Rajesh	Ganaesh kumar Thangavel Venketesh Sivakumar
Champion/Sponsors:	**Key Stake Holders**
Loganathan.K-CEO	
Problem Statement:	**Goal Statement:**
Over the past nine months, the manufacturing line has experienced inconsistent scrap rates averaging 8%, peaking as high as 10%.	Reduce FPY scrap rate from the current average of 8% to 1% within **6 months**
Secondary Metric	**Assumptions Made:**
Productivity	50% of scrap comes from Machining process as per sample

Project Charter

Tangible and Intangible Benefits:	Risk to Success:
Estimated saving = • ₹15 lakhs annual reduction • **Other benefits –** • Yield increase from 70% to 85% • Improved operator ownership	Operator resistance to process changes Equipment instability during initial improvements
In Scope:	**Out of Scope:**
Production line A components Operator performance and training Material handling and process parameters	Non-production departments External supplier defect analysis
Signatories:	**Project Timeline:**
Jayaprakash, Production Manager Loganathan.K-CEO	6 months

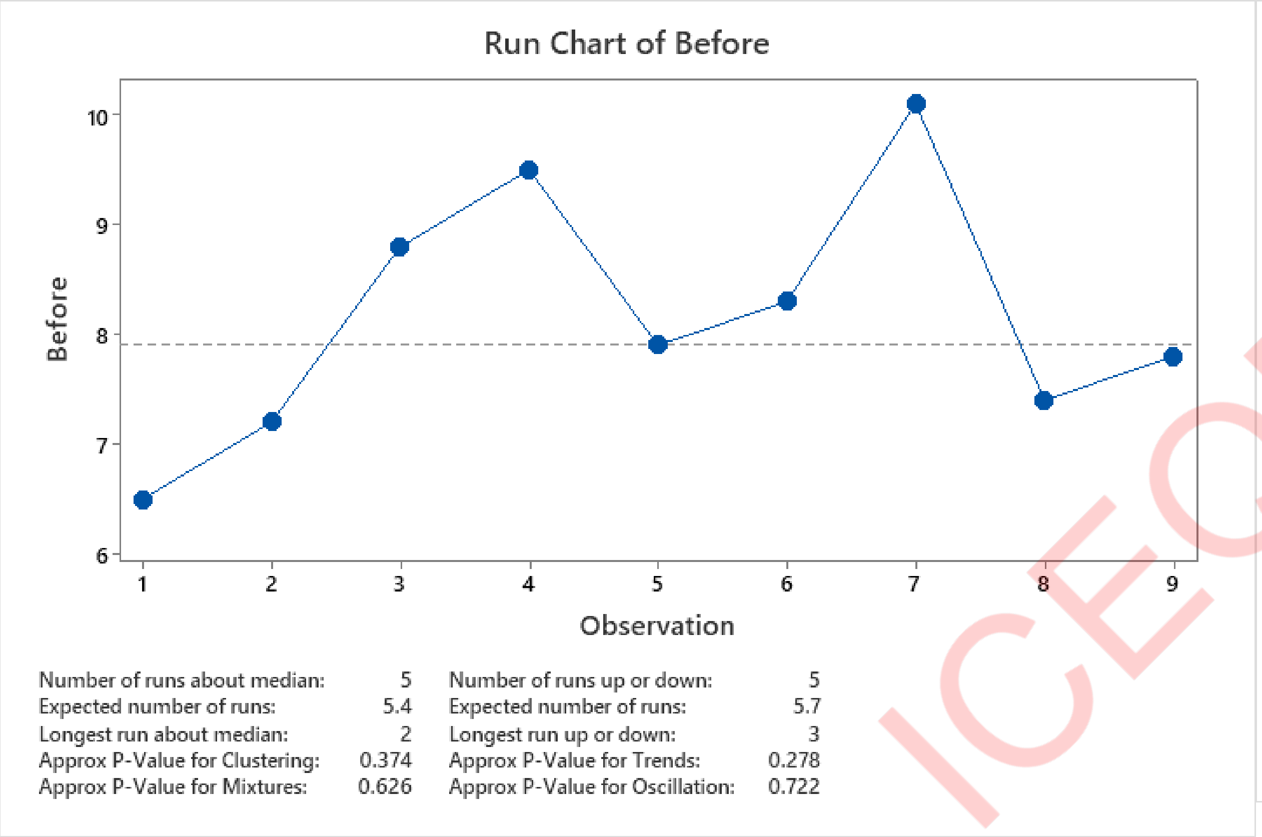
MEASURE PHASE

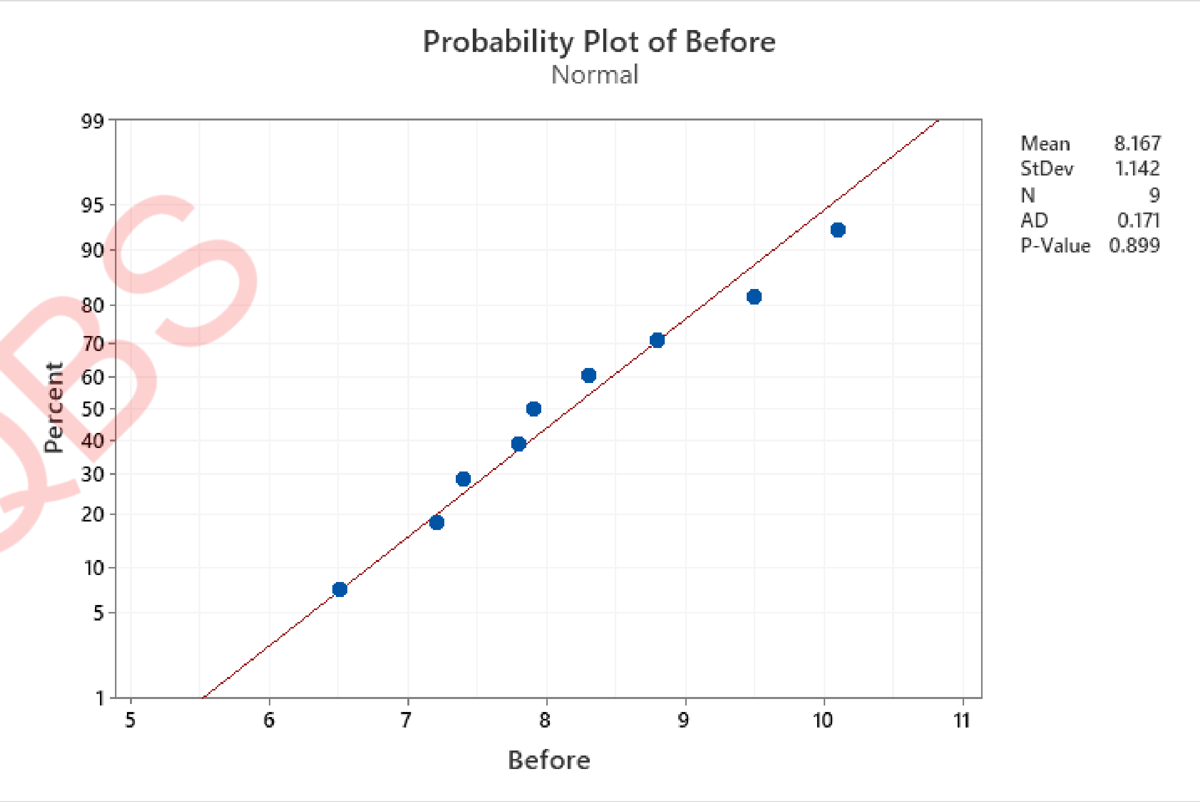


SIPOC

Suppliers (S)	Inputs (I)	Process (P)	Outputs (O)	Customers (C)
- Raw material vendors (steel, plastic, etc.)	- Raw material batches	1. Receive and inspect raw materials	- Manufactured parts/components	- Final assembly unit
- Equipment maintenance team	- Machine settings and calibration data	2. Load material and set up machines	- First Part Yield (FPY) inspection results	- Quality control department
- Production planner	- Production schedule and work orders	3. Operate production line	- Accepted good parts	- Customer/order fulfillment
- Quality assurance team	- Inspection tools, gauges, and checklists	4. Conduct FPY inspection and record defects	- Scrap/rework parts data	- Internal management reporting
- Training department	- Operator skill and training plans	5. Record results and log scrap data	- Updated process performance reports	- End customers (OEM clients)

