Reduction of Injection Molding Defects in Plastic Crates

ICEQES

Chakkaravarthi

ROADMAP

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OVERVIEW

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Background

- The injection molding process for plastic crates is currently experiencing an average defect rate of 8.5%, primarily due to warpage, sink marks, and cracks.
- This high process variation has led to increased scrap, rework, production losses, and customer complaints, negatively impacting operational efficiency and delivery performance.
- The current defect level results in an estimated scrap and rework cost of SAR 48,000 per month, creating a significant recurring financial burden.
- Reducing the defect rate to below 3.0% within four months will stabilize the process and reduce defect variation by at least 50%.
- Achieving the target state is expected to deliver annual cost savings of approximately SAR 400,000, along with improved process capability, customer satisfaction, and sustainable quality performance.

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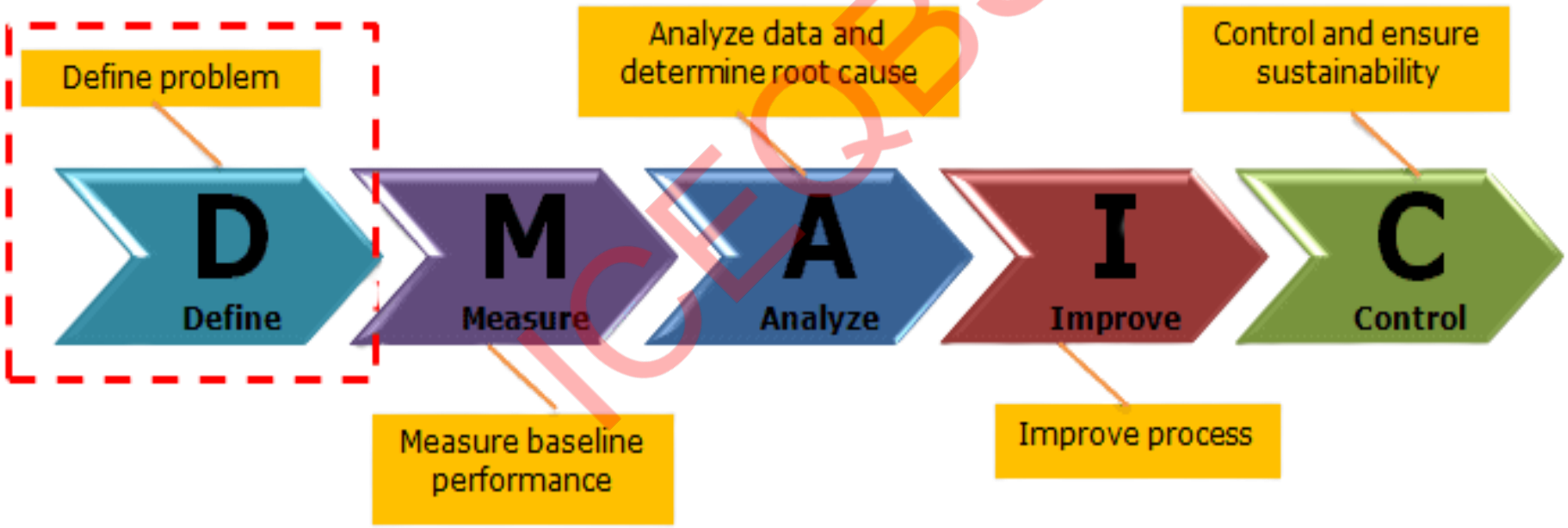
DEFINE PHASE



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VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
Crates should be dimensionally stable, defect-free, and stack properly	CTQ - Defect Rate (%)	**Primary Metric -** Defect Rate (%) **Secondary Metric -** FPY (%)

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

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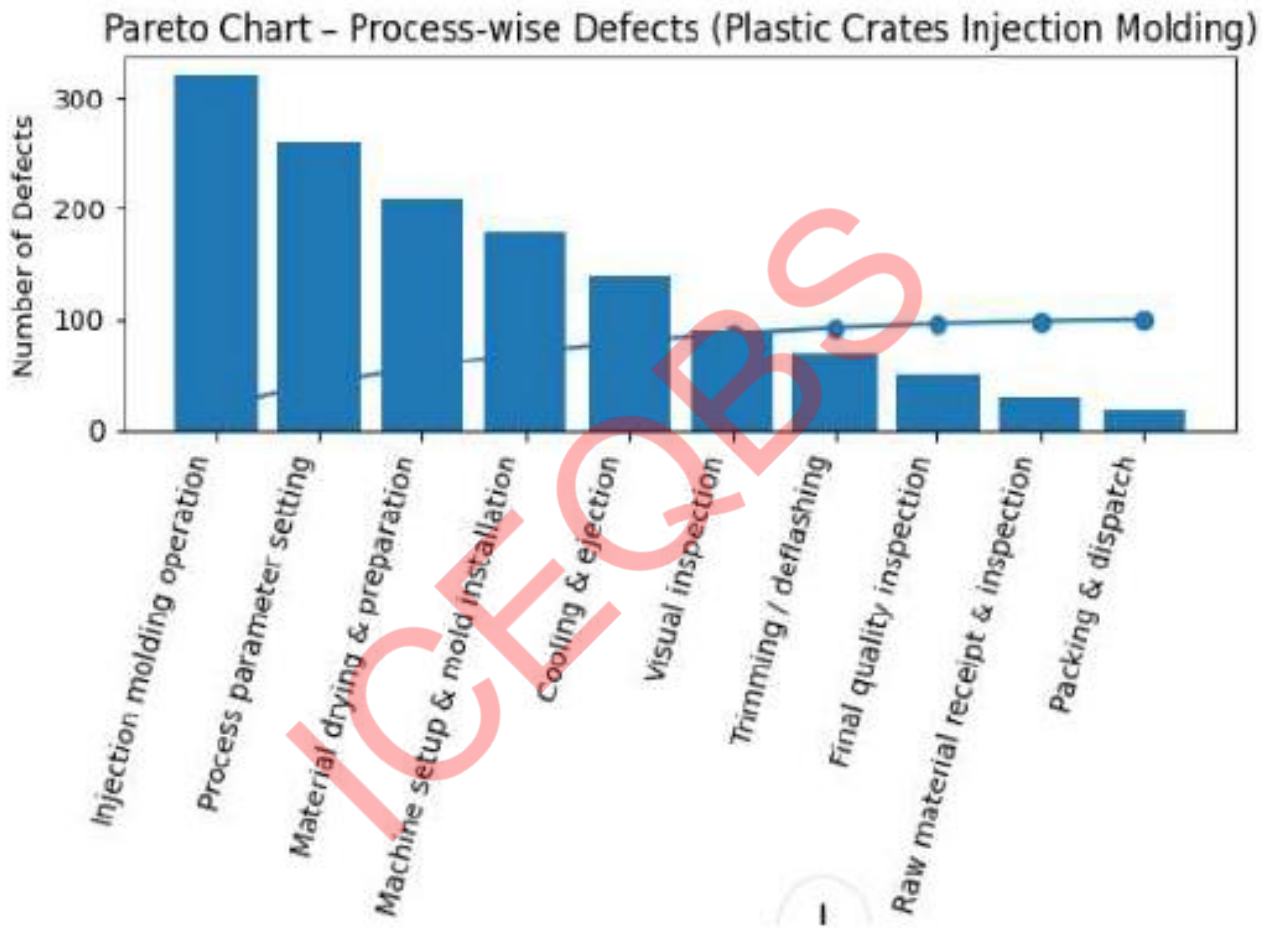
Inference :

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

Pareto chart



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Inference :

- Most defects are concentrated in **injection molding operation and process parameter settings**, making them the key focus areas for improvement.

