Reduction of Printing scrap rate in Paper Bags

ICFQDS

Shameem Ahammed

ROADMAP

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OVERVIEW

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Background

High scrap generation in the printing stage of paper bag manufacturing—currently averaging around 5%—is leading to significant material wastage, rework, and delivery delays. The primary causes include smudges, print misalignment, and inconsistent color density, all of which increase the consumption of expensive consumables such as specialty papers, food-grade inks, and printing plates. These quality issues not only impact production efficiency but also affect customer satisfaction and brand credibility, especially among key FMCG and retail clients who demand consistent packaging quality.

By reducing the scrap rate to 2% or lower, the project aims to save considerable amount annually, while achieving higher first-pass yield and better process capability (Cp, Cpk > 1.67). The improvement will help ensure faster turnaround times, reduced rework, and more reliable color and print consistency, directly contributing to cost optimization, leaner operations, and stronger customer relationships.

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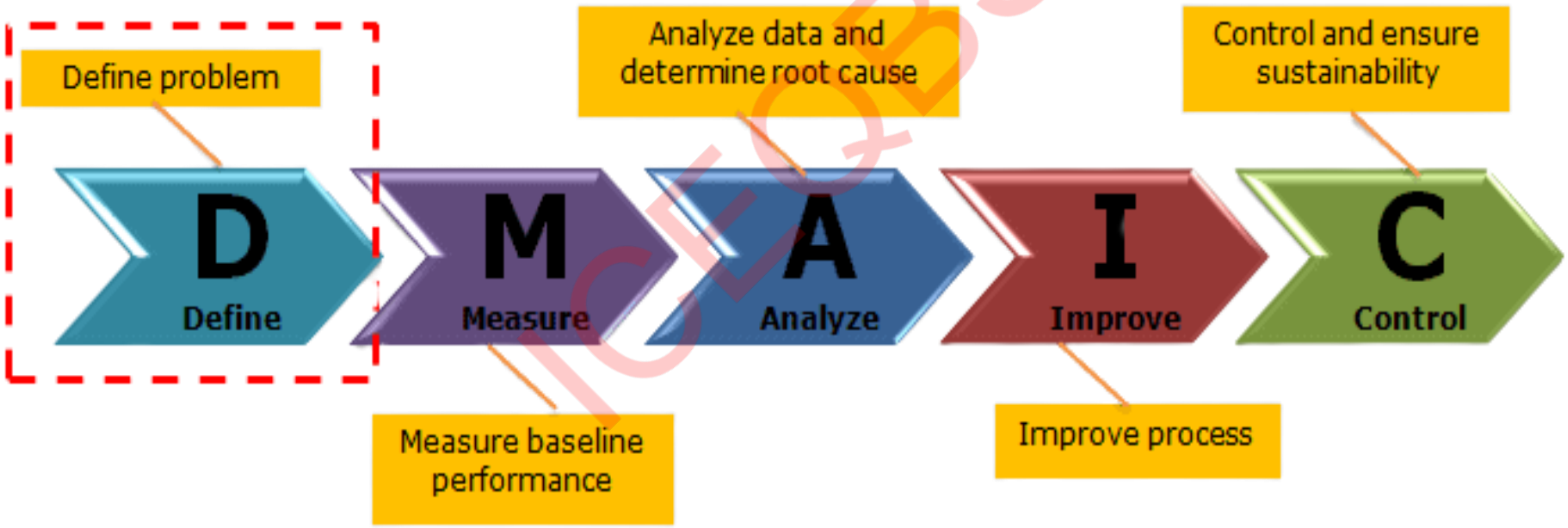
DEFINE PHASE



VOC & CTQ

CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
“We need sharp, color-consistent, defect-free prints.”	CTQ – **Print sharpness, ink consistency**	Primary Metric - **Y = % Scrap (Printing)** Secondary Metric - **Productivity**

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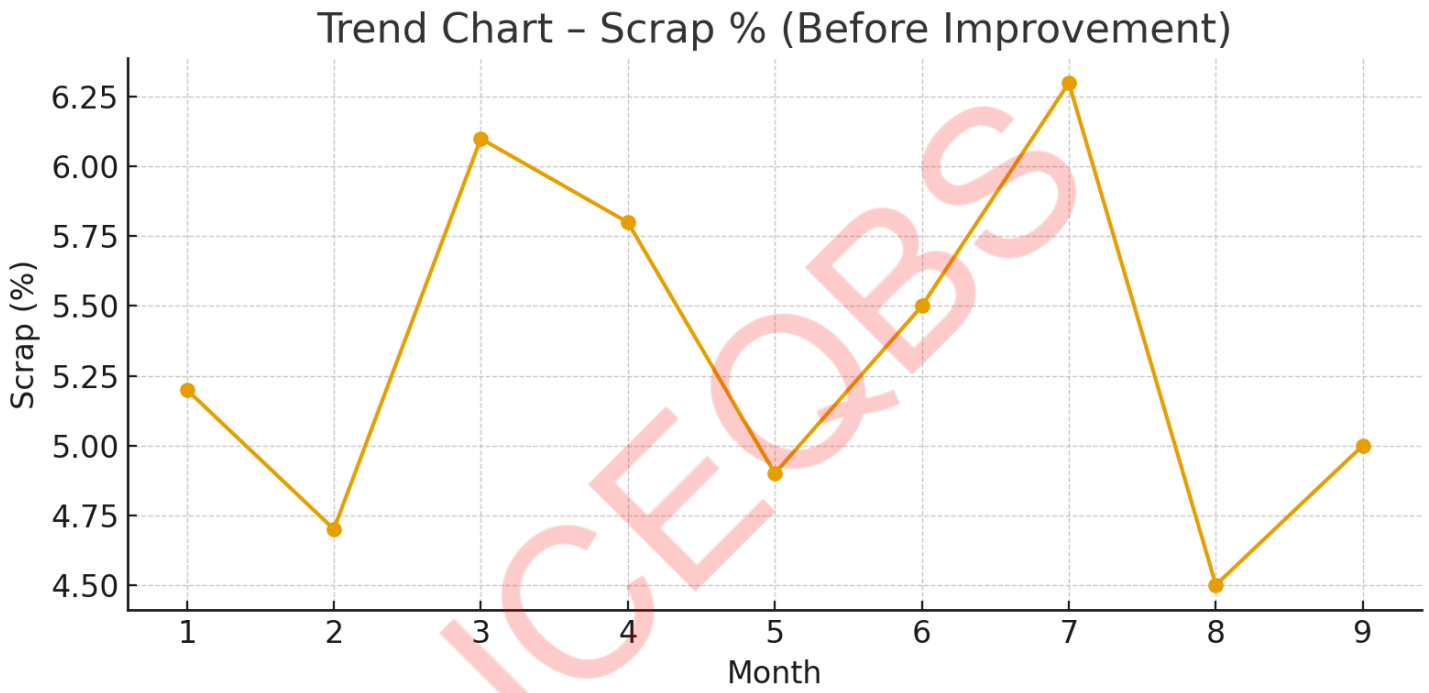
Baseline Performance of Primary Metric (9 months data as Line chart)



