Reducing Bore Oversize Rejection Rate

VIGNESH

ROADMAP

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

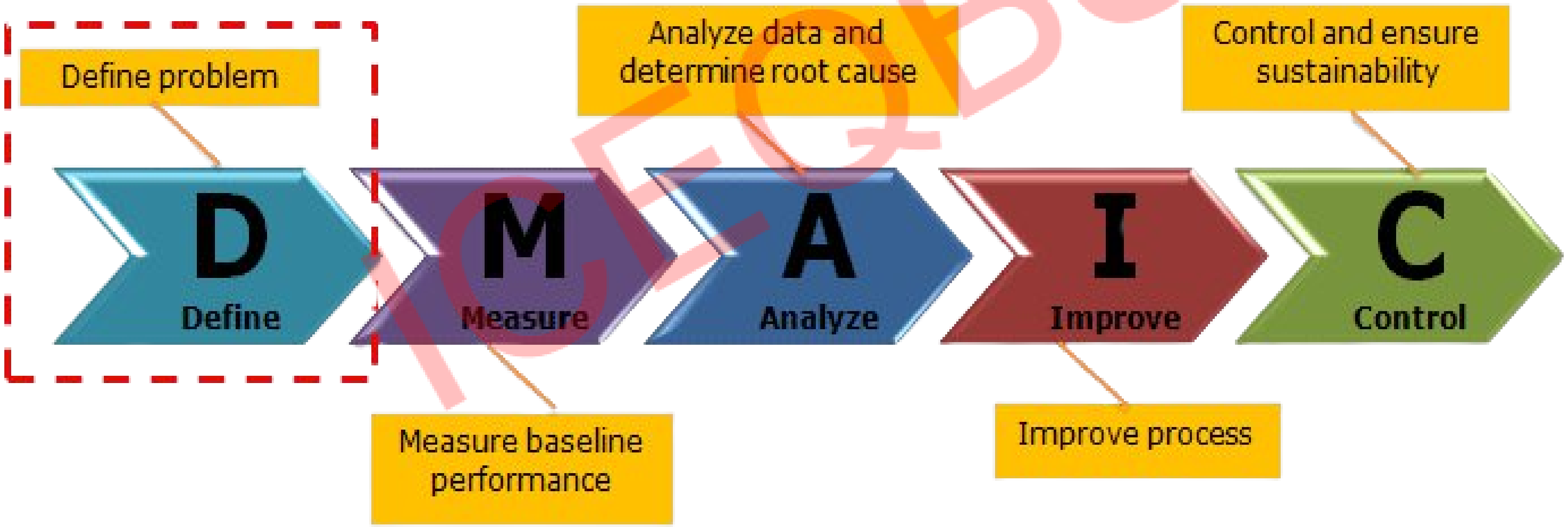

OVERVIEW

Background

The machining process currently generates a 2.5% rejection rate due to bore oversize, leading to increased scrap, rework, production delays, and additional operational costs. These defects directly impact customer satisfaction by causing delivery delays and quality concerns. By reducing the rejection rate to 1%, the organization can significantly improve product quality, ensure dimensional compliance, and strengthen customer confidence.

Financially, the improvement presents a strong cost-saving opportunity. With an estimated cost of $100 per part, reducing defects from 2.5% to 1% in a lot of 10,000 components can result in savings of approximately $20,000. This project supports the company's goals of waste reduction, improved process capability, timely delivery, and enhanced competitiveness in the market.

DEFINE PHASE

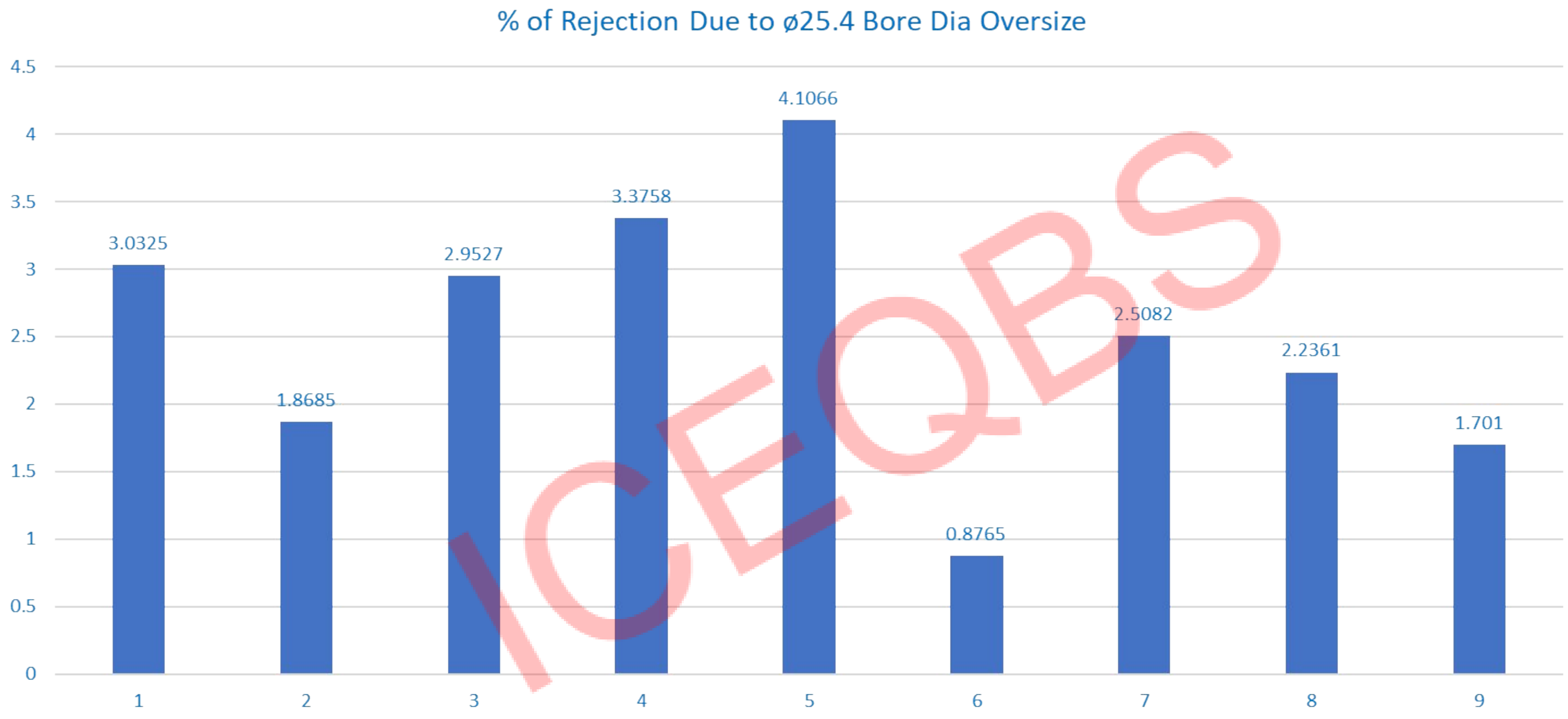


VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
"Machined Bores size must be within specified dimensional tolerance with Consistent quality"	CTC – % of parts rejected due to oversize	**Primary Metric -** Y = Reduce % of scrap in Bore Dia oversize **Secondary Metric -** Productivity / Output per day

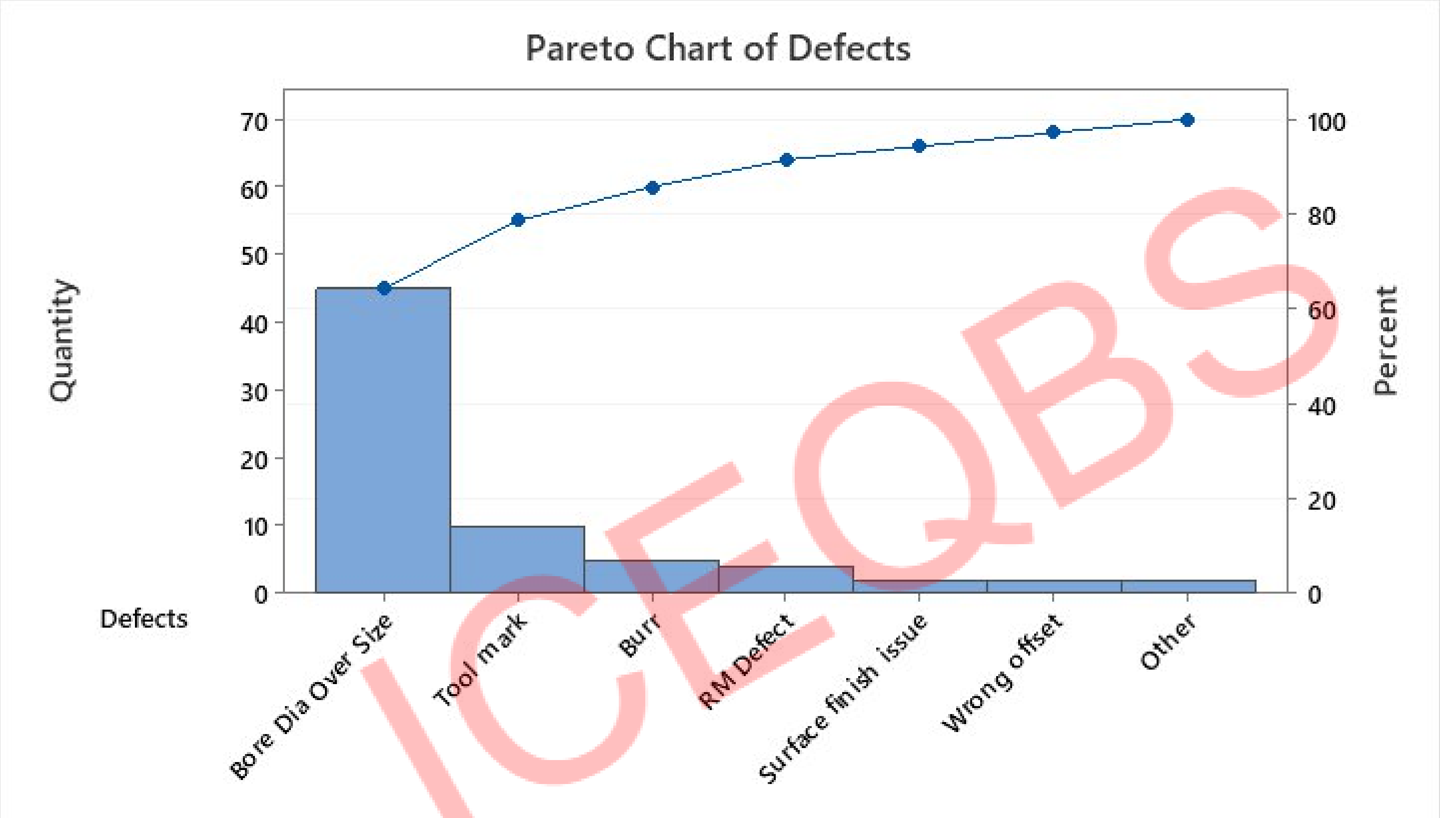
Baseline Performance of Primary Metric (9 months data as Line chart)



