Reduction of Internal Rejection Rate in Injection Molding Process

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ROADMAP

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

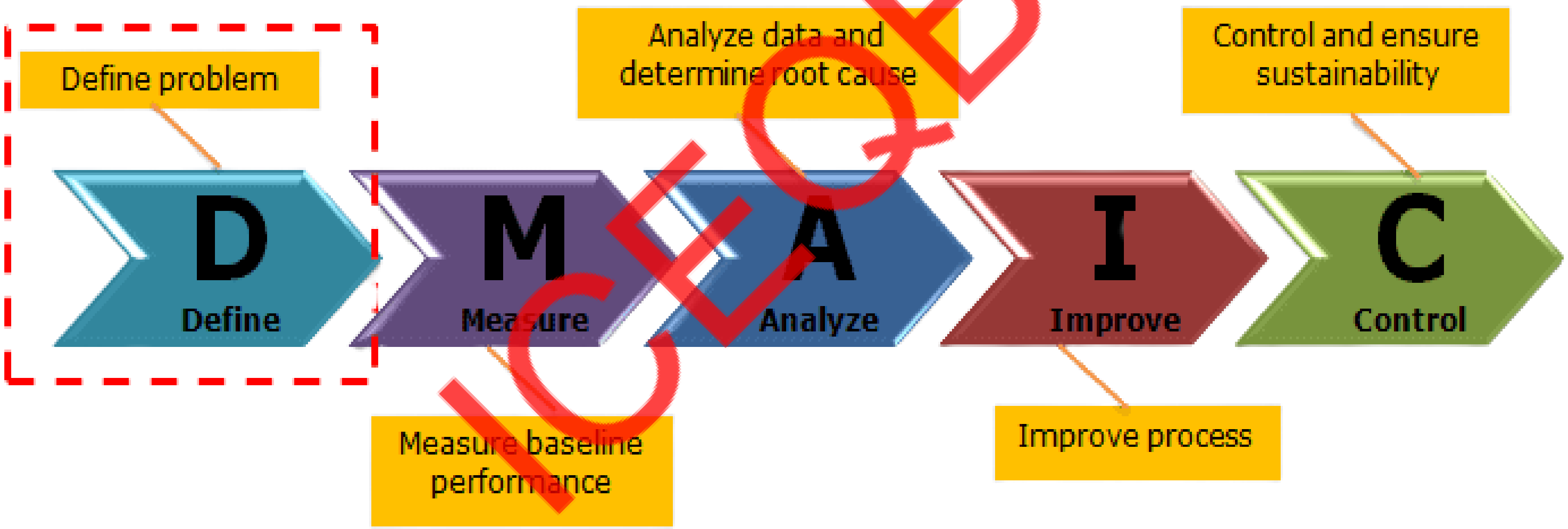
OVERVIEW

Background

•The injection molding process currently has an unstable internal rejection rate averaging 6.1% over the last nine months, resulting in increased scrap, rework, inspection effort, and production delays. This performance level drives an estimated COPQ of ₹18 lakhs per annum and limits the organization’s ability to consistently meet OEM quality and capability requirements.

•Reducing the rejection rate to ≤3.0% and stabilizing month-to-month variation by 50% will generate annual savings of ₹9–10 lakhs, improve First Pass Yield and machine utilization, and reduce inspection and rework workload. The project will also strengthen process capability (Cpk ≥ 1.33), improve audit readiness, and support sustained quality performance and customer satisfaction.

DEFINE PHASE



VOC & CTQ

CTQ Tree :

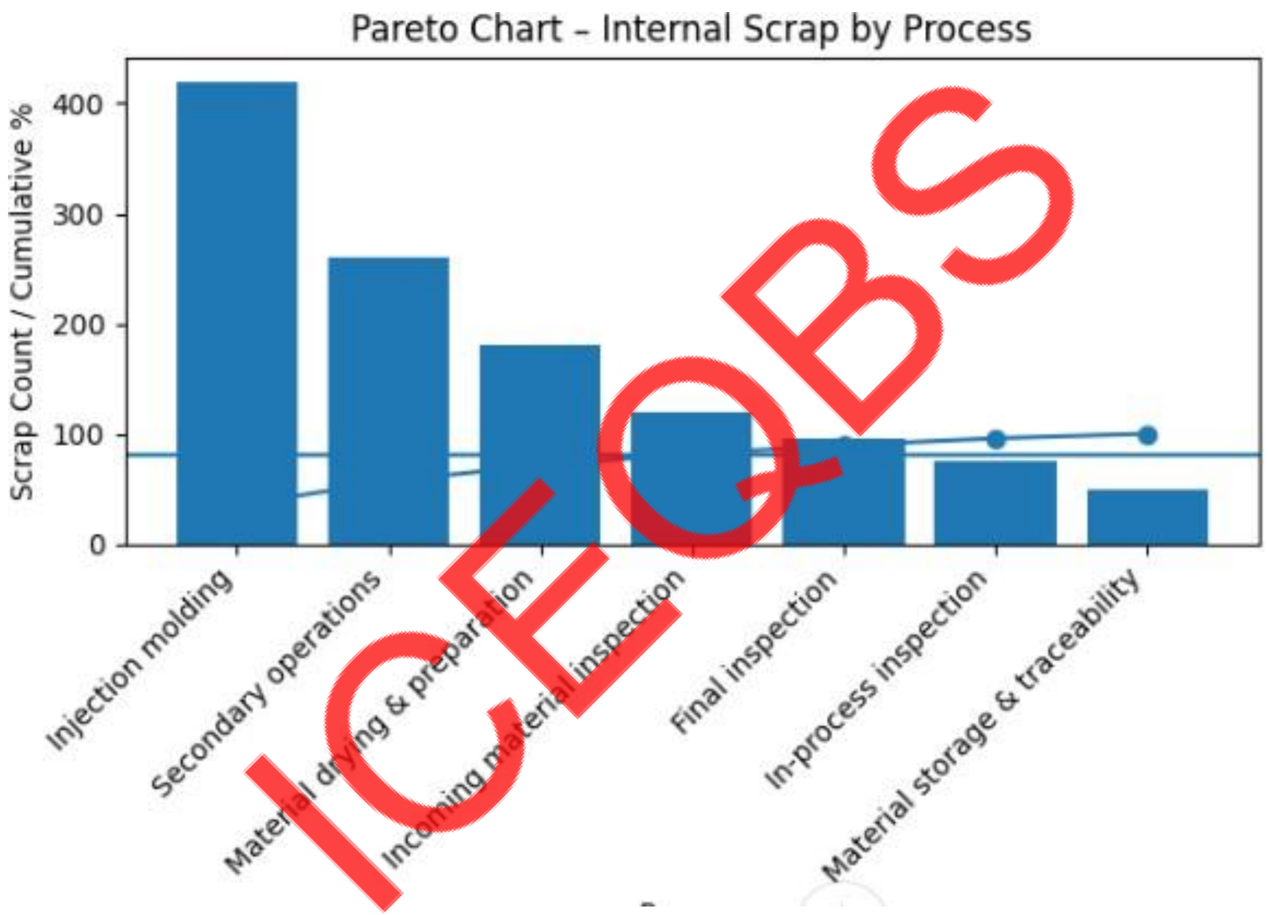
Voice of customer	Critical to X	Primary Metric for improvement
Molded parts must meet dimensional specifications consistently without fitment issues.	CTC – % internal scrap in molding process	**Primary Metric -** Y = % internal scrap in molding **Secondary Metric -** output/hour

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 :

- Injection molding contributes substantially and included in the scope of the project

