

# Reduction of Rejection in VMC Machining

Ankit Kumar

# ROADMAP



OVERVIEW



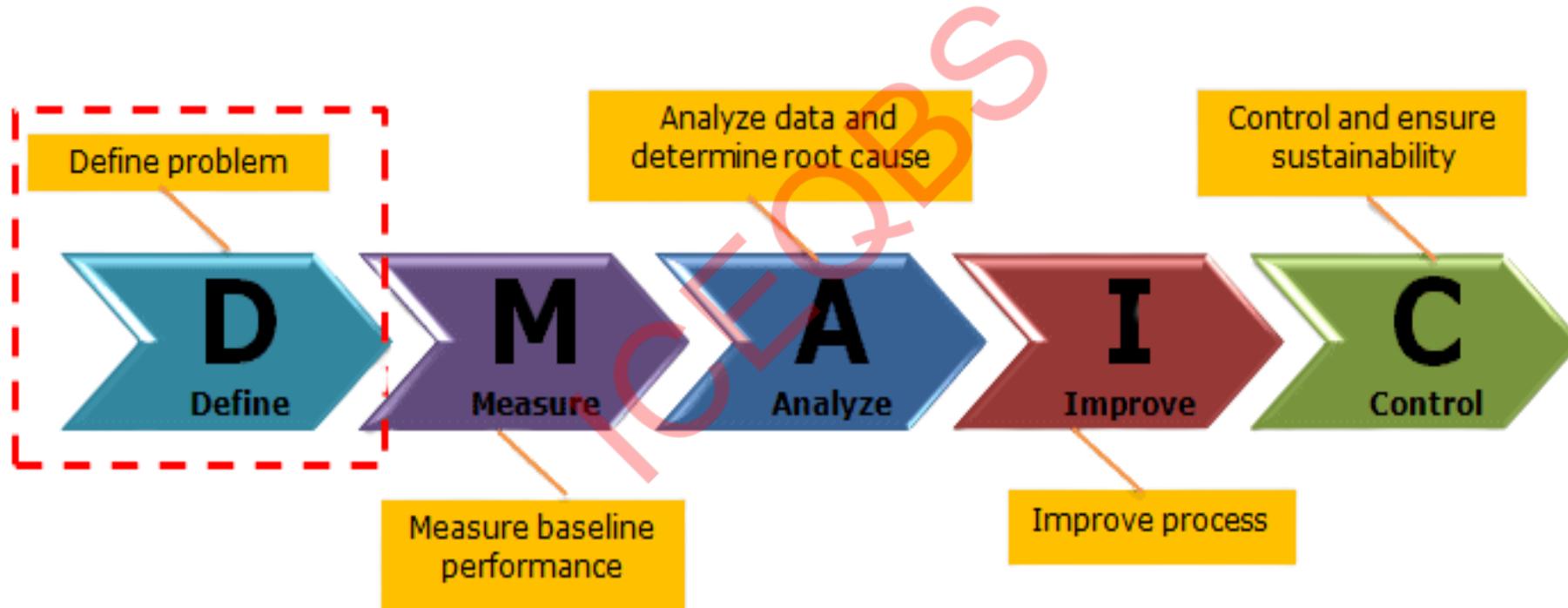
# Background

The VMC machining process currently experiences a **rejection and rework rate of approximately 5%**, which is significantly higher than the organization's defined quality standards. These rejections result in **material wastage, additional rework hours, increased tooling and inspection costs, and unplanned production delays**, directly affecting overall operational efficiency.

High rejection levels also lead to **extended lead times and inconsistent delivery performance**, increasing the risk of **customer dissatisfaction and loss of repeat business**. Continued operation at the current rejection level impacts **profit margins**, strains production capacity, and diverts resources from value-added activities.

Reducing the rejection rate will enable the organization to **improve first-pass yield, stabilize the machining process, lower cost of poor quality (COPQ), and enhance customer confidence**, while supporting long-term competitiveness and operational excellence.

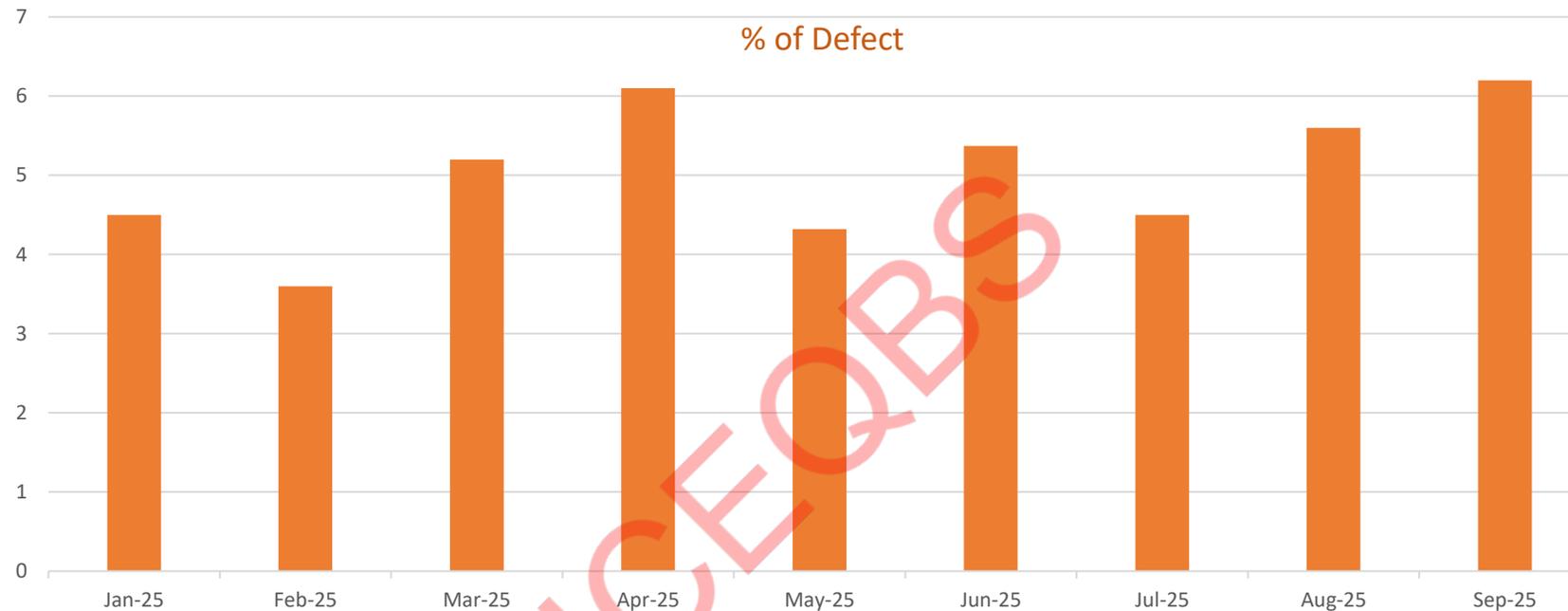
# DEFINE PHASE



## CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
<p><i>It means that customer expects zero defects, high reliability, and timely delivery of parts that meet fit, form and function without needing rework.</i></p>	<p>CTC – First Pass Yield (FPY)</p>	<p><b>Primary Metric -</b>            Rejection Rate (%) = (Number of rejected parts ÷ Total parts produced) × 100</p> <p><b>Secondary Metric -</b></p> <ul style="list-style-type: none"> <li>• Cycle time</li> </ul>

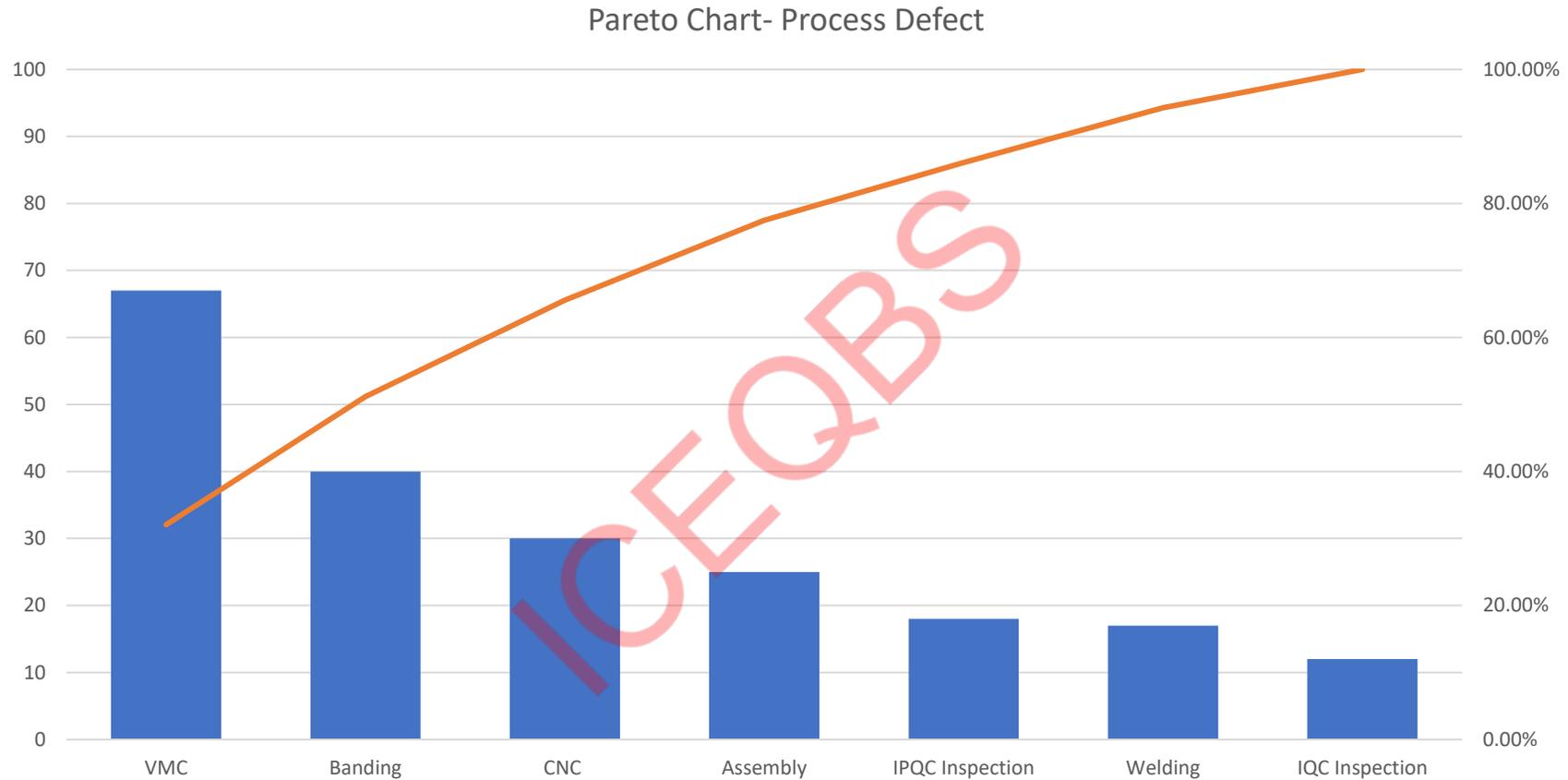
# Baseline Performance of Primary Metric (9 months data as Line chart)



