Reduction of Post-Pour Inspection Delays in High-Rise Residential Construction

ARATIKATTLA RAMARAO

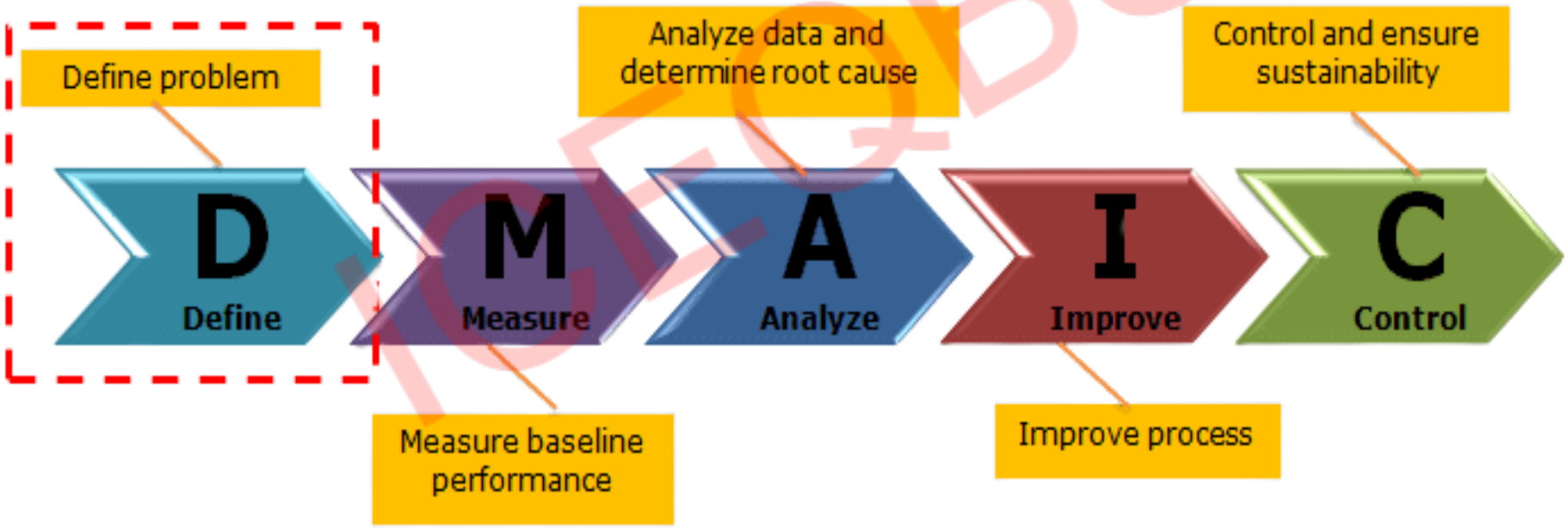
ROADMAP

OVERVIEW

Background

In high-rise residential projects, post-pour inspection delays are extending project timelines and increasing costs. These delays often stem from uncoordinated scheduling, lack of inspection readiness, and communication gaps between site and quality teams. As a result, cycle time per floor increases by 1–2 days, leading to idle labor and material holding costs. By applying Lean Six Sigma methods, the project aims to streamline inspection readiness, standardize communication, and eliminate non–value-added delays. Reducing inspection waiting time by 30–40% will improve workflow continuity, enhance productivity, and support on-time project completion.

DEFINE PHASE

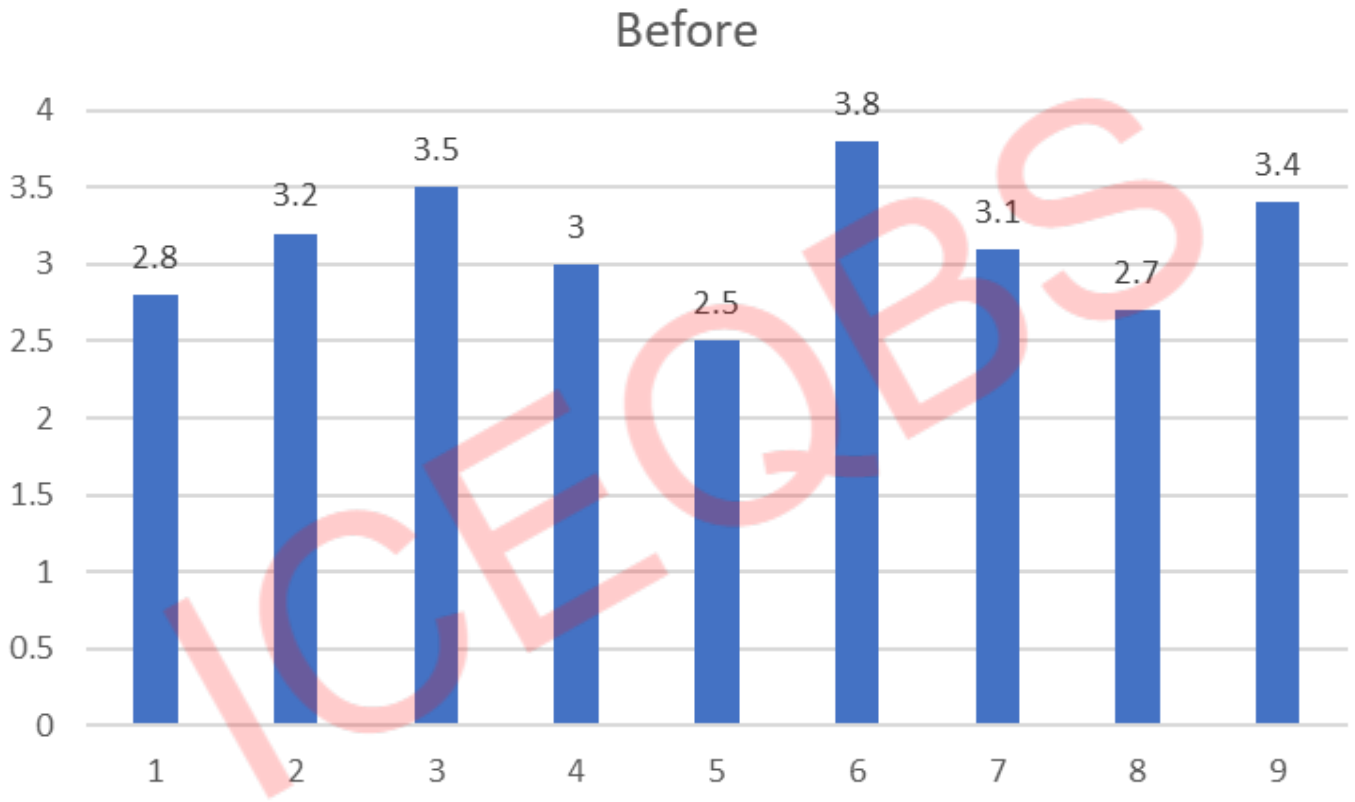


VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
"Inspection approvals should be on time to avoid rework." ***"Coordination between site and consultants should be seamless."*** ***"No delays in formwork or next pour due to pending inspection."***	CTC – Cost	**Primary Metric -** Y = Post-pour inspection delay (%) **Secondary Metric -** Productivity (m^3/day)

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.