Project Charter

Project Title:	Reduction of Injection Molding Defects in Plastic Crates
Project Leader	**Project Team Members:**
Chakkaravarthi	Quality Engineers Maintenance Engineer Shift Supervisor
Champion/Sponsors:	**Key Stake Holders**
Plant Manager	Manufacturing Manager / Production Head Quality Assurance & Process Engineering Team
Problem Statement:	**Goal Statement:**
Injection-molded plastic crates are experiencing an average defect rate of 8.5% over the last 9 months, primarily due to warpage, sink marks, and cracks.	Reduce the defect rate from 8.5% to below 3.0% within 4 months and stabilize the process by reducing defect variation by at least 50%.
Secondary Metric	**Assumptions Made:**
FPY %	Existing machines and molds are capable of meeting quality targets with optimized settings

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Project Charter

Tangible and Intangible Benefits:	Risk to Success:
Reduction in scrap and rework cost by approximately **SAR 400,000 annually** Improved productivity through reduced defects and rework time Improved customer satisfaction and reduced complaints	Resistance to process changes by operators Inconsistent adherence to standardized process settings
In Scope:	**Out of Scope:**
Injection molding process parameters and machine setup Defects related to warpage, sink marks, and cracks	Mold design changes and major equipment replacement Packaging, logistics, and post-dispatch handling
Signatories:	**Project Timeline:**
Sponsor	Out of Scope

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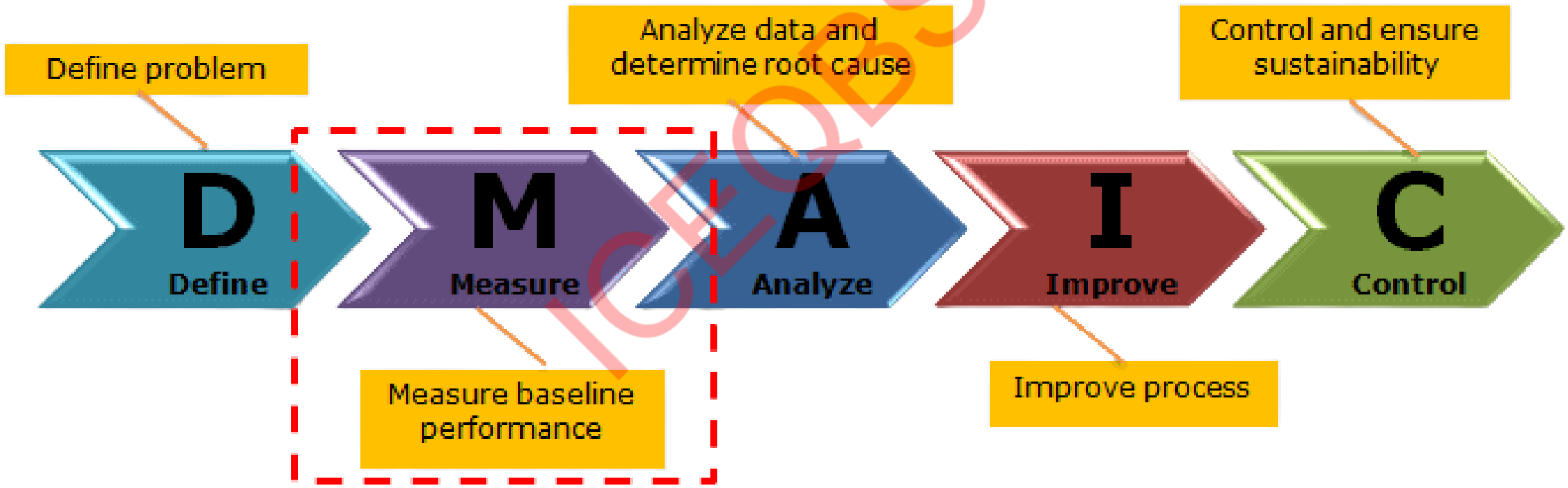
MEASURE PHASE



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SIPOC

Suppliers	Inputs	Process	Outputs	Customers
Resin Supplier	HDPE/PP	Injection molding	Plastic crates	Customers
Maintenance	Mold	Inspection	Accepted crates	Warehouse
Utilities	Power, water	Packing	Rejected crates	Rework

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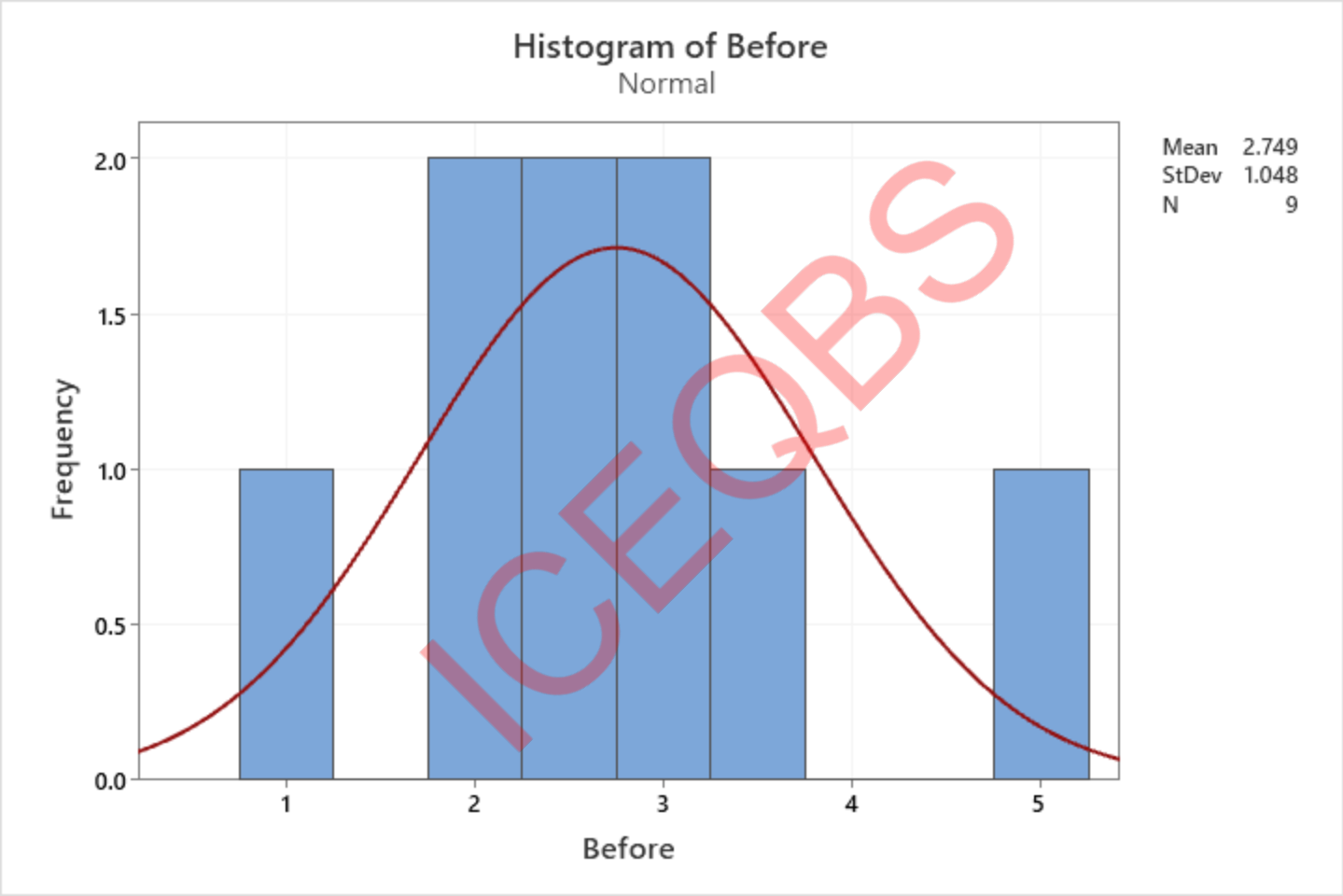
Data collection – Histogram (Before improvement)