## Inference :

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

# Pareto chart



## Inference :

- VMC process contributes substantially and included in the scope of the project

# Project Charter

<b>Project Title:</b>	Reduction of Rejection in VMC Machining Process		
<b>Project Leader</b>		<b>Project Team Members:</b>	
Mr. Ankit Kumar		Mr. Rakesh Shah Ms. Riya Dixit Mr. Sunil Tomar	
<b>Champion/Sponsors:</b>		<b>Key Stake Holders</b>	
Mr. Kunal Sachdeva			
<b>Problem Statement:</b>		<b>Goal Statement:</b>	
The VMC machining process currently experiences a <b>rejection and rework rate of approximately 5% based on the past 9 months data from Jan 2025 to September 2025</b>		To reduce the rejection rate from 5% to below 2% in the VMC process within 4 months, without negatively impacting cycle time or tool life.	
<b>Secondary Metric</b>		<b>Assumptions Made:</b>	
Cycle time		No <b>major product, design, or volume changes</b> during the project period. Existing <b>machines, tooling, and manpower</b> will be used without capital investment.	

# Project Charter

## Tangible and Intangible Benefits:

Reduction in **scrap and rework cost** by lowering rejection from 5% to <2%.  
Improvement in **First Pass Yield and machine productivity**.  
Better **on-time delivery** through reduced rework and delays.

## Risk to Success:

Inaccurate or **poorly classified rejection data**.  
**Resistance to change** in shop-floor practices.

## In Scope:

Tooling, clamping, and machining parameter optimization  
Operator training and setup verification

## Out of Scope:

Design changes to product geometry  
Processes outside machining (assembly, inspection)

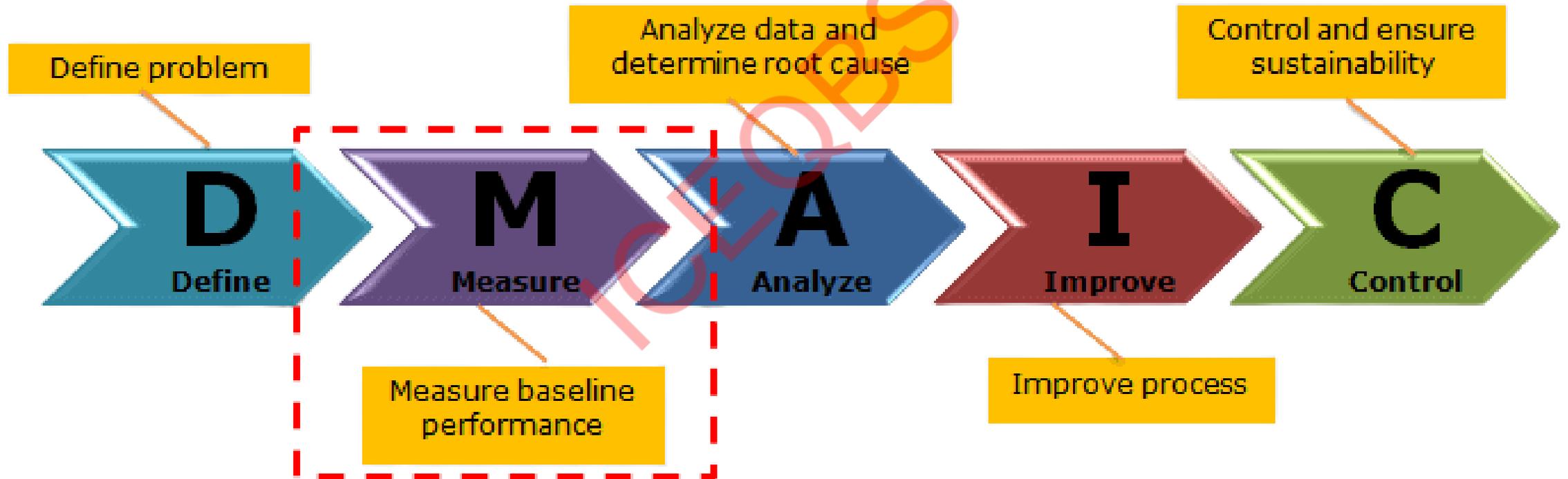
## Signatories:

Project Sponsor - Mr. Kunal Sachdeva  
Process Owner - Mr. Ravi Gupta  
Quality Representative - Mr. Parmod Gupta

## Project Timeline:

6 Months

# MEASURE PHASE



# SIPOC

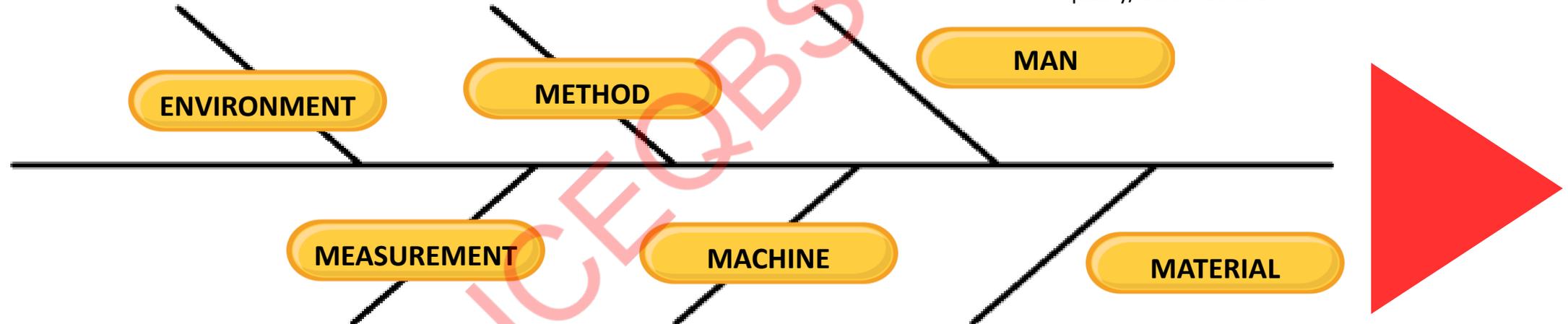
SUPPLIERS (S)	INPUTS (I)	PROCESS (P)	OUTPUTS (O)	CUSTOMERS (C)
<b>Raw material supplier (steel sheets, components)</b>	Raw materials (steel sheet, components)	Receive and inspect raw materials	Conforming products	Next process/assembly line
<b>Process engineering (drawings, specs)</b>	Production drawings/specs	Set up machines and tools	Production performance data	QC / Inspection team
<b>Maintenance team</b>	Machine calibration data	Select and mount cutting tools	Components with proper Bore Diameter	Assembly department
<b>QC team</b>	Inspection instruments	4. Inspect parts (bore size)	Rejection reports	Production / Maintenance team
<b>Tool suppliers (cutting tools, inserts)</b>	Cutting parameters (speed, feed, depth)	Change worn tools / adjust parameters	Machined components	External Customer

# Fish Bone Diagram

1. Temperature and humidity variations affecting machining accuracy and material behavior.
2. Presence of dust, coolant mist, or chips impacting machine performance and part quality.
3. Poor workplace lighting affecting inspection and setup accuracy.

1. Process work instructions/SOPs are missing, outdated or not followed.
2. Lack of standardization between shifts/teams.
3. Changeovers or special runs not managed well (setup time, changeover checklist missing).

1. Operators not sufficiently trained on the process or on changes.
2. High operator turnover or inexperienced staff.
3. Lack of awareness or understanding of quality/defect criteria



1. Inspection equipment not calibrated or in poor condition.
2. Poor data on defect types, causes and root-cause trending.
3. Inadequate measurement/monitoring of process parameters (e.g., no real-time feedback).