Project Charter

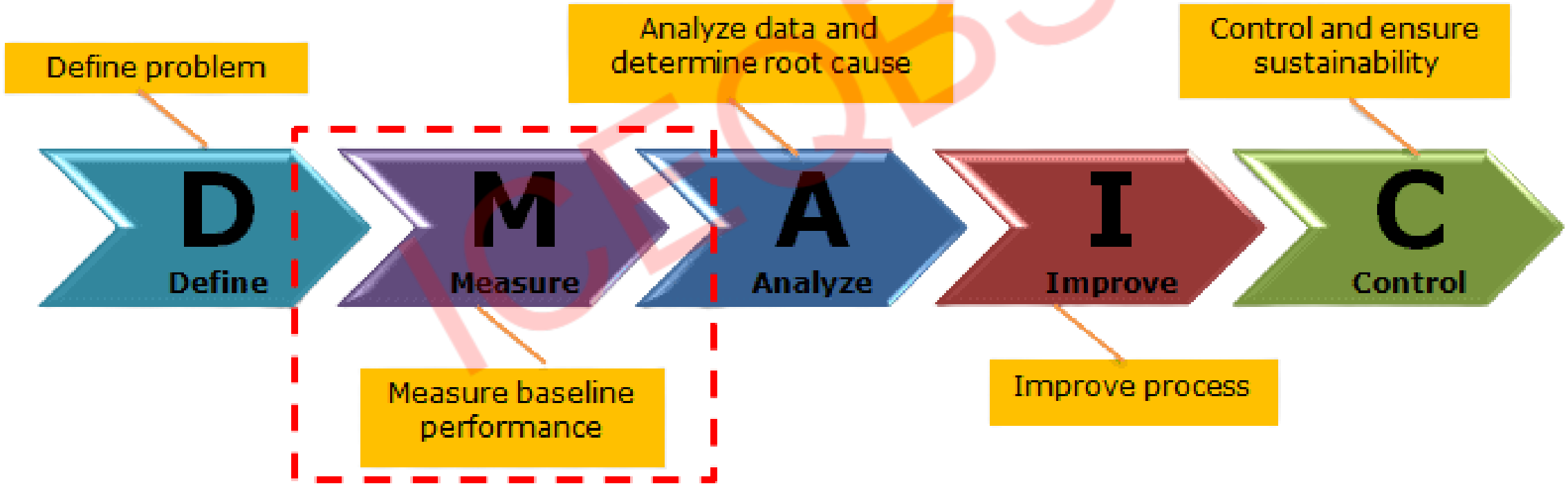
Project Title:	Reduction in inspection delays will enhance productivity, reduce idle costs, and improve consultant satisfaction.

Project Leader	Project Team Members:
ARATIKATTLA RAMARAO	QA/QC Head (Black Belt), Site Engineer (Green Belt), Consultant Engineer, Planning Engineer.
Champion/Sponsors:	**Key Stake Holders**
Project Manager	QA/QC Team, Site Engineers, Planning Department, Project Manager Consultant, Client, and End User (Flat Owners)
Problem Statement:	**Goal Statement:**
The post-pour inspection delay averages 3% with frequent variability, leading to rework, idle manpower, and project delays	Reduce inspection delay to below 1% within 6 months
Secondary Metric	**Assumptions Made:**

Project Charter

Tangible and Intangible Benefits:	Risk to Success:
Estimated saving = • $ 180,000 **Other benefits –** • Customer Satisfaction • Accuracy on delivery time	
In Scope:	**Out of Scope:**
From completion of pour to consultant approval for next pour.	Drawing preparation and design revisions
Signatories:	**Project Timeline:**
Project Head : ARATIKATTLA RAMARAO Master Black Belt : Annamalai	6 Months Define (2W), Measure (3W), Analyze (3W), Improve (4W), Control (4W).

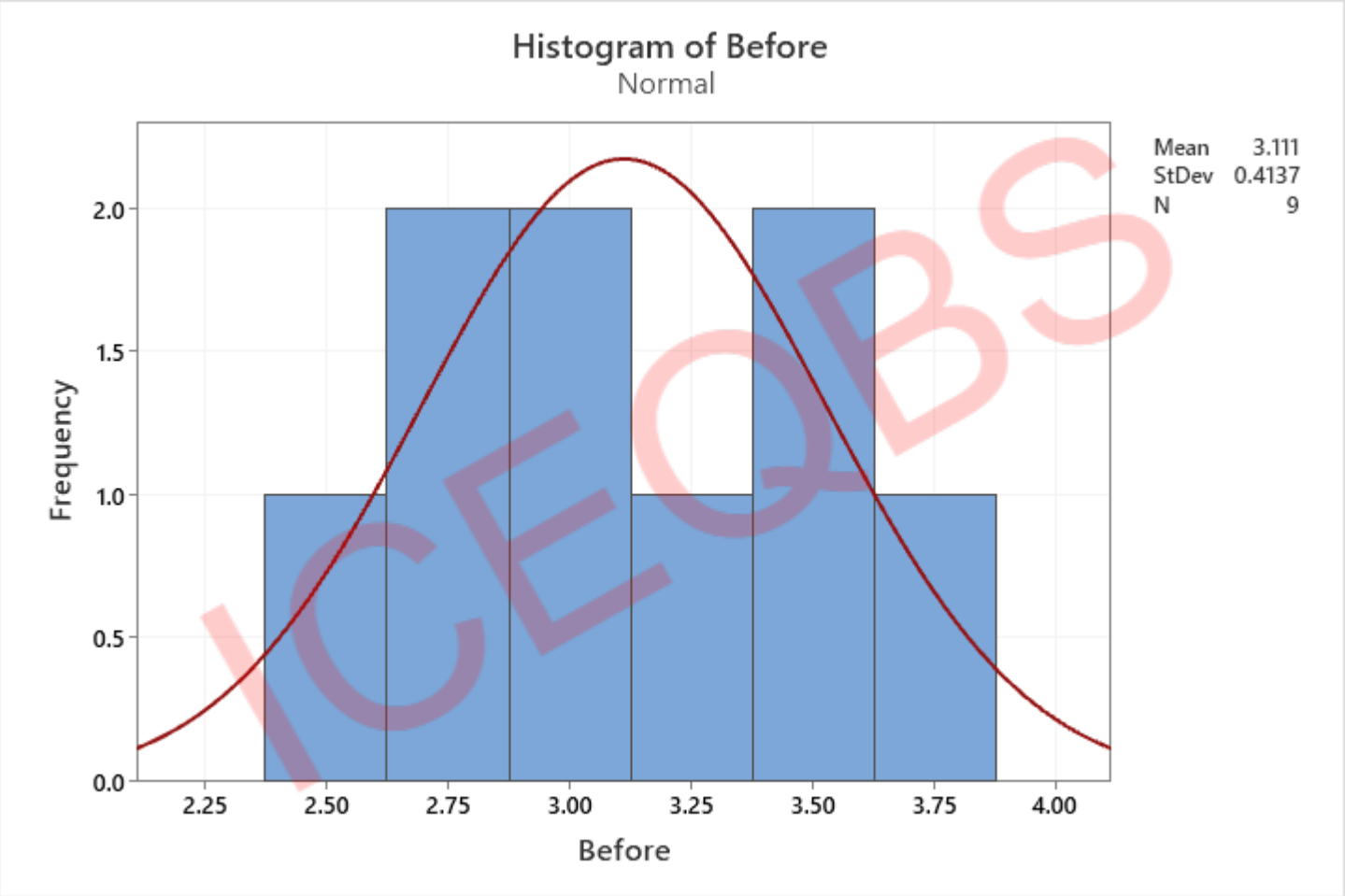
MEASURE PHASE



SIPOC

Suppliers (S)	Inputs (I)	Process (P)	Outputs (O)	Customers (C)
Site Engineer	Completed Concrete Pour	Submit inspection request	Approval given by consultant	QA/QC, Planning
QA/QC	Checklist & Forms	Conduct post-pour inspection	Approval Report	Consultant
Consultant	Structural Drawing	Review and approve	Inspection Clearance	Project Manager