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



Defects	Bore Dia Over Size	Tool mark	Burr	RM Defect	Surface finish issue	Wrong offset	Other
Quantity	45	10	5	4	2	2	2
Percent	64.3	14.3	7.1	5.7	2.9	2.9	2.9
Cum %	64.3	78.6	85.7	91.4	94.3	97.1	100.0

Inference :

•Bore Diameter oversize contributes substantially for the scrap and included in the scope of the project

SIPOC

S (Suppliers)	I (Inputs)	P (Process)	O (Outputs)	C (Customers)
Tool suppliers (cutting tools, inserts)	Cutting parameters (speed, feed, depth)	Replace worn tools / adjust parameters	Machined components	External Customer OEM
Machine manufacturer / service	Raw material	Perform machining operation	Components within tolerance	QC / Inspection team
Maintenance team	Machine calibration data	Select and mount cutting tools	Components with proper Bore Diameter	Assembly department
Engineering team (process specs)	Lubricants / coolant	1. Setup machine and fixtures	Rework parts (if any)	Production department
QC team	Inspection instruments	4. Inspect parts (bore size)	Rejection reports	Production / Maintenance team

Project Charter

Project Title:	Reducing Bore Oversize Rejection Rate

Project Leader	Project Team Members:
Vignesh M	Arunkumar A Prabu R Thanveer A Tijo V
Champion/Sponsors:	**Key Stake Holders**
Plant Head – Production	Production Department End Customer / Client Third-Party Inspection Agency
Problem Statement:	**Goal Statement:**
Currently, the machining process produces components with bore oversize resulting in **2.5% rejection rate**, causing increased rework, delayed delivery, and additional cost to the organization, The high scrap rate affects delivery timelines and customer satisfaction	Reduce the rejection rate from 2.5% to 1% within 3 months by eliminating bore oversize issues, ensuring all parts meet dimensional tolerance specifications.
Secondary Metric	**Assumptions Made:**
Productivity / Output per day	The bore oversize issue is primarily due to controllable process factors (tool wear, machine condition, operator method, etc.). Production volume, material grade, and customer specifications will remain consistent during the improvement period.

Project Charter

Tangible and Intangible Benefits:

Reduction in rejection rate from 2.5% to 1%, resulting in direct annual savings (~$20,000 per 10,000 parts).
Lower rework cost and improved machine utilization.

Enhanced customer satisfaction and improved brand reputation due to consistent quality.

Risk to Success:

Machine downtime or breakdowns during the improvement phase could delay implementation.
Operator resistance to new procedures or process changes may affect consistency.

In Scope:

This project focuses on reducing scrap due to bore diameter oversize in the machining process from 3% to 1%. It includes analysis and improvement of factors affecting bore size on the identified machine/process line.

Out of Scope:

Design changes in components.
Non-machining related processes (painting, assembly beyond fit check).

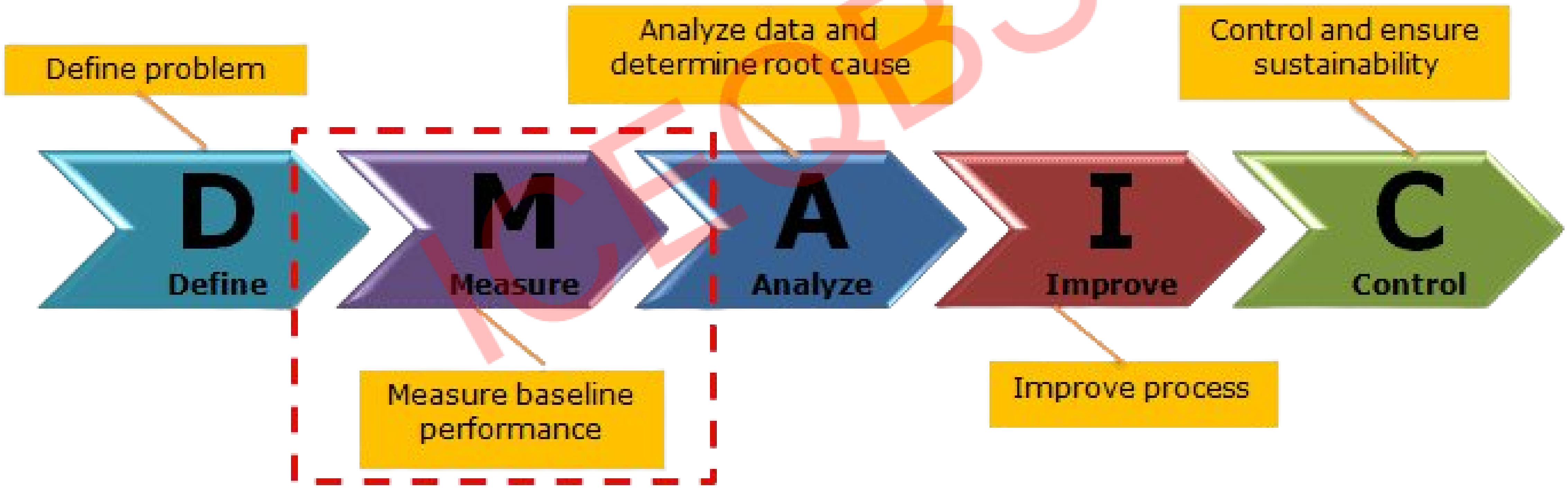
Signatories:

Mr. Suresh Kumar - Plant Head
Mr. Srinivasan S N - Quality Manager

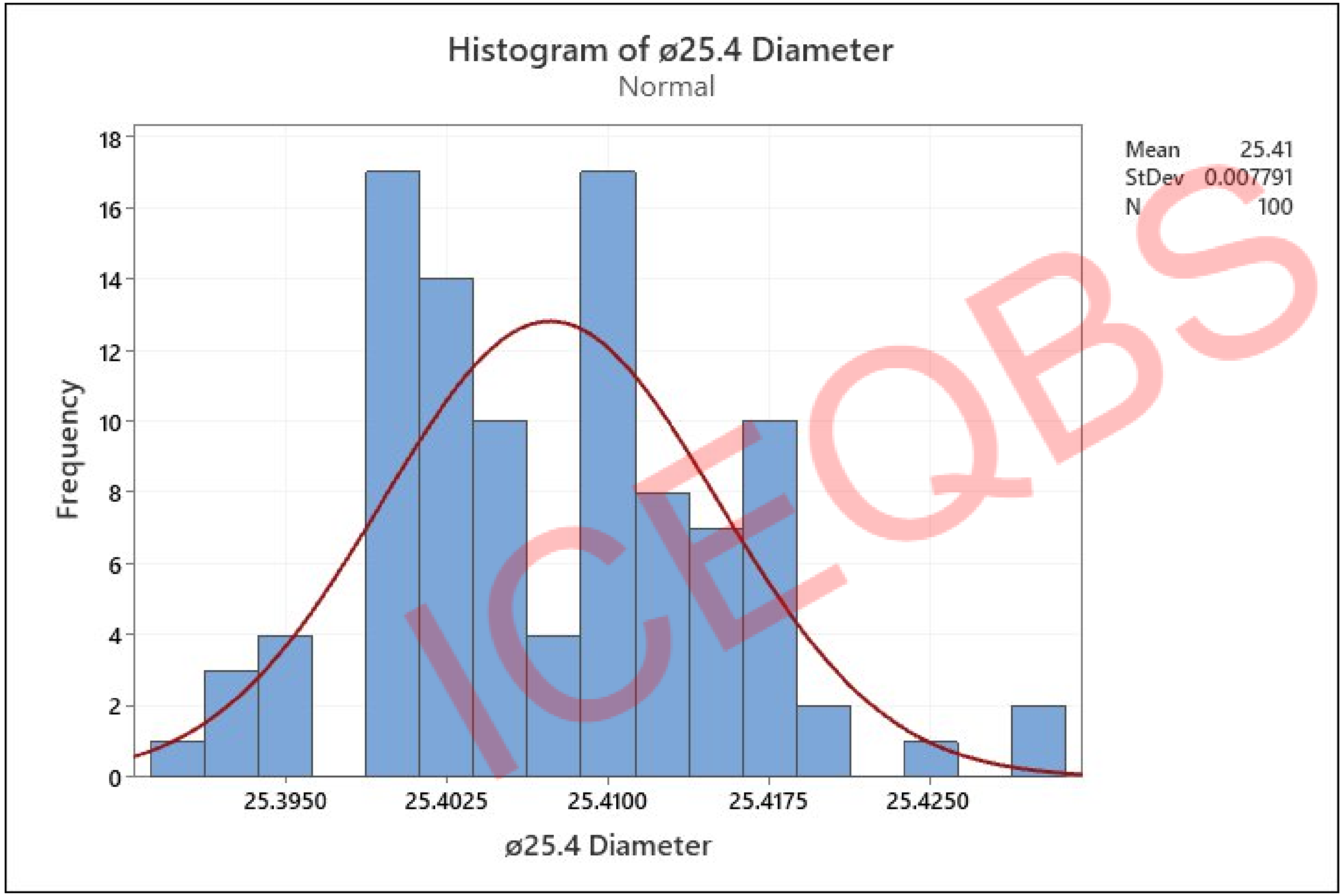
Project Timeline:

6 Months

MEASURE PHASE



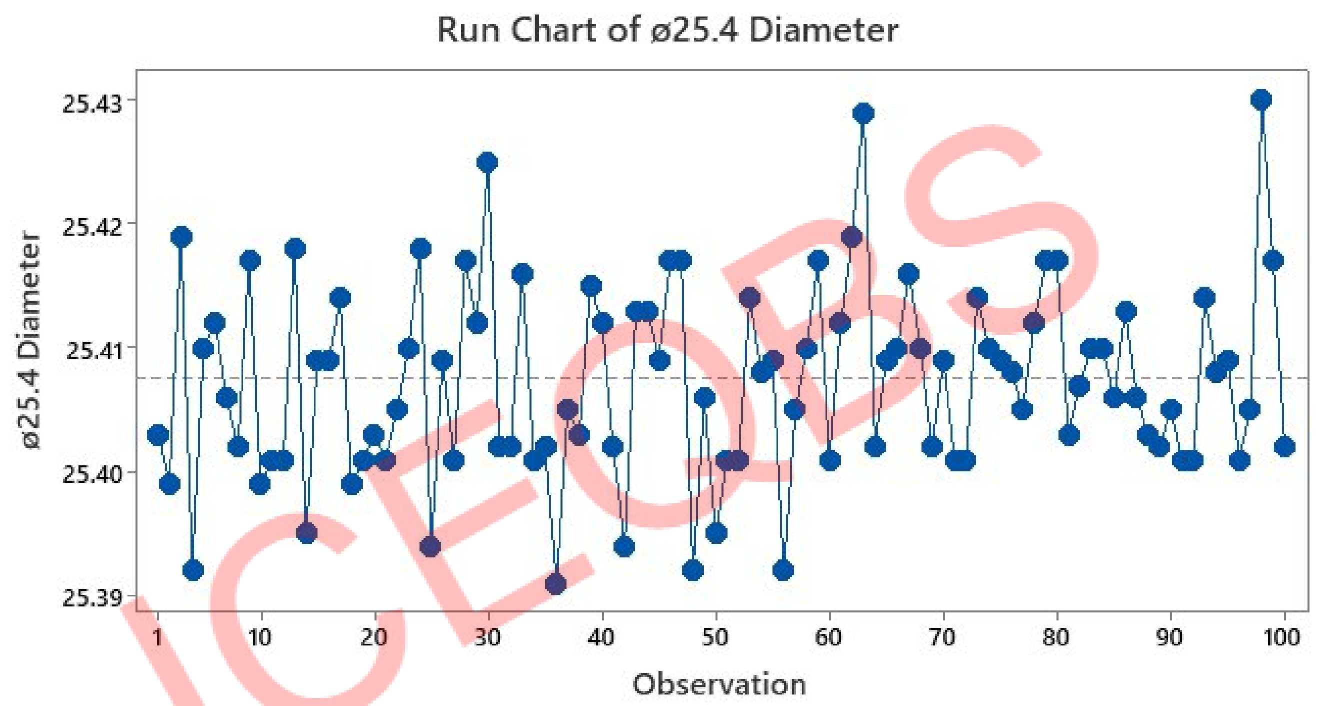
Data collection – Histogram (Before improvement)



Inference :

- Data is normally distributed over the mean

Data collection – Run Chart (Before improvement)

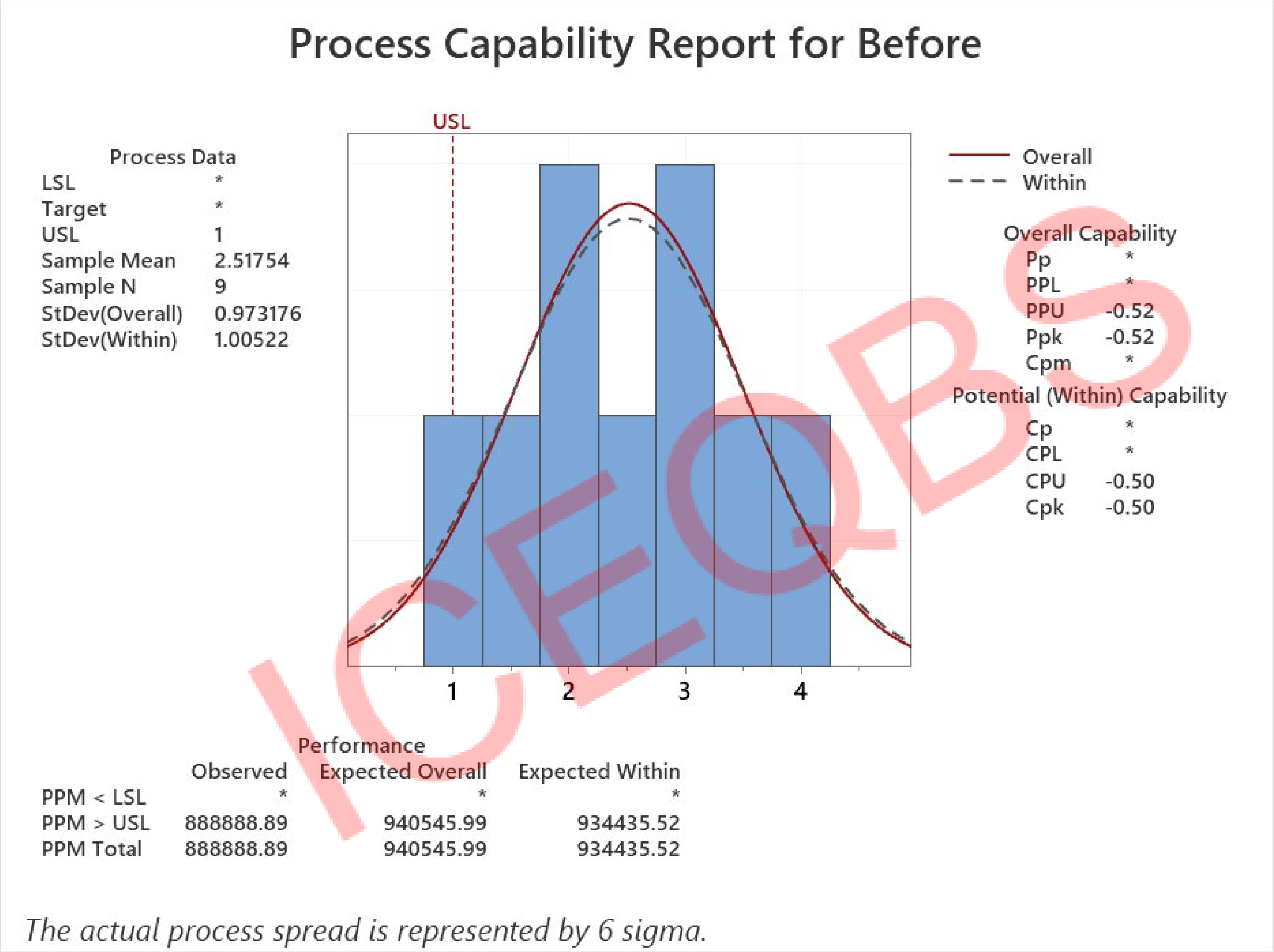


Number of runs about median:	45	Number of runs up or down:	69
Expected number of runs:	51.0	Expected number of runs:	66.3
Longest run about median:	6	Longest run up or down:	4
Approx P-Value for Clustering:	0.114	Approx P-Value for Trends:	0.738
Approx P-Value for Mixtures:	0.886	Approx P-Value for Oscillation:	0.262

Inference :

P > 0.05 – No special causes in the process. Data can be used for further analysis

Data collection – Normality plot (Before improvement)



Inference :

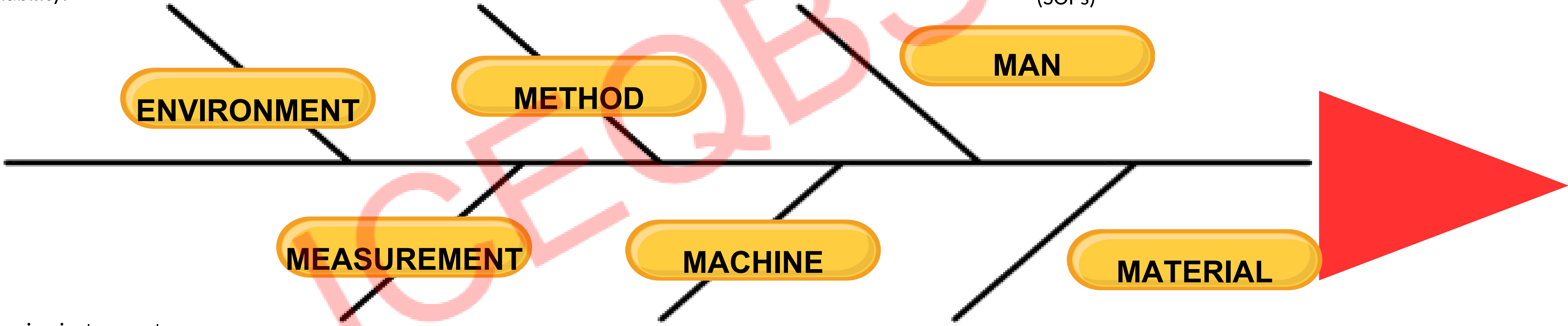
- The process is not capable, as the mean is far from the USL and the Ppk/Cpk (≈ –0.50) indicate the process is producing a high number of out-of-spec parts

Fish Bone Diagram

1. Reducing scrap lowers metal waste and minimizes environmental burden.
2. Improved machine efficiency reduces power consumption and carbon footprint.
3. Less rework cuts coolant, tooling, and material usage, supporting sustainability.