1. Equipment not calibrated correctly or drifted out of specification.
2. Tooling or fixtures are worn, damaged or incorrectly set up.
3. Machine breakdowns or unexpected stoppages.

1. Material storage/handling issues (humidity, contamination, damage).
2. Incoming materials or components have variable quality.
3. Wrong material or component used (mislabeling, mix-up) in process

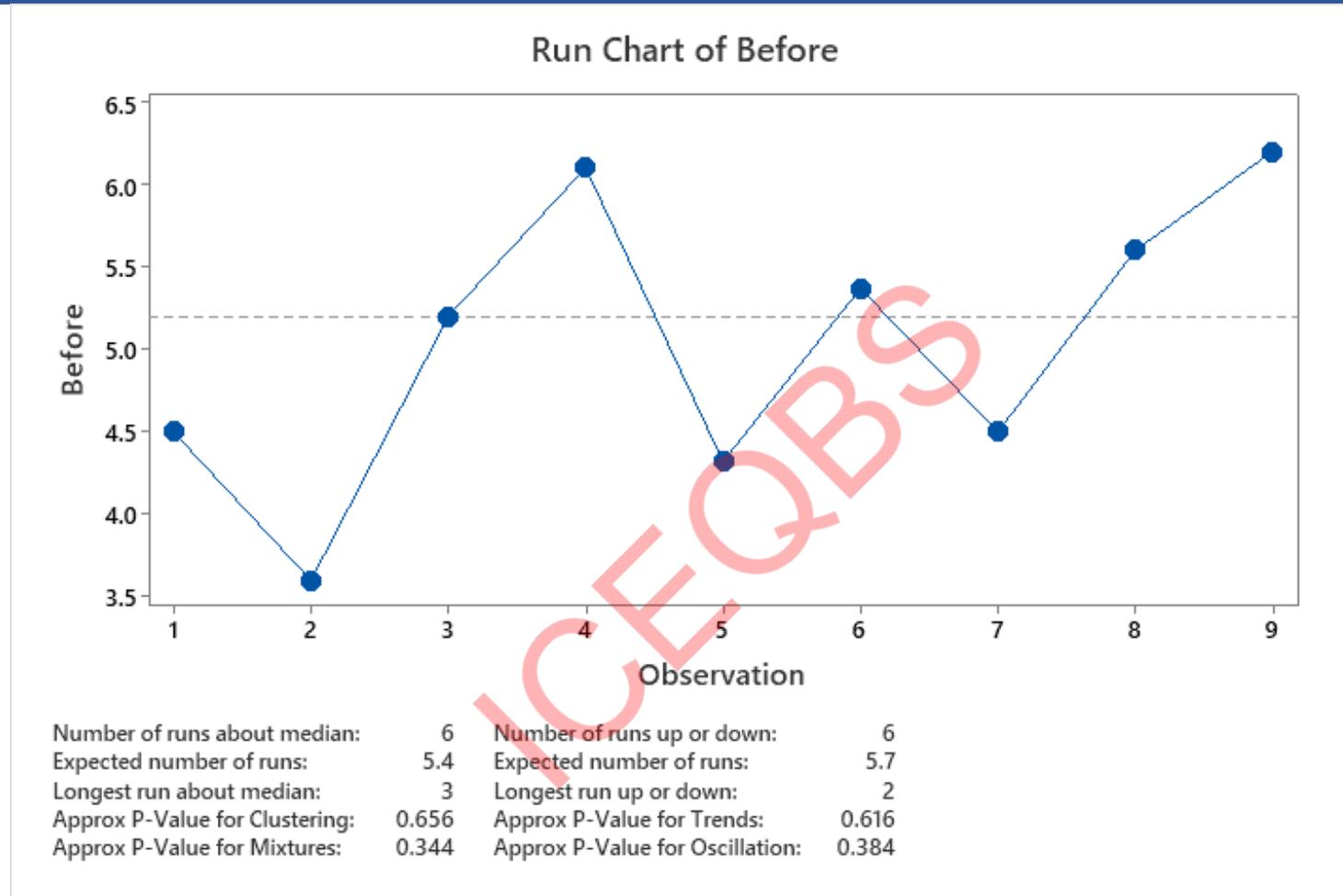
# Data collection – Histogram (Before improvement)



## Inference :

- Data is normally distributed over the mean

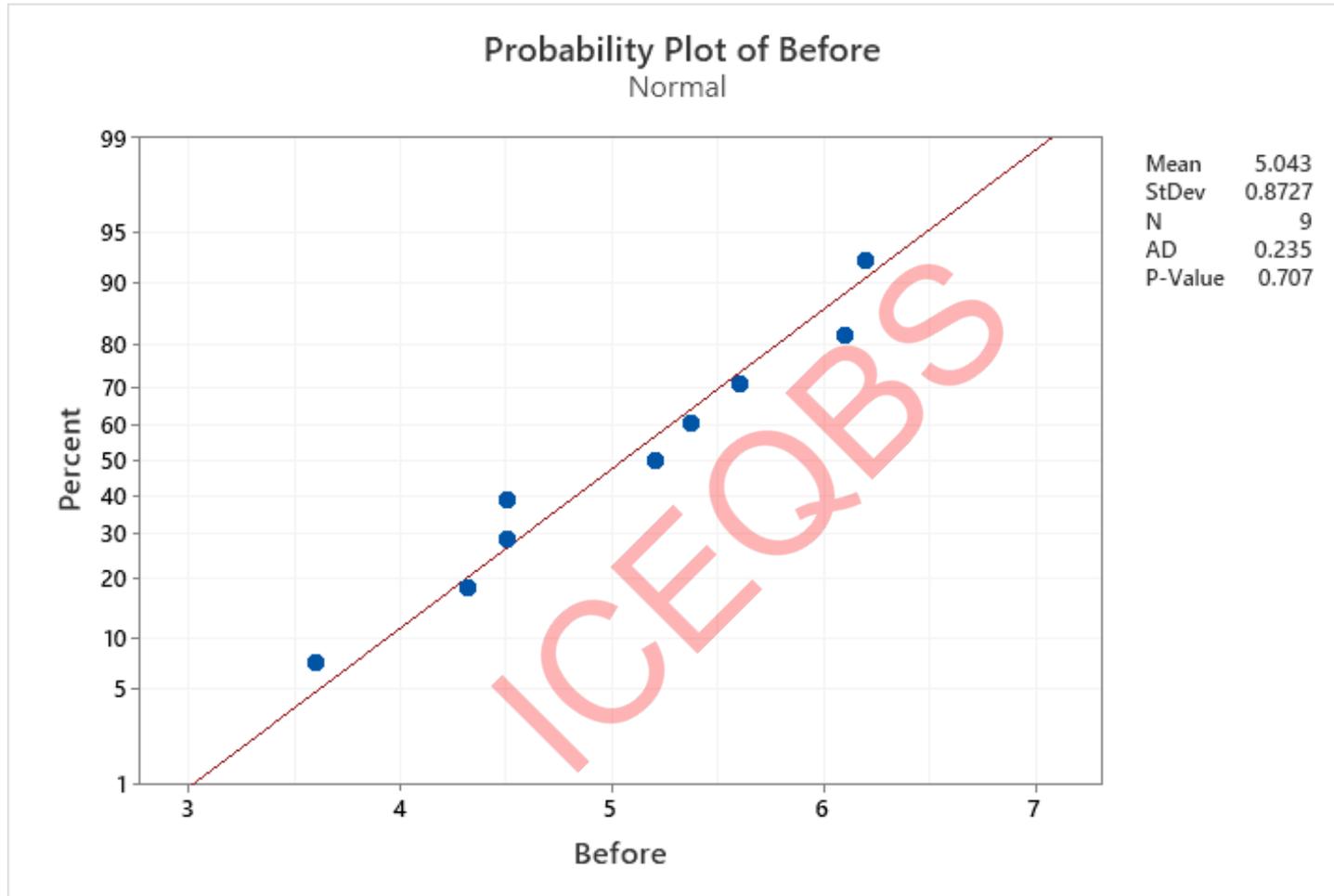
# Data collection – Run Chart (Before improvement)



## Inference :

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

# Data collection – Normality plot (Before improvement)



## Inference :

- $P > 0.05$  in all scenarios, thus all the data is normally distributed

# 3M Analysis for Waste

## MUDA

- Producing more units than required and holding excess inventory.
- Operators walking long distances between workstations because layout is inefficient.
- Reworking parts because defects were not caught early in the process

## MURA

- Workload peaks at the end of shift and then a lull at the start.
- Order arrivals fluctuate significantly, causing production ramp-ups and ramp-downs.
- Machine cycle times vary widely between batches causing inconsistent throughput

## MURI

- An operator being asked to perform multiple complex tasks simultaneously without sufficient breaks.
- Setup times being shortened unrealistically, causing increased stress on operators and higher error rates.

# 8 Wastes Analysis

## Defects

- Rejected parts due to dimensional inaccuracy.
- Rework caused by incorrect assembly or finishing

## Overproduction

- Manufacturing extra units to “cover” expected rejections.
- Running machines for longer batches than customer demand.

## Waiting

- Machines idle due to delayed maintenance or tool changeovers.
- Operators waiting for rework instructions or quality approval.