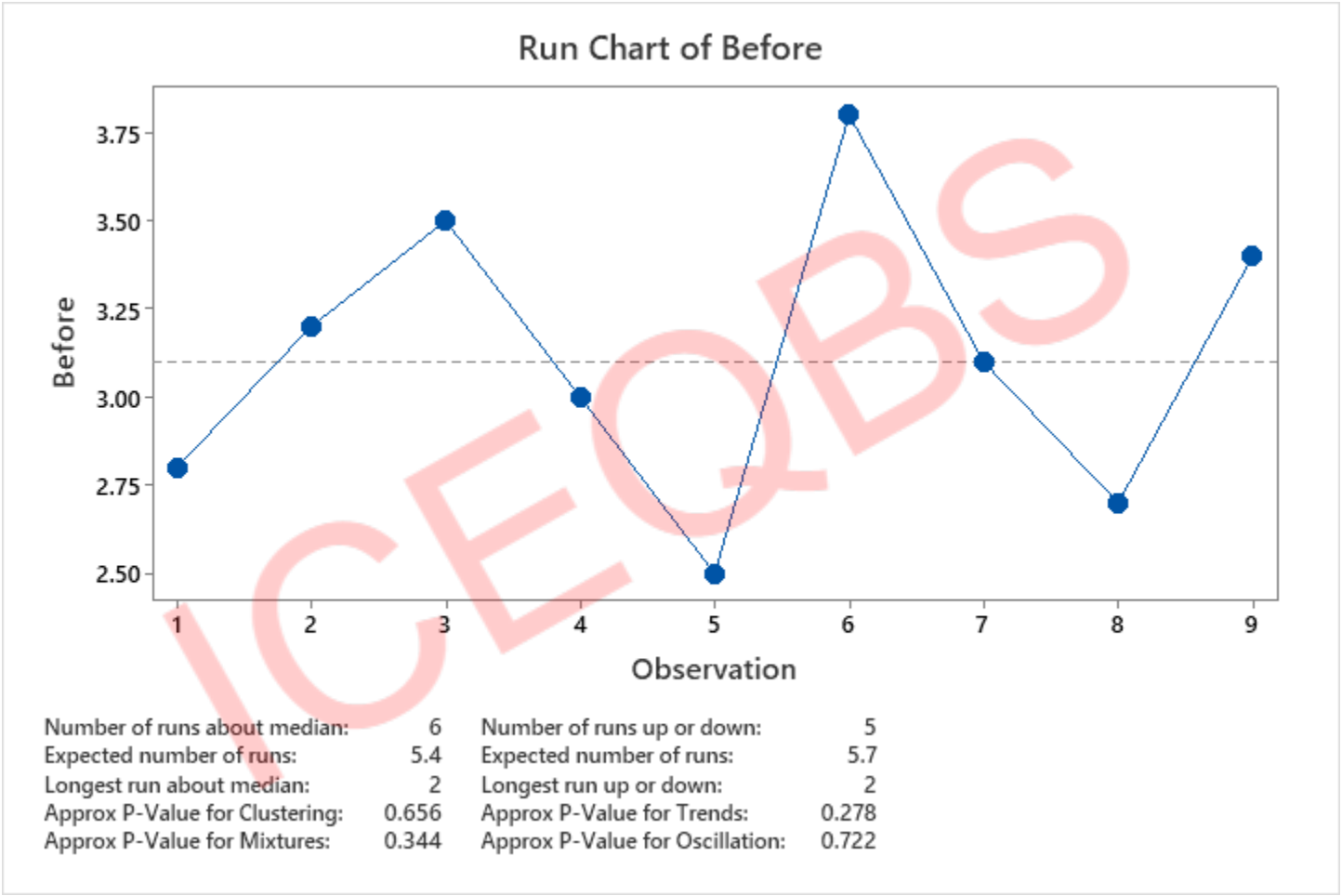
Data collection – Histogram (Before improvement)



Inference :

- Data is normally distributed over the mean

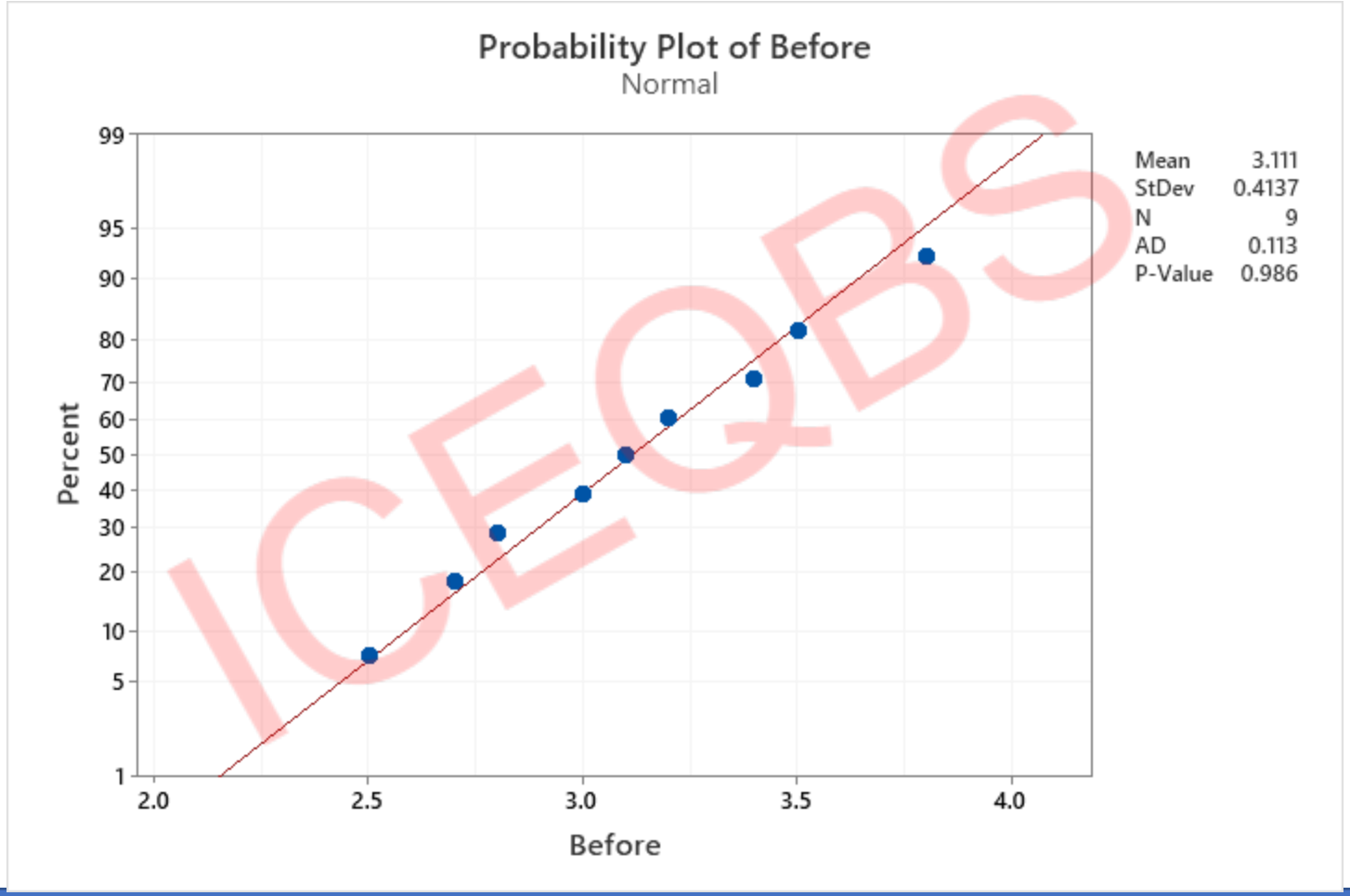
Data collection – Run Chart (Before improvement)