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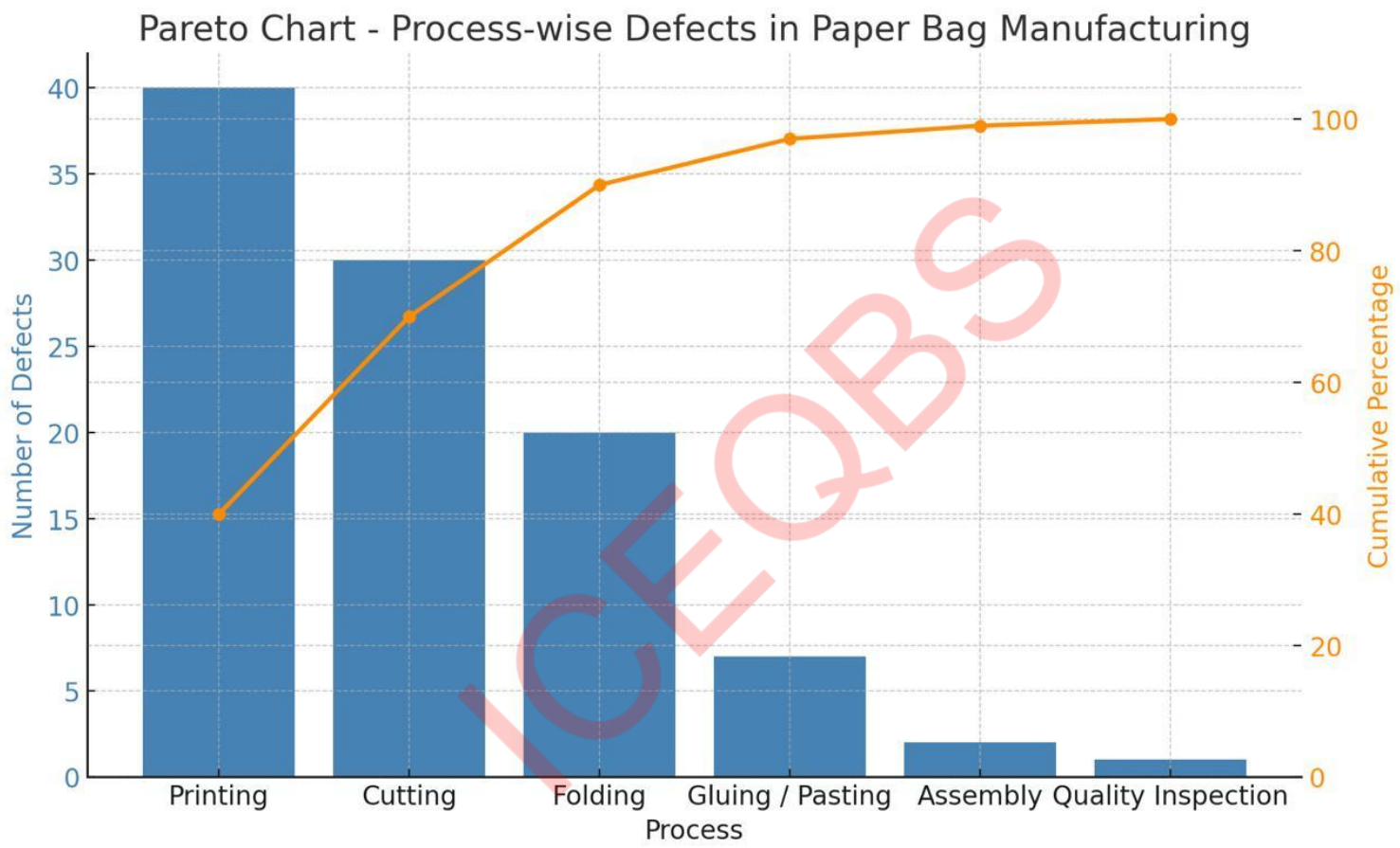
Inference :

- 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 : The project is going to focus only on **Printing Process**

SIPOC

Scrap Reduction in Printing

Suppliers	Inputs	Process	Outputs	Customers
Paper suppliers	Paper rolls	Load roll	Printed bags	FMCG brands
Ink suppliers	Ink & solvents	Ink mixing	Scrap bags	Retail chains
Operators	Setup sheets	Plate alignment	Inspection reports	Food chains
Maintenance	Machine uptime	Printing	Quality report	QC team

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Project Charter

Project Title:	Reduction of Scrap% in Machining process from 3% to 1%

Project Leader	Project Team Members:
Shameem Ahammed	Printing Operator, QC Inspector, Maintenance Technician, Ink Technician
Champion/Sponsors:	**Key Stake Holders**
Plant Head	Cutting teams, Folding teams, Assembly teams, QC teams, Packaging teams, FMCG brands, Food chains, Retailers, Distributors
Problem Statement:	**Goal Statement:**
Currently, the **printing process in paper bag manufacturing** has an **average scrap rate of ~5%**, primarily due to defects such as smudges, misalignment, and inconsistent color density. This results in wasted paper rolls and ink, higher rework costs, and delayed deliveries. The high rejection percentage directly impacts profitability, customer satisfaction, and brand image for FMCG and retail clients	Reduce the **printing scrap rate from 5% to ≤2%** within the next 6 months, while maintaining compliance with **packaging quality standards** and ensuring consistent print quality (sharpness, alignment, color uniformity). Additionally, improve **process capability (Cp, Cpk > 1.67)** to sustain improvements.
Secondary Metric	**Assumptions Made:**
Productivity	Stable production volume and order mix Operator adherence to new SOPs Reliable quality measurement data

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Project Charter

Tangible and Intangible Benefits:	Risk to Success:
Tangible: Scrap reduced from 5% → ≤2%, **Intangible:** Better quality consistency, higher customer satisfaction, stronger team collaboration	Operator resistance to process changes Machine downtime or setup delays Variation in paper or ink quality
In Scope:	**Out of Scope:**
Printing operations – setup, plate alignment, ink viscosity control, registration accuracy, drying process.	Cutting, folding, gluing, packaging
Signatories:	**Project Timeline:**
Project Head : Shameem Ahammed Sponsor : Plant Head	6 Months

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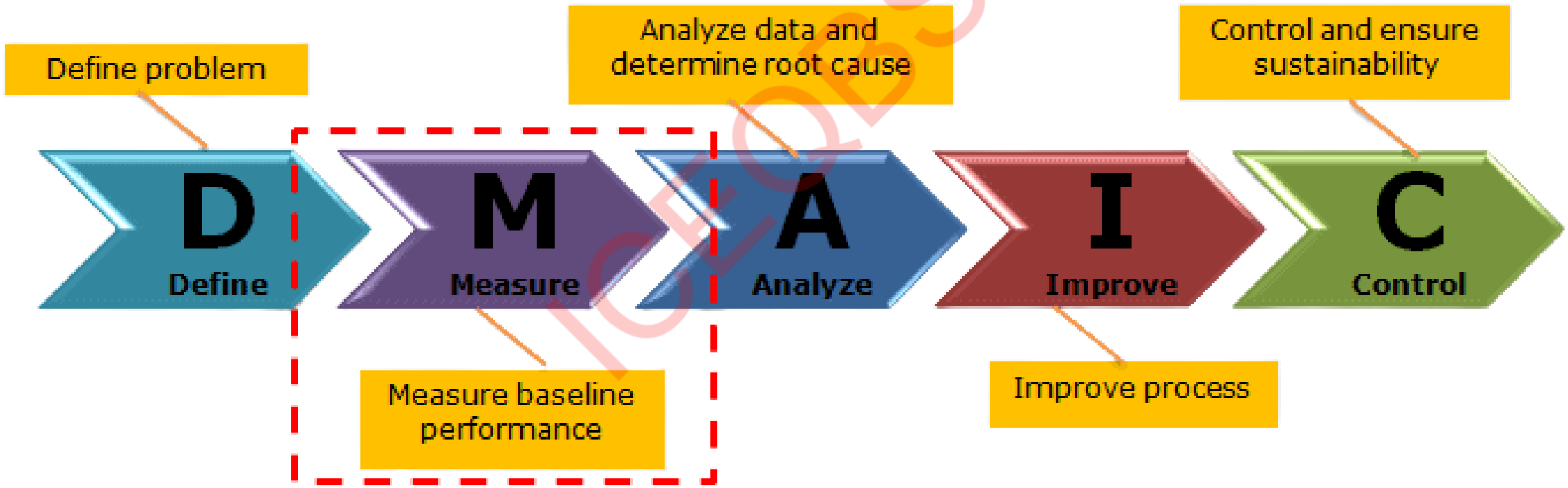
MEASURE PHASE