1. Incorrect cutting speed, feed, or depth of cut
2. Poor coolant or lubrication practices
3. Lack of standard process for tool change intervals
4. Improper machining sequence

1. Lack of training on proper machining techniques
2. Inconsistent skill levels between operators
3. Improper handling of tools
4. Failure to follow standard operating procedures (SOPs)



1. Inaccurate measuring instruments
2. Inconsistent inspection methods
3. No frequent calibration of gauges
4. Delay in detecting defects
5. Misinterpretation of tolerance limits

1. Worn-out cutting tools / inserts
2. Machine vibration or spindle instability
3. Improper machine calibration
4. Inadequate maintenance of CNC machines

1. Raw material hardness variation
2. Incorrect material grade or specification

Common Causes vs Special Causes

Common Causes

- Lack of training on proper machining techniques (Man)
- Inconsistent skill levels between operators (Man)
- Improper handling of tools (Man)
- Failure to follow standard operating procedures (SOPs) (Man)
- Inattention or human error during machining (Man)
- Worn-out cutting tools / inserts (Machine)
- Inadequate maintenance of CNC machines (Machine)
- Raw material hardness variation (Material)
- Incorrect cutting speed, feed, or depth of cut (Method)
- Poor coolant or lubrication practices (Method)
- Inconsistent inspection methods

Special Causes

- Machine vibration or spindle instability (Machine)
- Improper machine calibration (Machine)
- Incorrect material grade or specification (Material)
- Lack of standard process for tool change intervals (Method)
- Improper machining sequence (Method)
- Inaccurate measuring instruments (Measurement)
- No frequent calibration of gauges (Measurement)
- Misinterpretation of tolerance limits (Measurement)

3M Analysis for Waste

MUDA

- Rework of oversize bores – extra labor and time spent correcting defective parts.
- Scrap of rejected components – material and cost loss.
- Excess inspection time – repeated checks due to inconsistent machining quality.

Mura

- Variation in bore size between parts – inconsistent dimensional control.
- Fluctuating cutting parameters – different speeds or feeds applied by operators or machines.
- Irregular tool wear – causing inconsistent machining results and surface finish.

Muri

- Operators working overtime to meet production despite high defect rates.
- Machines running beyond recommended speed/feed to reduce cycle time, increasing tool wear.
- Tool holders or fixtures overstressed by repeated adjustments to compensate for process variation.

8 Wastes Analysis

Defects	• Parts rejected due to bore oversize.
Overproduction	• Producing more parts than needed before quality check, leading to more rejects. • Machining extra units to compensate for anticipated rejections.
Waiting	• Parts waiting for inspection due to bottlenecks. • Machine downtime while waiting for tool replacement.
Non-Utilized Talent	• Operators or engineers not being involved in root cause analysis or process improvement discussions
Transportation	• Transporting scrap material to disposal area
Inventory	• Excess raw material waiting to be machined due to slow process.
Motion	• Operators walking back and forth to inspect parts repeatedly. • Searching for correct measuring instruments or fixtures.
Overprocessing	• Reworking parts multiple times to meet bore tolerance. • Increased Number passes in bore diameter machining.

Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Observation / Issue (Gemba Walk)	Root Cause	Proposed Lean Improvement	Expected Outcome / Metric
High rejection due to bore oversize	Worn-out cutting tools	Implement regular tool inspection & replacement schedule	Reduction in bore oversize rejection rate
Inconsistent surface finish	Improper cutting speed/feed	Standardize cutting parameters & provide operator training	Improved surface finish
Excessive rework	Operators performing manual adjustments inconsistently	Introduce standard operating procedures (SOPs) & checklists	Decrease in rework time & scrap
Delays in detecting defects	Inspection only at final stage	Implement in-process inspection & poka-yoke measures	Early defect detection, lower scrap
Material variation affecting bore size	Raw material hardness differences	Work with suppliers on material specification compliance	Fewer bore oversize issues due to material
Operator underutilization	Skilled operators not contributing to process improvements	Conduct Kaizen workshops to leverage employee ideas	Improved process efficiency, engagement
Machine vibration / instability	Poor machine maintenance	Schedule preventive maintenance & machine calibration	Stable machining, reduced defects
Excess motion & waiting	Parts and tools not organized	Implement 5S in the machining area	Less motion/waiting, improved workflow

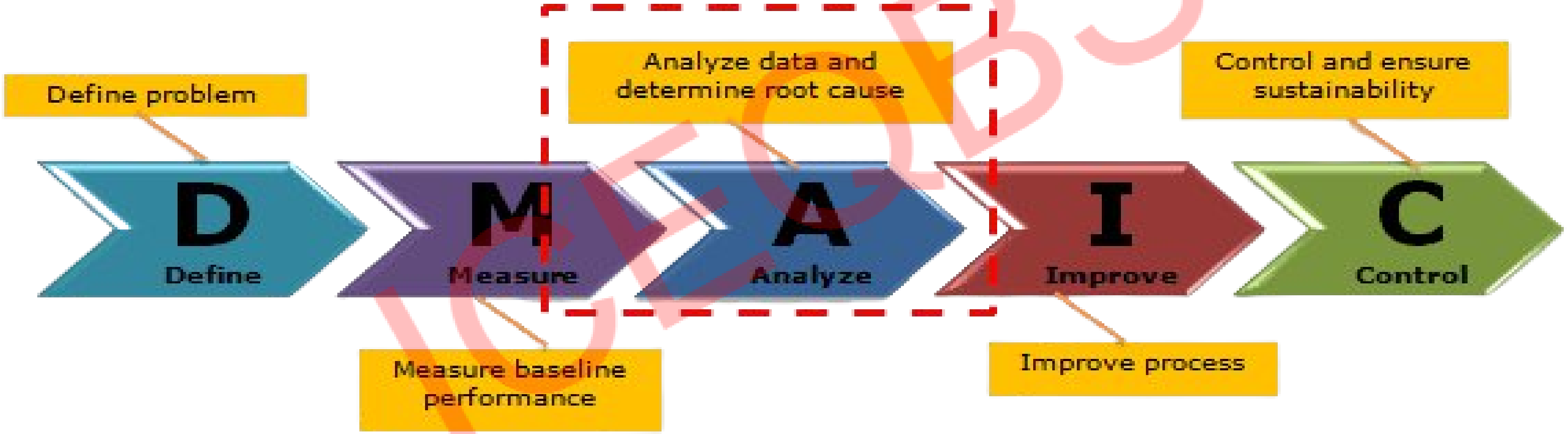
Top 12 Prioritized Root Causes (Based on Net Score)

Root Cause	Score
Worn-out cutting tools	195
Improper cutting speed/feed/depth	195
Inadequate tool change intervals	195
Improper machine calibration	141
Incorrect material grade	141
Poor coolant / lubrication	135
Machine vibration	125
Inconsistent operator skill	129
Lack of training / SOP	129
Operator inattention	129
Inaccurate measuring instruments	109

Data Collection Plan

Parameter	Method	Instrument / Tool	Frequency	Responsible Person
Bore Diameter	Direct measurement	Bore gauge / Vernier	Every 10th part	QC Inspector
Tool Wear	Visual	Microscope	Every tool change	Operator / QC
Cutting Parameters	Program / Machine log check	CNC display	Start & end of shift	Operator
Coolant Condition	Visual + flow meter	Flow meter	Once per shift	Maintenance
Rejection Count	Visual / QC report	Inspection record	Continuous	QA Engineer

ANALYSE PHASE



Analyse – Hypothesis testing

Regression Analysis: Bore_Oversize_Rejection_pct versus \

Regression Equation

Bore_Oversize_Rejection_pct = -1.2665 + 0.025790 Cutting_Speed_Dev_Index + 0.06623 Machine_Calibration_Error_um

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-1.2665	0.0866	-14.62	0.000	
Cutting_Speed_Dev_Index	0.025790	0.000842	30.65	0.000	1.01
Machine_Calibration_Error_um	0.06623	0.00378	17.50	0.000	1.01

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0594560	98.03%	97.88%	97.53%

Model Summary

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0.0594560	98.03%	97.88%	97.53%

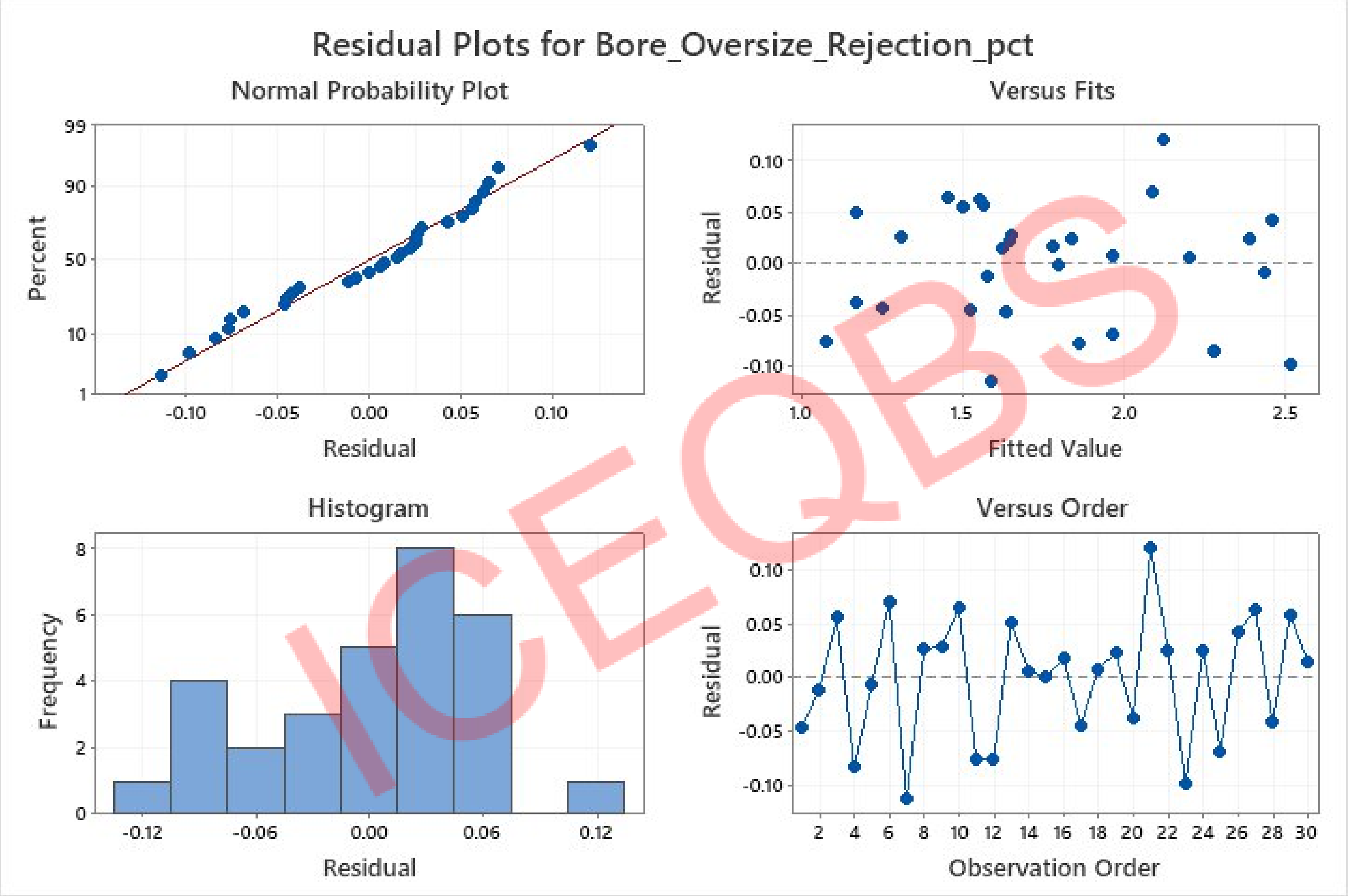
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	4.74769	2.37384	671.52	0.000
Cutting_Speed_Dev_Index	1	3.31991	3.31991	939.15	0.000
Machine_Calibration_Error_um	1	1.08309	1.08309	306.39	0.000
Error	27	0.09545	0.00354		
Total	29	4.84313			