## Non-Utilized Talent

- No cross-training; skilled workers limited to repetitive tasks.
- Ignoring operator feedback on recurring defect causes.

## Transportation

- Moving defective parts back and forth between production and rework areas.
- Excessive handling during inspection or storage.

## Inventory

- Stockpiling raw materials “just in case” of rejections.
- Large piles of semi-finished parts waiting for rework.

## Motion

- Operators walking long distances to fetch tools or inspection gauges.
- Frequent manual adjustments due to poor workstation layout.

## Overprocessing

- Over-polishing or over-measuring parts beyond tolerance requirements.
- Double inspection due to lack of trust in quality results

# Action Plan for Low Hanging Fruits

## Muda (Waste)

Issue	Lean Tool	Action Plan
Frequent rework due to incorrect setup parameters	Standard Work, Poka-Yoke	Develop and implement a setup checklist & train operator

## Mura (Unevenness)

Issue	Lean Tool	Action Plan
Irregular production flow causing bottlenecks	Takt Time Analysis.	Analyse cycle times and redistribute work.

## Muri (Overburden)

Issue	Lean Tool	Action Plan
Operators manually handle heavy parts repeatedly	5S, Kaizen	Analyse cycle times and redistribute work.

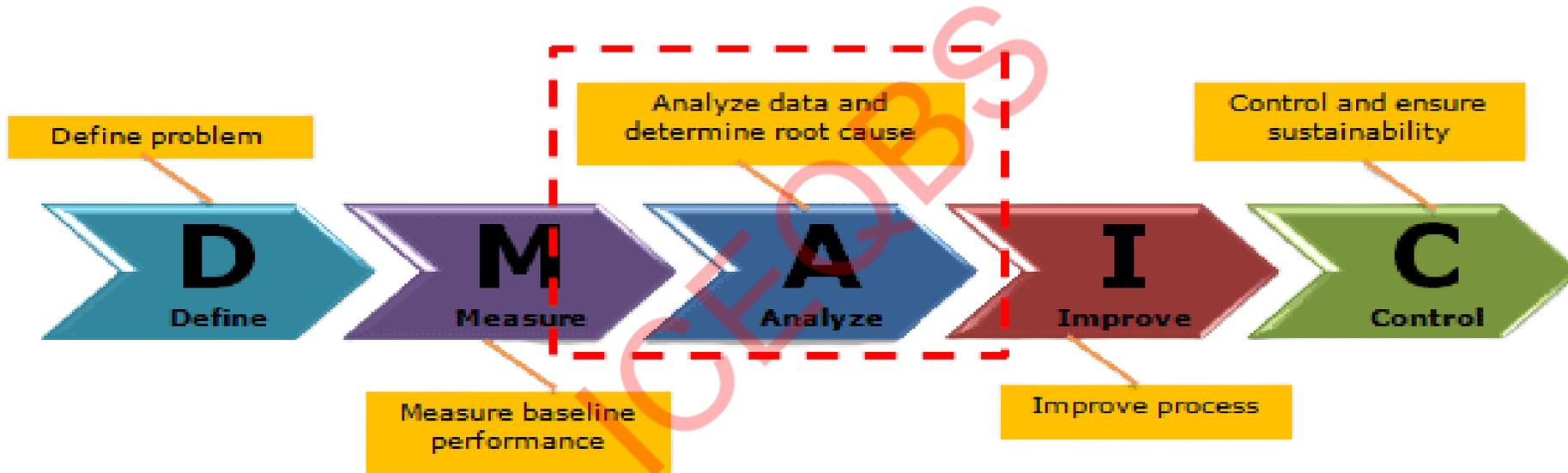
# Top Prioritized Root Causes (Based on Net Score)

Root Cause	Score
Process complexity (too many steps, rework loops)	216
Operator skill / training	206
Measurement instrument calibration / accuracy	152
Inspection procedures / inspection frequency	146
Machine Calibration	108
Improper Setup parameter	108
Poor Workstation Layout	92
Material Quality Variation	83
Work Instruction	74
Communication Gap	74
Power supply stability / voltage fluctuations	66
Poor Material Handling	36

# Data Collection Plan

Output / Input	Measurement Method	Unit	Frequency	Responsibility
Rejection rate	Review of rejection log / quality report	%	Daily	Quality Engineer
Defect type (dimension, surface, burr, etc.)	Defect classification during inspection	Count	Daily	Quality Inspector
Rework quantity	Rework register / job card review	Nos	Daily	Production Supervisor
Machine downtime	Machine logbook / downtime sheet	Minutes	Shift-wise	Maintenance Engineer
Tool wear / tool life	Tool change record & visual inspection	Nos / Hours	Per batch	CNC Operator
Process parameters (speed, feed, depth)	Machine parameter sheet	RPM / mm/min	Per setup	CNC Operator
Material batch quality	Incoming inspection report	Pass / Fail	Per lot	Stores / Quality
First Pass Yield (FPY)	Production vs accepted quantity data	%	Daily	Process Engineer

# ANALYSE PHASE



## Regression Equation

Scrap\_Percentage = 2.282 + 0.4626 Process\_Complexity\_Score - 0.05077 Operator\_Skill\_Score + 0.6804 Instrument\_Calibration\_Error\_um

## Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.282	0.759	3.01	0.006	
Process_Complexity_Score	0.4626	0.0506	9.15	0.000	1.05
Operator_Skill_Score	-0.05077	0.00753	-6.75	0.000	1.07
Instrument_Calibration_Error_um	0.6804	0.0323	21.09	0.000	1.06

## Model Summary

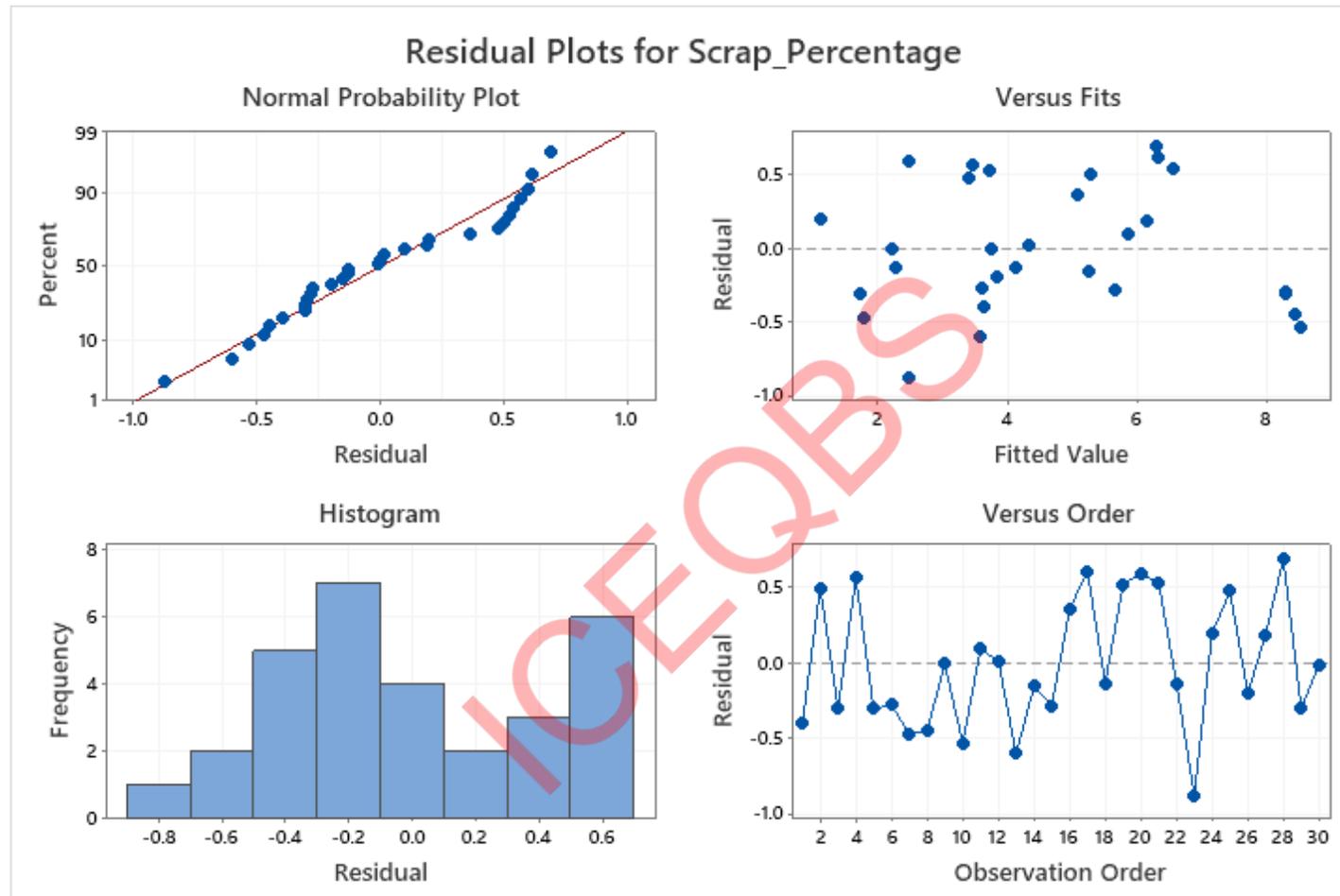
S	R-sq	R-sq(adj)	R-sq(pred)
0.450291	96.10%	95.65%	94.75%

## Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	129.834	43.2781	213.44	0.000
Process_Complexity_Score	1	16.966	16.9661	83.67	0.000
Operator_Skill_Score	1	9.227	9.2271	45.51	0.000
Instrument_Calibration_Error_um	1	90.214	90.2141	444.93	0.000
Error	26	5.272	0.2028		
Total	29	135.106			

## Inference :

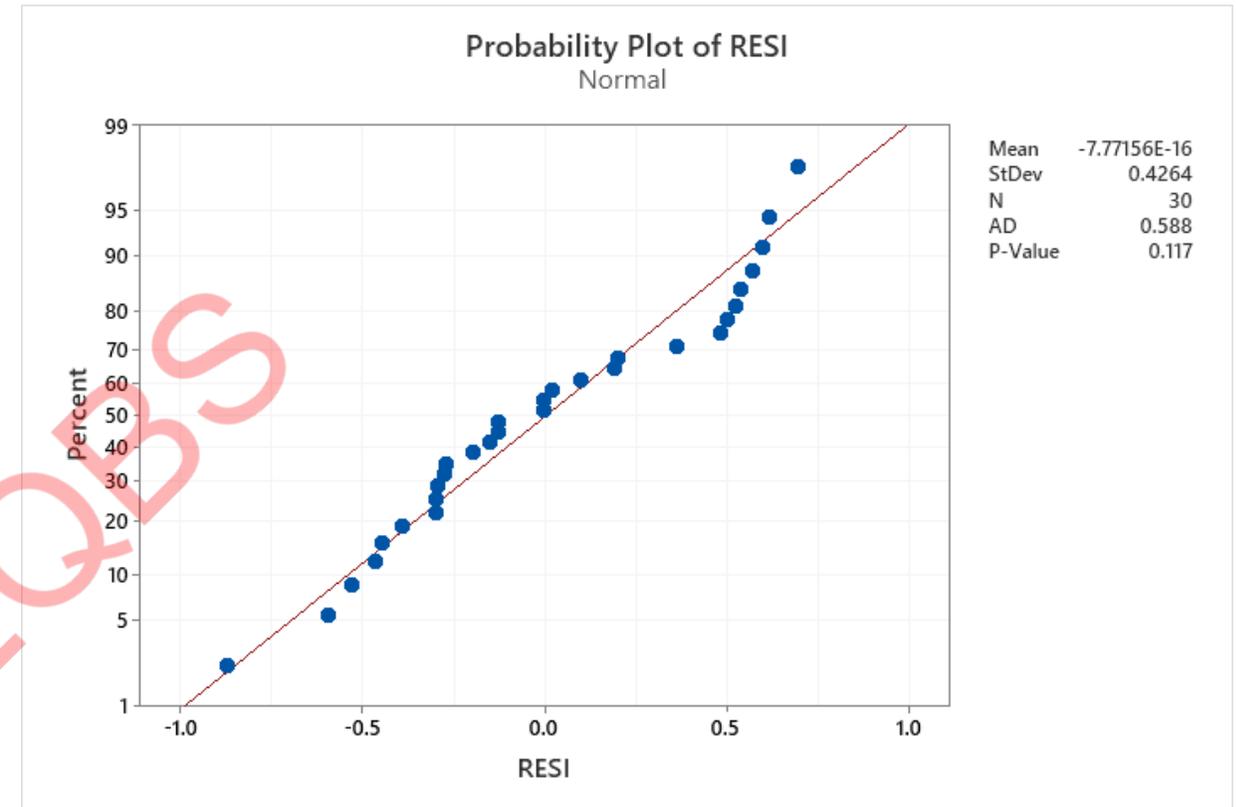
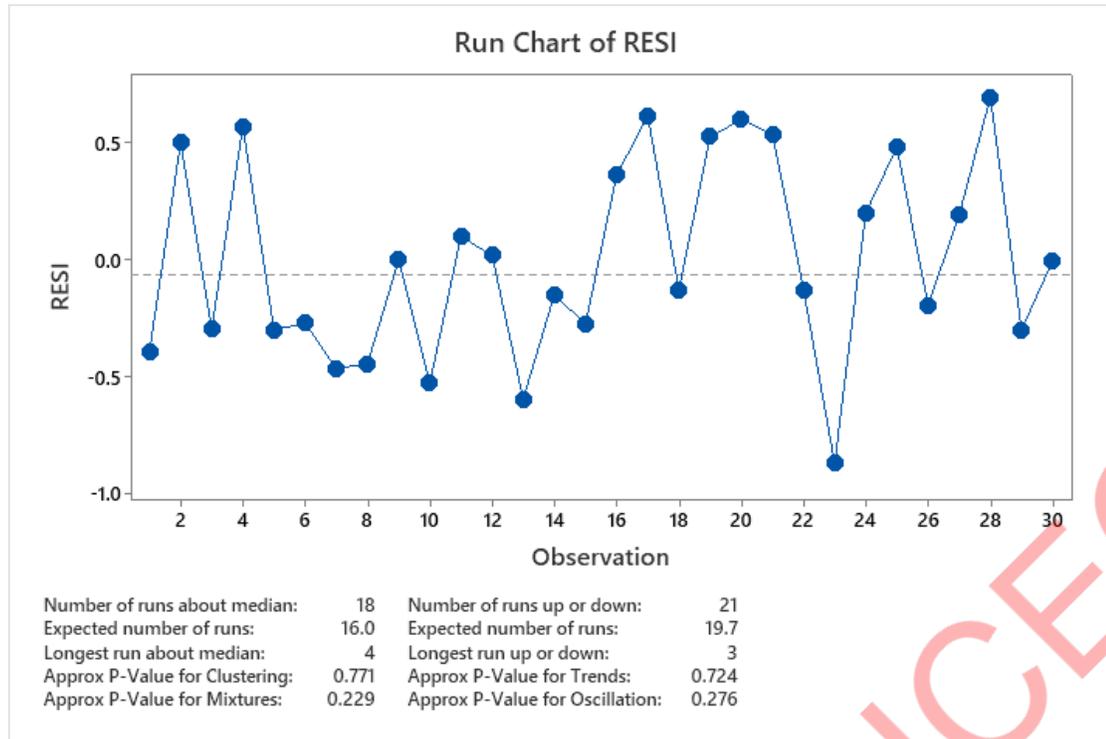
- Since  $p < 0.05$ , thus not all means are equal



## Inference :

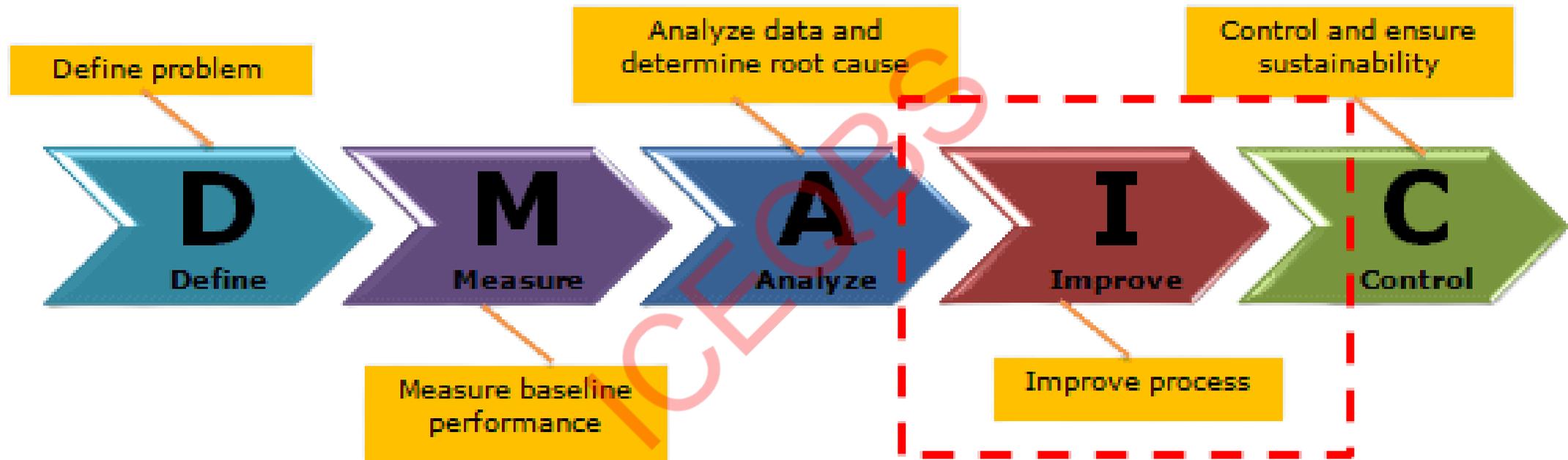
- plots confirm that the residuals are normal, independent, and random — meaning the model fits the data well, and the underlying assumptions for regression or process analysis are satisfied.

# Summary of Statistically validated Root causes



The data is randomly distributed with no trends or patterns and follow a normal distribution ( $p > 0.05$ ), indicating that the process is stable and the model assumptions are valid.