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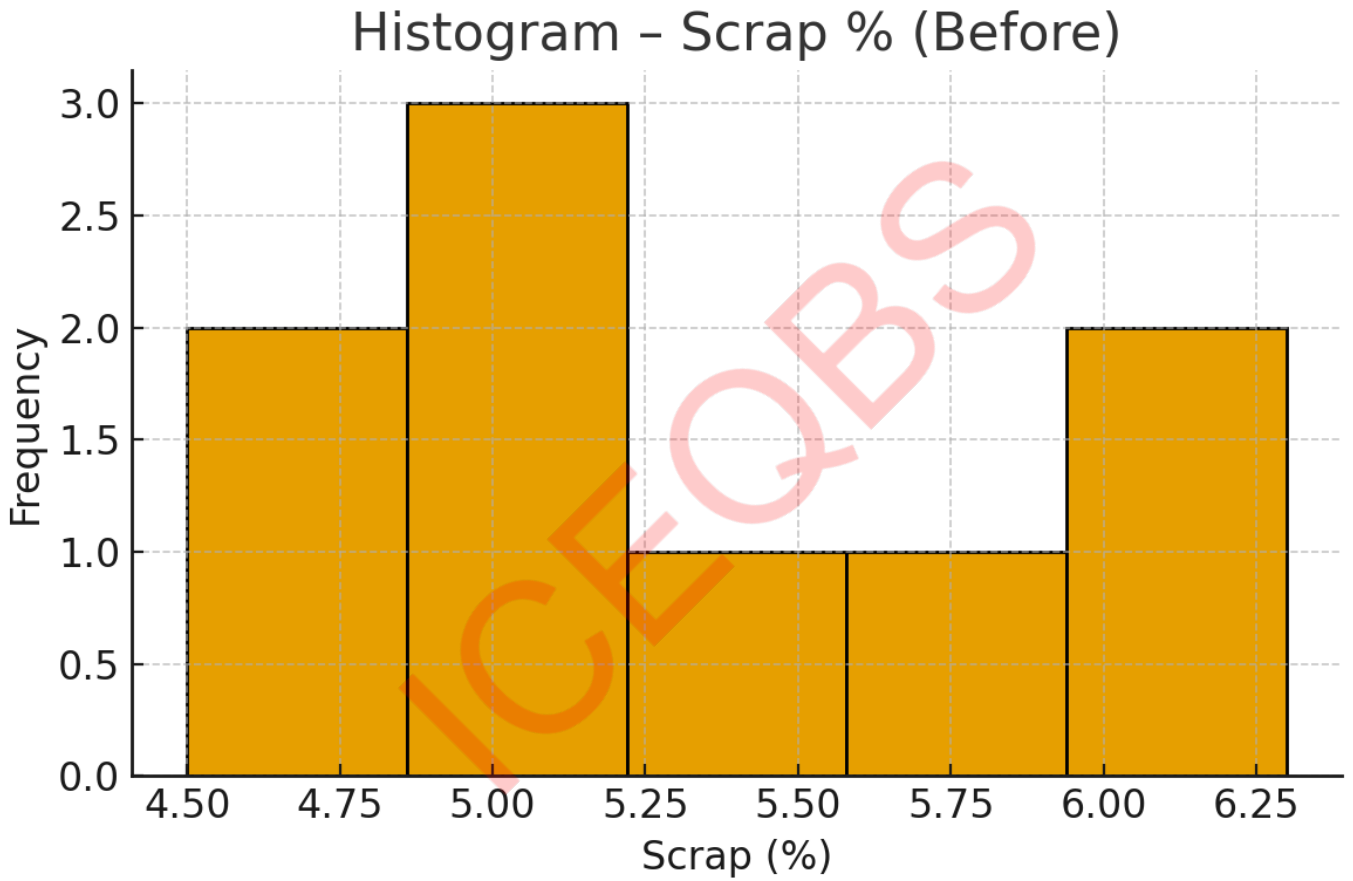
Data collection – Histogram (Before improvement)



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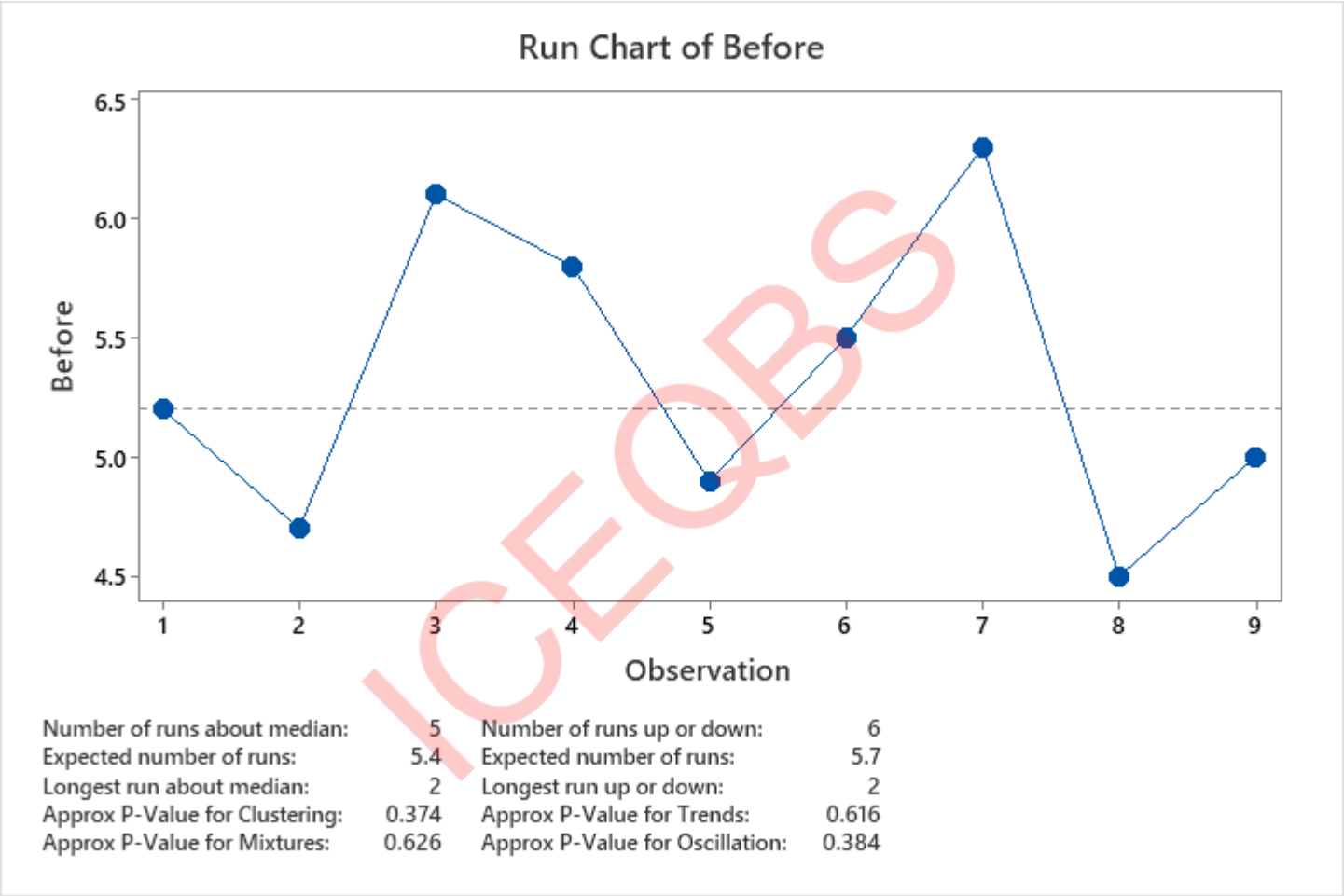
Inference :