Data collection

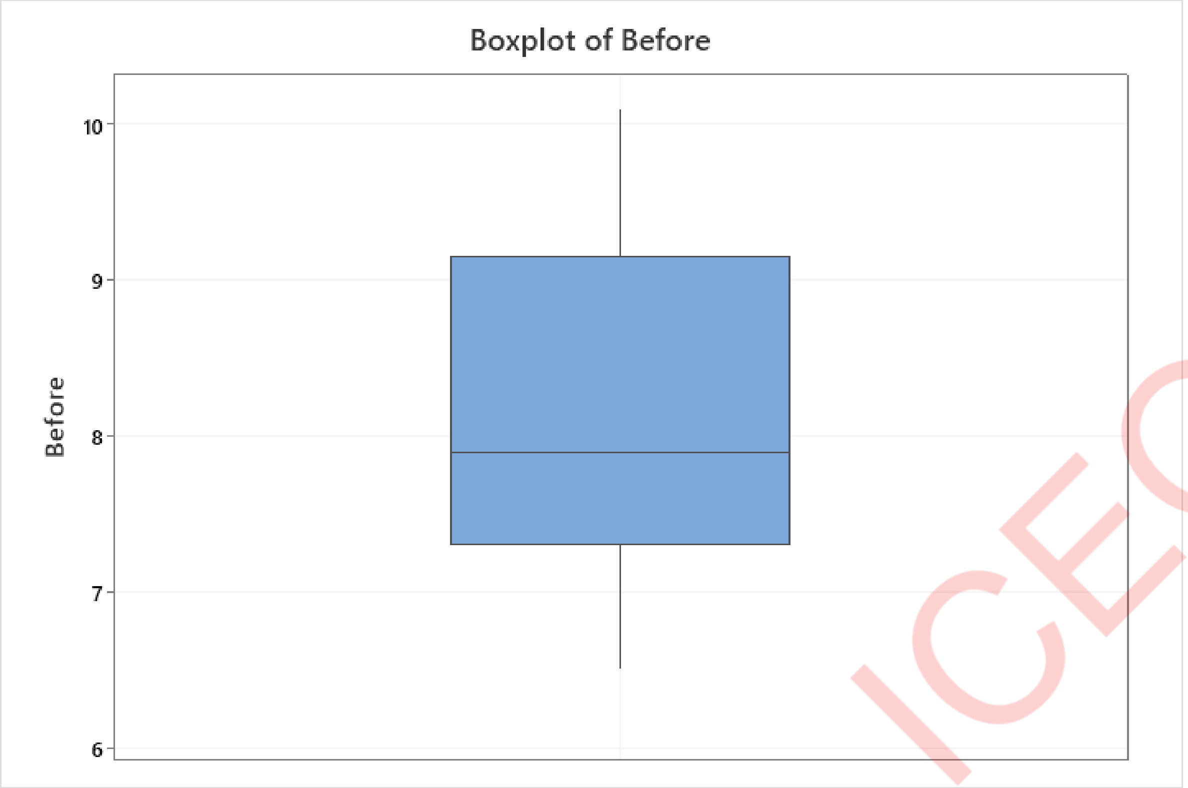


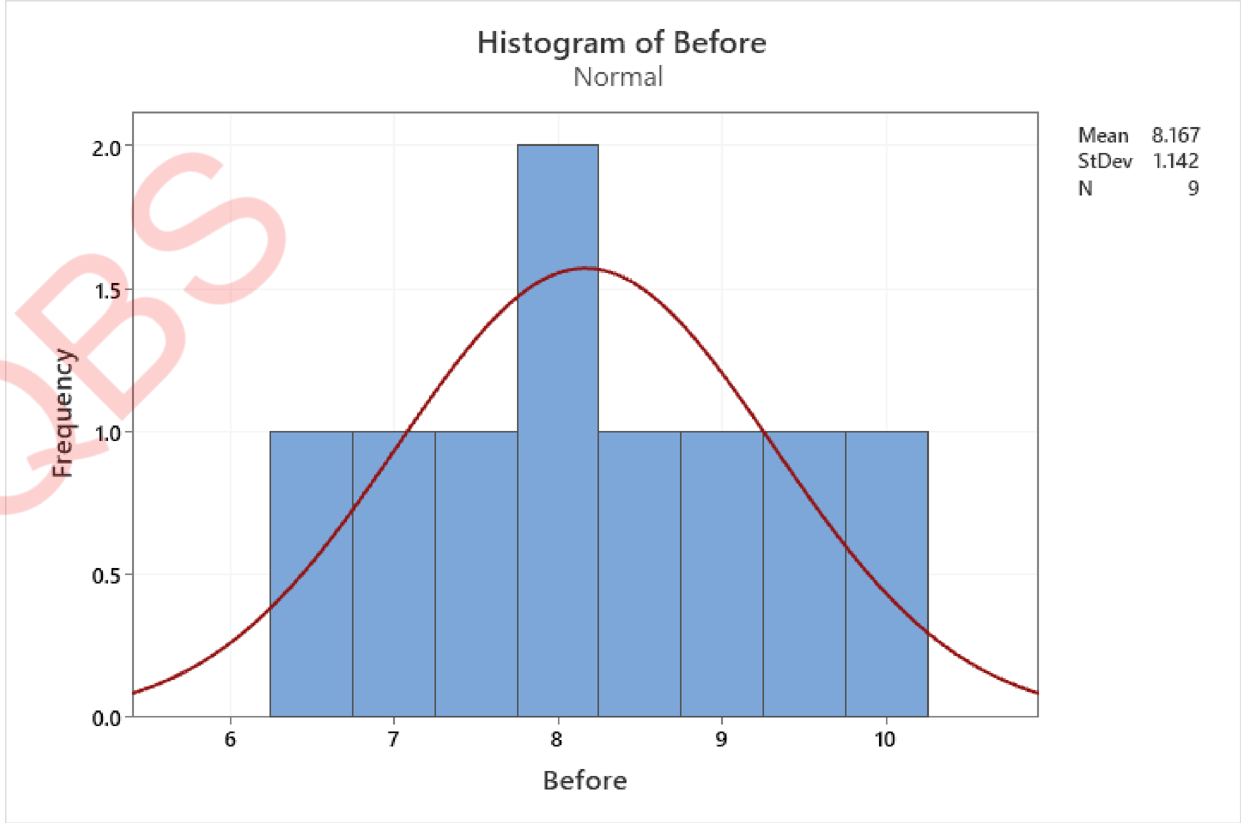


Inference :

- Unstable FPY scrap rate averaging ~8.2%, with normal distribution, confirming a valid but poor-performing process