Inference :

- Since $p < 0.05$, thus not all means are equal

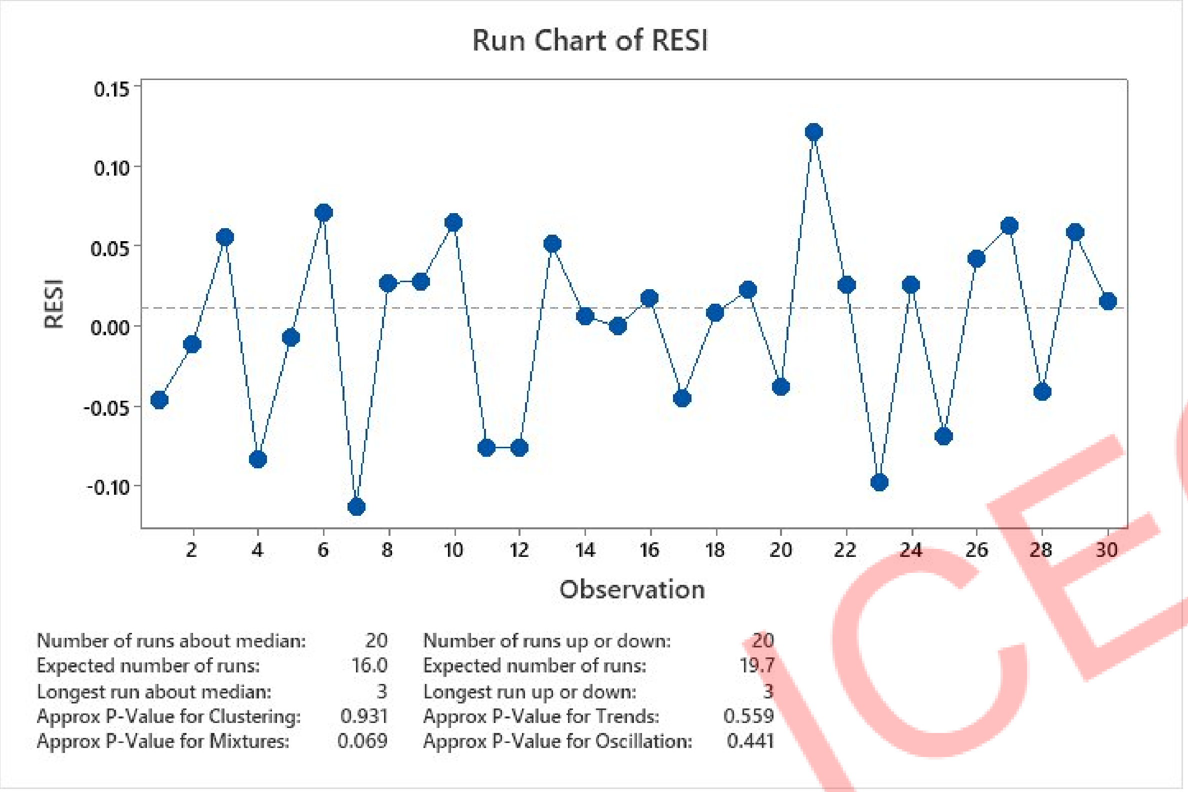
Analyse – Hypothesis testing

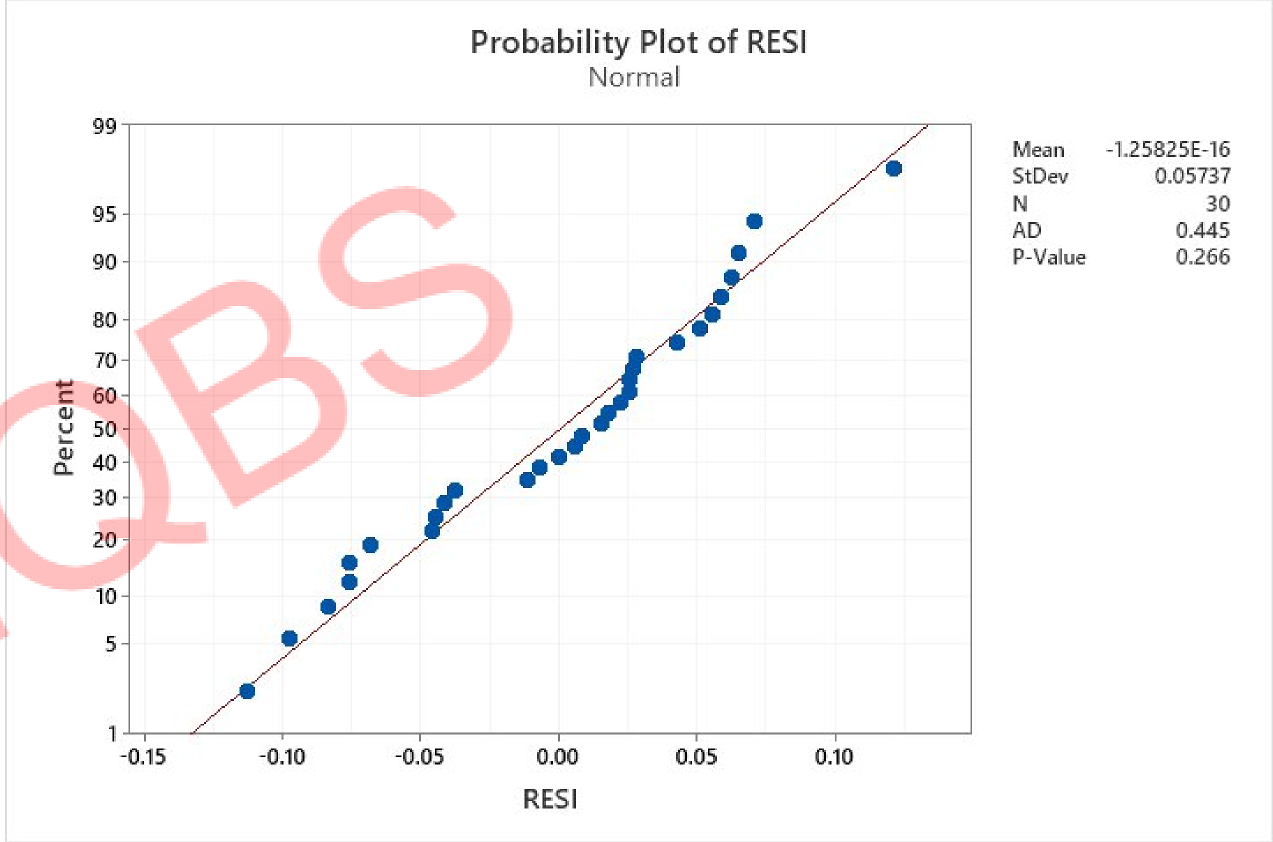


Inference :

•Residuals appear random with no visible patterns and follow near-normal behavior, indicating the regression model is adequate for the data.

Summary of Statistically validated Root causes

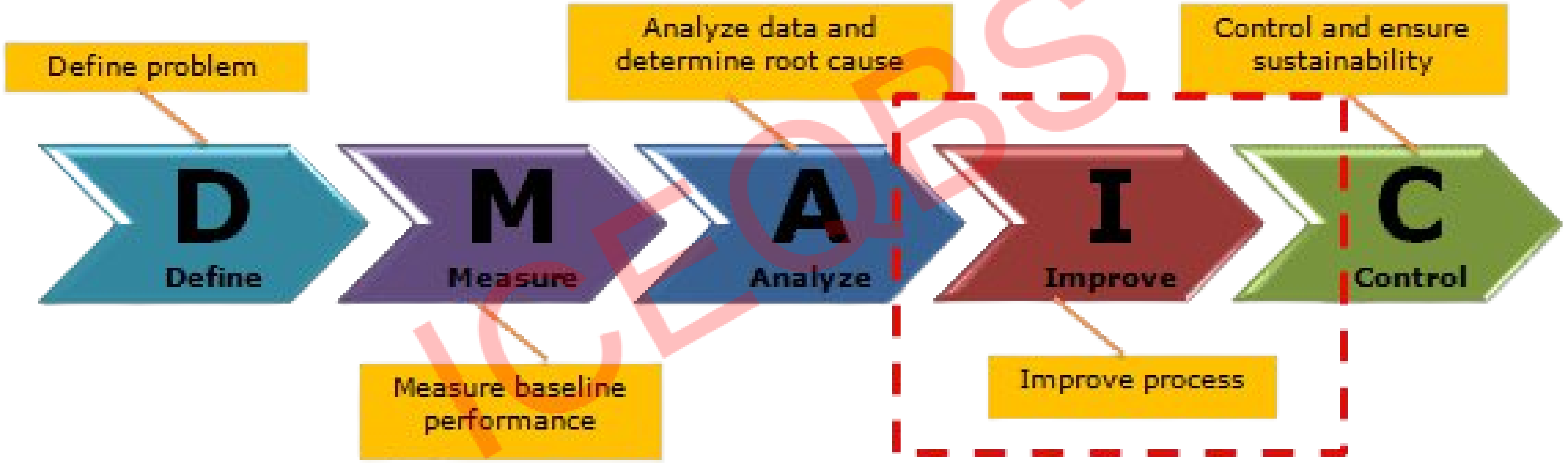




Inference :

- The run chart shows no non-random patterns and the probability plot confirms normality, indicating the residuals are stable and statistically valid.