- Data is normally distributed over the mean

Data collection – Run Chart (Before improvement)



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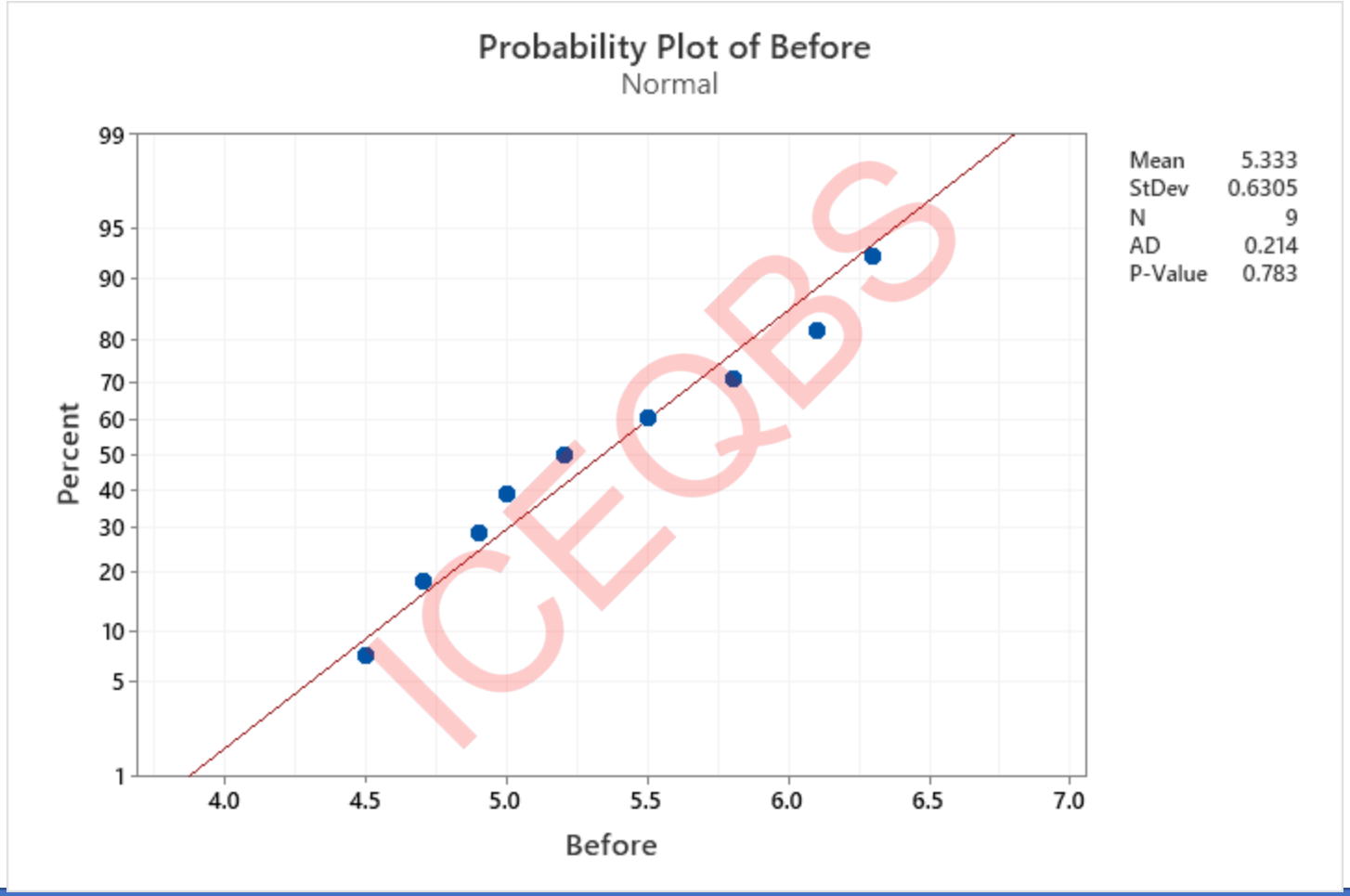
Inference :

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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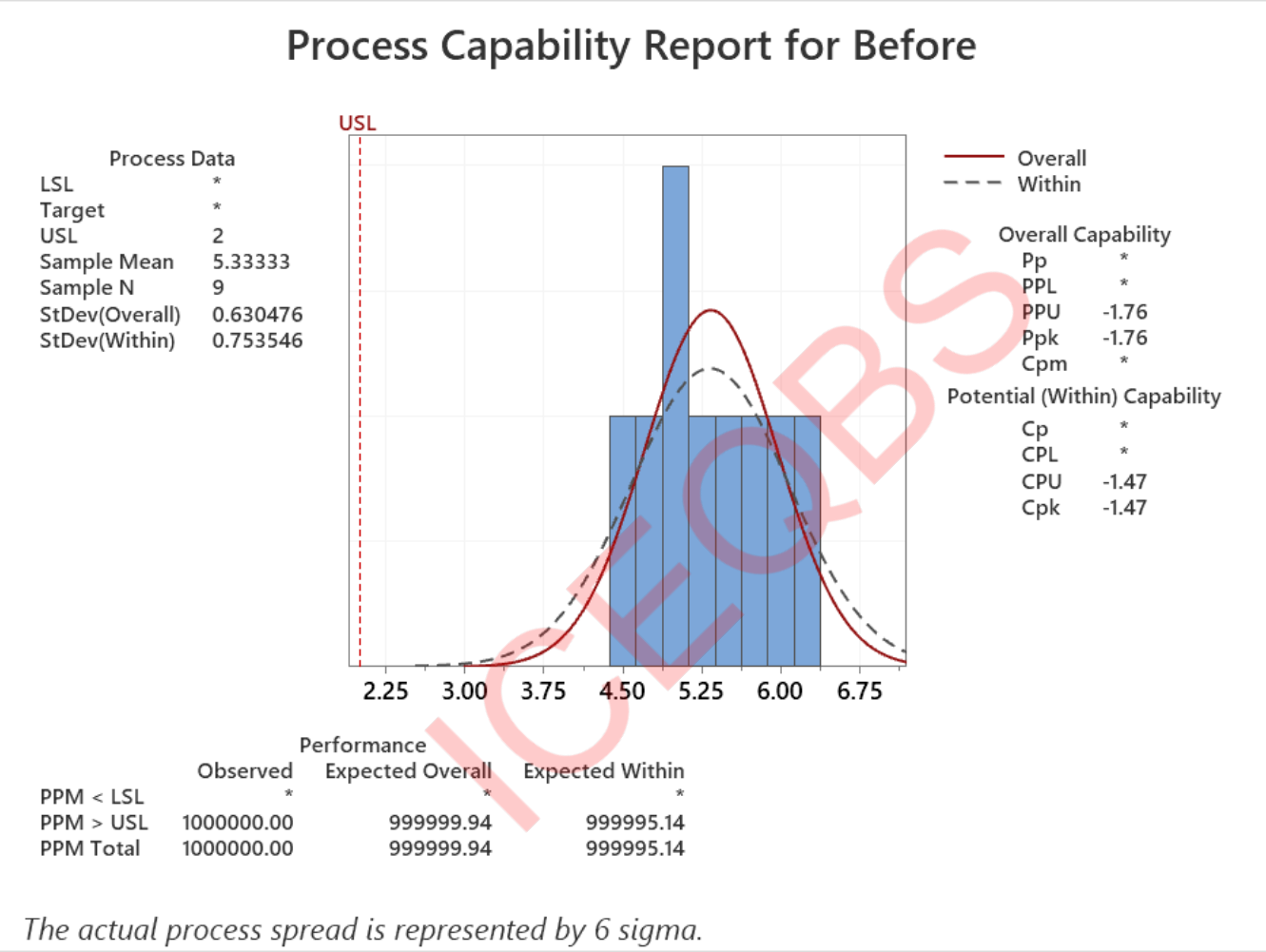
Inference :