Data collection

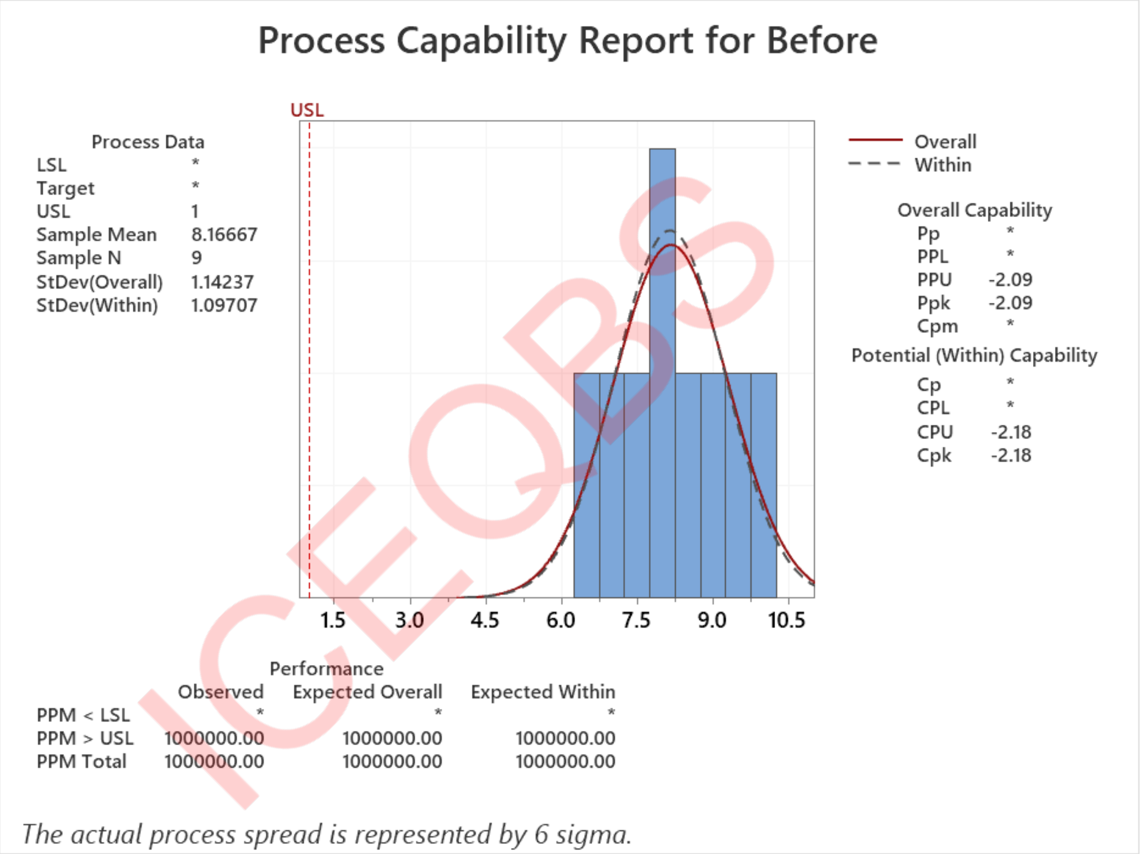




Inference :

FPY scrap rate is centered around ~8% with wide spread and normal variation, indicating consistently high scrap and poor process capability

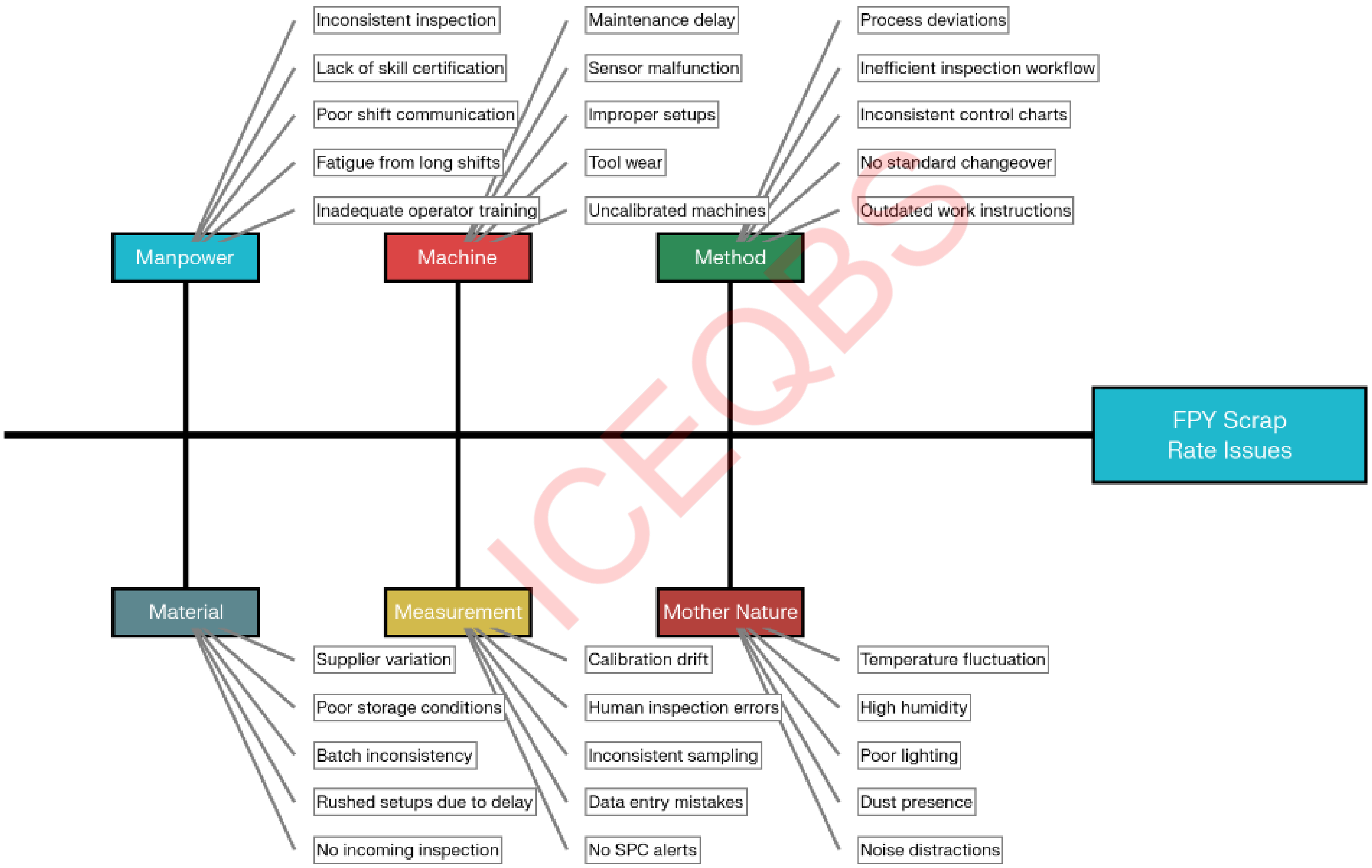
Data collection – Normality plot (Before improvement)



Inference :

- The process is completely incapable \ with the mean scrap rate (~8.17%) far above the USL of 1%, resulting in negative Cpk/Ppk and nearly 100% nonconformance.

Fish Bone Diagram



Common and Special causes

Common Causes

- Minor operator skill variation
- Normal tool wear from usage
- Batch-to-batch raw material variation
- Routine environmental changes (temperature, humidity)
- Systemic process delays or communication lags
- Normal measurement system precision limits
- Minor setup variation between shifts
- Slight calibration drift within tolerance
- Regular equipment vibration and age
- Tool Offset issue

Special Causes

- Machine breakdown or sensor malfunction
- Use of incorrect machine settings
- Sudden raw material contamination or wrong batch
- Operator error due to skipped SOP step
- Incorrect calibration or forgotten gauge reset
- Power fluctuation or electrical failure
- Sudden spike in humidity or uncontrolled heat event
- Tool crash during production setup
- Missing inspection data or data entry error

Urgent rework run under abnormal conditions

3M Analysis for Waste

MUDA

- Excess inventory storage
- Redundant setup adjustments
- Overproduction beyond demand

Mura

- Inconsistent material arrival times
- Variable setup time between operators
- Uneven machine speeds or operator pacing

Muri

- Handling heavy or bulky raw materials manually
- Rushing setup leading to errors
- Machines running beyond capacity

Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Issue Area	Action Items	Lean Tools / Techniques	Expected Benefits	Target Timeline	Responsible
Special Causes	1. Immediate equipment repairs and sensor recalibration	Immediate Kaizen event	Rapid elimination of scrap spikes caused by breakdowns	Within 1 week	Maintenance
	2. Operator retraining on SOP adherence and error-proofing steps	Poka-Yoke, Standard Work	Reduce human errors causing special cause scrap	2 weeks	Quality
	3. Improve incoming material inspection rigor and traceability	5S, Visual Management	Improved raw material quality prevents downstream defects	3 weeks	Procurement
	2. Optimize changeover procedures to minimize errors and variation	SMED (Single-Minute Exchange of Dies)	Reduce variation and downtime during changeovers	5 weeks	Production

Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Issue Area	Action Items	Lean Tools / Techniques	Expected Benefits	Target Timeline	Responsible
Man (Operator)	1. Conduct skills gap analysis and targeted training programs	Training Within Industry (TWI)	Reduce variability and errors	4 weeks	HR/Production
	2. Implement job rotation and empowerment to reduce fatigue	Workload leveling, Job Design	Improved operator engagement and consistent quality	6 weeks	Production
Machine	1. Establish preventive maintenance schedules and checklists	TPM (Total Productive Maintenance)	Reduce unplanned downtime and defects	4 weeks	Maintenance
	2. Use machine data analytics for early fault detection	Condition Monitoring, SPC	Early detection of issues reduces scrap	6 weeks	Maintenance

Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Issue Area	Action Items	Lean Tools / Techniques	Expected Benefits	Target Timeline	Responsible
Method	1. Standardize work instructions and update documentation	Standardized Work, Visual SOPs	Consistency in process reduces variability	4 weeks	Process Engineering
	2. Optimize changeover procedures to minimize errors and variation	SMED (Single-Minute Exchange of Dies)	Reduce variation and downtime during changeovers	5 weeks	Production
Waste (Muda) Elimination	1. Identify and reduce waiting times through line balancing	Value Stream Mapping (VSM)	Improved flow reduces idle time and associated scrap	5 weeks	Lean Team
	2. Eliminate excess motion and transportation via 5S workplace organization	5S (Sort, Set in order, Shine)	Streamlined workspace reduces inefficiencies	3 weeks	Production

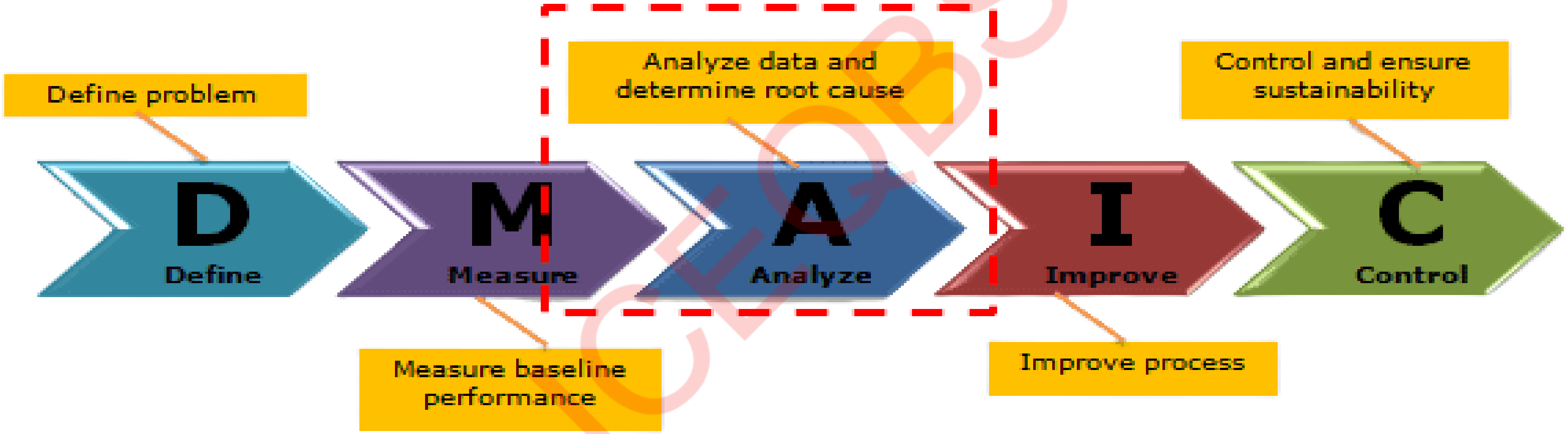
Top 12 Prioritized Root Causes (Based on Net Score)

Root Cause	Score
Tool Wear Condition	171
Tool Offset error	165
Clamping / Fastening of Workpiece	165
Fixture Stability	165
Cutting Speed	135
Feed Rate	135
Tool Path Programming (CAM)	117
Workpiece Material Hardness	117
Raw Material Variability	117
Cutting Tool Material / Grade	117
Tool Wear Condition	171
Tool Offset error	165