Project Charter

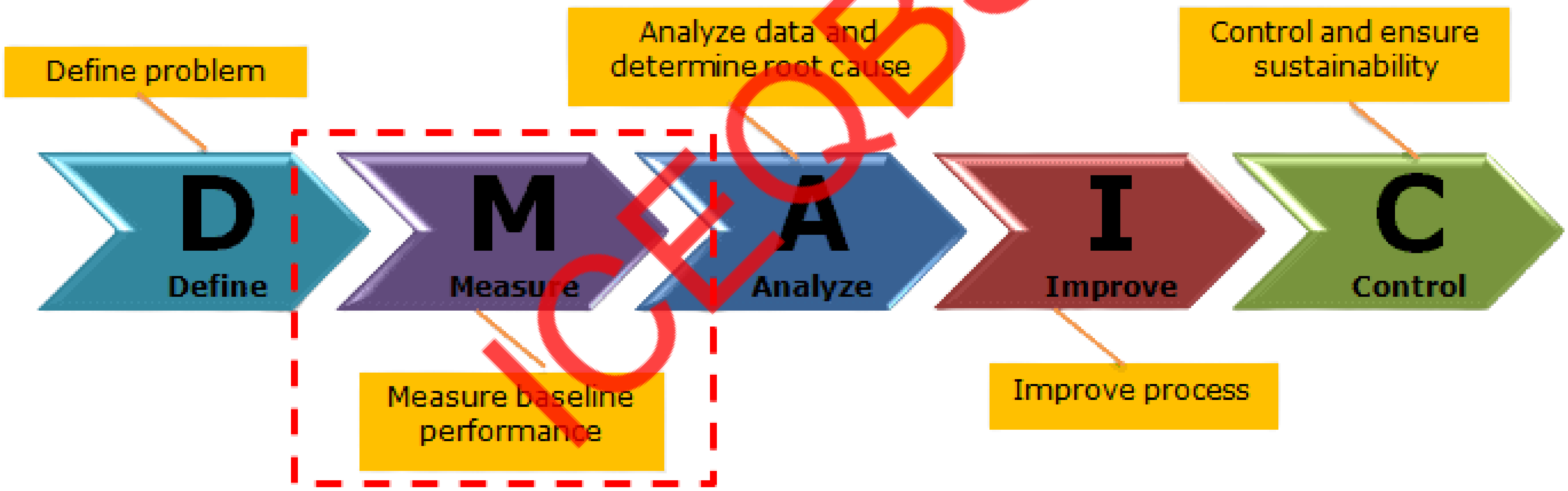
Project Title:	Reduction of Internal Rejection Rate in Injection Moulding Process

Project Leader	**Project Team Members:**
Marimuthu, Madhesh, Manikandan	Quality Engineer Production Supervisor Maintenance Engineer Operator Representative
Champion/Sponsors:	**Key Stake Holders**
Production Manager	**In-Process Quality (IPQC) Team** **Secondary Operations Team** **OEM Customers**
Problem Statement:	**Goal Statement:**
The injection moulding process is currently experiencing a **high and inconsistent internal rejection rate**, averaging **6.1% over the last 9 months**, with monthly values ranging from **3.9% to 9.0%**.	Reduce the **average internal rejection rate** in the injection moulding process from **6.1% to ≤3.0%** and stabilize the process by **reducing month-to-month variability by at least 50%** within **16 weeks**, without any negative impact on productivity, safety, or customer delivery
Secondary Metric	**Assumptions Made:**
output/hour	Rejection data and defect classification are accurate, consistent, and reliably recorded.

Project Charter

Tangible and Intangible Benefits:	Risk to Success:
Improved First Pass Yield (FPY) and better machine utilization. Improved process capability and readiness to meet OEM quality targets (PPM, Cpk ≥ 1.33). Enhanced customer confidence, delivery reliability, and organizational quality culture.	Operator non-adherence to standardized process settings and SOPs. Variation in raw material quality or supplier inconsistency impacting process stability.
In Scope:	**Out of Scope:**
Injection moulding process Material drying and preparation Machine parameter settings	Tool redesign or new Mold development Supplier process changes beyond incoming material inspection Secondary operations (trimming, painting, assembly) Customer usage or field failures
Signatories:	**Project Timeline:**
Project Sponsor Process Owner	6 Months

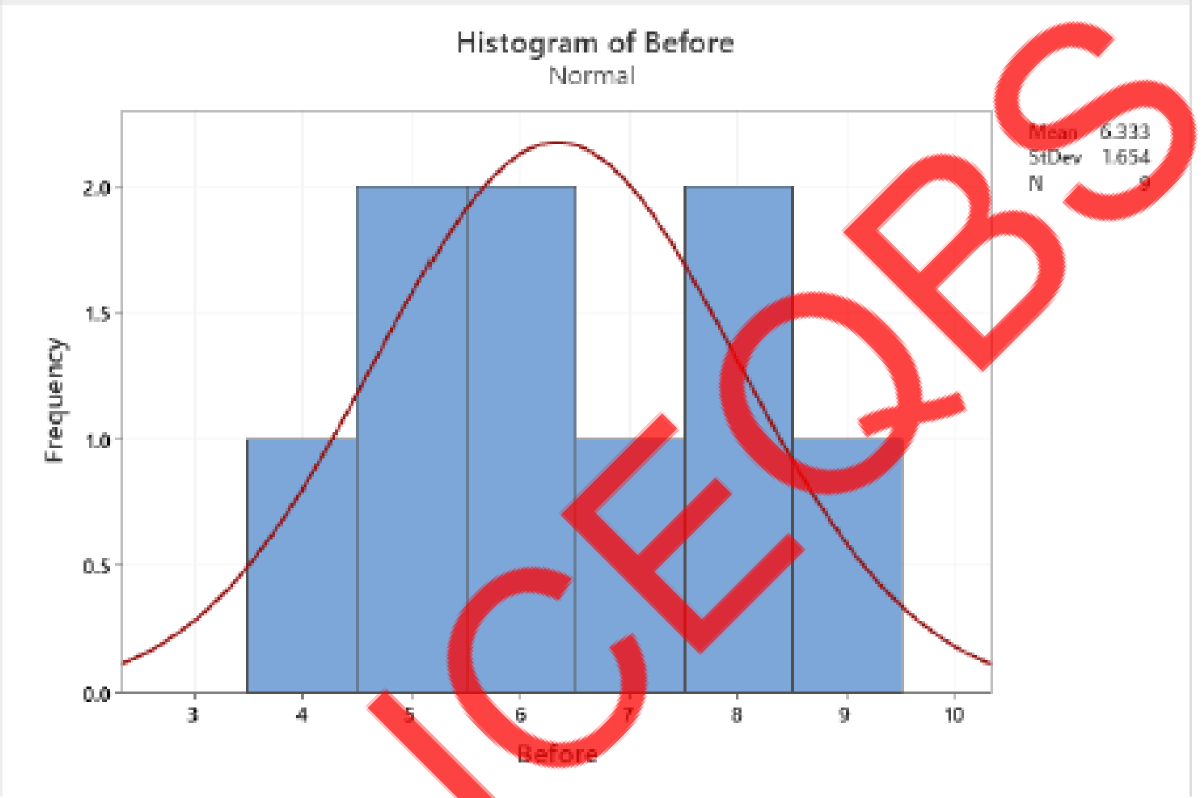
MEASURE PHASE



SIPOC

Suppliers	Inputs	Process (High-Level)	Outputs	Customers
Approved resin suppliers	Plastic resin (granules)	1. Receive raw material	Moulded plastic components	Secondary operations
Masterbatch suppliers	Masterbatch / additives	2. Dry and prepare material	Accepted parts	In-process quality
Tool room	Injection mould	3. Set machine parameters	Rejected parts (scrap/rework)	Final inspection
Maintenance team	Injection moulding machine	4. Perform injection moulding	Production data	Production planning
Utilities / facilities	Power, compressed air, cooling water	5. In-process inspection	Scrap records	Process engineering
Production planning	Production schedule	6. Segregate OK / NG parts	Quality reports	Management
Quality department	Inspection standards			OEM / Tier-1 customers (indirect)