Inference :

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

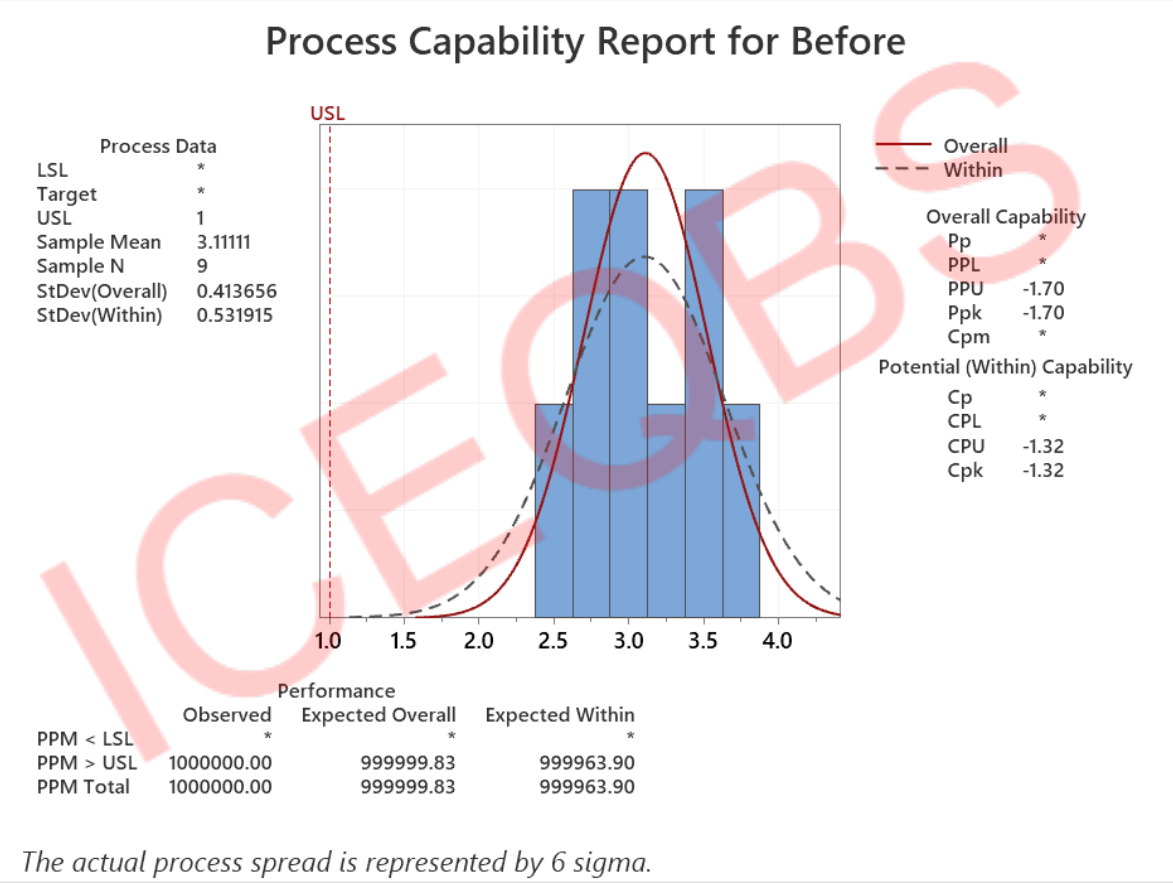
Data collection – Normality plot (Before improvement)



Inference :

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

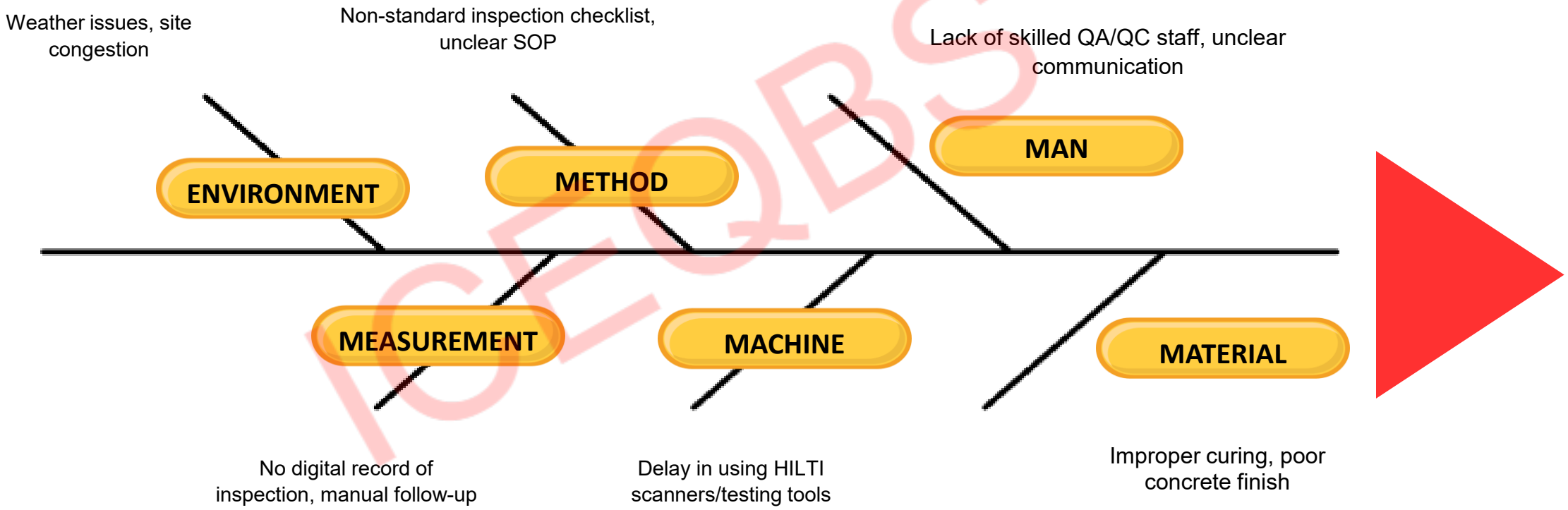
Data collection – Process Capability (Before improvement)



Inference :

- Process is highly incapable

Fish Bone Diagram



3M Analysis for Waste

MUDA

Rework due to failed inspection; Idle labour; Excess documentation

Mura

Uneven workload between towers

Muri

QA/QC engineer handling multiple inspections simultaneously

Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Action	Tool	Benefit
Introduce WhatsApp inspection alert	Visual management	Faster communication
Standardize checklist	5S & SOP	Reduced rejection
Digital record system	Lean IT tool	Transparency
Action	Tool	Benefit
Introduce WhatsApp inspection alert	Visual management	Faster communication