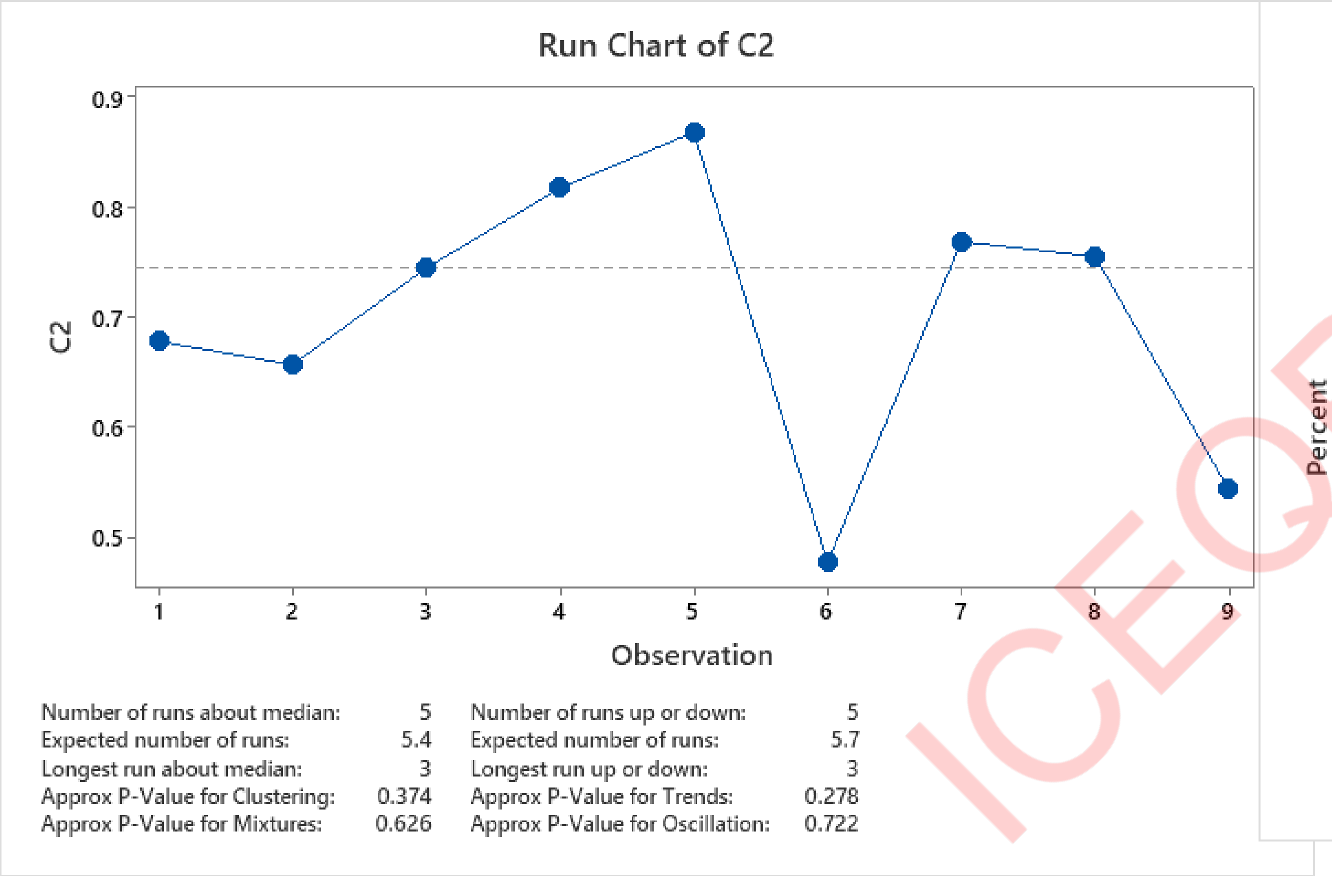
Data Collection Plan

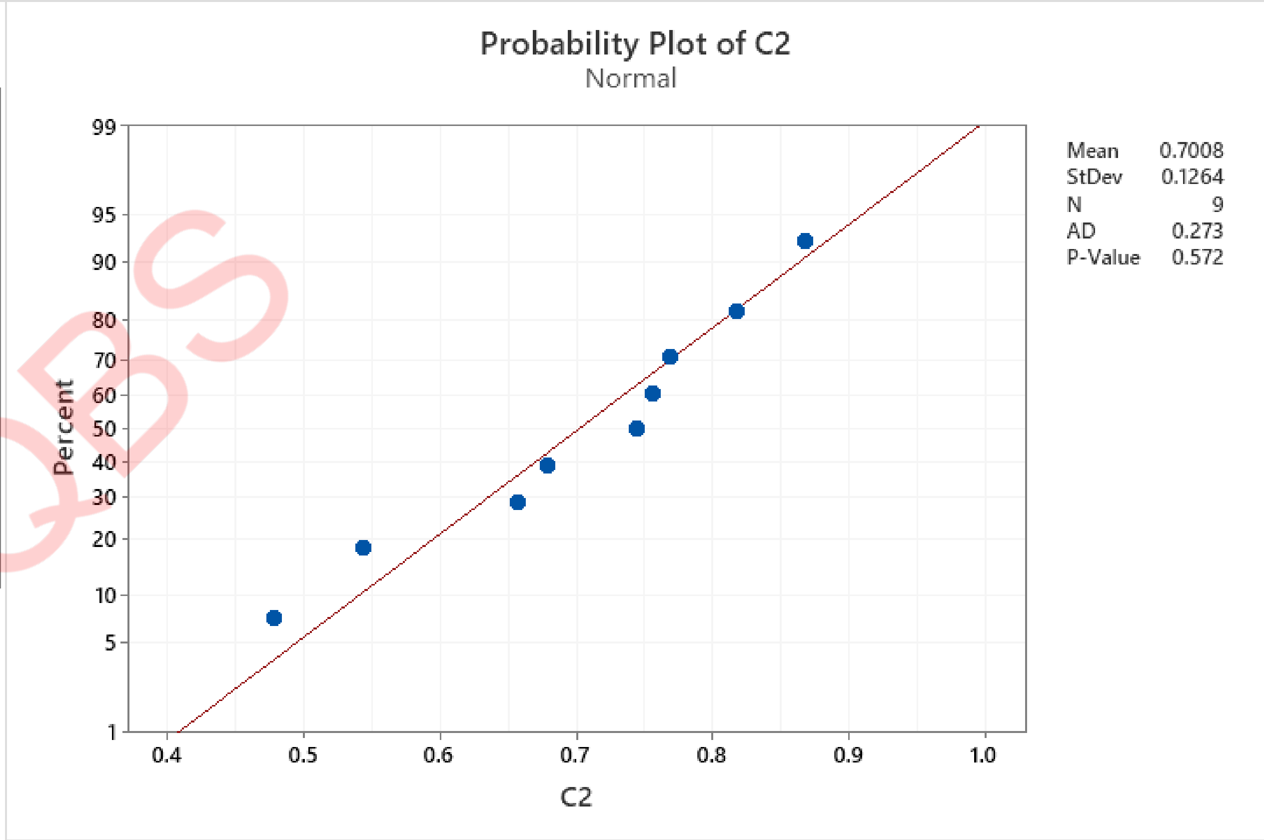
Output / Input	Type of Data	Measurement Method	Unit	Frequency	Responsibility
FPY scrap rate	Output	Production & scrap log review	%	Daily	Quality Engineer
Scrap quantity	Output	Scrap bin count & weighment	Nos / Kg	Daily	Line Supervisor
Rework rate	Output	Rework register	%	Daily	Production Supervisor
Process cycle time	Input	Stopwatch / system time stamp	Minutes	Per shift	Industrial Engineer
Machine downtime	Input	Maintenance log	Minutes	Daily	Maintenance Engineer
Tool change frequency	Input	Tool change record	Count	Daily	Operator
Operator skill level	Input	Skill matrix review	Level	Monthly	Production Manager
Setup variation	Input	Setup checklist verification	Pass / Fail	Per setup	Line Supervisor
Process parameter variation	Input	SPC/control chart	Value	Hourly	Quality Inspector
Maintenance adherence	Input	Preventive maintenance checklist	% compliance	Weekly	Maintenance Head

ANALYSE PHASE



Analyse – Hypothesis testing

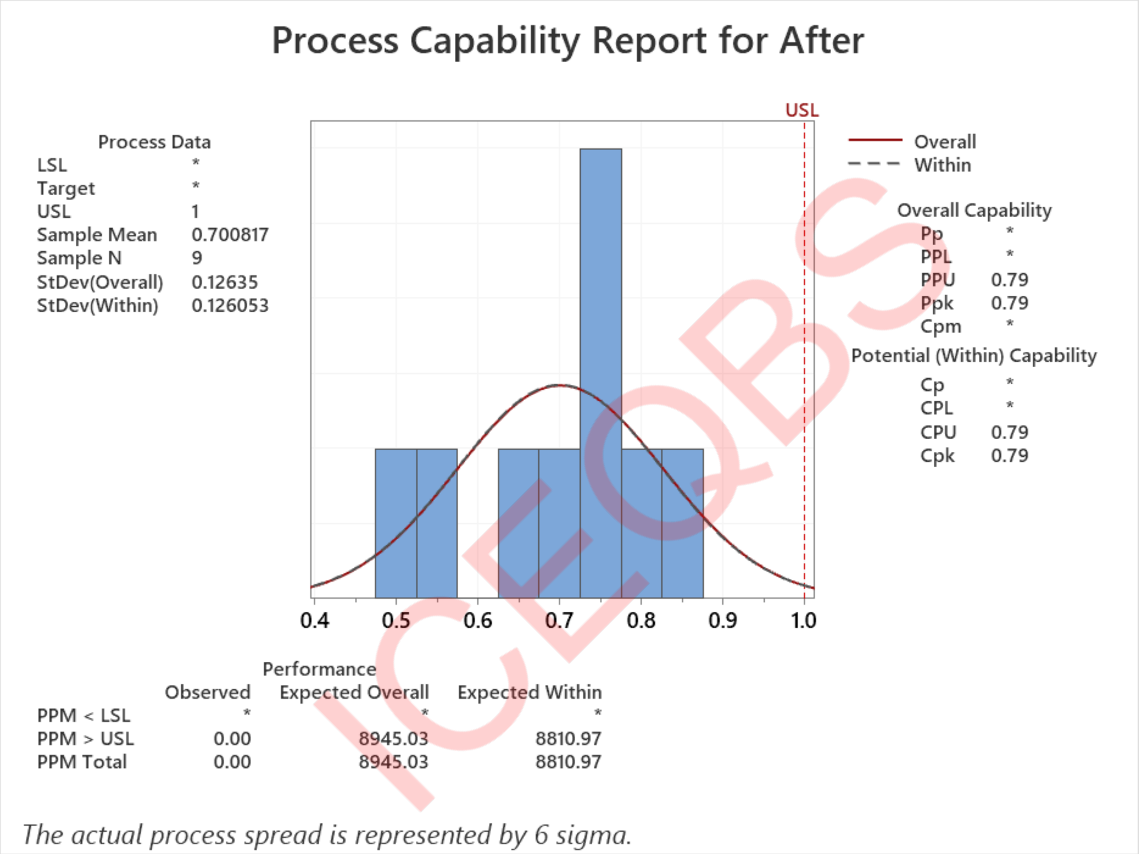




Inference :