Data collection – Histogram (Before improvement)



Inference :

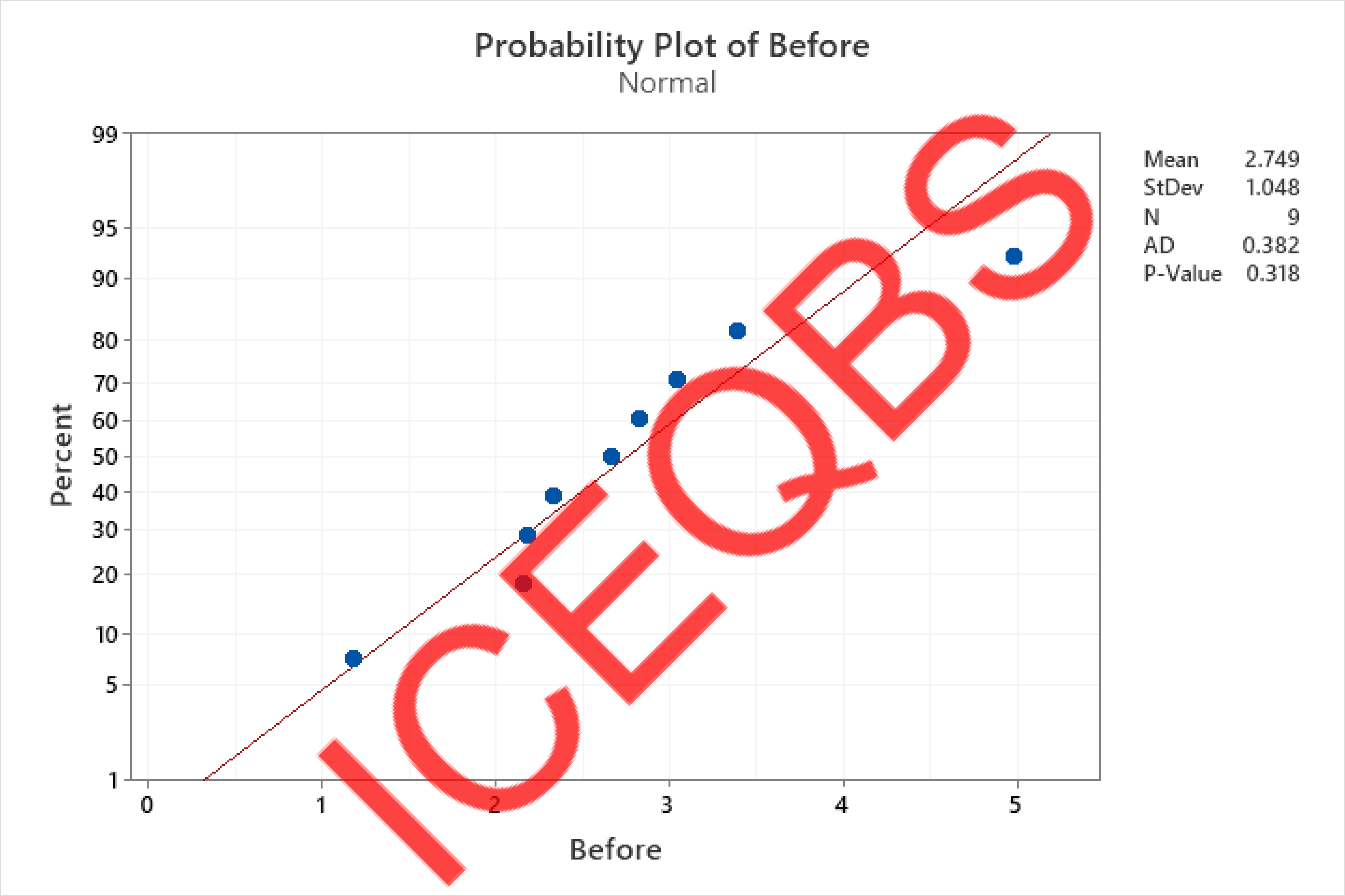
- Data is normally distributed over the mean

Data collection – Run Chart (Before improvement)

Inference :

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

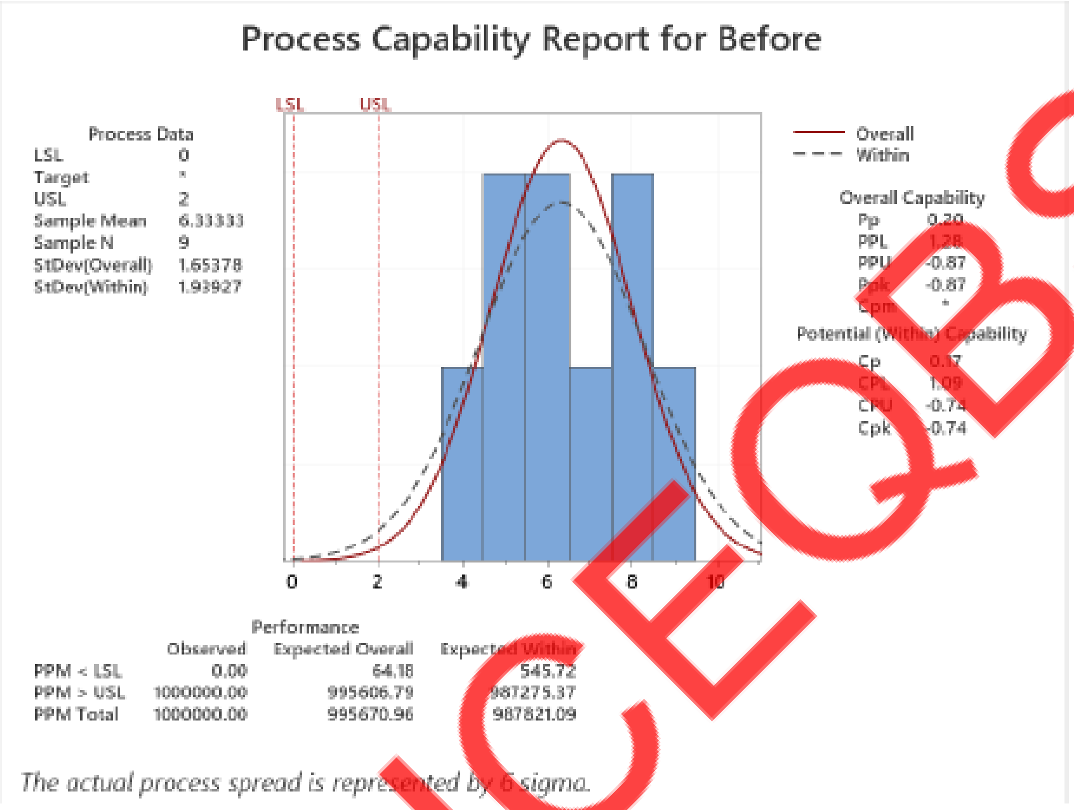
Data collection – Normality plot (Before improvement)



Inference :

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

Process Capability – Before



Inference :