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

Process Capability (Before improvement)



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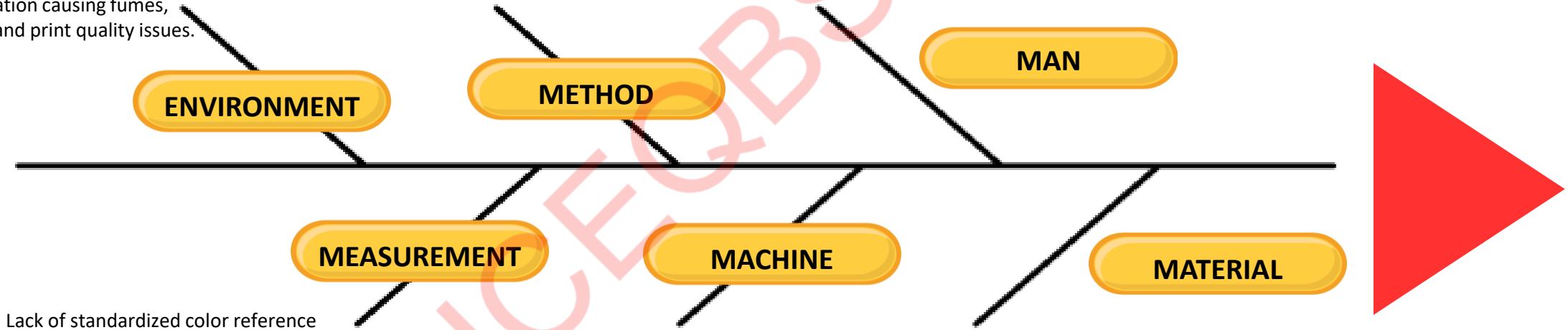
Inference :

- Process is highly not capable

Fish Bone Diagram



- High humidity affecting ink drying and adhesion.
- Temperature fluctuations altering ink viscosity.
- Dust or contamination in the printing area.
- Poor lighting leading to missed inspection of defects.
- Inadequate ventilation causing fumes, operator fatigue, and print quality issues.

- Incorrect ink viscosity settings.
- Poor web tension control during printing.
- Lack of standardized plate mounting and registration methods.
- Ineffective process control for ink density and alignment.
- Excessive trial runs during setup due to poor changeover practices.

- Operator skill variation in handling printing setups.
- Inconsistent adherence to Standard Operating Procedures (SOPs).
- Fatigue or distraction during long shifts.
- Inadequate training in print quality standards (color density, alignment).
- Communication gaps between operators, QC, and supervisors.

- Lack of standardized color reference (Pantone/Delta E checks).
- Inaccurate or uncalibrated densitometers and gauges.
- Subjective visual inspection by operators.
- No regular Gauge R&R validation for inspection tools.
- Inconsistent sampling frequency and methods across shifts.

- Printing plate wear or roller misalignment.
- Ink pump or feeder malfunction causing uneven ink spread.
- Inadequate preventive maintenance of printing machines.
- Drying unit malfunction leading to smudges.
- Vibration or web tension instability affecting registration.

- Paper GSM inconsistency across batches.
- Moisture in paper rolls causing warping or poor print absorption.
- Ink contamination or improper mixing.
- Surface defects on paper (wrinkles, uneven coating).
- Variation in adhesive or coating compatibility with inks.

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3M Analysis for Waste

MUDA

- Reprinting paper bags due to smudged or misaligned logos.
- Excessive paper waste during print registration and trial runs.
- Waiting time for quality approval before starting bulk production

MURA

- Variation in print density and color tone between different shifts.
- Inconsistent bag dimensions after printing and cutting processes.
- Fluctuations in ink viscosity and drying time across batches.

MURI

- Overloading operators with multiple printing machines simultaneously.
- Running printing plates and rollers beyond recommended usage, causing breakdowns.
- Operating machines continuously without preventive maintenance, leading to sudden stoppages.

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8 Wastes Analysis

Defects	Bags rejected due to misaligned logos or blurred printing. Scrap generated from color mismatch and ink smudging.
Overproduction	Printing extra bags “just in case” of customer order increase. Running multiple trial prints before stabilizing machine registration and ink settings.
Waiting	Printing machines idle while waiting for QC approval of first samples. Operators waiting for paper rolls or inks to be issued from stores.
Non-Utilized Talent	Operators not involved in problem-solving or process improvement discussions. Lack of training opportunities for skill enhancement in print quality control.
Transportation	Unnecessary movement of semi-finished bags between distant production areas. Carrying paper rolls long distances to printing machines due to poor layout
Inventory	Excess WIP (work-in-progress) paper stacks stored near printing machines. Overstock of inks, plates, and rollers not immediately required for current jobs.
Motion	Operators walking frequently to fetch color samples, plates, or inspection tools. Manual handling of heavy paper rolls without proper trolleys or lifts.
Overprocessing	Re-printing or overlaying designs to cover smudges or faded ink. Applying excess ink layers beyond customer’s visual quality requirement.

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Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Issue Observed	Lean Tool	Action Plan	Benefit
Sudden printing roller/plate failure	TPM (Total Productive Maintenance)	Implement preventive maintenance and daily operator-led roller inspection	Reduced downtime, stable printing accuracy
Ink pump/drying unit breakdown	Visual Controls + TPM	Add ink level/dryer temperature indicators and daily checklists	Fewer smudges, improved ink adhesion
Out-of-spec paper batch from supplier	Incoming Quality Control (Poka-Yoke)	Strengthen supplier certification and incoming roll inspections	Fewer rejections, reduced paper scrap
Printing software/control system crash	Standardized Work	Maintain validated backup machine programs & settings	Faster recovery, less production delay
Abrupt power fluctuation	Andon System + Backup	Install voltage stabilizers and provide UPS backup for critical controls	Avoid unexpected stoppages, ensure continuity

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Action Plan for Low Hanging Fruits

Special Causes (sudden failures / abnormalities)