- C2 data is normally distributed (mean ≈ 0.70),

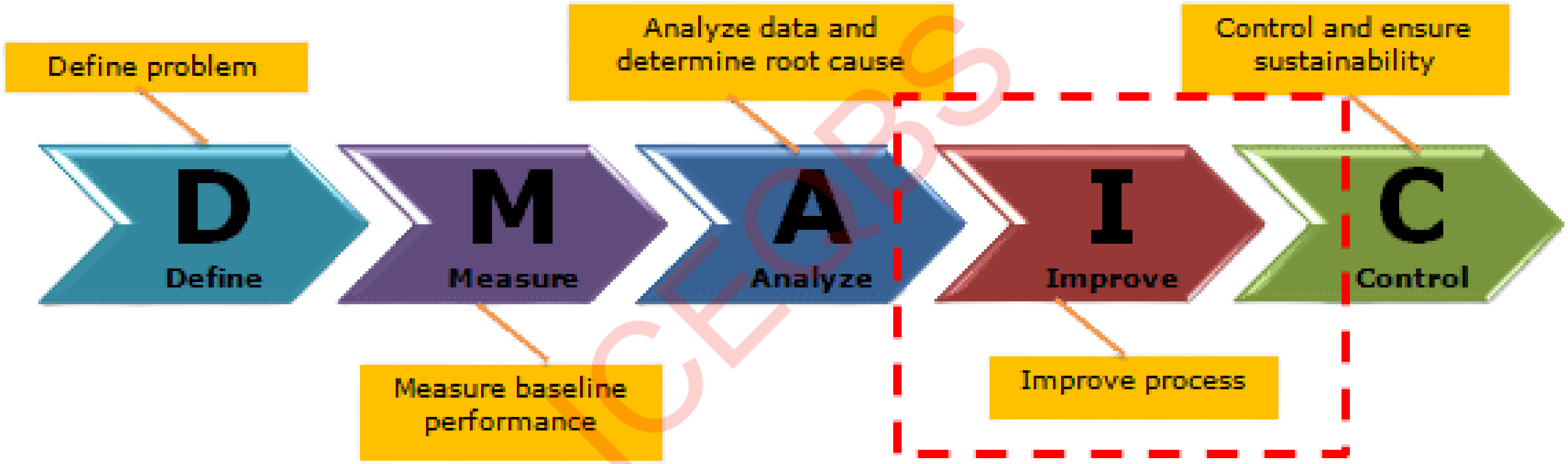
Analyse



Inference :

- After improvement, the process shows significant reduction in variation with a mean of ~0.70 below the USL of 1, and a positive Cpk (~0.79), indicating a stable and improved— process.

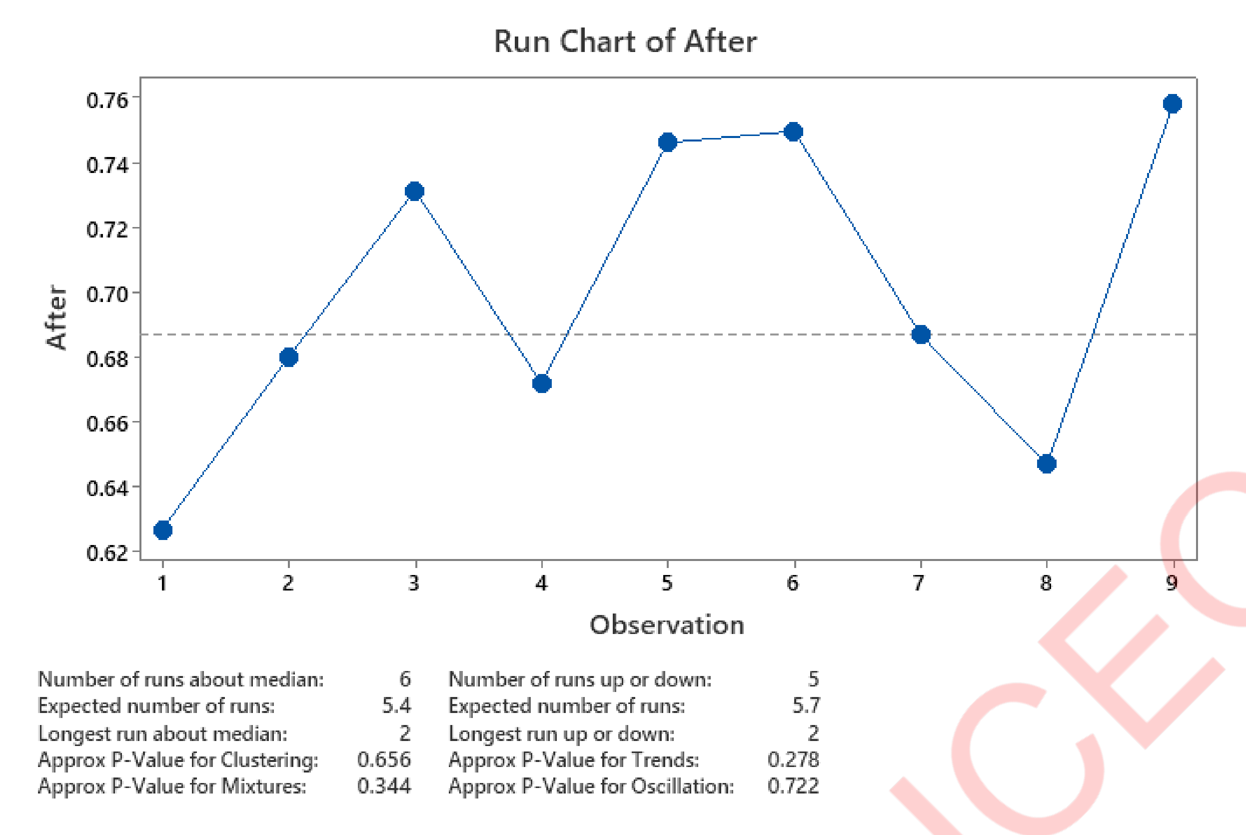
IMPROVE PHASE

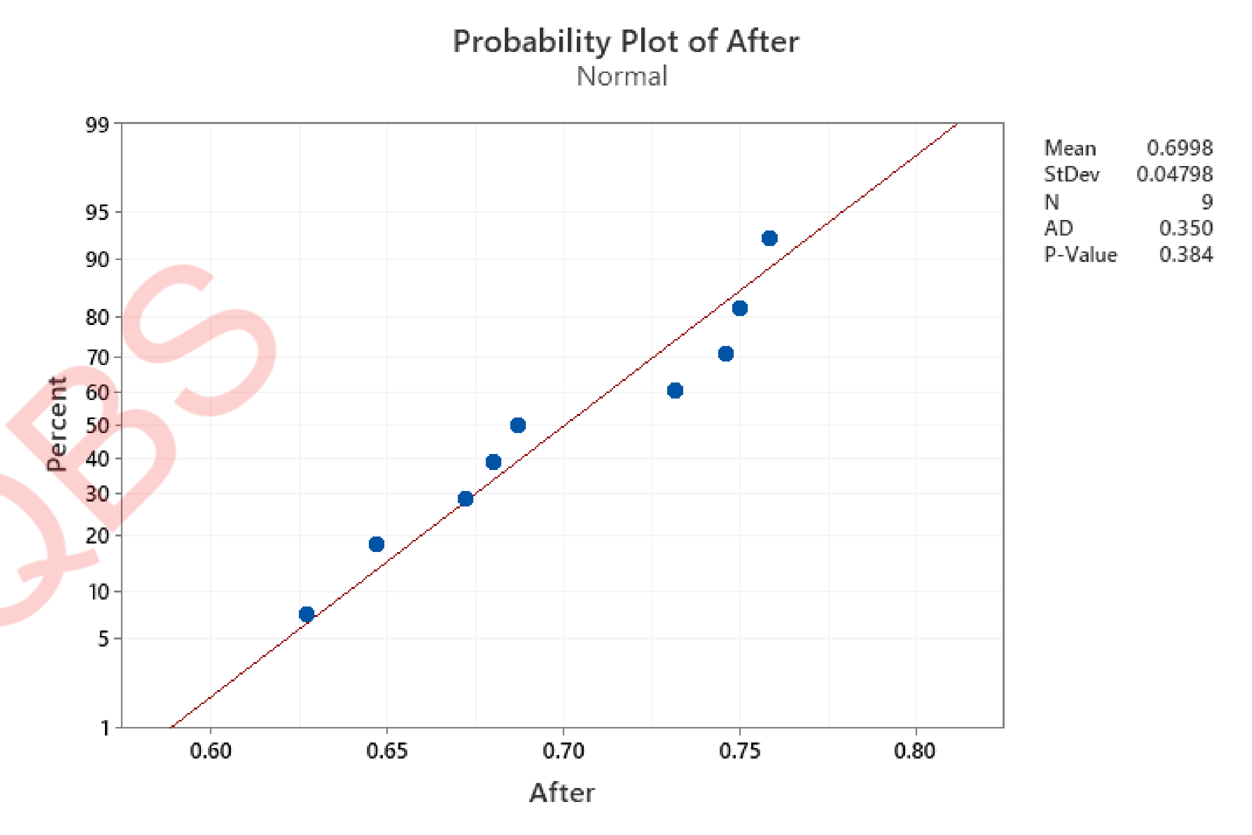


Improve Design of Experiment

Run Order	Type	A_ToolWear_code	B_ToolLifeOverrun_code	C_CutParamDev_code	Tool_Wear_mm	Tool_Life_Overrun_%	CutParam_Dev_%	Scrap_Machining_%
1	Factorial	1	1	-1	0.25	40	3	0.00
2	Factorial	-1	-1	-1	0.05	0	3	0.94
3	Factorial	-1	-1	1	0.05	0	13	0.00
4	Center	0	0	0	0.15	20	8	9.61
5	Factorial	1	-1	1	0.25	0	13	0.00
6	Center	0	0	0	0.15	20	8	9.43
7	Factorial	-1	1	1	0.05	40	13	30.68
8	Center	0	0	0	0.15	20	8	9.52
9	Factorial	1	1	1	0.25	40	13	38.14
10	Factorial	1	-1	-1	0.25	0	3	27.70
11	Factorial	-1	1	-1	0.05	40	3	0.00