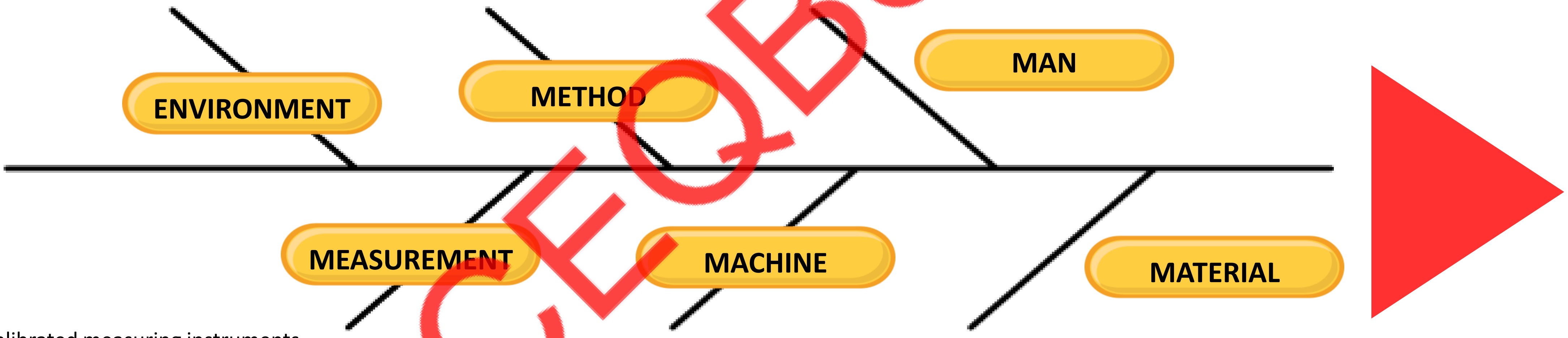
- The process is **incapable and not centered**, with the mean rejection rate above the USL and a **negative Cpk**, indicating a high risk of excessive rejections and the need for immediate process improvement.

Fish Bone Diagram

1. High ambient humidity affecting material moisture
2. Temperature variation on shop floor
3. Dust contamination near moulding area

1. No standardized process parameter window
2. Incorrect material drying time or temperature
3. Improper machine start-up and changeover procedure

1. Inadequate operator skill on machine parameter setting
2. Lack of awareness on defect types and causes
3. Improper material handling by operators



1. Inaccurate or uncalibrated measuring instruments
2. Poor Gauge R&R for critical dimensions
3. Subjective visual inspection criteria

1. Injection moulding machine parameter drift
2. Inconsistent clamping force
3. Worn-out screw or barrel affecting melt quality

1. High moisture content in plastic resin
2. Variation in resin melt flow index (MFI)
3. Improper masterbatch mixing ratio

common and special causes

Common Causes

1. Inadequate operator skill on machine parameter setting
2. Lack of awareness on defect types and causes
3. Improper material handling by operators
4. Inconsistent adherence to SOPs
5. Injection moulding machine parameter drift
6. Worn-out screw or barrel
7. Poor temperature control of heater bands
8. Inadequate preventive maintenance
9. High moisture content in plastic resin
10. Variation in resin melt flow index (MFI)

Special Causes

1. Operator fatigue due to long shifts
2. Manpower shortage during peak production
3. Inconsistent clamping force
4. Sudden heater band failure
5. Use of mixed or contaminated material
6. Batch-to-batch variation from supplier
7. Lack of reaction plan during abnormal conditions
8. Delayed feedback of rejection data
9. Poor ventilation around machines
10. Inadequate lighting affecting inspection

3M Analysis for Waste

MUDA

- Scrap of moulded parts due to defects such as short shots, sink marks, and warpage
- Rework and re-inspection of rejected parts increasing handling and cycle time

Mura

- Variation in rejection rate from shift to shift or batch to batch
- Inconsistent cycle times due to frequent parameter adjustments

Muri

- Operators handling multiple machines leading to errors in parameter monitoring
- Quality inspectors overloaded due to high rejection and sorting requirements

8 Wastes Analysis

Defects

- Scrap due to short shots, sink marks, warpage, or burn marks
- Rejection of parts due to dimensional non-conformance

Overproduction

- Producing parts beyond daily customer demand
- Running machines to build excess inventory to “keep machines busy”

Waiting

- Machine idle time during material drying or mold changeover
- Operators waiting for quality clearance or first-off approval

Non-Utilized Talent

- Operators not involved in problem solving or improvement activities
- Quality inspectors used only for sorting instead of root cause analysis

Transportation

- Unnecessary movement of moulded parts between machines and inspection areas
- Shifting material multiple times due to poor layout

Inventory

- Excess raw material stored near machines
- High WIP due to batch production and inspection delays

Motion

- Operators walking frequently to fetch tools, documents, or gauges
- Repeated bending or reaching due to poor workstation design

Overprocessing

- 100% inspection due to poor process capability
- Repeated parameter trials because standard settings are not defined

Action Plan for Low Hanging Fruits

#	Issue Observed (Gemba)	Category Addressed	Lean Tool Used	Action to be Taken	Expected Benefit
1	Heater band failures causing sudden defects	Special Cause	Preventive Maintenance	Introduce daily heater band condition check and spare availability	Reduced sudden scrap and downtime
2	Operators overloaded handling multiple machines	Muri	Line Balancing	Reassign machine–operator ratio based on cycle time	Reduced errors and fatigue
3	High scrap due to inconsistent material moisture	Mura	Standard Work	Standardize drying temperature and time with visual display	Reduced variation in defects
4	Excess rework and re-inspection	Muda (Defects)	Poka-Yoke	Add moisture indicator alarm on dryer	Prevention of moisture-related defects
5	Waiting for first-off approval	Waiting	Visual Management	First-off approval checklist with pre-defined limits	Reduced waiting and faster start-up
6	Subjective visual inspection decisions	Special Cause	Standardization	Create defect catalogue with sample images	Consistent inspection and fewer disputes
7	Excess movement of parts for inspection	Motion / Transportation	Layout Improvement	Relocate inspection closer to machines	Reduced handling and damage
8	Parameter drift across shifts	Mura	Control Plan + SPC	Display control charts at machine level	Early detection and stable process

Top Prioritized Root Causes (Based on Net Score)

Output (Y)	Description	Importance (1–10)
Y1	Internal Rejection Rate (%)	**10**
Y2	Scrap Cost (₹)	**9**
Y3	First Pass Yield (%)	**8**
Y4	Customer PPM (Indirect)	**7**