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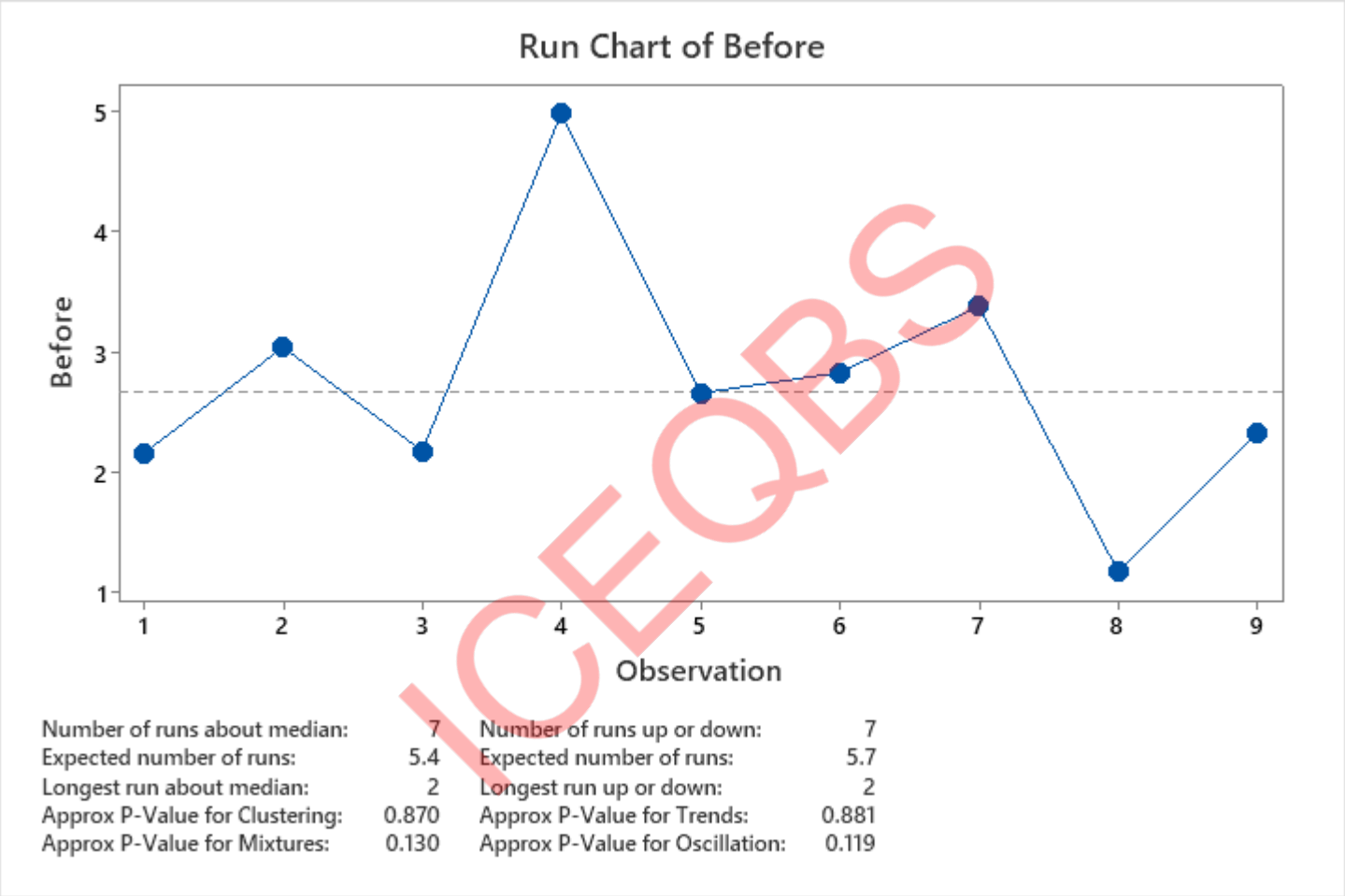
Inference :

- Data is normally distributed over the mean

Data collection – Run Chart (Before improvement)



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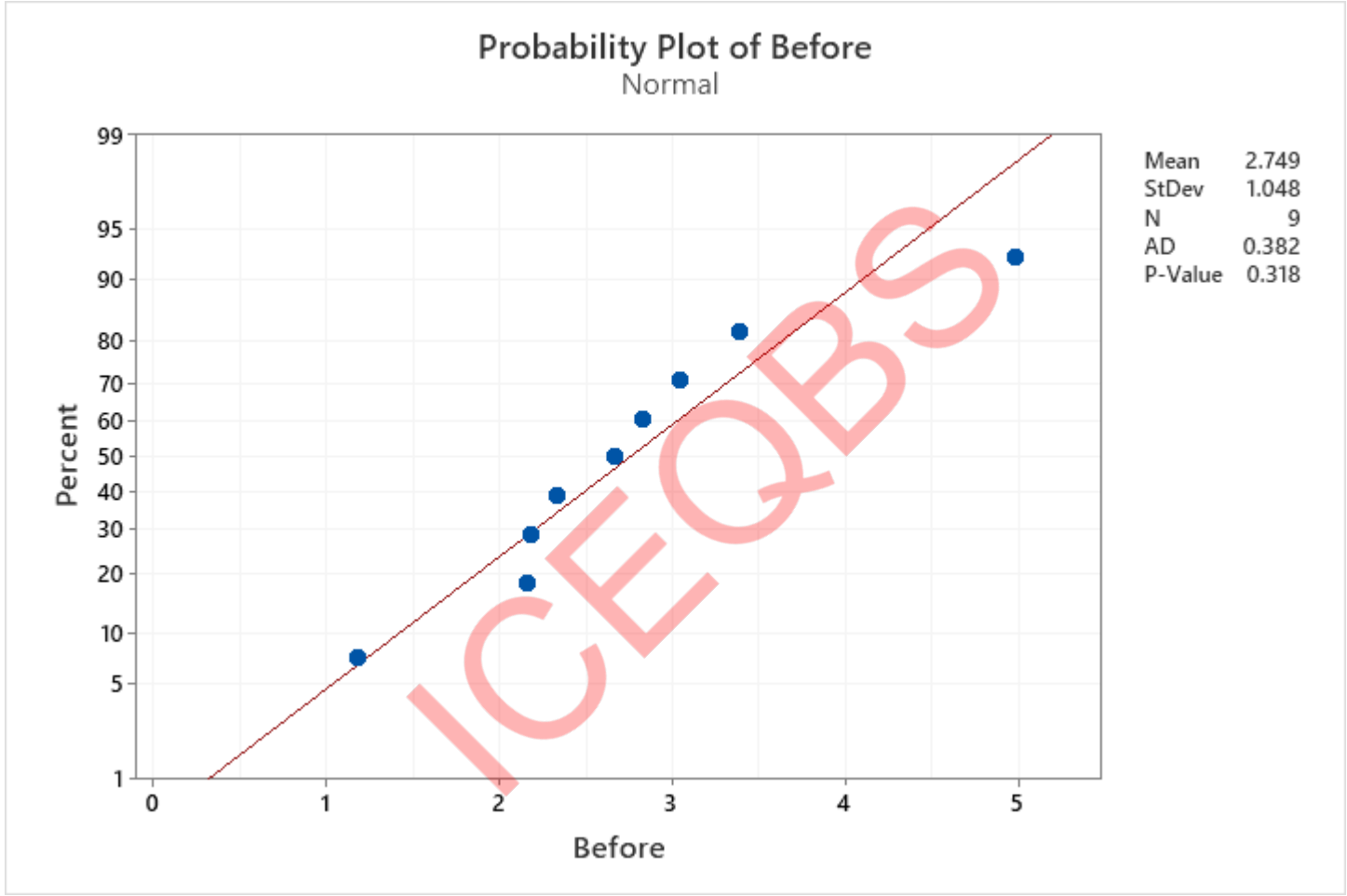
Inference :

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

Data collection – Normality plot (Before improvement)



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Inference :

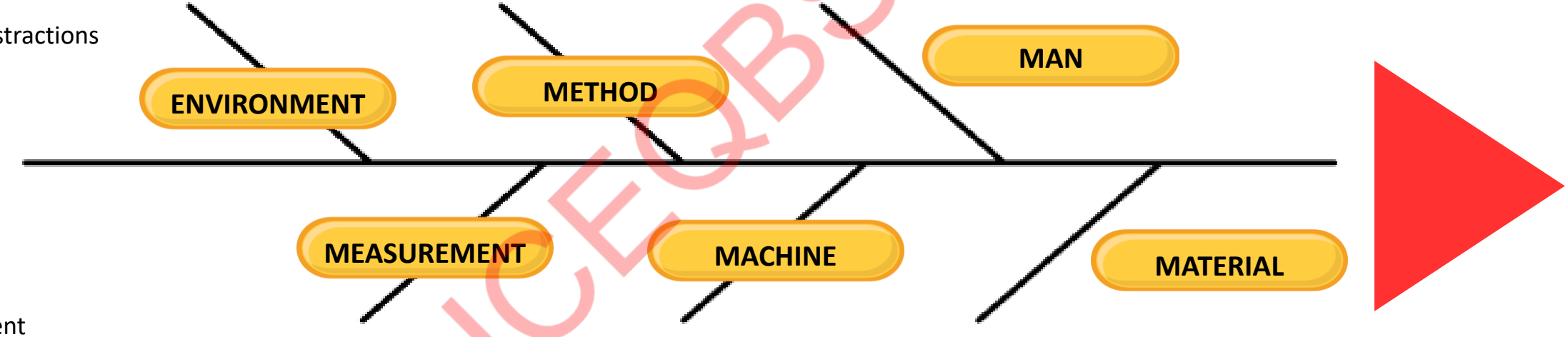
- P > 0.05 in all scenarios, thus all the data is normally distributed