Issue	Lean Tool	Action Plan	Benefit
Operators overloaded with multiple machines	Work Balancing / Line Balancing	Redistribute machine responsibilities and use helper operators	Reduced errors, improved operator focus
Overused printing plates and rollers	Kanban for Plate/Roller Change	Visual tool life tracking and Kanban replacement cards	Prevents breakdowns, reduces scrap
Variation in print density	Standard Work + SMED	Standardize ink viscosity, registration parameters, and quick-change setup	Consistent productivity, fewer defects
Inconsistent finish quality	SPC Control Charts	Monitor color density and alignment stability with control charts	Stable quality, customer satisfaction
Rework due to misprints/defects	Poka-Yoke	Error-proof plate alignment and registration setup	Lower rework hours, higher FPY
Waiting for QC approval	Point-of-Use Inspection	Provide in-line color reference charts and go/no-go print templates	Reduced waiting, faster flow

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Action Plan for Low Hanging Fruits

Eight Wastes

Waste	Lean Tool	Action Plan	Benefit
Overproduction	Kanban Scheduling	Print only as per customer orders	Lower WIP, reduced scrap risk
Transportation	Cellular Layout	Place cutting/folding machines near printing line	Faster flow, less handling damage
Motion	5S	Keep inks, plates, and inspection tools at point of use	Reduced operator walking, faster setups
Inventory	Pull System	Limit paper rolls and WIP near machines with Kanban bins	Lower storage cost, smoother flow
Overprocessing	Standard Work	Eliminate unnecessary reprints and double inking	Saves time and material cost
Defects	Poka-Yoke	In-process visual checks for registration & ink spread	Scrap reduced from 5% → ≤2%
Waiting	Andon / Visual Boards	Signal QC delays or supply shortages immediately	Quick resolution, reduced idle time
Unused Talent	Kaizen Events	Involve operators in daily quality improvement	Engaged workforce, continuous improvements

ICEOPS

Top 12 Prioritized Root Causes (Based on Net Score)

1. Plate wear – **291**
2. Ink viscosity variation – **291**
3. Roller misalignment – **277**
4. Operator skill variation – **229**
5. Web tension variation – **229**
6. Ink contamination – **211**
7. Paper GSM inconsistency – **211**
8. Ink drying variation – **211**
9. Calibration errors – **211**
10. SOP adherence – **169**
11. Moisture in paper rolls – **195**
12. Humidity (environment) – **195**

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Data Collection Plan

Output / Input	Type of Data	Measurement Method	Unit	Frequency	Responsibility
% Scrap (Primary Y)	Continuous	Scrap count / production log	%	Daily	Production Engineer
Print Alignment Accuracy	Continuous	Visual inspection + alignment gauge	mm offset	Shift-wise	QC Inspector
Color Density Consistency	Continuous	Densitometer / Delta E measurement	ΔE units	Shift-wise	QC Inspector
Plate Wear	Continuous	Plate inspection (magnification, wear check)	mm wear	Weekly	Operator / QC
Ink Viscosity	Continuous	Zahn cup / viscosity cup test	sec	Shift-wise	Operator
Roller/Dryer Calibration	Attribute	Calibration record / checklist	Yes/No	Monthly	Maintenance Engineer
Web Tension Stability	Continuous	Tension gauge reading	N/m	Weekly	Maintenance Engineer
Paper GSM Consistency	Continuous	GSM tester / balance	g/m²	Lot-wise	QC Lab
Paper Moisture Content	Continuous	Moisture meter	%	Lot-wise	QC Lab
Ink Contamination Check	Attribute	Visual inspection / filtration test	Pass/Fail	Lot-wise	QC Lab
Operator Skill	Attribute	Training & certification record	Certified/Not	Once/operator	HR / Training
SOP Adherence	Attribute	Process audit checklist	Yes/No	Weekly	QA / Supervisor
First Pass Yield (FPY)	Continuous	Production & inspection log	%	Daily	Production Engineer
On-Time Delivery (OTD)	Continuous	Planning & dispatch report	%	Weekly	Planning Dept.

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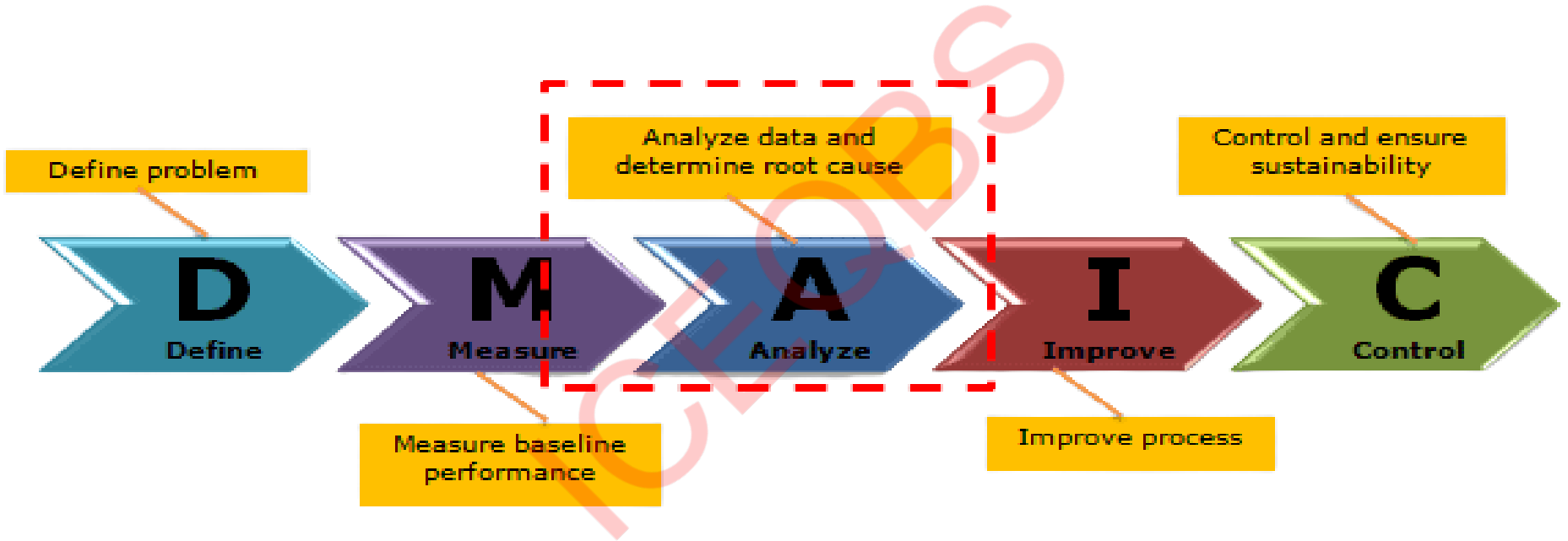
ANALYSE PHASE



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Analyse – Hypothesis testing

Regression Equation

Scrap_Print_% = 0.911 + 0.11286 Plate_Wear_Index_% + 0.6400 Ink_Viscosity_Dev_% + 3.2298 Roller_Misalignment_mm

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.911	0.113	8.04	0.000	
Plate_Wear_Index_%	0.11286	0.00520	21.70	0.000	1.01
Ink_Viscosity_Dev_%	0.6400	0.0102	62.94	0.000	1.01
Roller_Misalignment_mm	3.2298	0.0997	32.38	0.000	1.01

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.365930	97.33%	97.28%	97.18%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	712.66	237.553	1774.04	0.000
Plate_Wear_Index_%	1	63.07	63.066	470.98	0.000
Ink_Viscosity_Dev_%	1	530.39	530.393	3960.97	0.000
Roller_Misalignment_mm	1	140.43	140.426	1048.70	0.000
Error	146	19.55	0.134		
Total	149	732.21			