# IMPROVE PHASE



# Improve Design of Experiment

Run_Order	Block	A_Code	B_Code	C_Code	Process_Complexity_Score	Operator_Skill_Score	Instrument_Calibration_Error	Scrap_Percentage
1	1	0	0	0	6	78.5	5.5	2.11
2	1	-1	-1	1	3.5	65	9	3.13
3	1	-1	1	-1	3.5	92	2	0.6
4	1	1	-1	1	8.5	65	9	5
5	1	-1	1	1	3.5	92	9	1.26
6	1	1	1	-1	8.5	92	2	1.2
7	1	1	1	1	8.5	92	9	2.74
8	1	-1	-1	-1	3.5	65	2	1.65
9	1	1	-1	-1	8.5	65	2	2.28
10	1	0	0	0	6	78.5	5.5	2.35
11	1	0	0	0	6	78.5	5.5	2.29

## Factorial Regression: % scrap versus Process complexity, operator skill, Instrument calibration, CenterPt

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		2.2373	0.0357	62.66	0.000	
Process complexity	1.1450	0.5725	0.0419	13.67	0.000	1.00
operator skill	-1.5650	-0.7825	0.0419	-18.69	0.000	1.00
Instrument calibration	1.6000	0.8000	0.0419	19.11	0.000	1.00
Process complexity*Instrument calibration	0.5300	0.2650	0.0419	6.33	0.001	1.00
operator skill*Instrument calibration	-0.5000	-0.2500	0.0419	-5.97	0.002	1.00

### Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.118421	99.49%	98.98%	96.26%

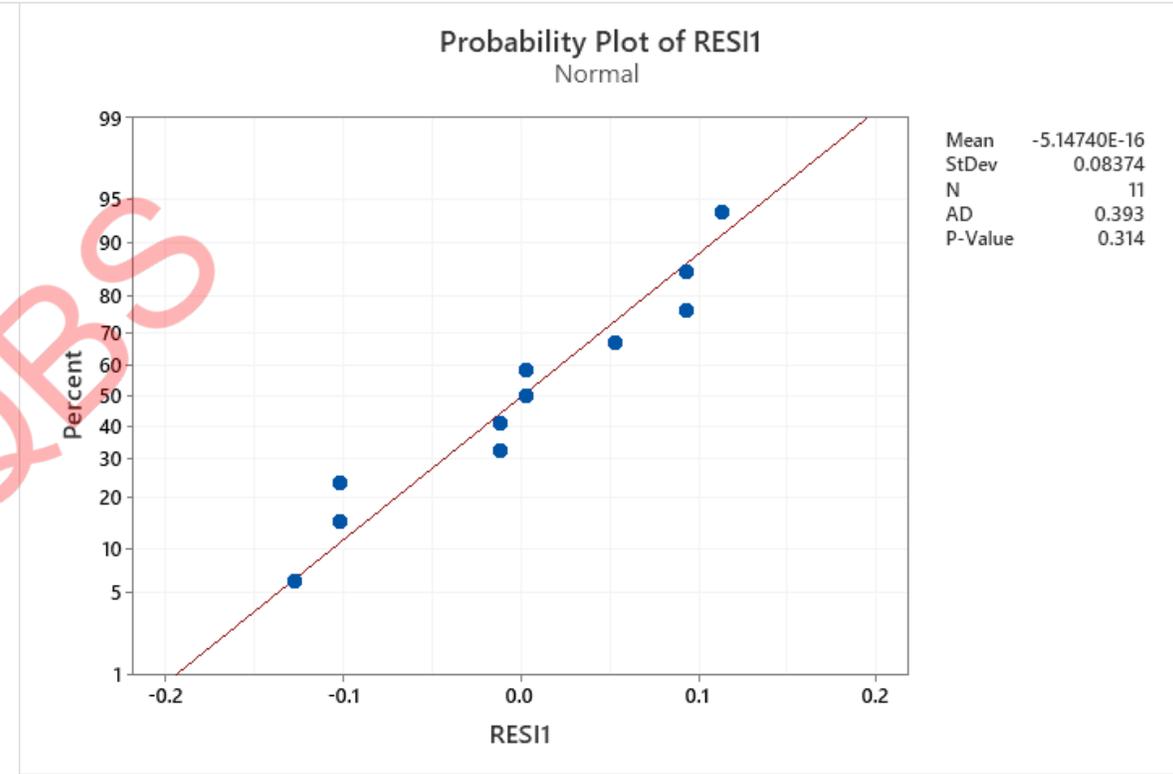
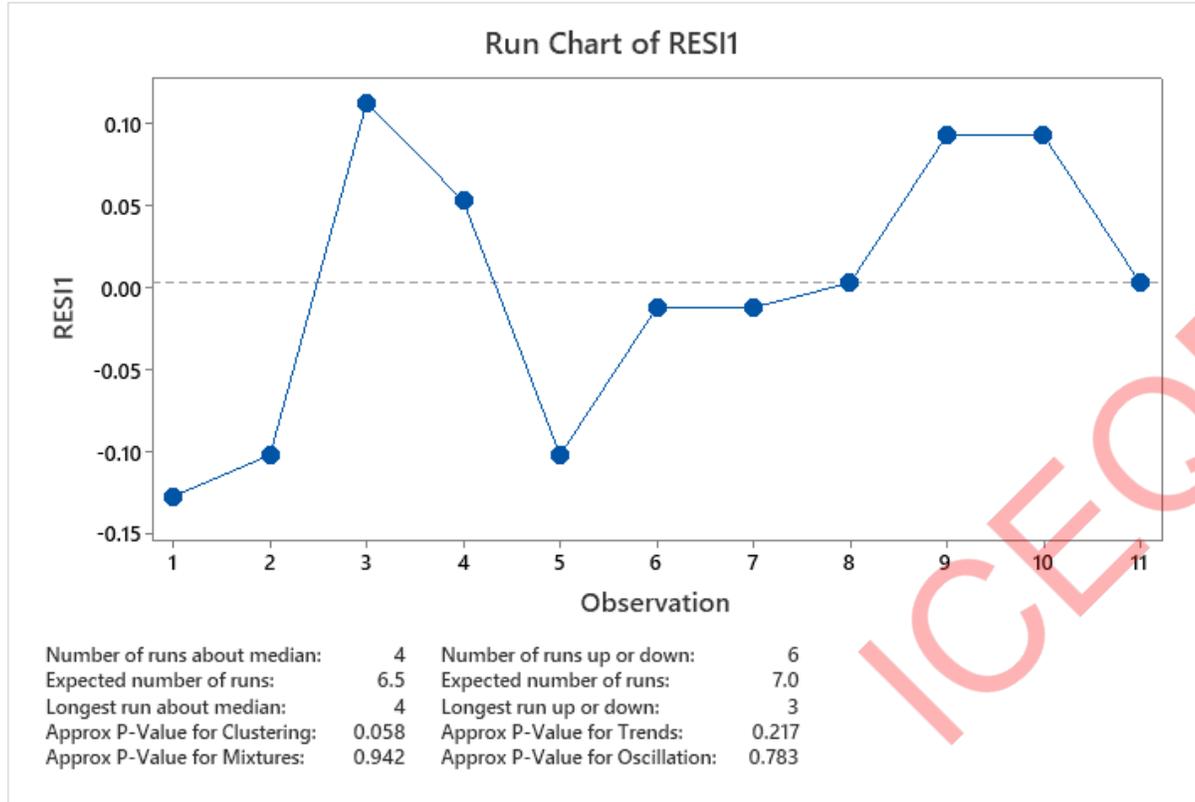
### Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	13.7023	2.74046	195.42	0.000
Linear	3	12.6405	4.21350	300.46	0.000
Process complexity	1	2.6221	2.62205	186.97	0.000
operator skill	1	4.8984	4.89845	349.30	0.000
Instrument calibration	1	5.1200	5.12000	365.10	0.000
2-Way Interactions	2	1.0618	0.53090	37.86	0.001
Process complexity*Instrument calibration	1	0.5618	0.56180	40.06	0.001
operator skill*Instrument calibration	1	0.5000	0.50000	35.65	0.002

#### Inference:

Process complexity, operator skill, and instrument calibration are key drivers of scrap, with the model showing a strong and reliable fit.