Fish Bone Diagram

1. Mother Nature
2. High ambient temperature
3. Dust in molding area
4. Power fluctuation
5. Poor ventilation
6. Noise and distractions

1. No standard parameter window
2. Inconsistent startup procedure
3. Poor changeover practice
4. No defect-based reaction plan
5. Improper inspection method

1. Improper machine setting by operators
2. Inadequate training
3. Fatigue during long shifts
4. Incorrect handling during ejection
5. Lack of process discipline



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1. Measurement
2. Visual inspection only
3. No defect trend monitoring
4. Delayed reporting
5. Inconsistent defect classification

1. Worn-out molds
2. Uneven cooling
3. Heater band variation
4. Clamp force instability
5. Injection pressure fluctuation

1. Moisture in resin
2. Batch-to-batch variation
3. Contamination
4. Improper regrind ratio
5. Inconsistent color masterbatch

Common & Special Causes

Common Causes	Special Causes
No standard process window	Sudden heater failure
Mold wear	Power interruption
Improper drying	Resin contamination incident
Operator skill gap	Emergency mold change
Inconsistent inspection	Cooling water blockage

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3M Analysis for Waste

MUDA

- Rework, waiting for machine approval, excess trimming

Mura

- Uneven defect rates between shifts, batch variation, inconsistent cycle time

Muri

- Operator handling multiple machines, high output pressure, long shifts

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Action Plan for Low Hanging Fruits

Issue Category	Gemba Walk Observation	Lean Tool / Action	Expected Benefit
Special Cause	Sudden defect spike during one shift due to heater band failure	**Andon + Preventive Maintenance** – Visual alarm for heater failure and daily heater resistance check	Prevents sudden quality deterioration and unplanned defects
Special Cause	Moist material loaded due to dryer breakdown	**Poka-Yoke** – Interlock machine start with dryer temperature & time confirmation	Eliminates moisture-related defects (splay, bubbles, cracks)
Special Cause	Parameter changes made without approval	**Standard Work + Authorization Control** – Parameter lock with supervisor approval	Prevents uncontrolled process variation
Special Cause	Mold cooling line blockage causing warpage	**Visual Management + PM Checklist** – Cooling flow indicator and weekly flushing	Prevents warpage and dimensional defects
Special Cause	Power fluctuation affecting cycle stability	**UPS & Voltage Monitor**	Eliminates electrical instability impact

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Top 12 Prioritized Root Causes (Based on Net Score)

Root Cause	Score
Tool wear	**306**
Overuse of cutting tools	**306**
Cutting parameters	**264**
Vibration in machines	**264**
Machine calibration	**258**
CMM program errors	**242**
Operator skill variation	**216**
Fixturing/clamping	**216**
Raw material hardness variation	**216**
Raw material surface defects	**216**
SOP adherence	**200**
Gauge accuracy/calibration	**200**

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Data Collection Plan

Data Type	Metric / Parameter	Source	Method	Frequency	Owner
Defect Data	Defect % by type (warpage, sink, cracks)	Production & QA records	Visual inspection & tally sheet	Per shift	Quality Engineer
Process Parameters	Temperature, pressure, cycle time	Injection molding machine	Machine log / auto capture	Per batch	Process Engineer
Material Data	Resin grade, moisture level	Raw material log	Material inspection	Per lot	Stores / QA
Setup Conditions	Mold setup & clamping conditions	Setup checklist	Standard checklist review	Per changeover	Production Supervisor
Rework & Scrap	Scrap quantity & rework hours	Production reports	Data extraction	Daily	Production Planner

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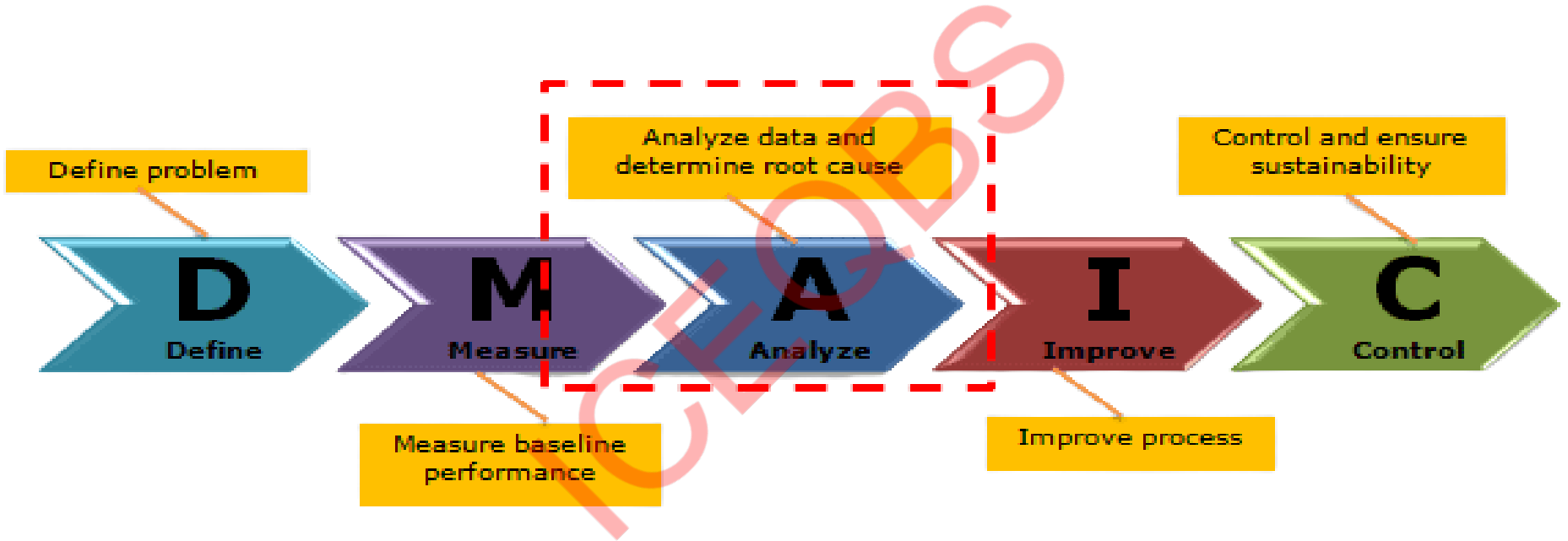
ANALYSE PHASE