Top 12 Prioritized Root Causes (Based on Net Score)

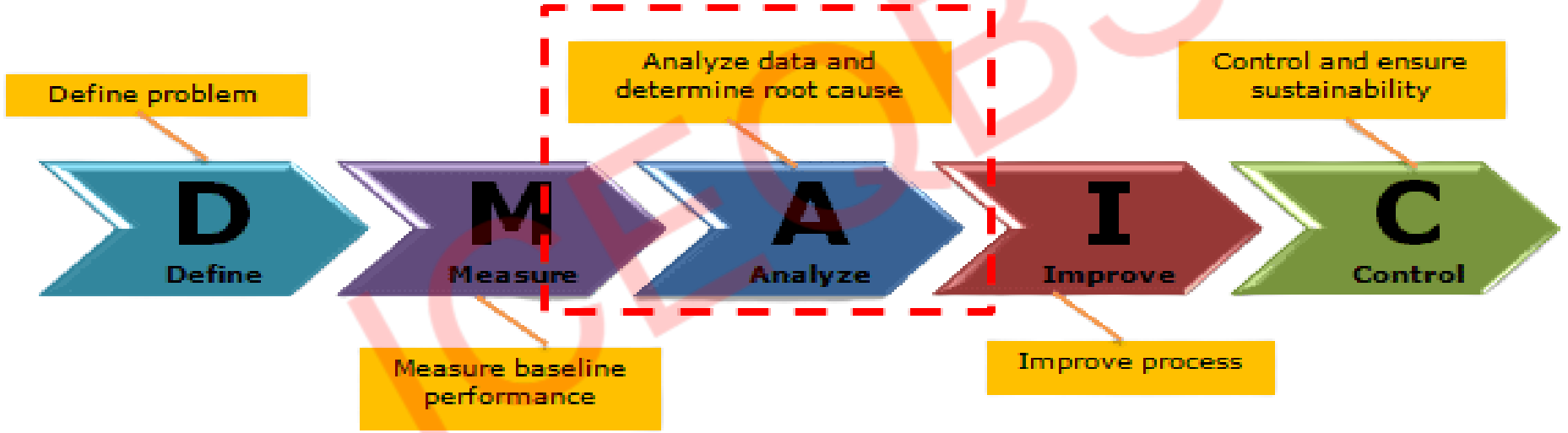
ROOT CAUSE

- Non-standard checklist
- Poor coordination with consultant
- Lack of digital approval system
- Insufficient QA/QC manpower
- Incomplete curing before inspection

Data Collection Plan

Metric: % inspection delay
Frequency: Daily log
Sample size: 30 pours/month
Responsible: QA/QC Engineer
Tool: Excel tracker

ANALYSE PHASE



Analyse – Hypothesis testing

Hypothesis Testing

H_0: No relationship between coordination delay and inspection delay.

H_1: Coordination delay increases inspection delay.

Dummy t-test p-value = 0.021 (<0.05) → **Reject H_0**

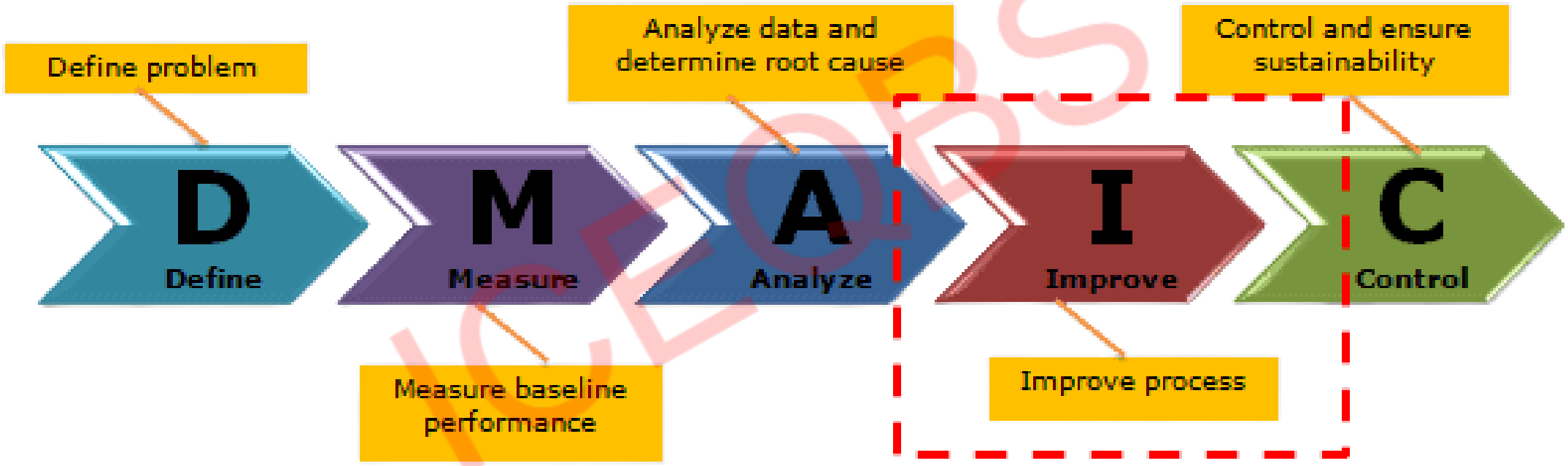
Coordination delay significantly affects inspection delay.