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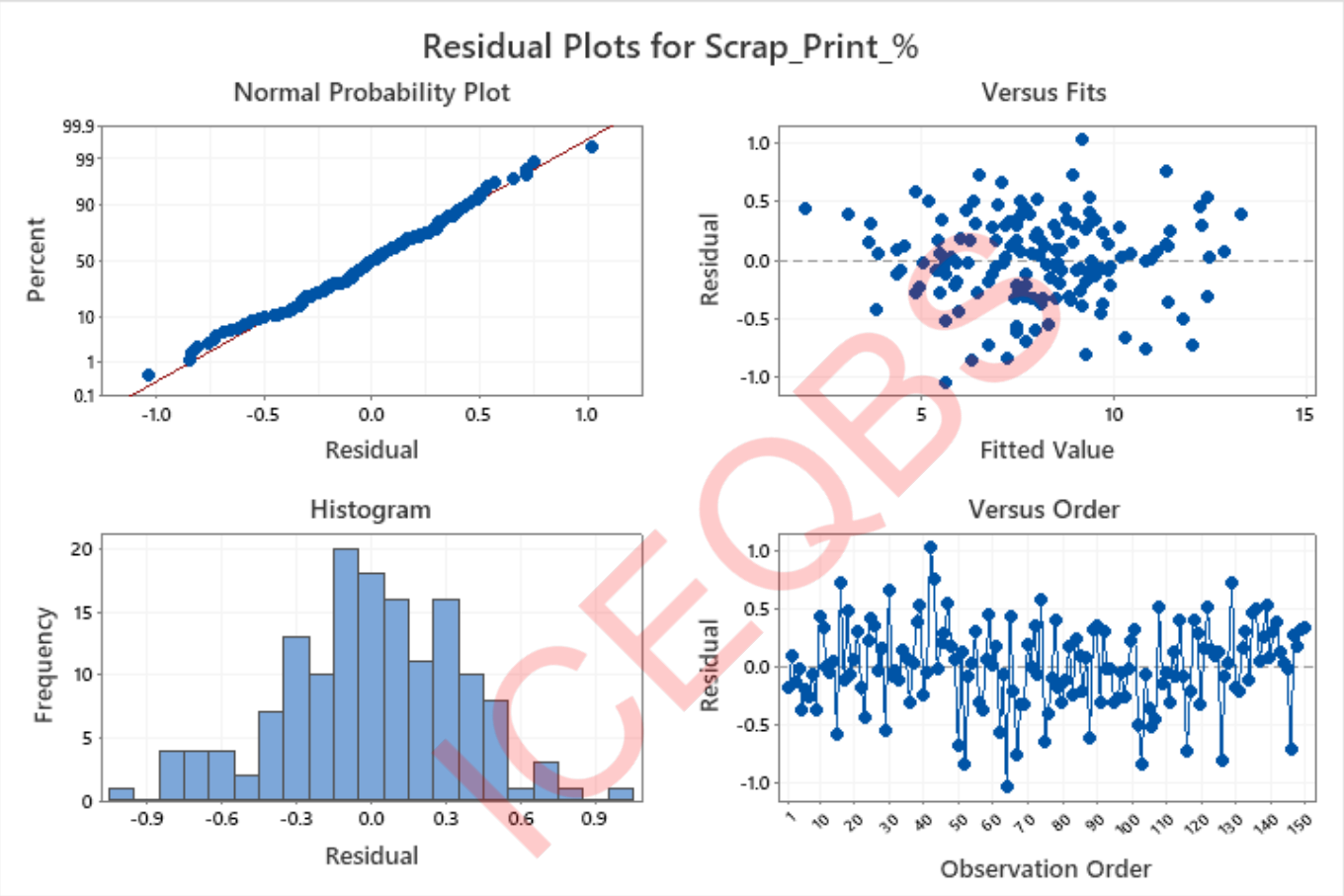
Inference :

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

Analyse – Hypothesis testing



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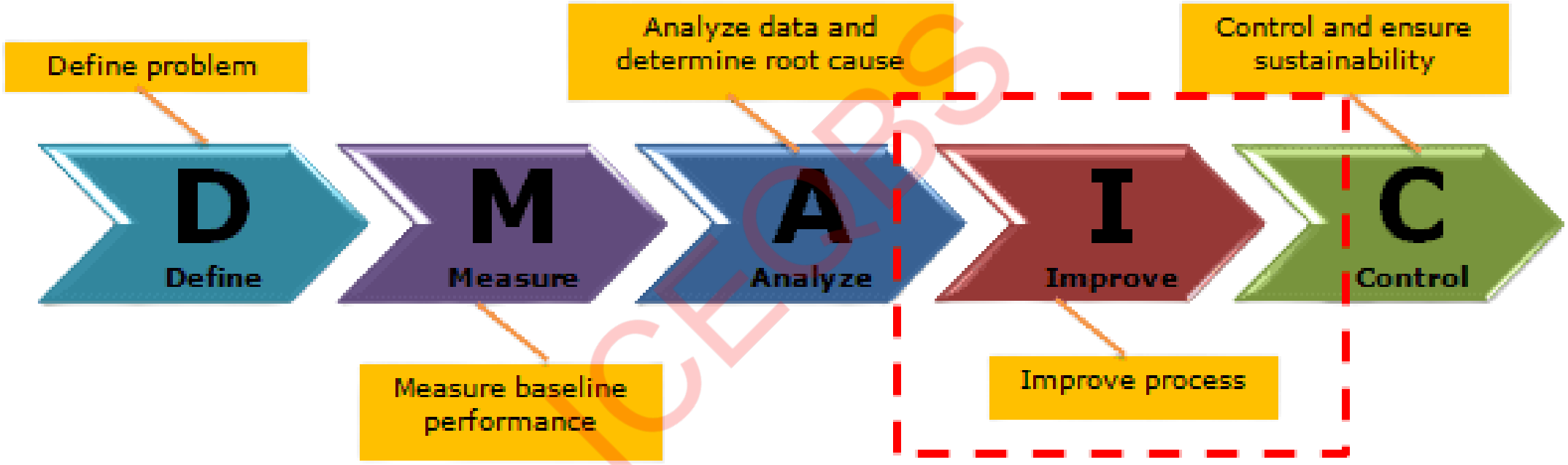
Inference :

- Both 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.

IMPROVE PHASE



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Improve

Validated Root Causes:

- Ink Viscosity
- Plate Wear
- Roller Alignment

Action Plan:

- Preventive Maintenance
- Viscosity Control
- Roller Alignment
- Operator Training
- Spc