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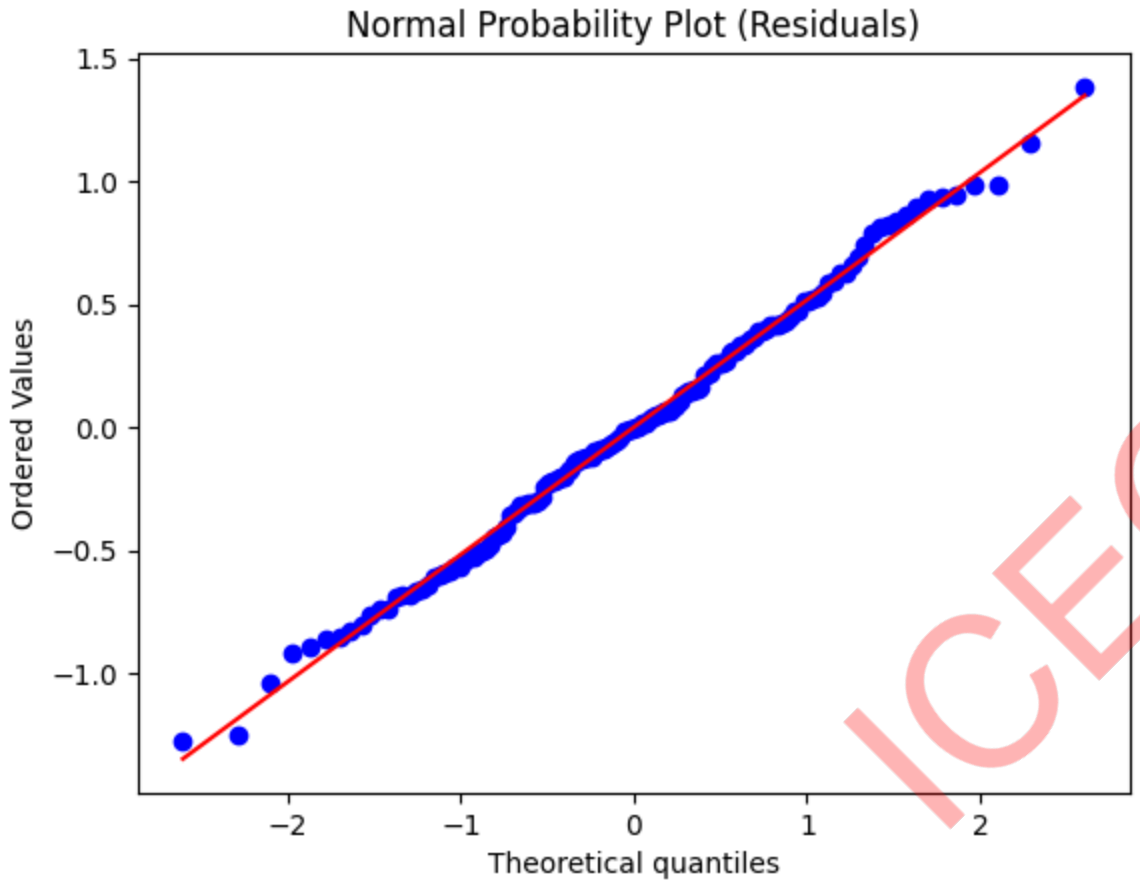
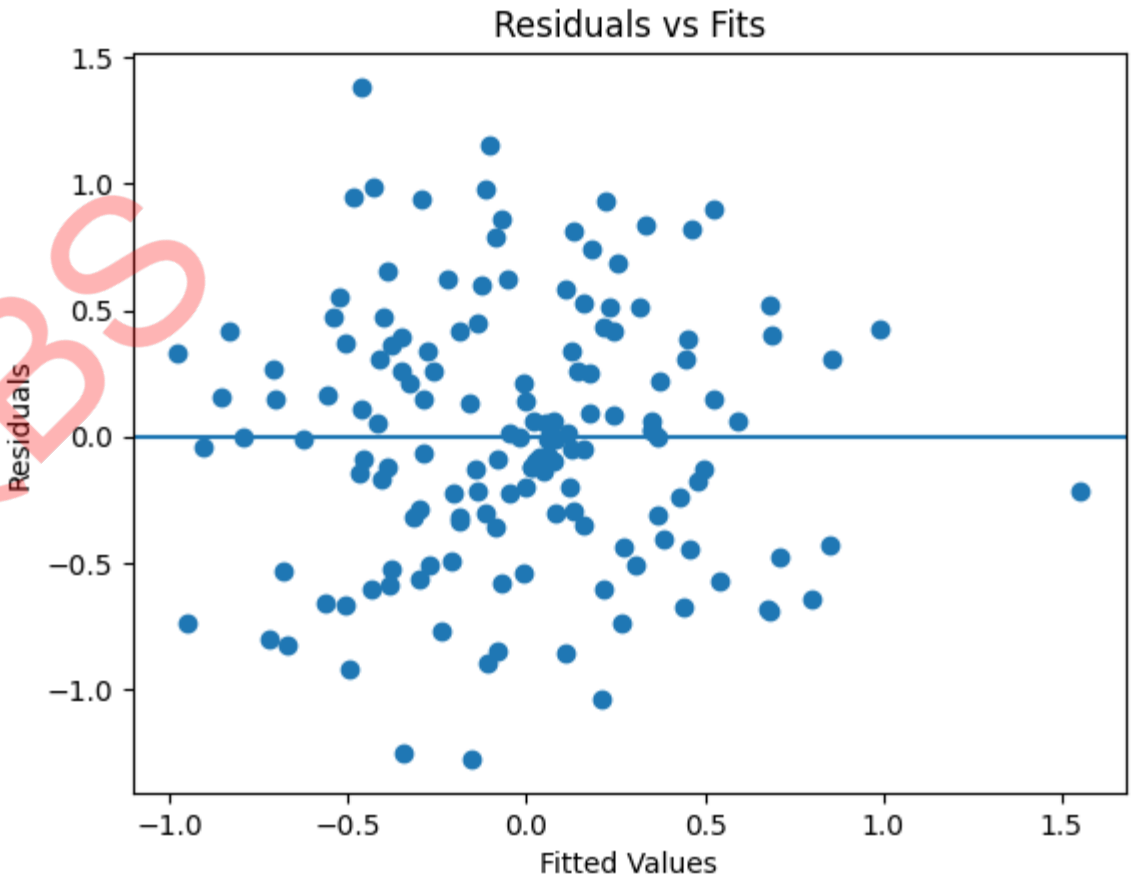
Analyse – Hypothesis testing