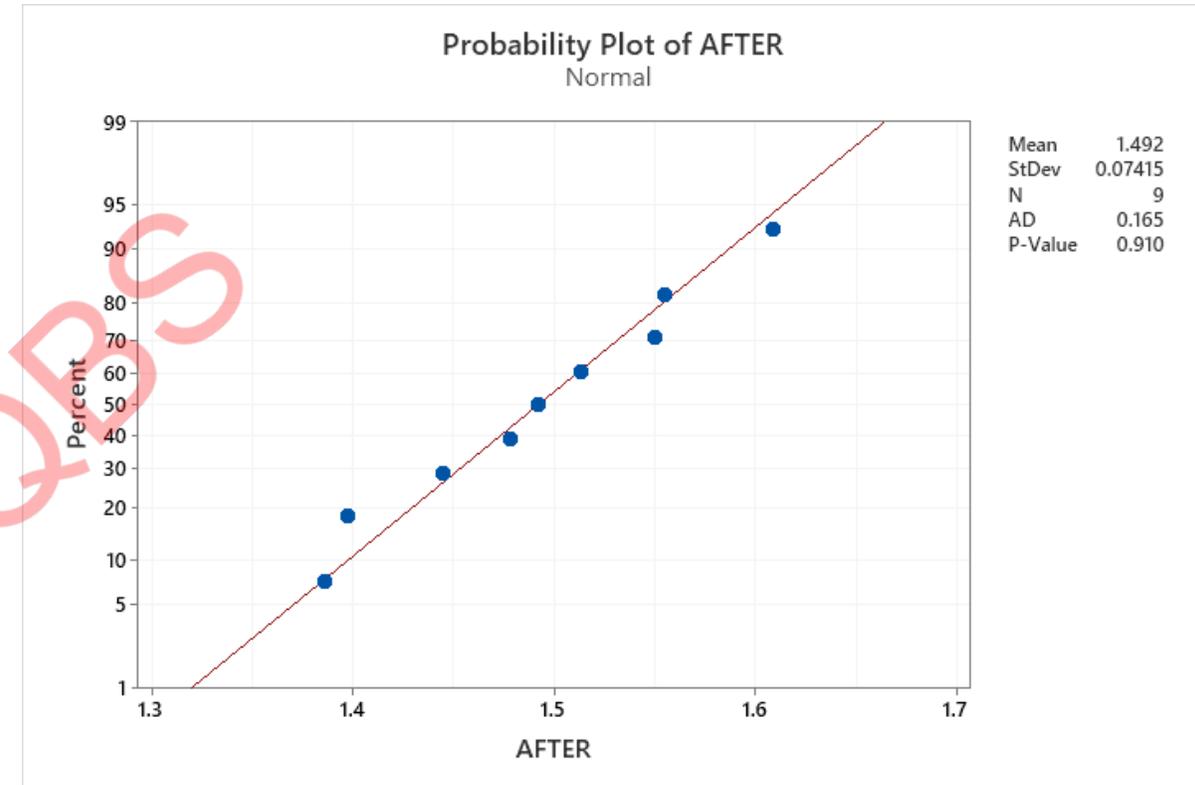
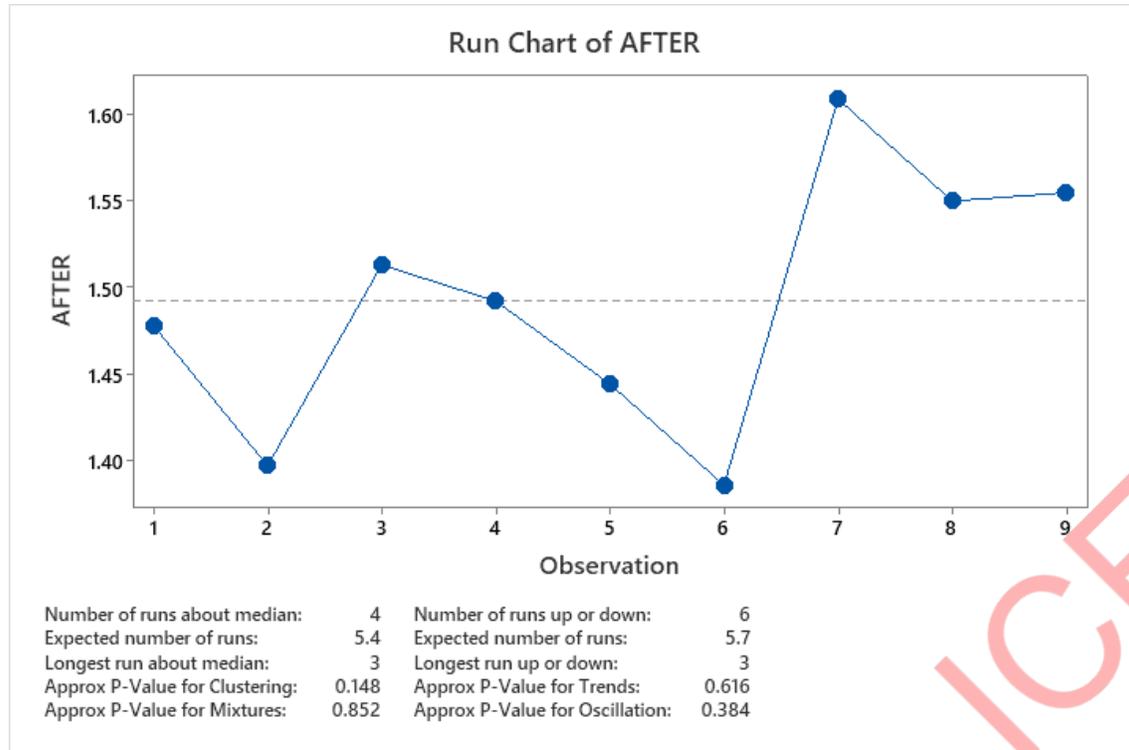
# Improve



**Inference:**

- No trends or patterns observed in residuals.
- Model assumptions are satisfied.

# Improve – Run chart and Normality Test (After Improvement)



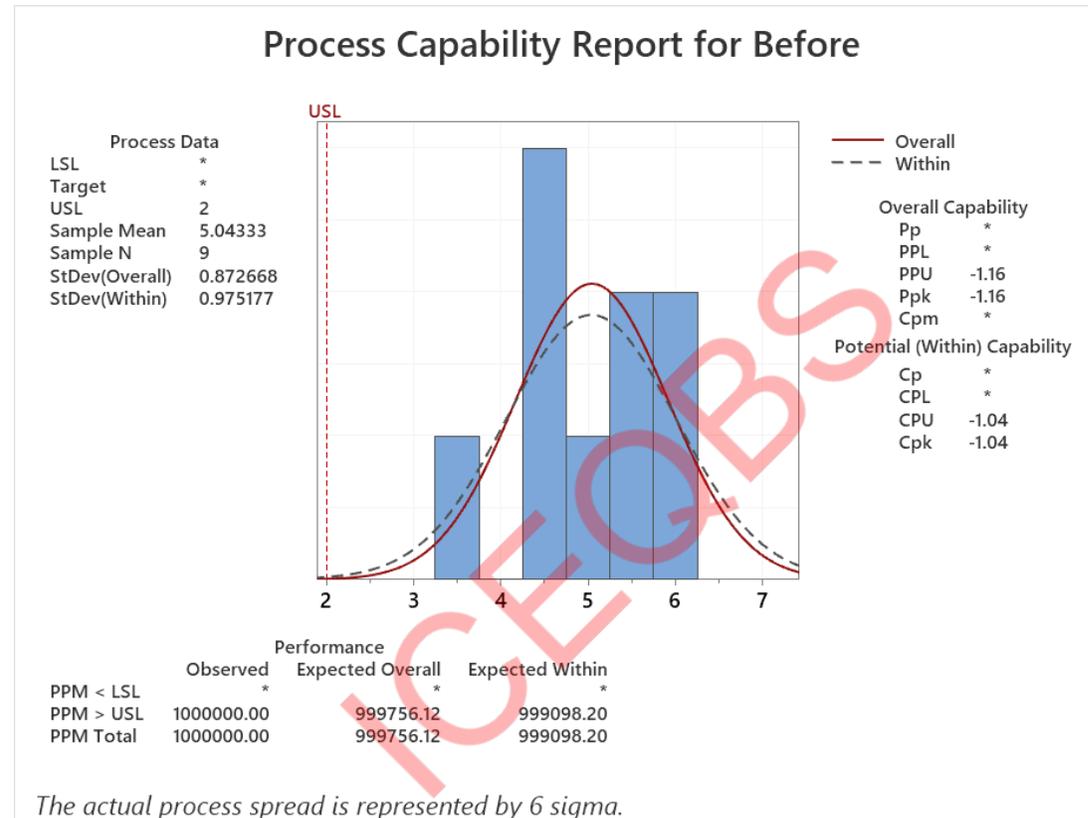
## Inference:

- 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



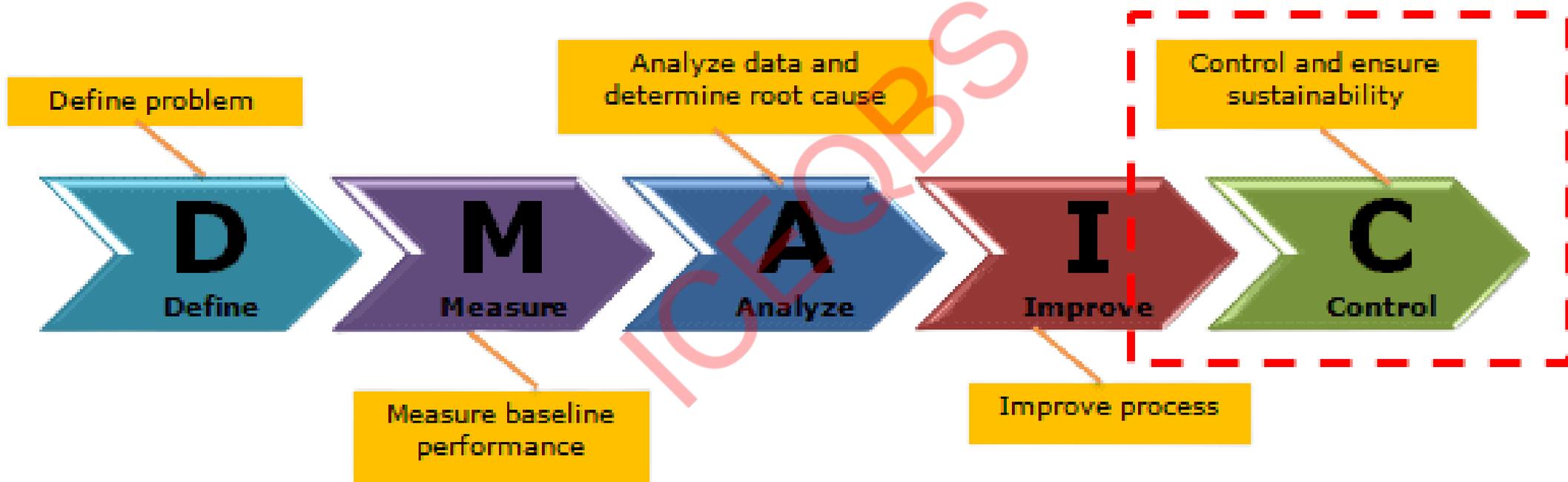
## Inference :

- The process is **not capable before improvement**, with  $Cpk < 0$  and a large portion of output exceeding the specification limit.