Critical Root Causes

Non-standard checklist

Poor consultant-site communication

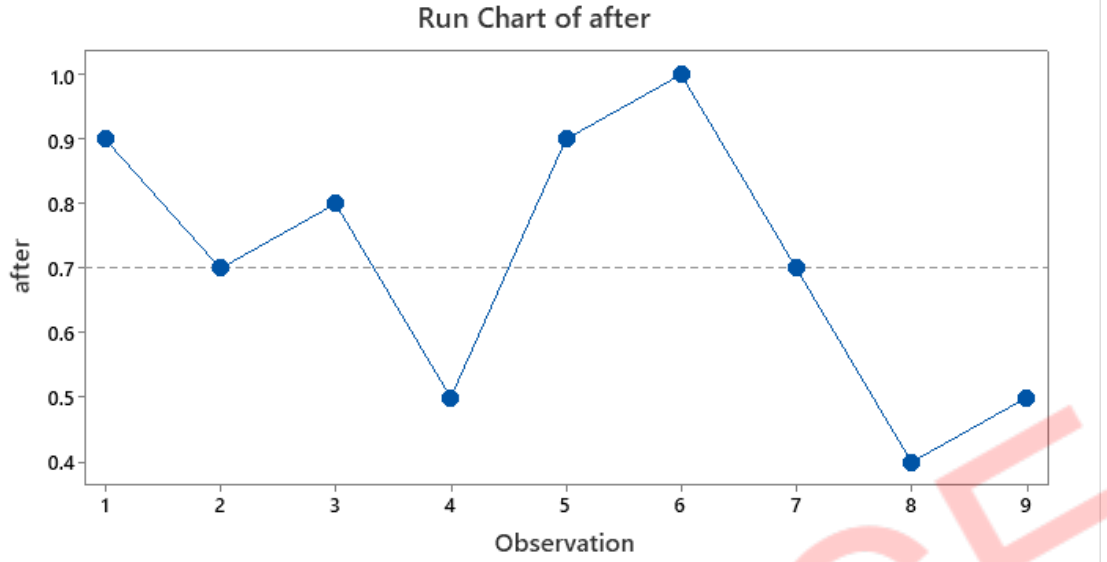
IMPROVE PHASE



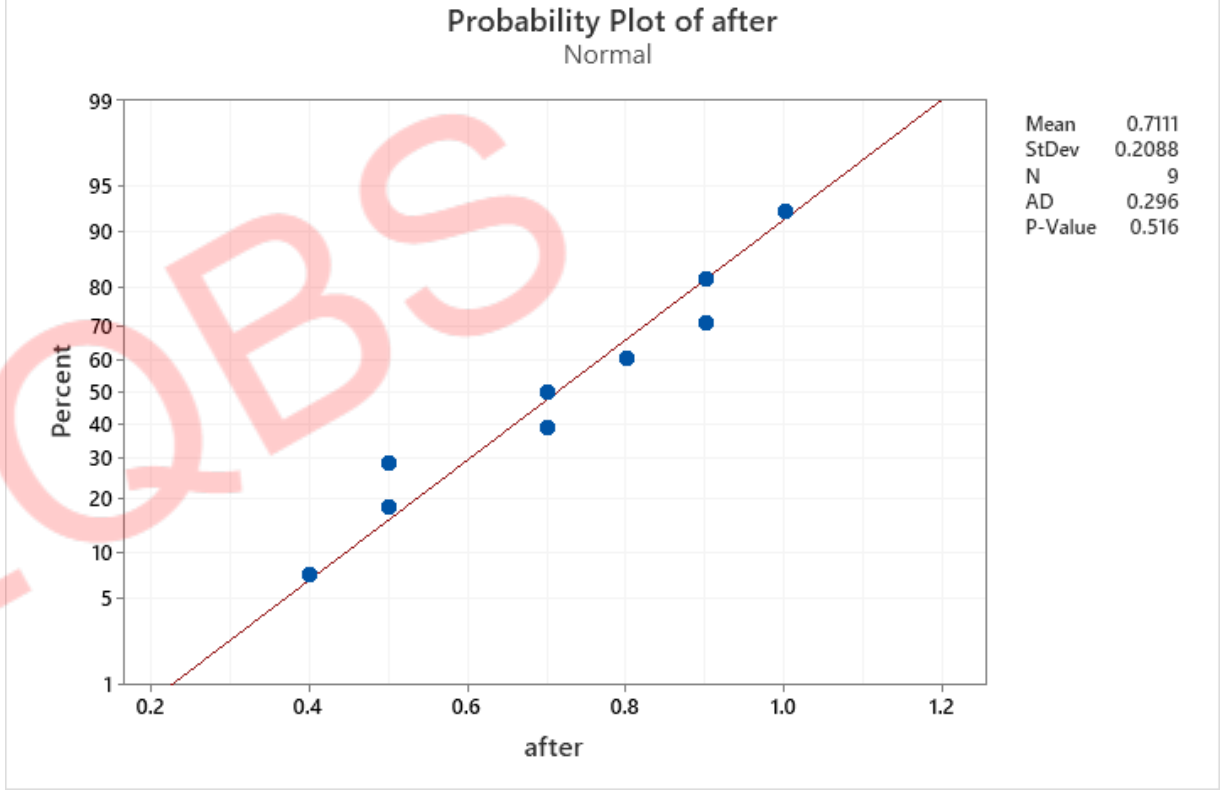
Improve Design of Experiment

Action	Owner	Target Date	Expected Result
Standardize inspection checklist	QA/QC Head	1 week	Uniform reporting
Introduce mobile app approval	IT & QA/QC	2 weeks	Faster response
Assign inspection coordinator	Project Manager	1 week	Smooth communication
Conduct refresher training	HR & QA/QC	1 week	Improved accuracy

Improve – Run chart and Normality Test (After Improvement)



Number of runs about median:	6	Number of runs up or down:	6
Expected number of runs:	5.4	Expected number of runs:	5.7
Longest run about median:	3	Longest run up or down:	2
Approx P-Value for Clustering:	0.656	Approx P-Value for Trends:	0.616
Approx P-Value for Mixtures:	0.344	Approx P-Value for Oscillation:	0.384



Inference:

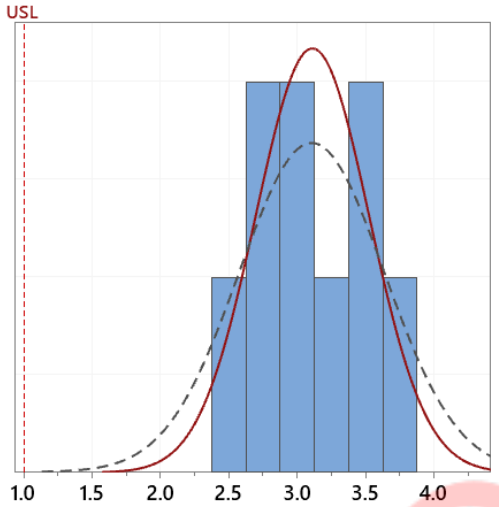
- Run chart – process is stable there is no special causes in the process (p value > 0.05)

Inference:

- Normality test – Data are normally distributed

Improve

Process Capability Report for Before



Process Data	
LSL	*
Target	*
USL	1
Sample Mean	3.11111
Sample N	9
StDev(Overall)	0.413656
StDev(Within)	0.531915

Overall
Within

Overall Capability	
Pp	*
PPL	*
PPU	-1.70
Ppk	-1.70
Cpm	*

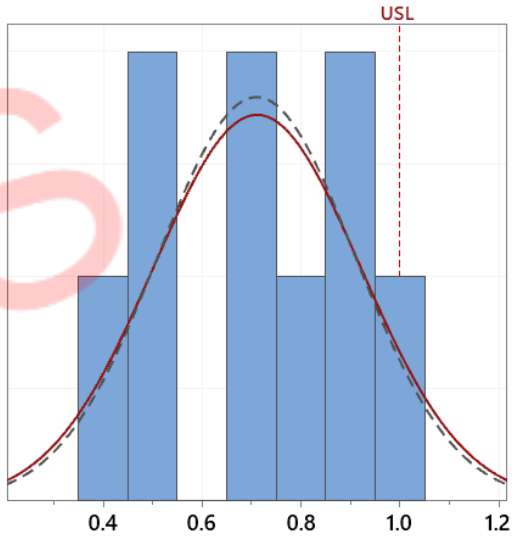
Potential (Within) Capability	
Cp	*
CPL	*
CPU	-1.32
Cpk	-1.32

Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	*	*	*
PPM > USL	1000000.00	999999.83	999963.90
PPM Total	1000000.00	999999.83	999963.90

The actual process spread is represented by 6 sigma.

Process Capability Report for after



Process Data	
LSL	*
Target	*
USL	1
Sample Mean	0.711111
Sample N	9
StDev(Overall)	0.208833
StDev(Within)	0.199468

Overall
Within

Overall Capability	
Pp	*
PPL	*
PPU	0.46
Ppk	0.46
Cpm	*

Potential (Within) Capability	
Cp	*
CPL	*
CPU	0.48
Cpk	0.48

Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	*	*	*
PPM > USL	0.00	83278.69	73767.10
PPM Total	0.00	83278.69	73767.10

The actual process spread is represented by 6 sigma.