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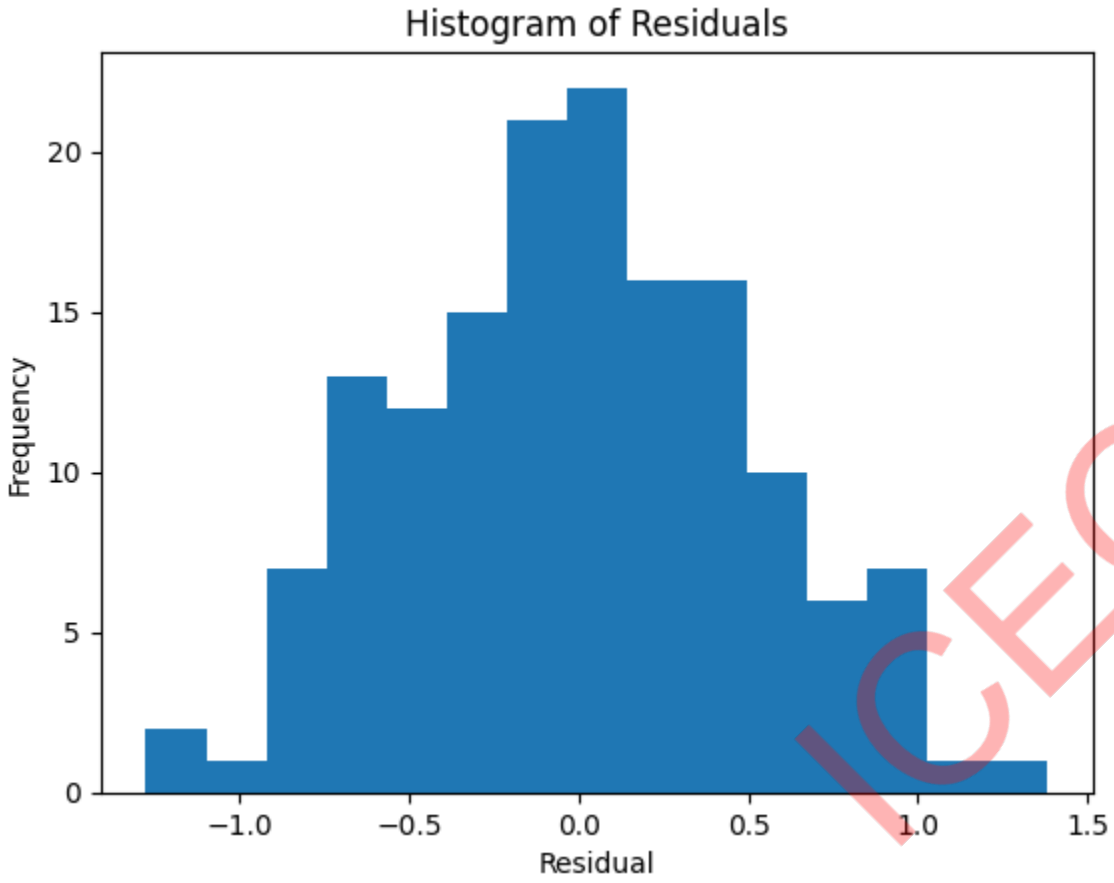
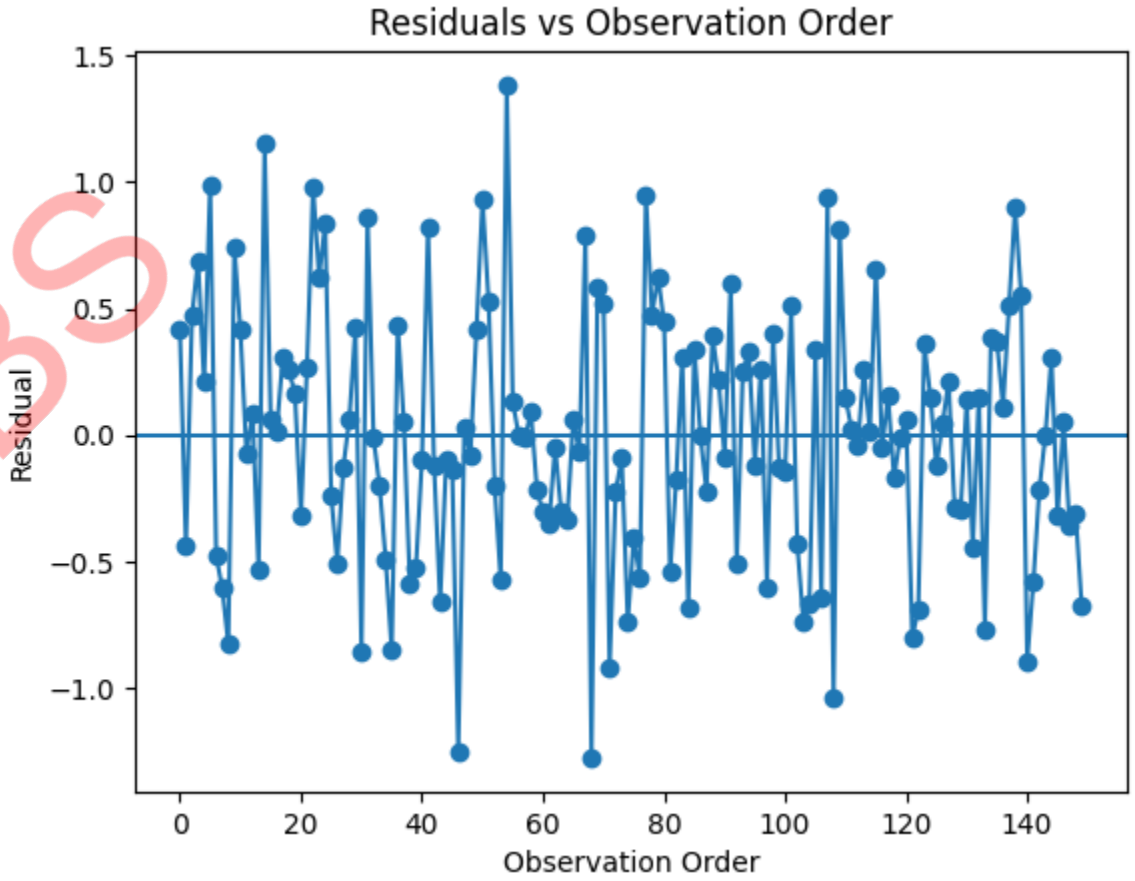
Inference :

The residuals are normally distributed and randomly scattered, confirming the model is valid and process parameters significantly influence defects.

Analyse – Hypothesis testing





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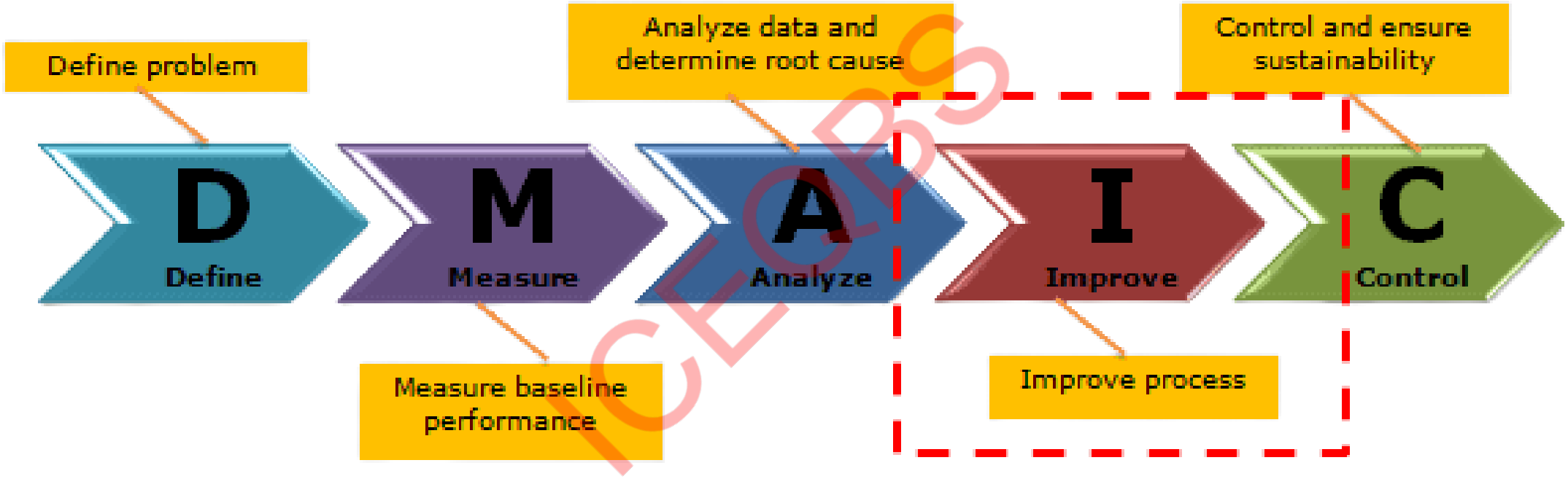
Inference :

- Residuals are approximately normally distributed and randomly varying over time, indicating process stability and no time-related special cause variation.

IMPROVE PHASE



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Improve Design of Experiment

Run Order	Type	A: Melt Temp (Code)	B: Injection Pressure (Code)	C: Cooling Time (Code)	Melt Temp (°C)	Injection Pressure (bar)	Cooling Time (sec)	Defect Rate (%)
1	Factorial	-1	-1	-1	215	110	16	—
2	Factorial	1	-1	-1	225	110	16	—
3	Factorial	-1	1	-1	215	130	16	—
4	Factorial	1	1	-1	225	130	16	—
5	Factorial	-1	-1	1	215	110	20	—
6	Factorial	1	-1	1	225	110	20	—
7	Factorial	-1	1	1	215	130	20	—
8	Factorial	1	1	1	225	130	20	—
9	Center	0	0	0	220	120	18	—
10	Center	0	0	0	220	120	18	—
11	Center	0	0	0	220	120	18	—