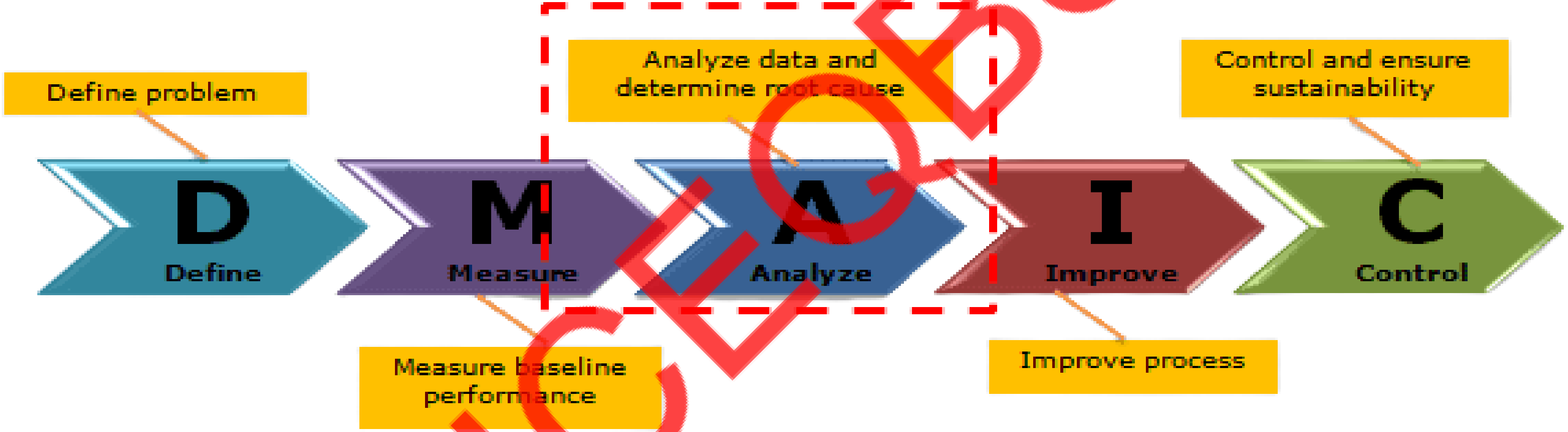
Data Collection Plan

#	Data to Collect	Data Type	Measurement Method	Frequency / Sample Size	Responsible Person	Notes / Tools
1	Part Defect Type (Short Shot, Flash, Sink, Warpage, etc.)	Categorical	Visual inspection / QC checklist	Every shot for 1st 100 parts, then every 50 parts	Operator / QC	Use defect codes; photos for reference
2	Number of OK / NG parts	Numeric	Count during in-process inspection	Per machine per shift	Operator / Shift Lead	Record in SPC sheet
3	Machine Parameters	Numeric	Machine readings: injection pressure, screw speed, temperature, clamp force	Every shift or batch	Operator / Maintenance	Can be exported from machine or PLC
4	Material Lot & Condition	Categorical	Material batch, moisture content, drying time	Each batch	Store / Material In-charge	Dew point readings, drying logs
5	Mold Condition	Categorical / Numeric	Vent cleaning, cavity number, mold temp	Daily / per mold	Maintenance / Operator	Mold logbook
6	Cycle Time	Numeric	Start to finish per shot	Per batch	Operator	Stopwatch or machine timer
7	Machine Downtime	Numeric	Record downtime reason & duration	Per shift	Maintenance	Categorize as planned / unplanned

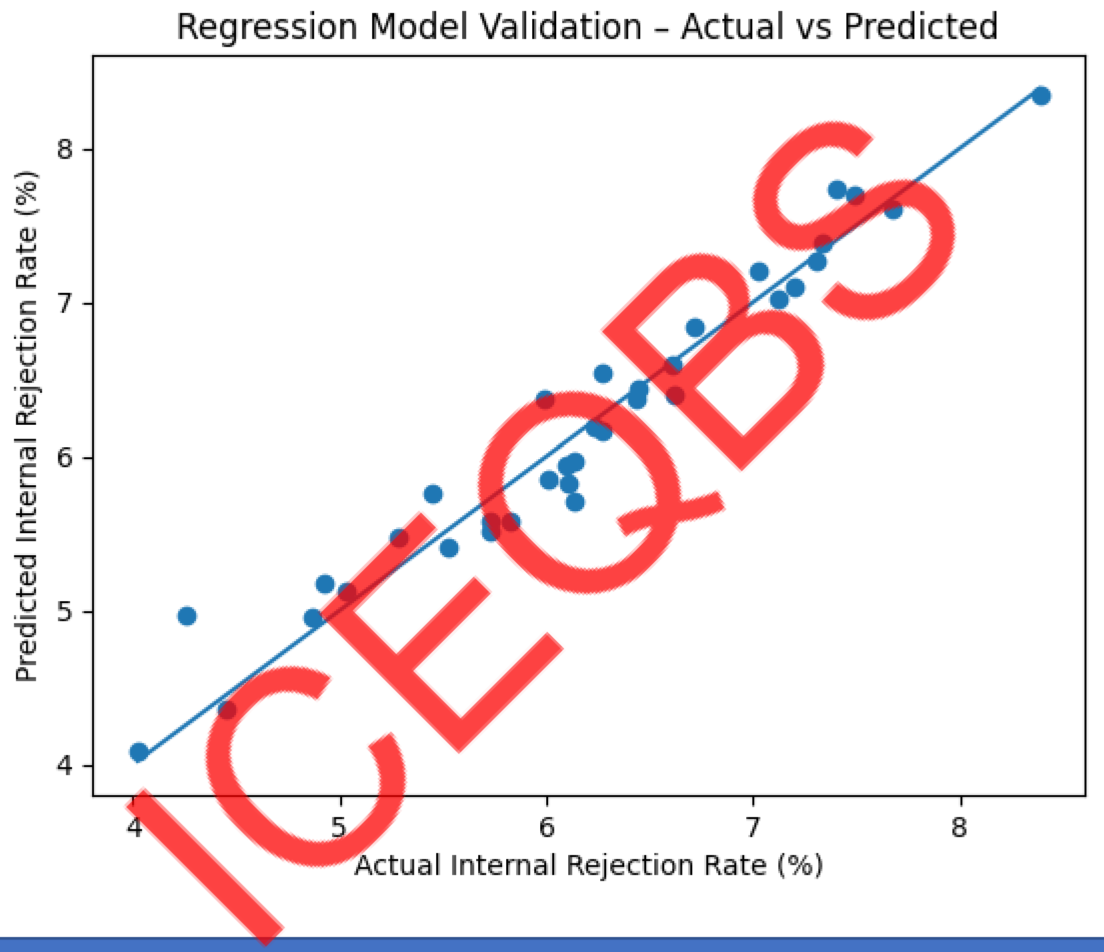
Data Collection Plan

#	Data to Collect	Data Type	Measurement Method	Frequency / Sample Size	Responsible Person	Notes / Tools
8	Operator & Shift Data	Categorical	Operator ID, shift timing	Daily	Supervisor	For human variation analysis
9	Environmental Conditions	Numeric	Factory temp, humidity	Daily	Maintenance / Operator	Optional: for moisture-sensitive resins
10	Rework / Scrap Cost	Numeric	Count of rework parts & material cost	Daily / Weekly	QC / Production Lead	Helps quantify COPQ

ANALYSE PHASE



Analyse – Hypothesis testing



Inference :
The close alignment between actual and predicted values confirms the regression model is valid and explains most of the variation in internal rejection rate.

Analyse

Regression Results – Key Outputs

Input Variable (X)	p-value	Decision	Conclusion
Resin Moisture %	**< 0.05**	Reject H_0	**Critical Root Cause – VALIDATED**
Machine Parameter Deviation Index	**< 0.05**	Reject H_0	**Critical Root Cause – VALIDATED**
Mold Temperature Delta (°C)	**< 0.05**	Reject H_0	**Critical Root Cause – VALIDATED**
PM Compliance %	> 0.05	Fail to reject H_0	Not statistically significant
Operator Skill Score	> 0.05	Fail to reject H_0	Not statistically significant
SOP Compliance %	> 0.05	Fail to reject H_0	Not statistically significant