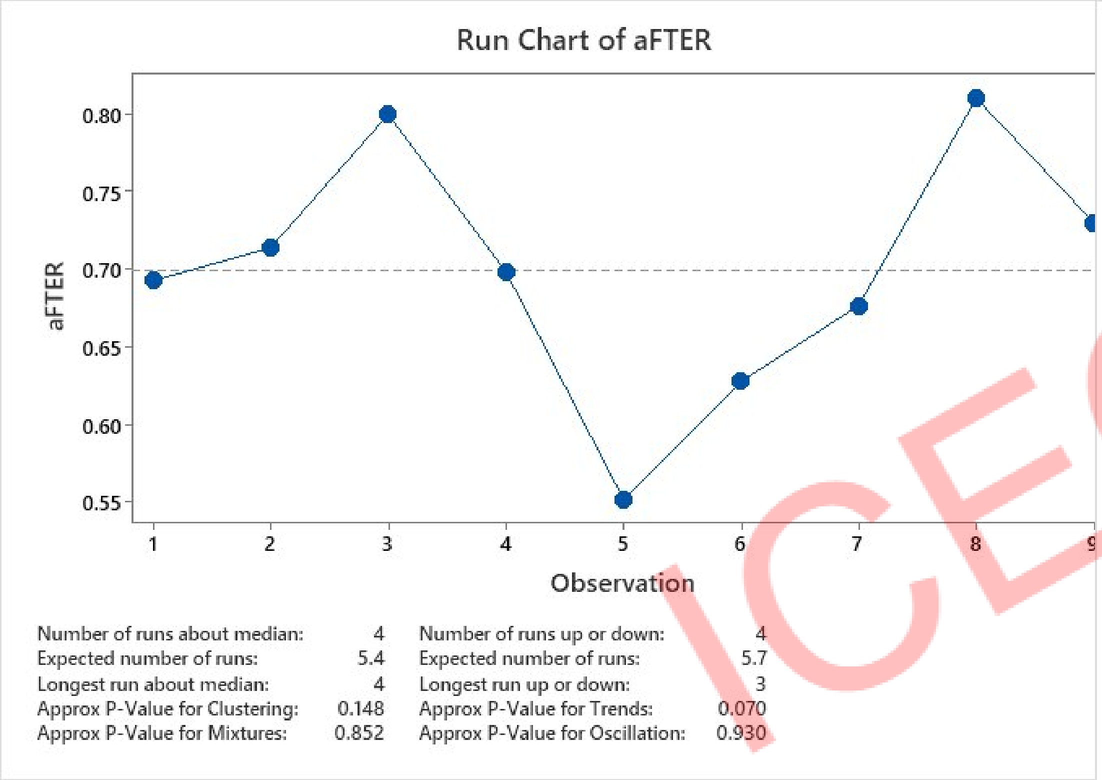
IMPROVE PHASE

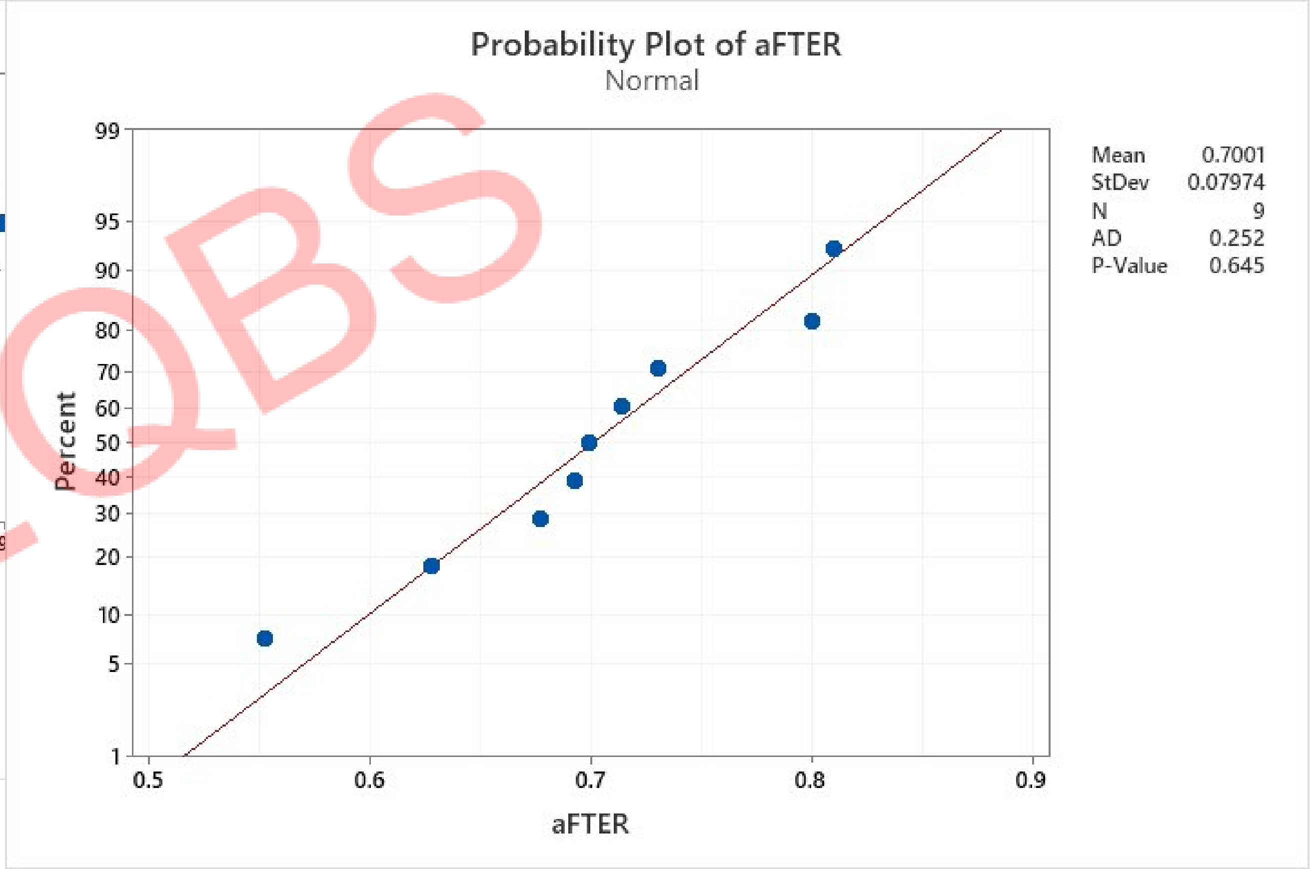


Improve Design of Experiment

Root Cause	Improvement Action
Cutting Speed Deviation	1. Establish standard cutting speed–feed–depth charts for each component and material grade.
	2. Integrate cutting speed control through CNC program standardization and locked parameters.
	3. Conduct operator training on correct speed/feed selection and deviations’ effect on bore size.
Machine Calibration Error	1. Implement monthly machine calibration schedule with traceable calibration records.
	2. Use dial indicators and laser alignment systems for spindle and axis calibration verification.
	3. Introduce poka-yoke checklist in daily machine startup inspection to verify calibration status.

Improve





The run chart shows no signs of special-cause variation, and the probability plot confirms normality, indicating the data is stable and normally distributed

Improve

Two-Sample T-Test and CI: Before, aFTER

μ_1: population mean of Before
μ_2: population mean of aFTER
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Before	9	2.518	0.973	0.32
aFTER	9	0.7001	0.0797	0.027

Estimation for Difference

Difference	95% CI for Difference
1.817	(1.067, 2.568)