Improve – Run chart and Normality Test (After Improvement)





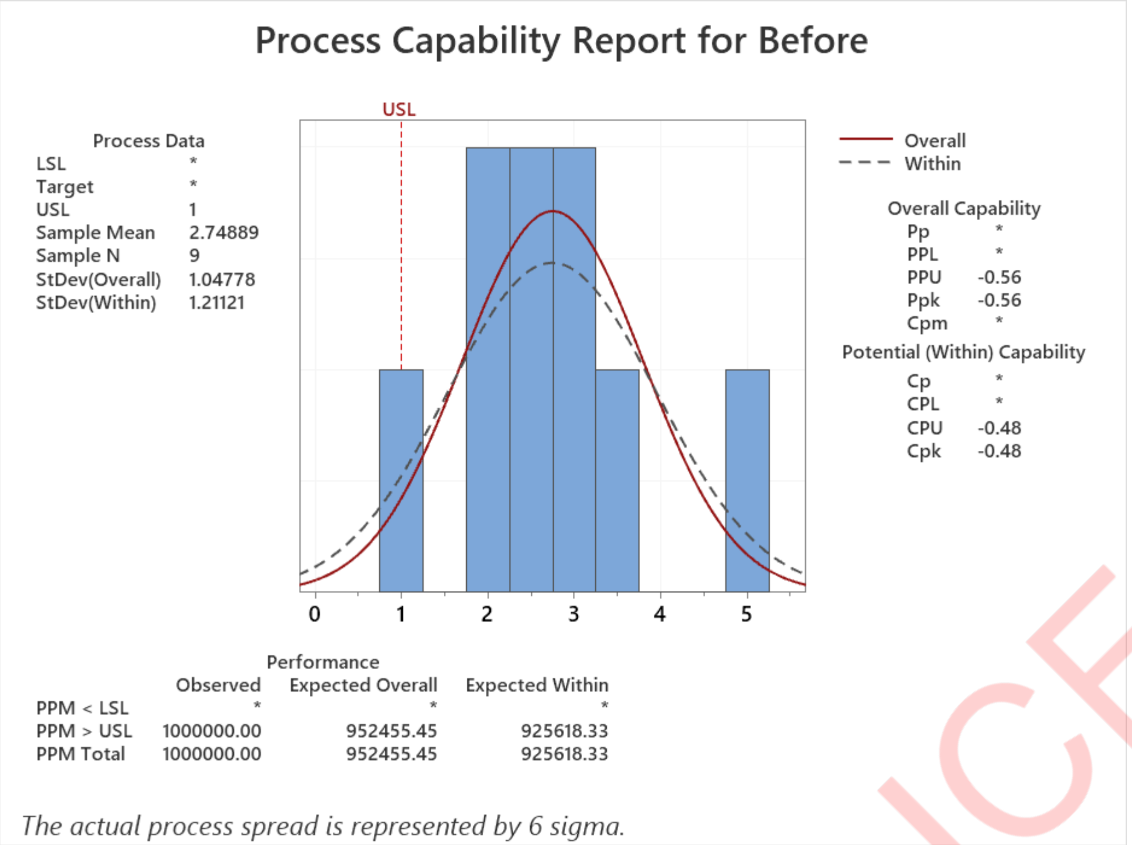
Inference:

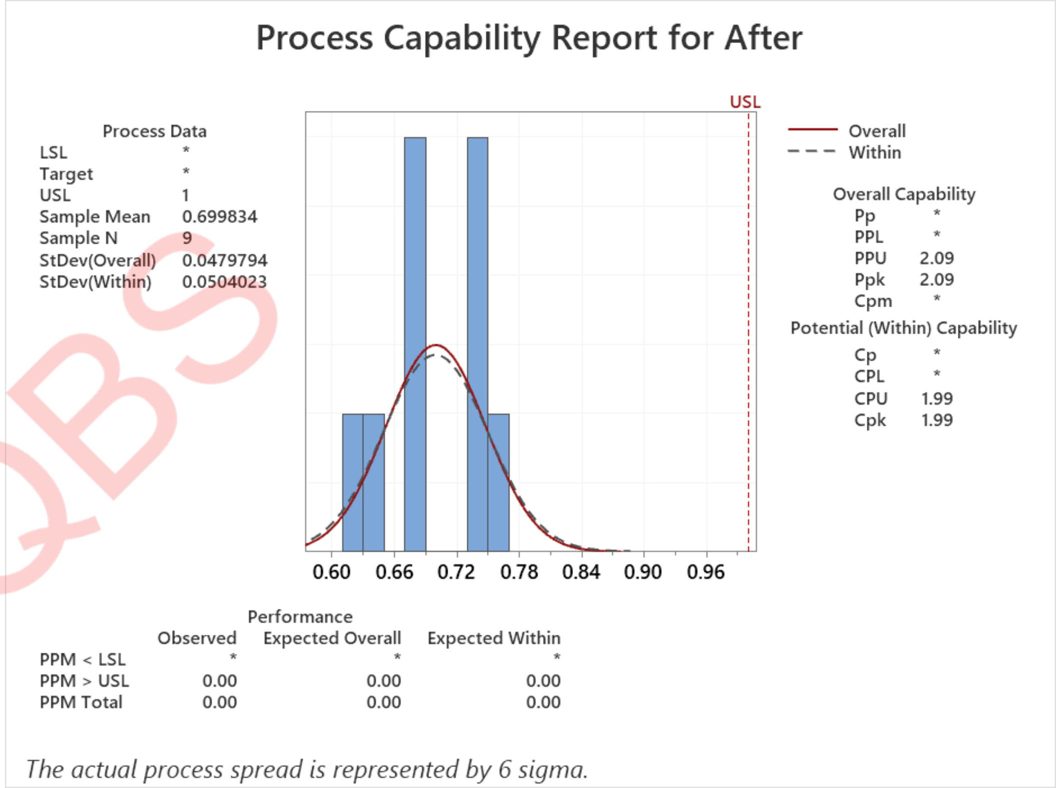
- Run chart – process is stable there is no special causes in the process (p value > 0.05)

Inference:

- Normality test – Data are normally distributed

Improve – Process capability – Before & After Improvement

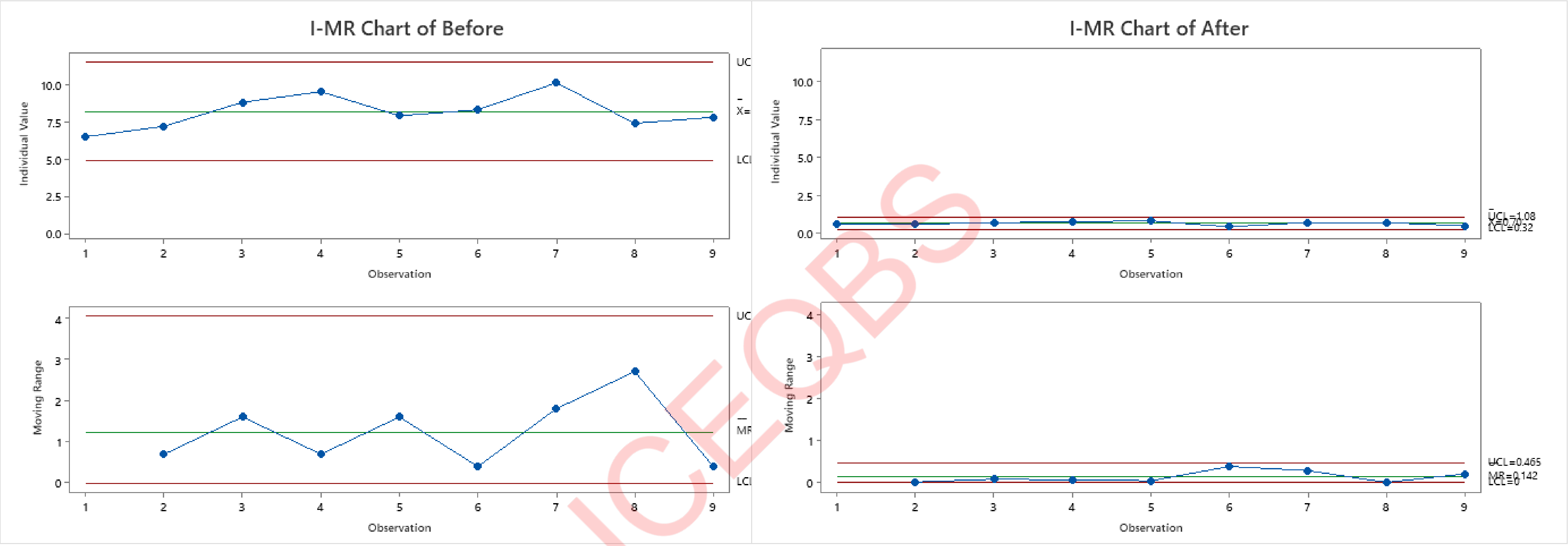




Inference :

- Before Cpk < After Cpk, which shows process is much more capable after improvement
- There is less variability in system since stdev reduced after improvement
- After improvement the data are normally distributed near the target within specified limit

Improve (Statistical validation for Improvement – I-MR Chart)

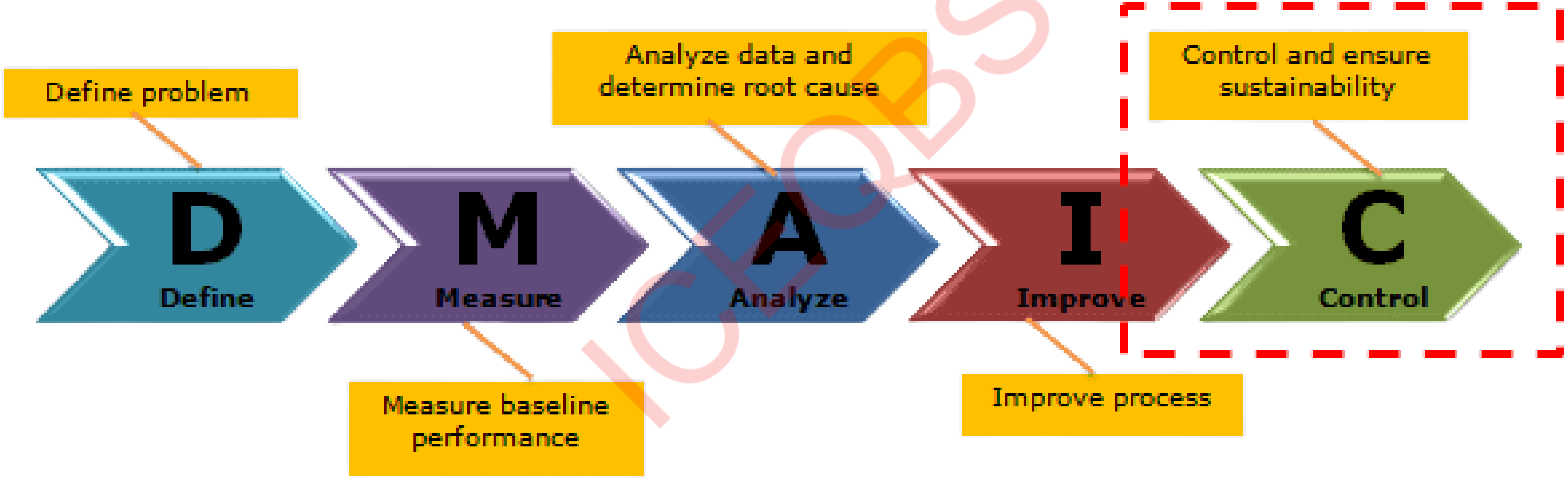


The I-MR charts show that after improvement the process mean has shifted downward with drastically reduced moving range, and all points are well within control limits, confirming a stable and controlled scrap reduction process.

FMEA

Process Step	Function / Requirement	Potential Failure Mode	Potential Effects	S	Potential Causes / Mechanisms	O	Current Controls (Prev / Det)	D	Recommended Actions (Acceptance Criteria)	Owner	Target	Residual S	Residual O	Residual D
Machining	Maintain dimensional accuracy	Excessive tool wear	High scrap, rework	9	Tool wear beyond limit	6	Periodic visual check	6	Define tool wear limit ≤0.15 mm; SPC monitoring	Production Engg	Feb-26	9	2	3
Machining	Complete operation within tool life	Tool life overrun	Surface defects, scrap	8	Tool used beyond life	5	Manual tool change log	5	Auto tool-life counter; change at ≤20% overrun	Maintenance	Feb-26	8	2	3
Machining	Maintain cutting parameters	Cutting parameter deviation	Dimensional variation	8	Operator adjustment	4	Setup sheet	6	Lock CNC parameters; deviation ≤±5%	CNC Lead	Mar-26	8	2	2
Setup	Correct setup before run	Improper setup	Initial batch scrap	7	Incomplete setup checklist	4	First-piece inspection	5	Mandatory setup checklist + sign-off	Shift In-charge	Jan-26	7	2	3
Maintenance	Equipment readiness	Poor machine condition	Process variation	7	Missed PM activities	3	Monthly PM	5	Weekly PM compliance ≥95%	Maintenance Head	Mar-26	7	1	3
Operator	Follow standard work	Skill variation	Inconsistent quality	6	Inadequate training	3	On-job training	4	Skill certification for operators	HR / Prod	Apr-26	6	1	3

CONTROL PHASE



Control Plan

Area / Process	Type (5S / Poka-Yoke)	Mechanism	Purpose	Responsibility
Tool storage	5S	Shadow boards with tool wear limits marked	Prevent use of worn tools	Line Supervisor
Tool change point	Poka-Yoke	Tool-life counter with auto stop	Avoid tool life overrun	Maintenance
CNC setup	5S	Standard setup checklist at machine	Ensure correct setup every time	CNC Operator
CNC parameters	Poka-Yoke	Parameter lock / password protection	Prevent unauthorized changes	Production Engg
Measurement tools	5S	Dedicated gauge locations with calibration tags	Ensure correct measurement usage	Quality
Raw material loading	Poka-Yoke	Orientation fixture / foolproof loading	Prevent wrong loading	Operator
Workstation	5S	Visual marking for WIP and scrap bins	Avoid mix-ups and delays	Line Supervisor
Process monitoring	Poka-Yoke	SPC alerts when limits breached	Early defect detection	Quality Engineer

Control Plan

Process Step	CTQ / KPI	Target	Monitoring Method	Frequency
Tool condition	Tool wear (mm)	≤ 0.15 mm	Tool wear gauge & SPC chart	Per shift
Tool life	Tool life overrun (%)	≤ 20%	Tool-life counter	Daily
CNC setup	Setup compliance	100%	Setup checklist	Per setup
Cutting parameters	Parameter deviation	≤ ±5%	CNC parameter audit	Daily
First-piece quality	FPY (%)	≥ 99%	First-piece inspection	Per batch
Scrap rate	Scrap %	≤ 1%	Scrap log & control chart	Daily
Preventive maintenance	PM compliance	≥ 95%	PM checklist	Weekly
Operator skill	Skill certification	100%	Skill matrix	Quarterly

Conclusion

Results after improvement

- **By stabilizing the process and embedding robust controls, this project delivers sustained FPY improvement, reduced scrap, and a culture of proactive quality excellence.**