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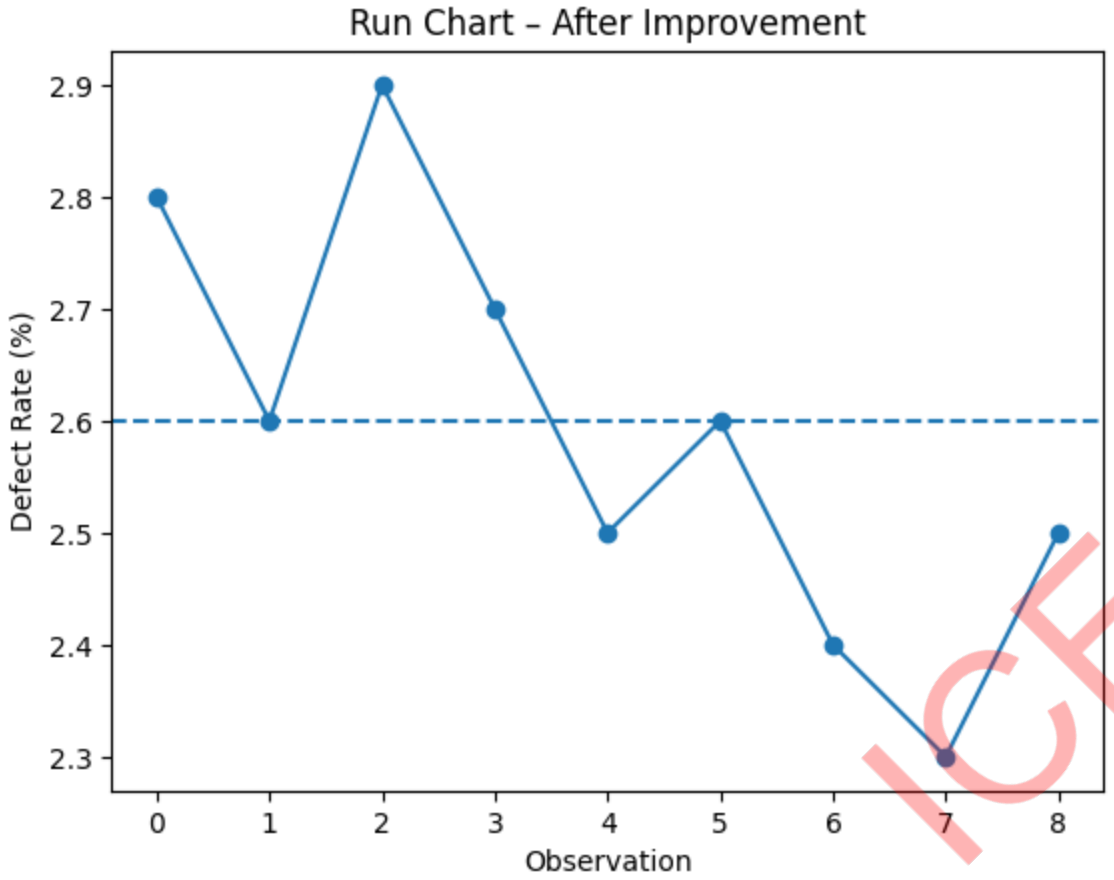
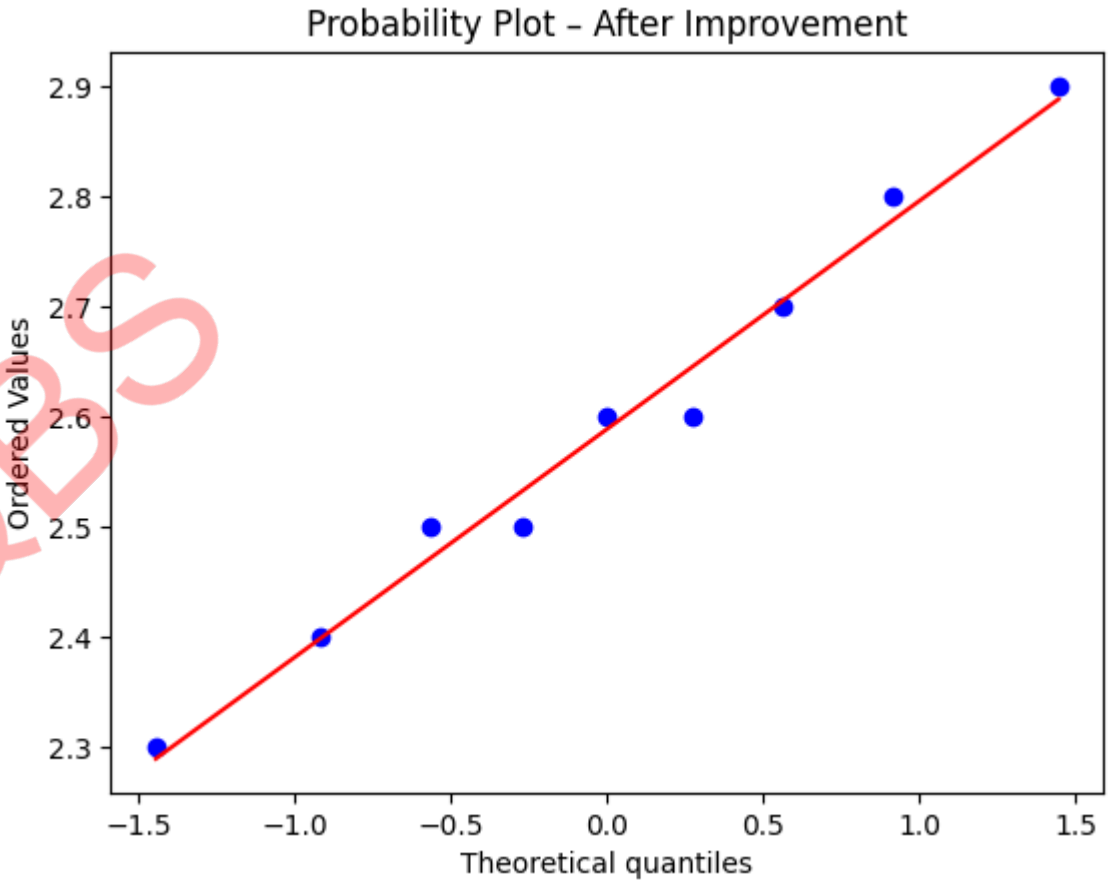
Improve – Run chart and Normality Test (After Improvement)





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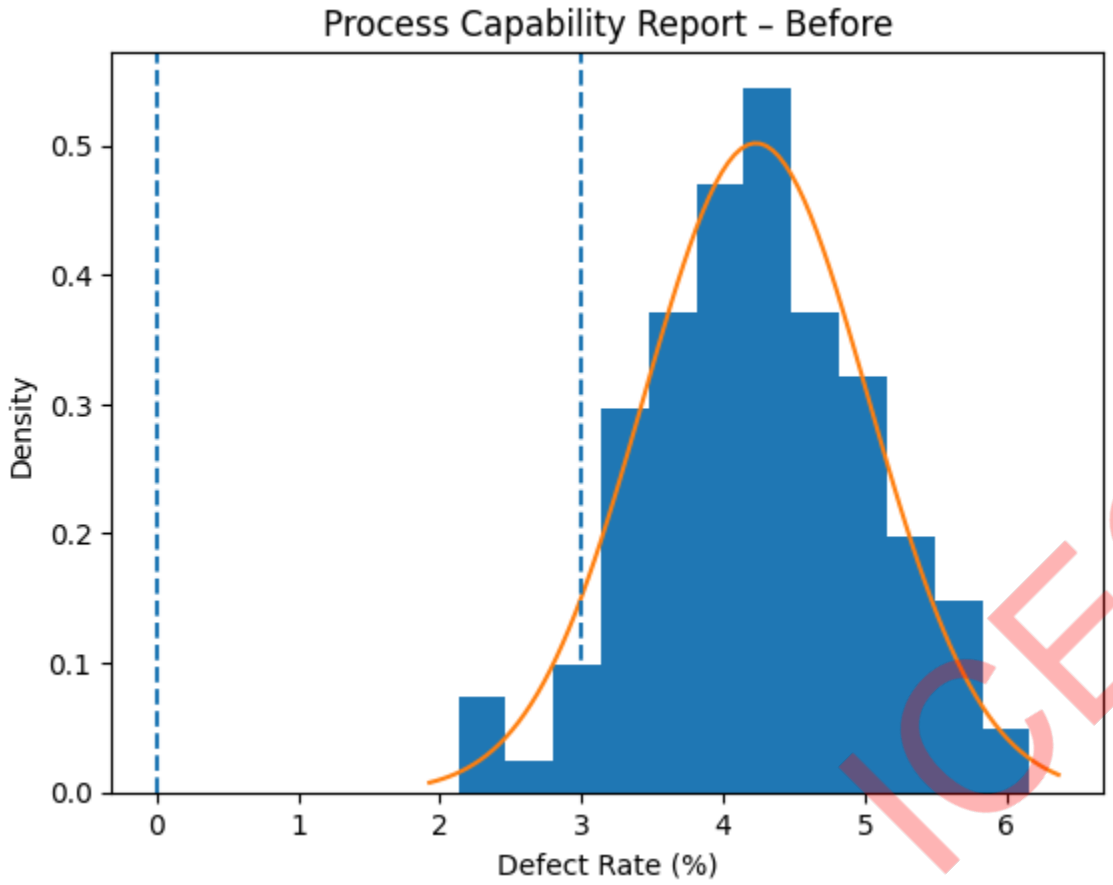
Inference:

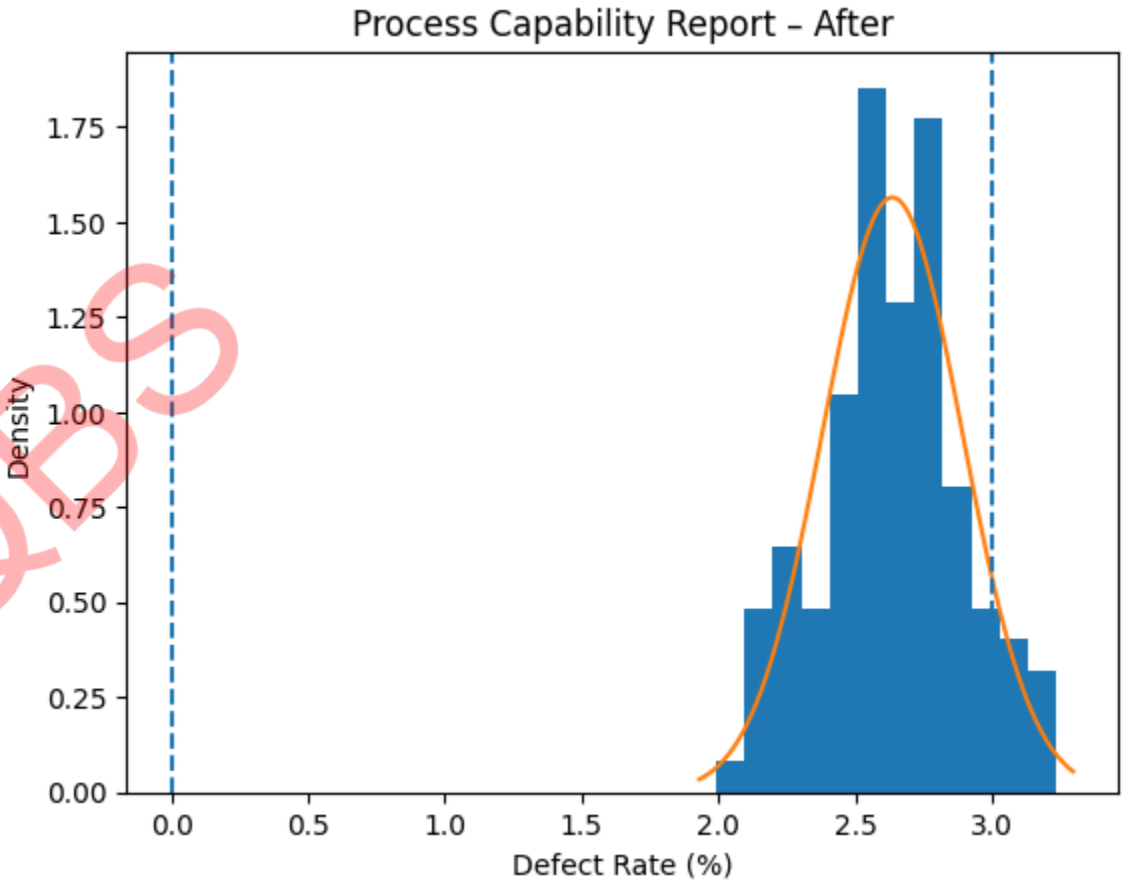
- Run chart – process is stable there is no special causes in the process (p value > 0.05)

Inference:

- Normality test – Data are normally distributed

Improve – Process capability – Before & After Improvement





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Inference :

- Process capability improved significantly after optimization, with defect rate centered below the USL and variation substantially reduced.t

FMEA

Process Step	Function / Requirement	Potential Failure Mode	Potential Effects	S	Potential Causes	O	Current Controls	D	RPN	Recommended Actions	Owner	Target	Residual S	Residual O	Residual D
Material drying	Maintain correct moisture level	High moisture in resin	Warpage, cracks, sink marks	8	Inadequate drying time/temp	6	Dryer setting checklist	5	240	Standardize drying parameters; moisture check before use	Process Engg	Week 2	8	3	3
Machine setup	Correct process parameters	Incorrect temp/pressure	Short fill, deformation	9	Manual setting errors	5	Setup sheet approval	5	225	Parameter locking & recipe management	Production	Week 3	9	2	3
Injection molding	Consistent molding cycle	Improper cooling time	Warpage, cracks	8	Cycle time variation	6	Operator monitoring	4	192	Optimize cooling time via DOE	Process Engg	Week 4	8	3	3
Tool condition	Mold integrity	Excessive tool wear	Surface defects, cracks	7	Delayed maintenance	5	Periodic visual check	5	175	Preventive maintenance plan	Tool Room	Week 4	7	2	3
Holding pressure	Proper material packing	Low holding pressure	Sink marks	7	Incorrect setting	6	Setup checklist	4	168	Define pressure window & SOP	Production	Week 3	7	3	3
Material handling	Correct resin grade	Wrong material mix	Strength loss, rejects	8	Labeling / handling error	4	Manual verification	5	160	Color-coding & barcode system	Stores	Week 2	8	2	3

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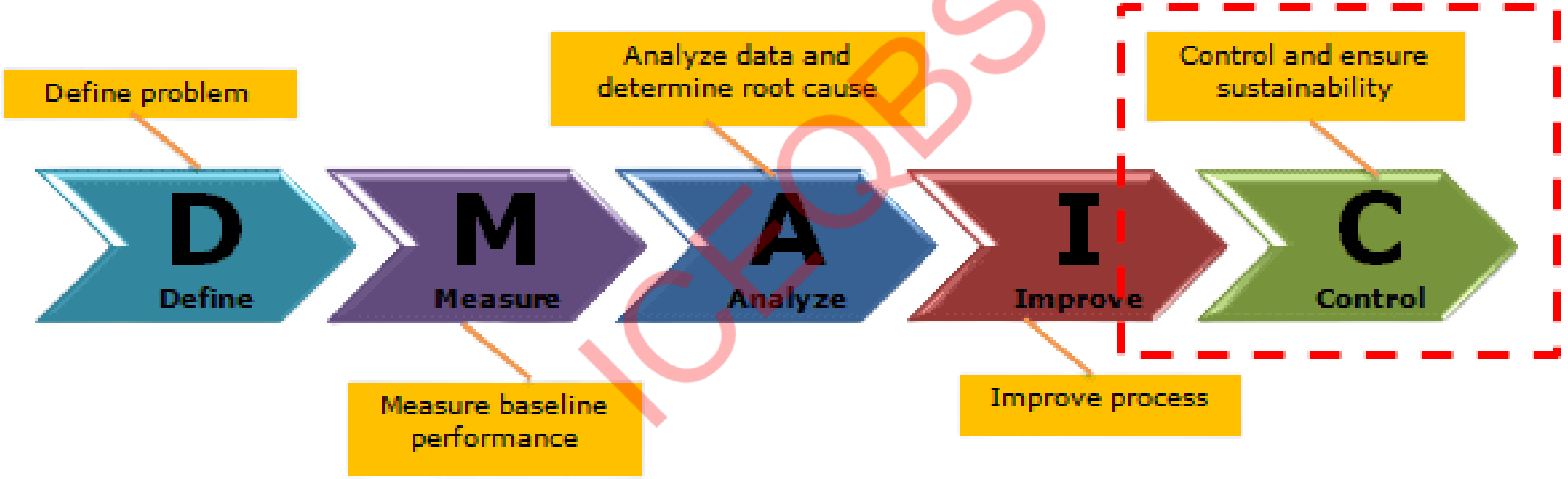
CONTROL PHASE



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Control Plan

CTQ	Monitoring Method	Frequency	Owner	Reaction Plan
Defect Rate	SPC Control Chart	Daily	QA	Stop process and investigate
Process Parameters	Parameter Audit	Shift-wise	Supervisor	Reset to standard settings
Material Moisture	Moisture Check	Daily	Production	Re-dry material
Mold Condition	Preventive Maintenance Checklist	Weekly	Maintenance	Repair mold
Operator Compliance	Skill / SOP Audit	Monthly	HR	Retraining

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Conclusion

Results after improvement

- The project achieved sustained defect reduction through improved process control and standardization.

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