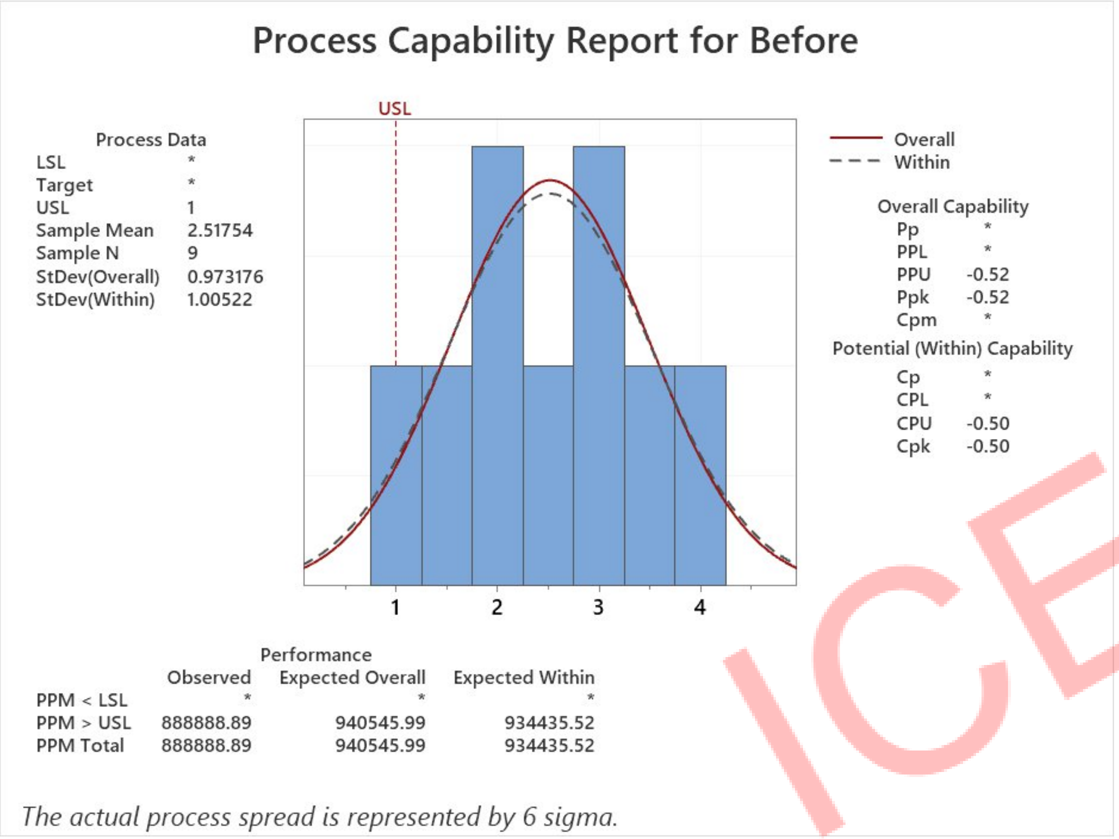
Test

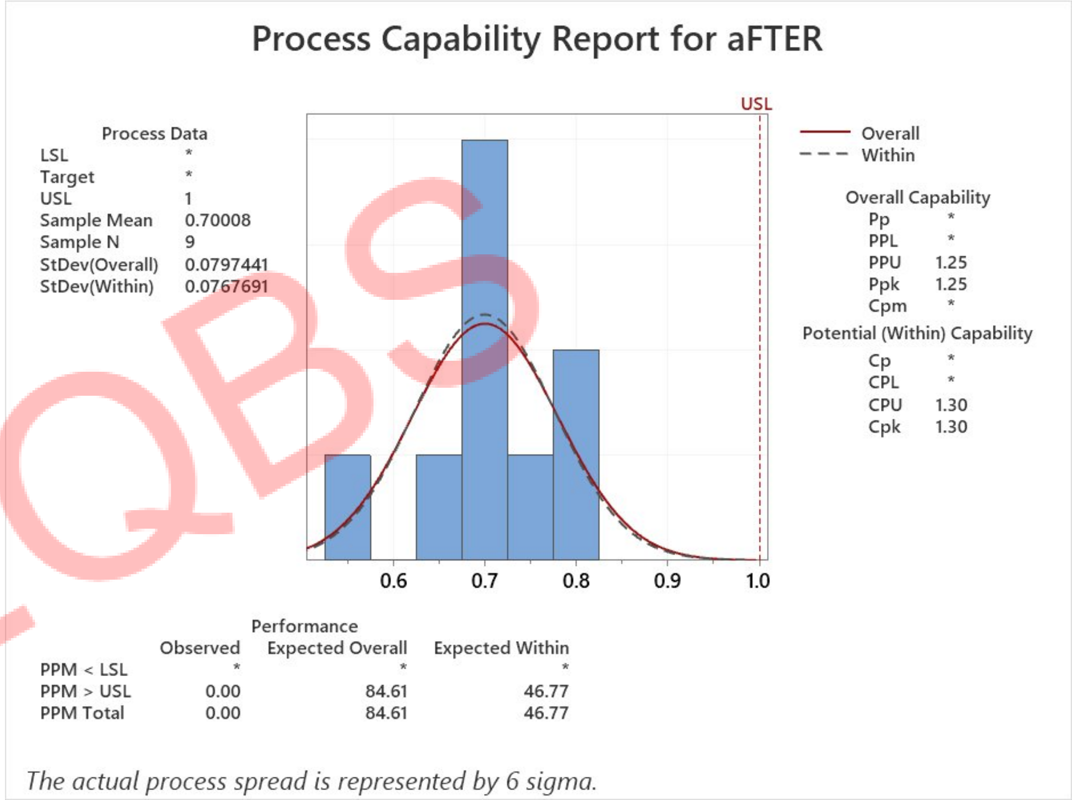
Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
5.58	8	0.001

The p-value (0.001) shows a statistically significant reduction in mean rejection after the improvement, confirming that the process change had a real positive impact

Improve – Process capability – Before & After Improvement

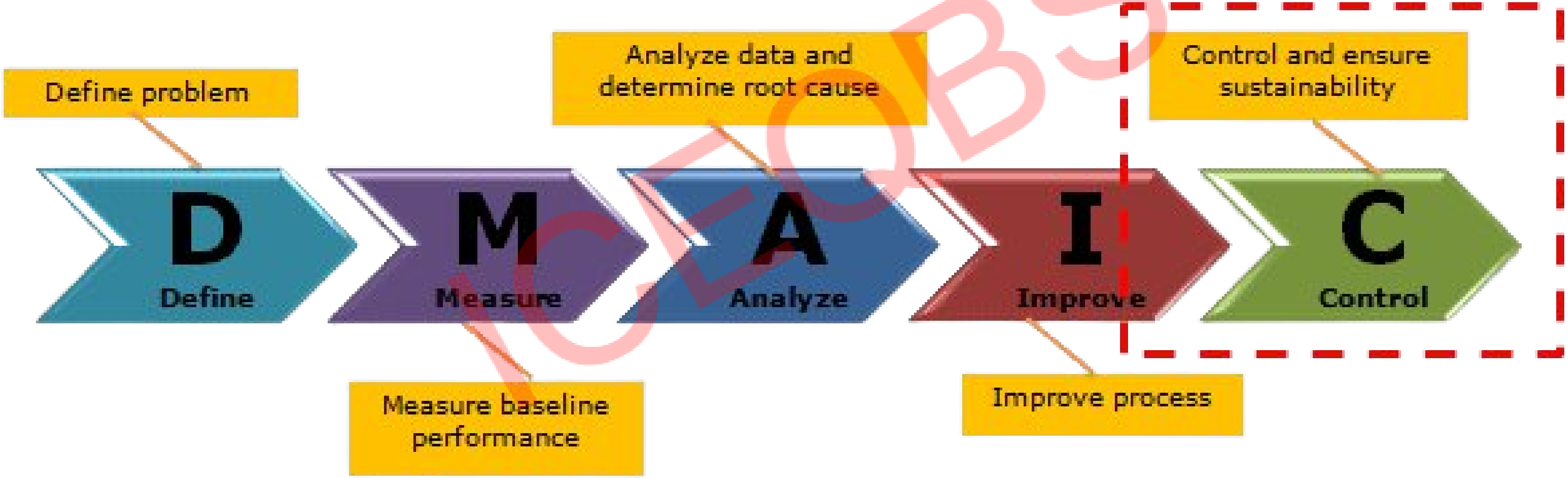




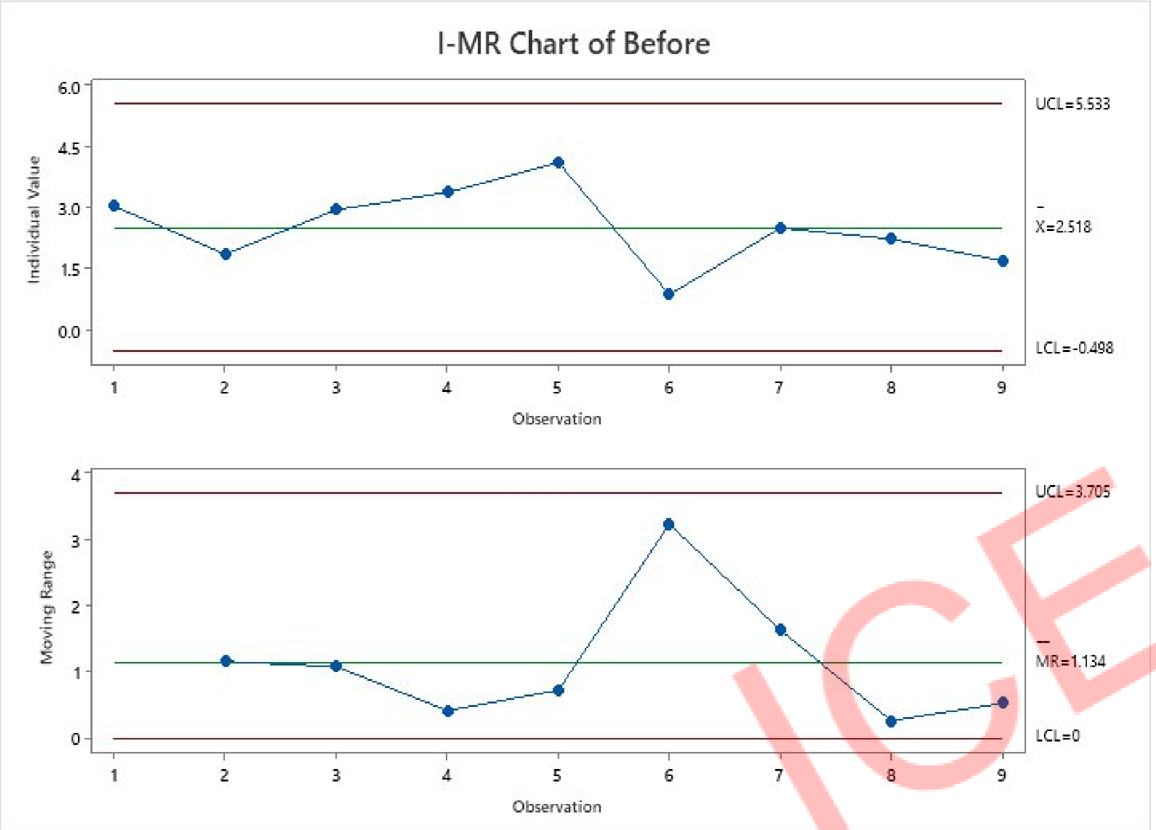
Inference :