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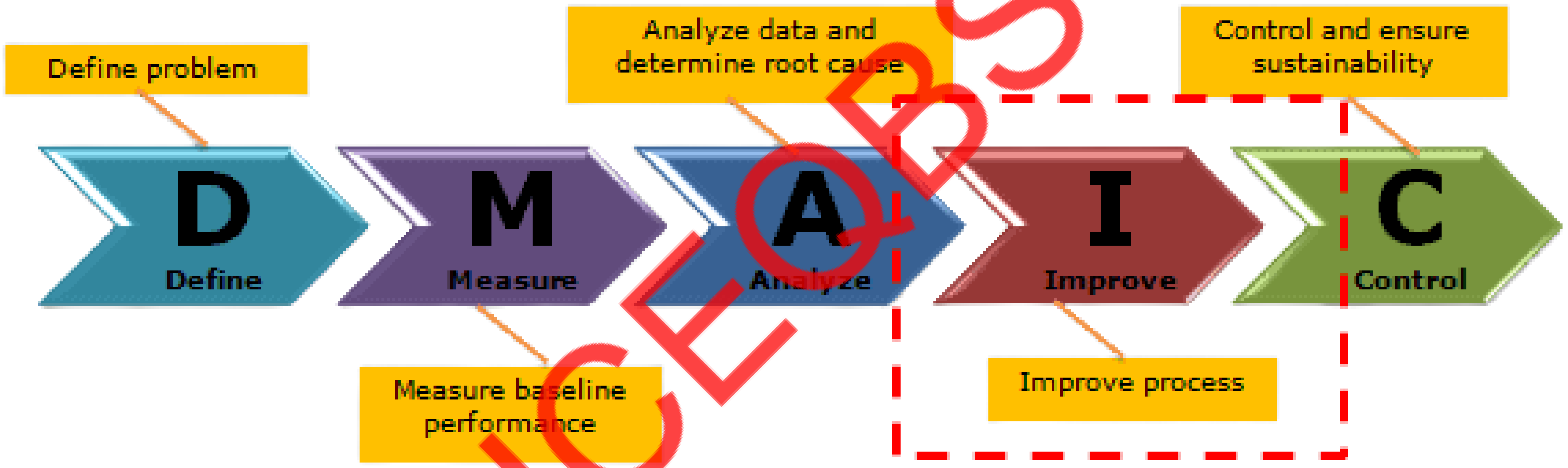
Validated Critical Root Causes

Based on hypothesis testing at **95% confidence level**, the following are **statistically significant drivers** of internal rejection rate:

1. **Resin Moisture Content (%)**
2. **Machine Parameter Deviation**
3. **Mold Temperature Variation**
4. **Improve phase:**

IMPROVE PHASE



Improve action plan for improvement

#	Critical Root Cause	Improvement Action	Lean / Six Sigma Tool Used	Owner	Expected Impact
1	Resin moisture variation	Define and enforce **standard drying temperature & time** for each resin grade with visual display at dryer	Standard Work	Process Engineer	Reduction in moisture-related defects
2	Resin moisture variation	Install **online moisture indicator / alarm** at dryer outlet to prevent feeding wet material	Poka-Yoke	Maintenance	Prevention of moisture-induced scrap
3	Machine parameter deviation	Establish **validated parameter window** (min–max) for key parameters and lock settings on HMI	Process Capability / Control Plan	Process Engineer	Reduced process variation
4	Machine parameter deviation	Implement **SPC charts** for melt temperature, injection pressure, and cycle time at machine level	SPC / Visual Management	Quality Engineer	Early detection of abnormal variation

Improve action plan for improvement

#	Critical Root Cause	Improvement Action	Lean / Six Sigma Tool Used	Owner	Expected Impact
5	Mold temperature variation	Standardize **mold temperature control** with inlet–outlet monitoring and reaction plan for deviations	Standardization + Reaction Plan	Production Supervisor	Improved dimensional and visual stability

Improve

The run chart shows no significant trends, shifts, or clustering, indicating the post-improvement process is stable and consistently performing around the target level.

Improve

•The probability plot shows that the post-improvement rejection data follows a normal distribution (p-value > 0.05), confirming process stability and suitability for ongoing statistical control.

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	6.33	1.65	0.55
After	9	2.567	0.158	0.053

Estimation for Difference

Difference	95% CI for Difference
3.767	(2.490, 5.044)