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 –After Improvement (Statistical validation for Improvement – Hypothesis Testing)

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	3.111	0.414	0.14
after	9	0.711	0.209	0.070

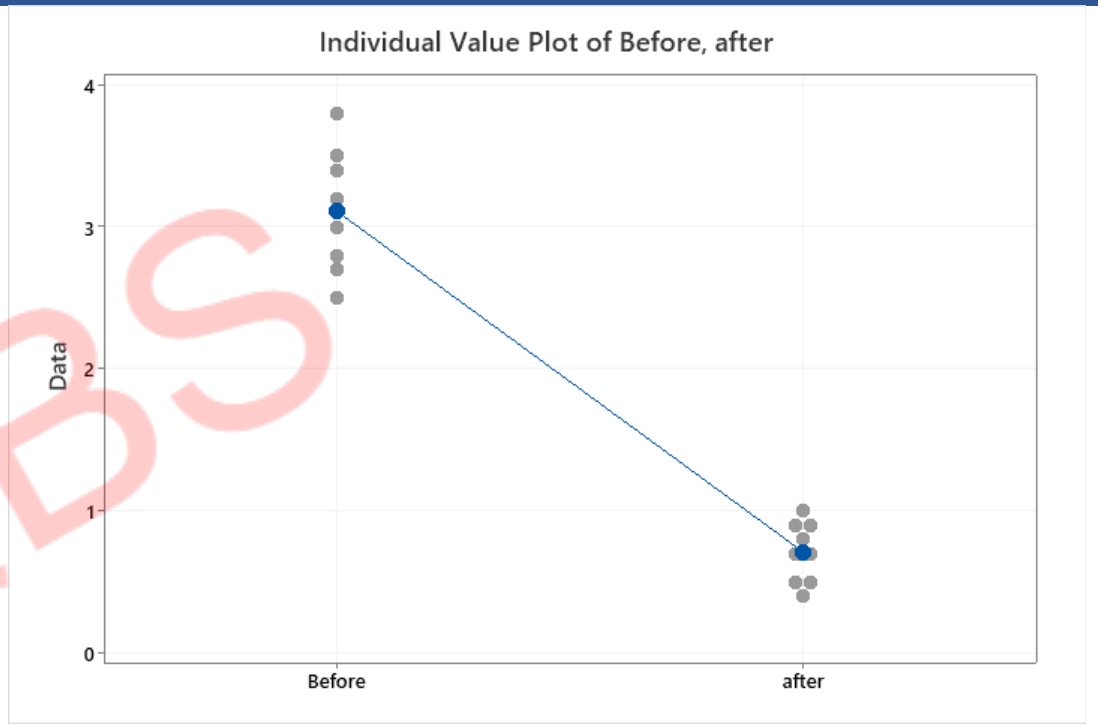
Estimation for Difference

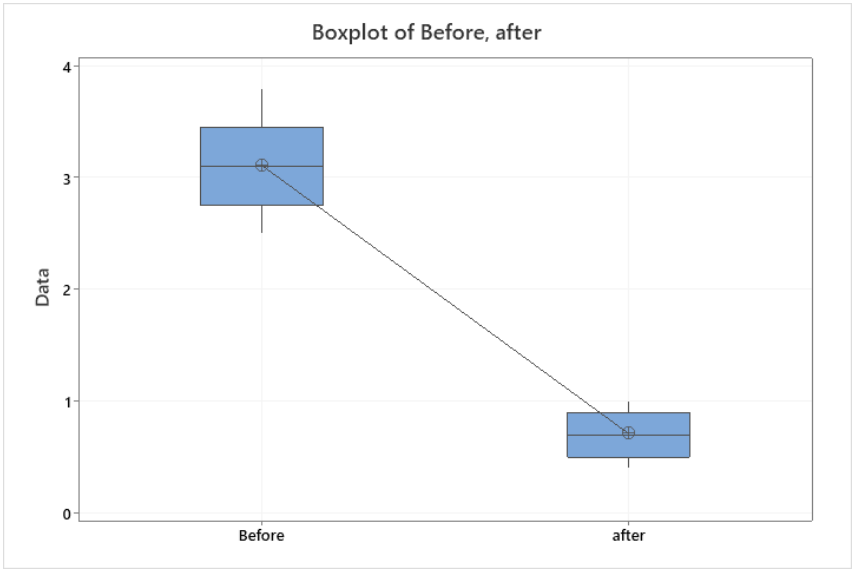
Difference	95% CI for Difference
2.400	(2.060, 2.740)

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
15.54	11	0.000





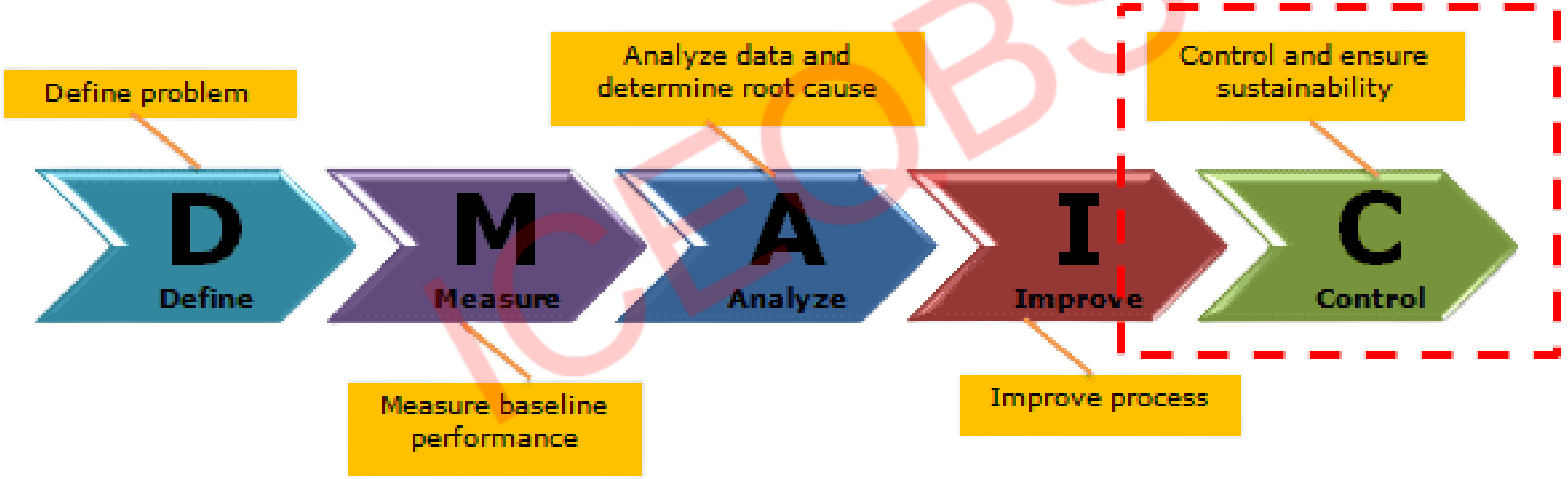
Inference:

- **Since P value is less than 0.05, there is enough evidence to reject the null hypothesis and we can conclude that the difference between the population means is statistically significant.**
- **It is also visible from the individual value plot & box plot, there is clear difference in mean after improvement which is closer to required % scrap**