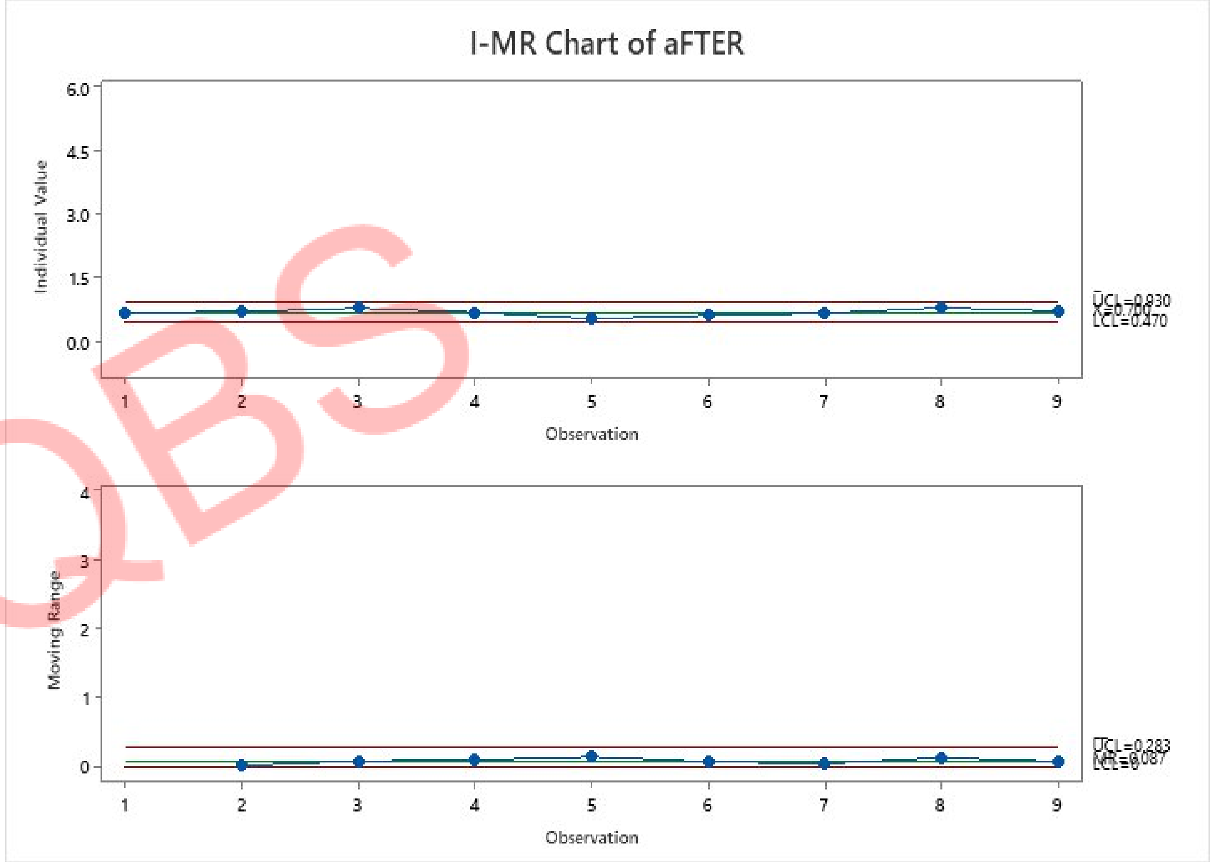
•The process capability improved significantly after the intervention, with Cpk increasing from –0.50 to 1.30, showing that the process is now capable and consistently meeting the USL

CONTROL PHASE



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





Inference:

- The I-MR charts show that the process was highly variable before but is now completely stable and in statistical control after the improvement

Control Plan

5S Step	Action in Machining Area	Purpose
Sort (Seiri)	Remove unused cutting inserts, outdated speed/feed charts, and redundant tools from CNC stations.	Eliminate confusion and reduce setup errors.
Set in Order (Seiton)	Create shadow boards for tool holders, gauges, and calibration instruments with clear labels.	Ensure quick access and reduce tool search time.
Shine (Seiso)	Introduce daily cleaning checklist for machine beds, tool changers, and coolant tanks.	Prevent buildup that affects machining accuracy.
Standardize (Seiketsu)	Display visual SOPs for cutting speed settings, calibration frequency, and tool change intervals near each machine.	Maintain uniformity in operations.
Sustain (Shitsuke)	Conduct weekly 5S audits with scoring (≥90%) linked to supervisor performance.	Reinforce discipline and sustain 5S culture.

Control Plan

Area	Poka-Yoke Mechanism	How It Helps
Cutting Speed Deviation	1. CNC parameter lockout — restricts manual editing of feed/speed values beyond standard range.	Prevents operator-induced variation.
	2. Auto-speed monitoring alarm — system alerts if deviation exceeds ±2% of standard.	Enables real-time correction.
	3. QR code tool sheet scanning — operator scans part ID to auto-load correct program with predefined speeds.	Eliminates wrong speed selection.
Machine Calibration Error	1. Digital calibration tag — machine starts only after daily calibration checklist confirmation (interlock).	Ensures calibration before use.
	2. Color-coded calibration stickers — green = calibrated, red = due/overdue.	Visual control for maintenance.
	3. Auto-log system — CNC software records calibration status and generates alerts for upcoming due dates.	Prevents missed calibrations.

Control Plan

#	Process Step / Change	Potential Failure Mode	Potential Effect (on project / process)	Potential Cause	S	O	D	RPN	Recommended Action (Proactive)	Owner
1	Create std cutting speed–feed–depth charts	Charts not accurate or incomplete	Bore oversize persists; no improvement in rejection	Wrong data source, no validation with trials	8	4	6	192	Validate charts via pilot runs on 2–3 parts before full release; review by Process & QA jointly	Process Engineer
2	Implement CNC program standardization	Operators bypass std program and edit speeds manually	High variation in speeds, unstable bore size	Culture of “adjust by feel”, lack of control access	8	5	5	200	Lock critical parameters with password; give edit rights only to authorized engineer; log program edits	Production Manager / CNC Programmer
3	Use visual SOPs for cutting parameters	SOPs not followed on shop floor	Gap between documented and actual practice; no sustained gain	SOP too complex, not in local language, poor placement	7	5	6	210	Simplify SOP with pictures; display at eye level near machines; translate to local language; include in daily startup checklist	Quality + Line Supervisor
4	Operator training on new settings	Inadequate or one-time training only	New settings misunderstood; wrong speeds used	Only classroom training; no skill assessment	7	4	6	168	Do structured OJT on real jobs; conduct short quiz / practical check; maintain training matrix and re-training plan	Training Coordinator / Supervisor
5	Define machine calibration schedule	Calibration not done as per plan	Machines drift out of tolerance; bore oversize increases gradually	No reminder system; production priority over maintenance	9	4	5	180	Use calibration calendar + ERP alert; escalation if overdue; link calibration adherence in monthly KPI	Maintenance Head
6	Daily machine start-up check (poka	Checklist filled as “tick box” without	Calibration or speed issues not	Lack of audit, habit of	8	5	6	240	Introduce surprise audits; cross-verification by QA once per shift; keep	QA Engineer

Control Plan

#	Process Step / Change	Potential Failure Mode	Potential Effect (on project / process)	Potential Cause	S	O	D	RPN	Recommended Action (Proactive)	Owner
7	Use color-coded calibration tags	Tags not updated after calibration / repair	Operators assume machine is OK when it is not	Missed step in maintenance SOP	8	3	6	144	Add “update tag” as a mandatory step in Maintenance SOP; QA to verify tag status during audits	Maintenance Team
8	Implement speed deviation alarm / interlock	Alarm disabled or ignored	Large deviations go unnoticed; rejection spikes	Alarm too frequent (nuisance), not acted upon	8	4	6	192	Set realistic thresholds; train operators to react to alarm with clear “Response SOP”; track alarm frequency & actions in log	Process Engineer / Automation
9	5S implementation around tools & gauges	5S deteriorates over time	Wrong tools / gauges used; more variation in results	No periodic 5S audit; leadership not reviewing score	6	5	6	180	Weekly 5S audit with score; display scores on board; recognize best area; corrective actions for low score	5S Champion / Supervisors
10	Bore oversize measurement & feedback	Measurement system not capable or inconsistent	Wrong conclusion about improvement; poor control	Gauge wear, operator technique variation, no MSA	9	3	7	189	Conduct MSA (GRR) on bore measurement; standardize method; calibrate gauges; train inspectors	Quality Engineer
11	Data collection & monitoring of rejection	Incorrect or incomplete rejection data	Cannot see trend; delayed detection of deterioration	Manual log errors; no defined data owner	8	4	6	192	Define single data owner; use simple digital log/Excel; daily review of bore oversize % on board; weekly trend chart	QA + Production
12	Change management / communication	Operators not convinced about new method	Resistance, hidden non-compliance,	Lack of involvement, no explanation of	7	5	7	245	Hold toolbox talks; share before/after data; involve senior operators in trials; ask feedback and adjust methods	Project Leader / Supervisor

Control Plan

Process Step / Area	Control Characteristic (X or Y)	Specification / Target	Measurement Method / Tool	Frequency	Reaction Plan if Out of Control	Responsibility
CNC Machining (Boring Operation)	Cutting Speed Deviation Index	±2% from Standard Setting	CNC Parameter Log / Auto Alarm	Per Shift	Stop machine; verify program lock; reset to standard; record deviation	CNC Operator / Programmer
CNC Machining	Feed and Depth of Cut	As per Standard Chart	CNC Monitor Verification	Daily	Correct the input and re-run sample part; inform process engineer	Production Supervisor
Machine Calibration	Spindle / Axis Calibration Error (µm)	≤5 µm	Dial Gauge / Laser Alignment	Monthly	Tag machine "Hold"; recalibrate before use; update tag color	Maintenance Engineer
Cutting Tool Management	Tool Wear (VB mm)	≤0.25 mm	Tool Presetter / Microscope	Per Shift	Replace insert; log wear; review tool life trend	Tool Room In-charge
Coolant System	Coolant Concentration (%)	5 ± 0.5 %	Refractometer	Daily	Add coolant or water; record correction	Operator / Maintenance
Measurement System	Bore Size (mm)	As per Drawing ± Tolerance	Bore Gauge / CMM	Every 10 parts	Stop production if 2 consecutive failures; inform QA & Engineer	Quality Inspector
Calibration System	Calibration Adherence %	100% of Machines Calibrated per Plan	Calibration Log	Monthly	Escalate to Maintenance Head; investigate delay reason	QA & Maintenance
Process Audit	5S Score	≥ 90%	5S Audit Checklist	Weekly	Action plan for low score; report in review meeting	5S Champion
Documentation	SOP Adherence	100%	Operator Log / Checklist	Daily	Retrain operator; supervisor sign-off	Line Supervisor
Process Output	Bore Oversize Rejection % (Y)	≤ 1 %	Rejection Log / Pareto	Weekly	Root cause revalidation; corrective action review	Quality Engineer

Conclusion

Results after improvement

- **Project has achieved its intended results after Reducing Bore Oversize Rejection Rate**