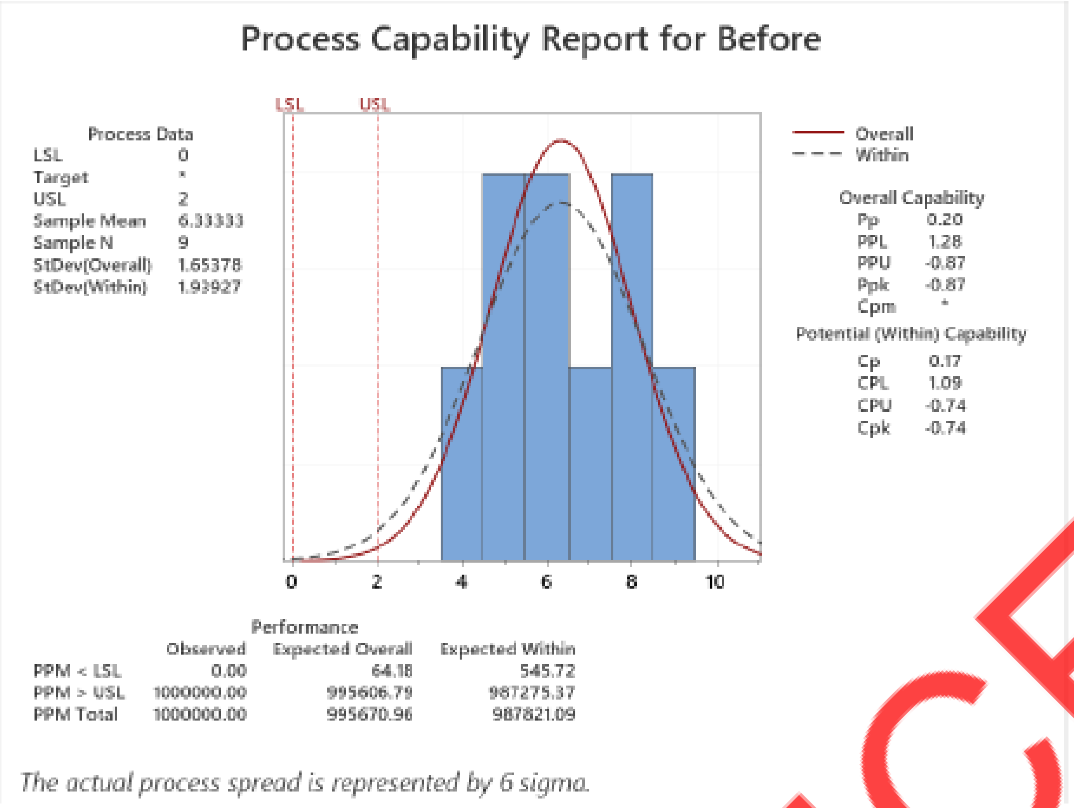
Test

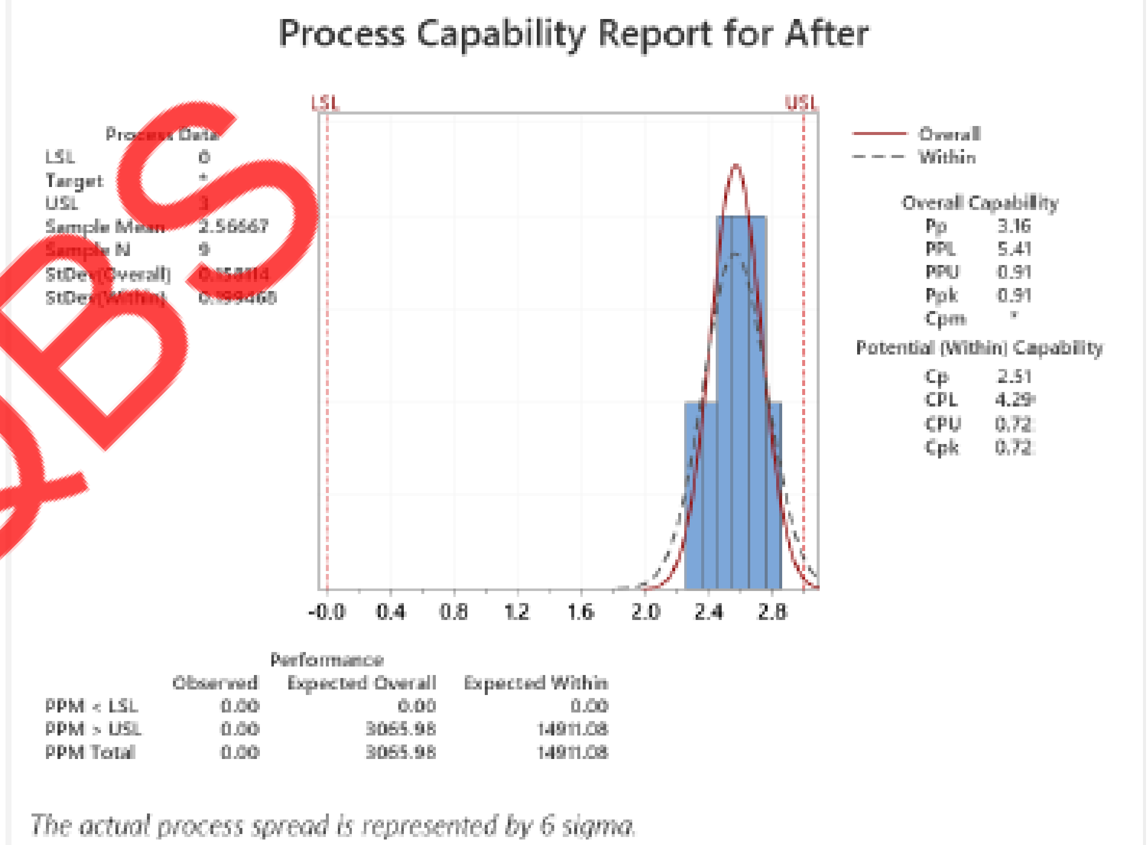
Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.80	8	0.000

The two-sample t-test indicates a statistically significant reduction in the mean rejection rate after improvement ($p < 0.001$), confirming that the implemented changes resulted in a substantial and measurable performance improvement.

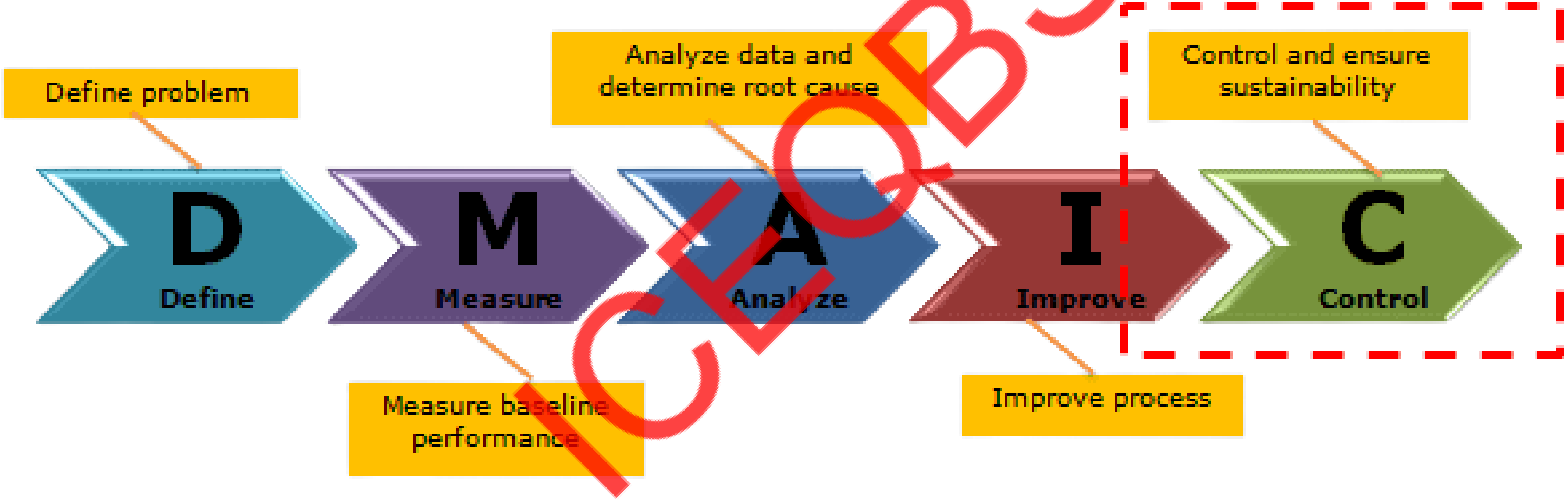
Improve – Process capability – Before & After Improvement