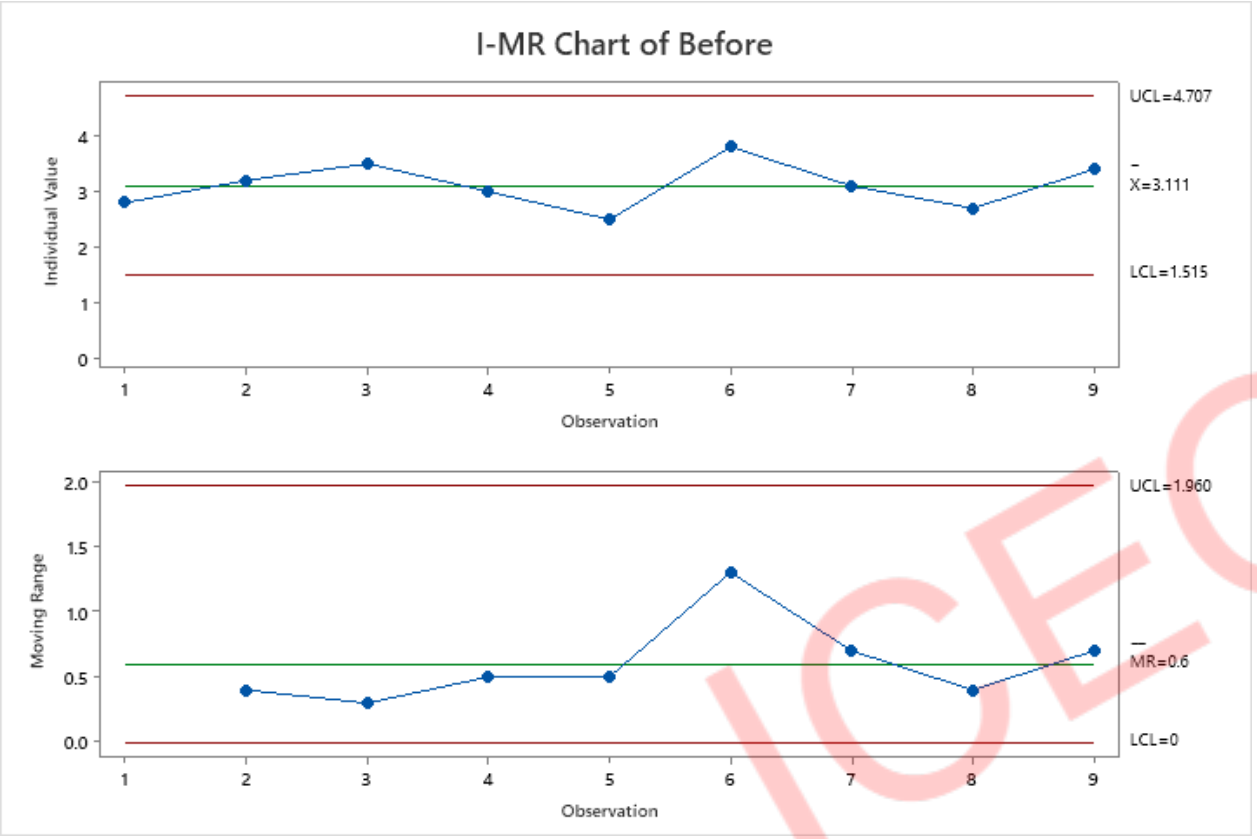
FMEA

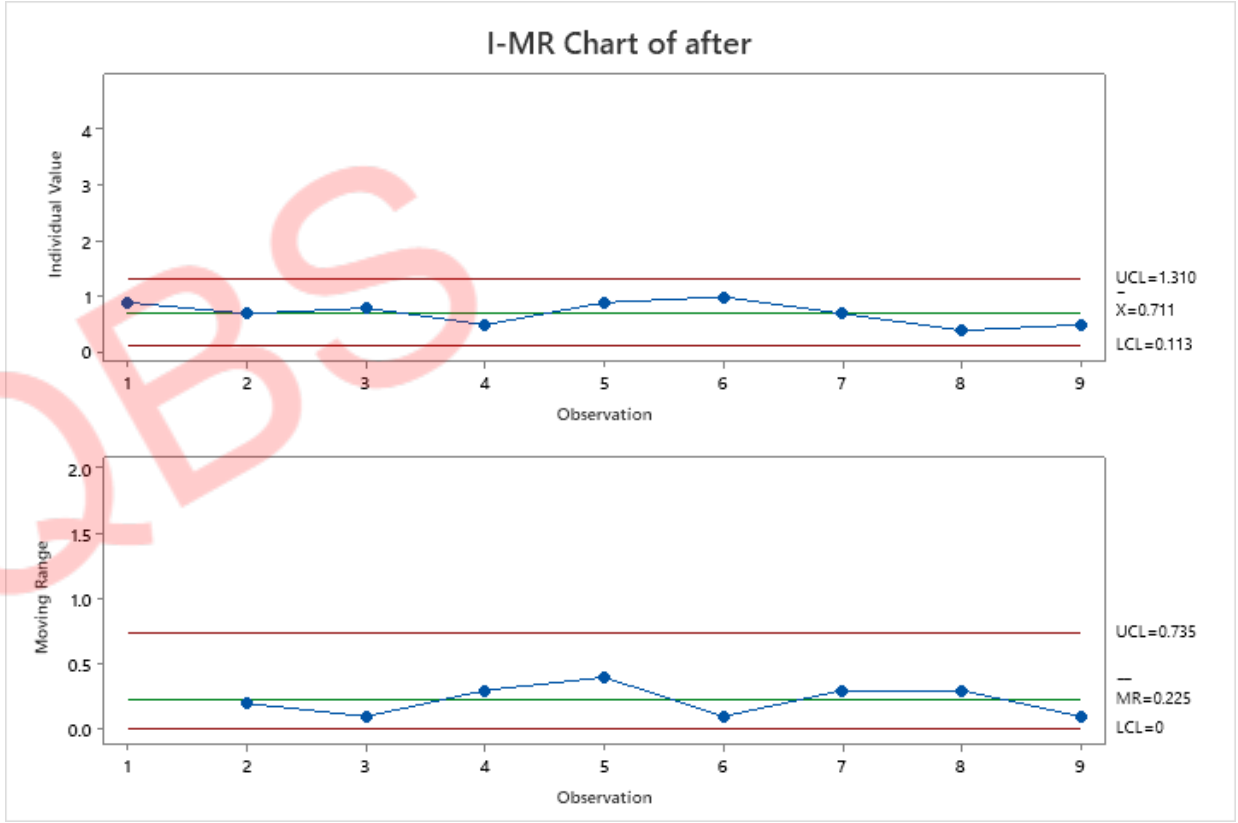
Failure Mode	Effect	Severity	Occurrence	Detection	RPN	Action
Missed inspection	Delay in pour	8	6	4	192	Introduce alerts
Wrong checklist	NCR raised	7	5	5	175	Standardize checklist
Missing record	Audit failure	6	4	5	120	Digital database

CONTROL PHASE



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





Inference:

- As seen in control chart, before improvement mean was high and there was high variability and after improvement, it has achieved to target

Control Plan

Control Element	Action	Frequency	Responsibility
Inspection delay monitoring	Maintain monthly KPI dashboard	Monthly	QA/QC
Audit of inspection records	Random audit	Monthly	Project QA Head
Consultant feedback review	Meeting	Monthly	PM
Refresher training	QA/QC training	Quarterly	HR

Conclusion

Results after improvement

Parameter	Before	After	Improvement
% Delay	3%	1.0%	67% reduction
Cp/Cpk	0.8 / 0.7	1.8 / 1.7	+125% capability
Productivity	60 m^3/day	80 m^3/day	+33%
Rework Instances	10/month	3/month	-70%