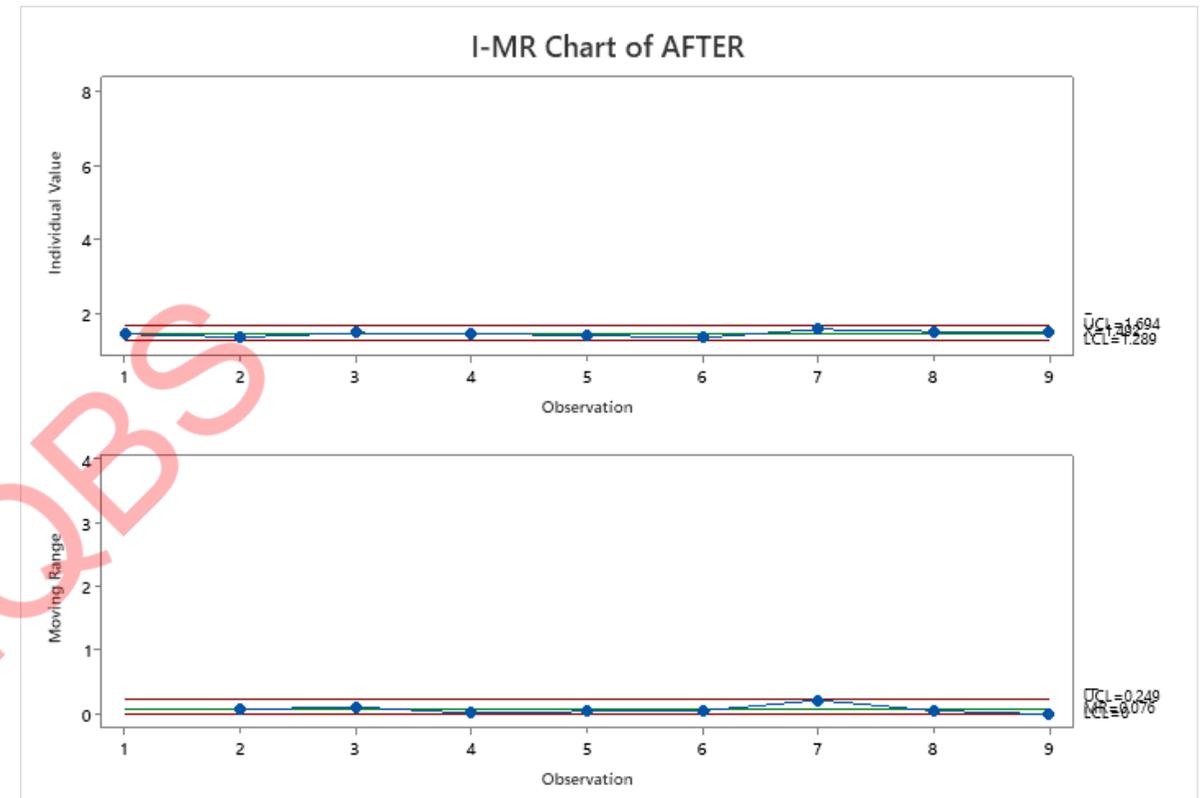
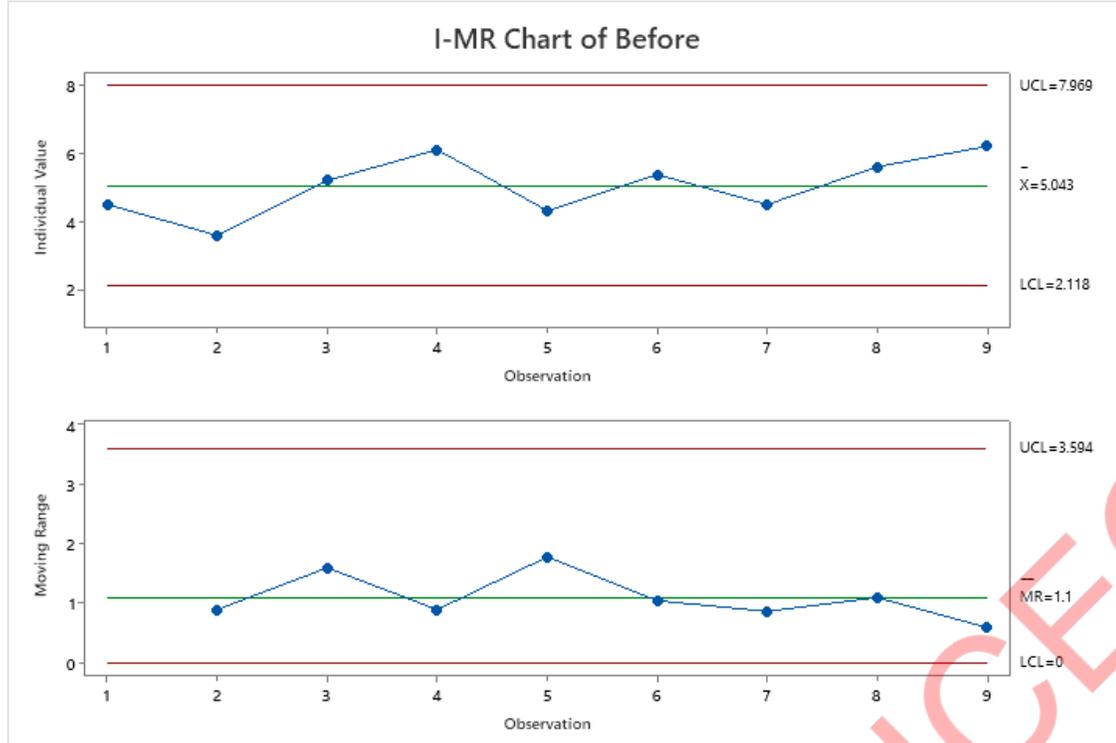
# FMEA

Process Step	Function / Requirement	Potential Failure Mode	Potential Effects	S	Potential Causes / Mechanisms	O	Current Controls (Prev / Det)	D	RPN	Recommended Actions (Acceptance Criteria)	Owner	Target	Residual S	Residual O
Machine setup	Correct setup as per drawing	Incorrect machine parameters	Dimensional rejection	8	Wrong speed/feed setting, setup error	5	Setup sheet, first piece inspection	4	160	Standardized setup checklist; verify parameters before run	Production Engg	30 days	8	2
Tool selection	Use correct tool condition	Worn or damaged tool used	Poor surface finish, rework	7	Tool wear not monitored	6	Visual check by operator	4	168	Tool life monitoring; mandatory tool change limits	CNC Supervisor	30 days	7	2
Machining operation	Maintain dimensional accuracy	Tool offset deviation	Out-of-tolerance parts	8	Offset not updated after tool change	4	Periodic inspection	4	128	Offset verification after every tool change	Operator	Immediate	8	1
Material loading	Correct material orientation	Improper clamping / loading	Part damage, scrap	7	Fixture misuse, human error	5	Operator training	5	175	Poka-yoke fixture; visual aids at workstation	Maintenance	45 days	7	2
Measurement	Accurate inspection	Measuring instrument error	False accept / reject	6	Instrument not calibrated	3	Calibration schedule	3	54	Strict calibration adherence; daily zero check	Quality	Ongoing	6	1
Process control	Stable process output	Process variation not detected	Increased rejection trend	8	No real-time monitoring	4	End inspection	5	160	SPC charts with reaction plan	Quality Engg	60 days	8	2

# CONTROL PHASE



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



## Inference:

- The I-MR chart for Before shows higher variation with points closer to control limits, indicating an unstable process.
- The I-MR chart for After shows reduced variation with all points well within control limits, indicating improved process stability.
- Overall process control has significantly improved after implementation of corrective actions.

# Control Plan to sustain improvements

Critical X	Control parameter / metric	Target / limit	Control method (5S + Poka-Yoke)	Frequency	Reaction plan	Owner
Process Complexity	Process Complexity Index (PCI)	≤ approved standard	Approved routing only; barcode/QR program selection	Per lot	If PCI deviates → halt lot, revert to standard routing	Process Eng
Operator Skill	Certified operator for CTQ ops	≥ 95% coverage	Skill matrix displayed; machine login by operator ID	Each shift	Replace operator or assign certified support	Production
Measurement Accuracy	Instrument calibration error	≤ 2–3 μm	Color-coded gauge tags; expired gauges locked out	Daily	Stop inspection; replace gauge; re-measure parts	Quality
Gauge Verification	Master gauge check	Pass	Start-of-shift verification log (gate)	Each shift	Quarantine measurements since last good check	Metrology
Setup Accuracy	Setup checklist adherence	100%	Mandatory checklist before cycle start	Every setup	Correct setup; first-piece re-approval	Supervisor
Tool Condition	Tool life / offset accuracy	Within limits	Tool life counter + auto-stop; preset offsets	Continuous	Tool change; re-verify dimensions	Production



## Results after improvement

- **The project objectives were achieved within the defined timeline, delivering measurable quality improvement and long-term operational benefits.**