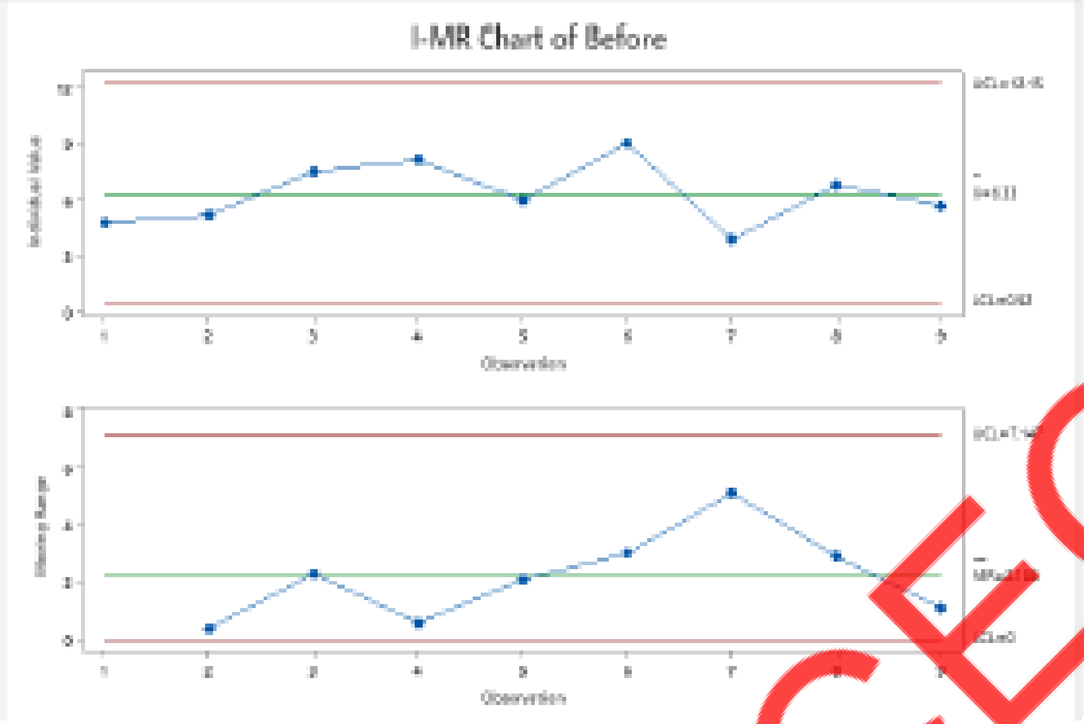


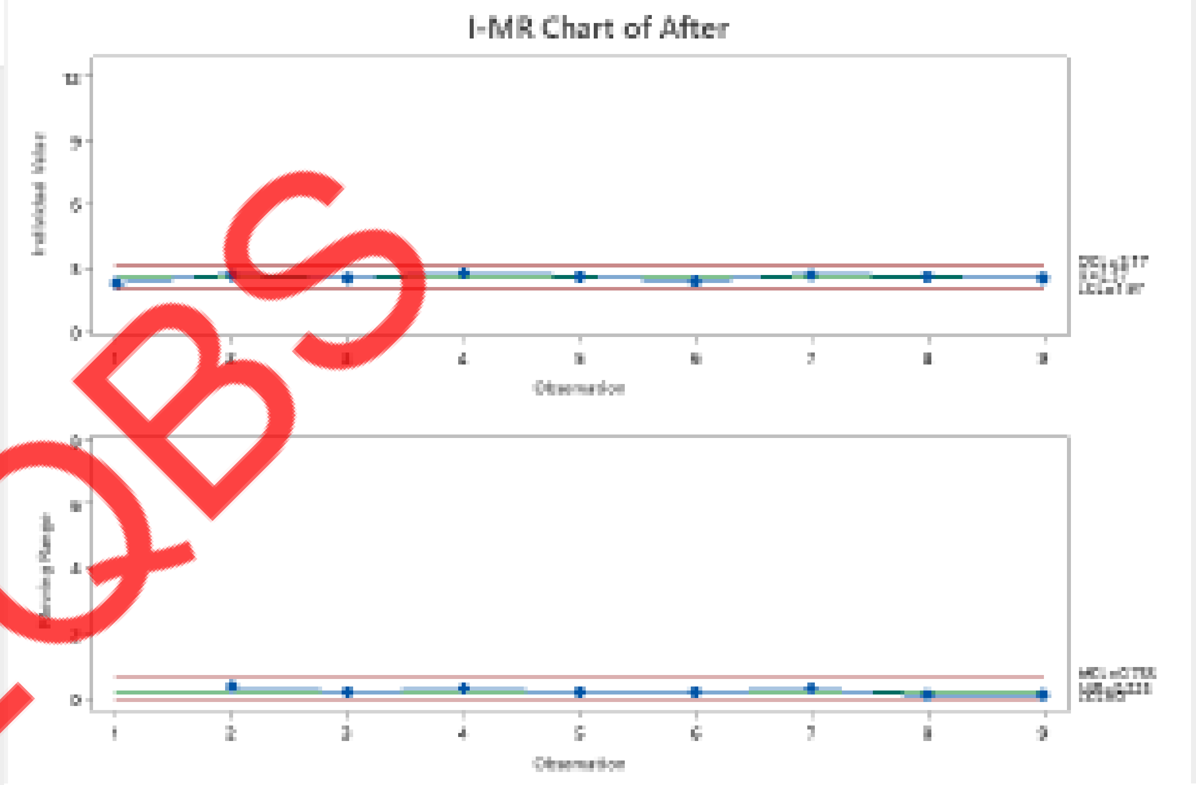
The process capability improved significantly from an incapable state before (Cpk < 0) to a capable and well-centered process after improvement (Cpk > 1), confirming sustained rejection reduction and process stability.

CONTROL PHASE



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





The I-MR charts demonstrate a clear shift from an unstable, high-variation process before improvement to a stable, well-controlled process after improvement, with significantly reduced variation and no out-of-control signals.

Control Plan

No.	Mechanism	Type	Description	Purpose / Benefit
1	Standardized Dryer Setup Board	5S + Poka-Yoke	Fixed display of approved drying temperature and time for each resin grade; physical parameter card mandatory before dryer start	Prevents use of incorrect drying settings
2	Moisture-Based Interlock at Material Feeding	Poka-Yoke	Hopper feeding enabled only when moisture % is within limits; audible/visual alarm if exceeded	Prevents wet material from entering the process
3	Machine Parameter Lock & Visual Limits	5S + Poka-Yoke	Color-coded min–max parameter windows on HMI; password-protected parameter changes	Prevents unauthorized or accidental parameter deviation
4	Mold Temperature Connection Standardization	Poka-Yoke	Unique inlet–outlet hose connectors with directional arrows and color coding	Prevents wrong connections and mold temperature imbalance
5	Layered Process Audit with Visual Checks	5S + Poka-Yoke	Daily visual checklist covering drying, machine parameters, and mold temperature	Ensures sustained adherence to standard conditions

Control Plan

Improvement Action Being Implemented	Potential Failure Mode	Potential Effect of Failure	S	Potential Cause	O	Current Controls (Prevention/D etection)	D	RPN	Proactive Action (to avoid failure)	Owner
Standardize dryer temp/time by resin grade (Standard Work)	Wrong drying settings used (wrong grade/time/te mp)	Moisture- related defects, scrap increase, instability returns	9	Wrong resin identification , outdated setting sheet, operator confusion	5	Dryer setting sheet near dryer; shift handover	5	225	Create resin- grade “Drying Recipe Card” + QR code at dryer; mandatory resin label verification before start; supervisor sign- off for first 2 weeks	Proces s Engg + Produc tion
Moisture indicator/alarm / interlock at feeding (Poka- Yoke)	Interlock bypassed or alarm ignored	Wet resin fed → short shot/splay/vo ids → high rejection	9	Bypass culture, urgency to meet output, unclear escalation	4	Alarm present; verbal instruction	6	216	Implement “No- Bypass” policy + physical lock on bypass switch; escalation rule (stop + inform QA); record all alarms as NC with closure	Produc tion + QA
Parameter window + HMI lock (standard settings)	Unauthorized parameter change or wrong window loaded	Variation increases; dimension/ap pearance defects	8	Password shared, wrong part program, inadequate changeover discipline	5	SOP; periodic audits	5	200	Role-based access control (unique logins); part-program checklist at changeover; daily audit of parameter history log for first month	Proces s Engg + IT/Mai nt.
Mold temperature inlet/outlet monitoring & standardized connections	Incorrect hose connection or unstable mold temperature	Warpage, dimensional drift, surface defects	8	Similar connectors, rushed setup, leaking hoses	4	Operator experience; visual check	6	192	Use keyed/color- coded quick couplers + flow-direction labels; add “start-up mold temp verification” checklist with 2 readings	Mainte nance + Produc tion
Layered Process Audit (LPA) for drying/paramet ers/mold temp	Audits not performed or done superficially	Deviations persist; controls degrade over time	7	Workload, lack of accountabilit y, audit fatigue	5	Weekly review meeting	6	210	Daily 10-min LPA rota with named auditor; visual board showing completion; missed audits trigger escalation; monthly calibration of audit checklist	QA + Produc tion Head

Control Plan

#	Control Item	What to Monitor	Method / Tool	Frequency	Owner	Reaction Plan
1	Resin Moisture Control	Moisture % before feeding	Moisture analyzer / dryer alarm	Every material lot / shift start	Production / IQC	Stop feeding, re- dry material, inform QA
2	Machine Parameter Stability	Melt temp, injection pressure, cycle time within window	SPC charts + HMI parameter lock	Each shift	Process Engineer	Investigate cause, reset parameters, record deviation
3	Mold Temperature Consistency	Inlet–outlet temperature delta	Mold temp controller display	Each shift	Maintenance / Production	Correct hose connection, stabilize temp, verify
4	Process Discipline (SOP)	Compliance to drying, start-up, changeover steps	Layered Process Audit (LPA)	Daily	Supervisor / QA	Immediate correction, retraining, escalation
5	Performance Monitoring	Internal rejection rate (%)	Trend chart / monthly review	Daily tracking, monthly review	Quality Head	Trigger corrective action if trend worsens

Conclusion

Results after improvement

- This project successfully reduced internal rejections, stabilized the injection molding process, and embedded robust controls to sustain improved quality and cost performance.