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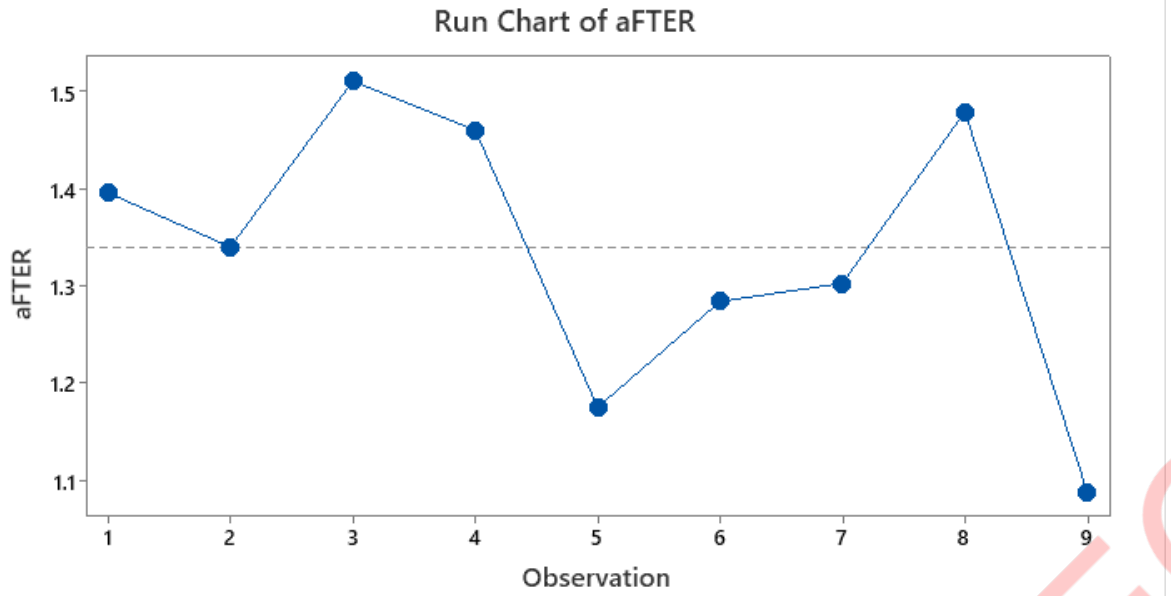
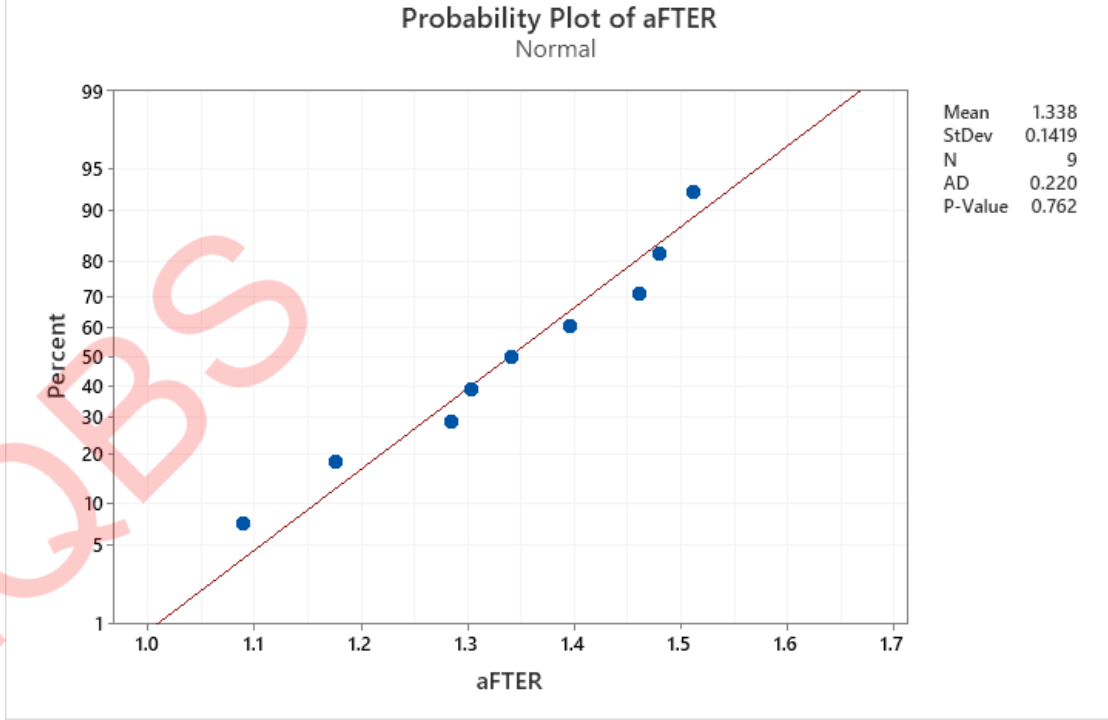
Improve – Run chart and Normality Test (After Improvement)



Number of runs about median:	6	Number of runs up or down:	5
Expected number of runs:	5.4	Expected number of runs:	5.7
Longest run about median:	3	Longest run up or down:	3
Approx P-Value for Clustering:	0.656	Approx P-Value for Trends:	0.278
Approx P-Value for Mixtures:	0.344	Approx P-Value for Oscillation:	0.722



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Inference:

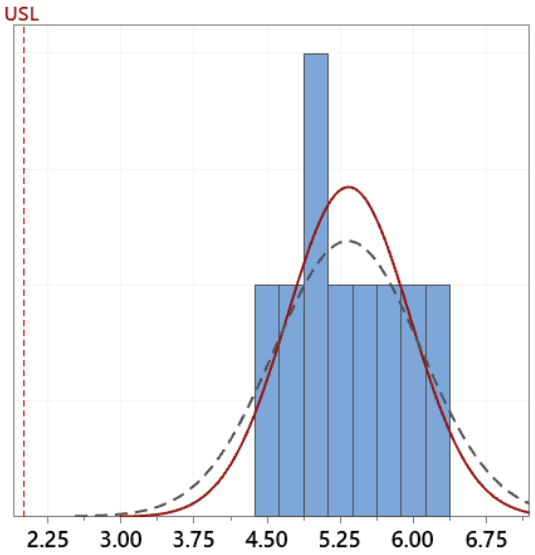
- Run chart – process is stable there is no special causes in the process (p value > 0.05)

Inference:

- Normality test – Data are normally distributed

Improve – Process capability – Before & After Improvement

Process Capability Report for Before



Process Data	
LSL	*
Target	*
USL	2
Sample Mean	5.33333
Sample N	9
StDev(Overall)	0.630476
StDev(Within)	0.753546

Overall
Within

Overall Capability	
Pp	*
PPL	*
PPU	-1.76
Ppk	-1.76
Cpm	*

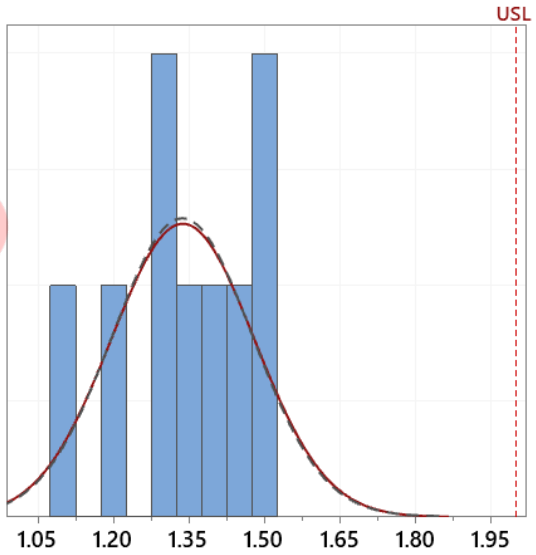
Potential (Within) Capability	
Cp	*
CPL	*
CPU	-1.47
Cpk	-1.47

Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	*	*	*
PPM > USL	1000000.00	999999.94	999995.14
PPM Total	1000000.00	999999.94	999995.14

The actual process spread is represented by 6 sigma.

Process Capability Report for aFTER



Process Data	
LSL	*
Target	*
USL	2
Sample Mean	1.33764
Sample N	9
StDev(Overall)	0.141878
StDev(Within)	0.139243

Overall
Within

Overall Capability	
Pp	*
PPL	*
PPU	1.56
Ppk	1.56
Cpm	*

Potential (Within) Capability	
Cp	*
CPL	*
CPU	1.59
Cpk	1.59

Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	*	*	*
PPM > USL	0.00	1.52	0.98
PPM Total	0.00	1.52	0.98

The actual process spread is represented by 6 sigma.

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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	5.333	0.630	0.21
aFTER	9	1.338	0.142	0.047

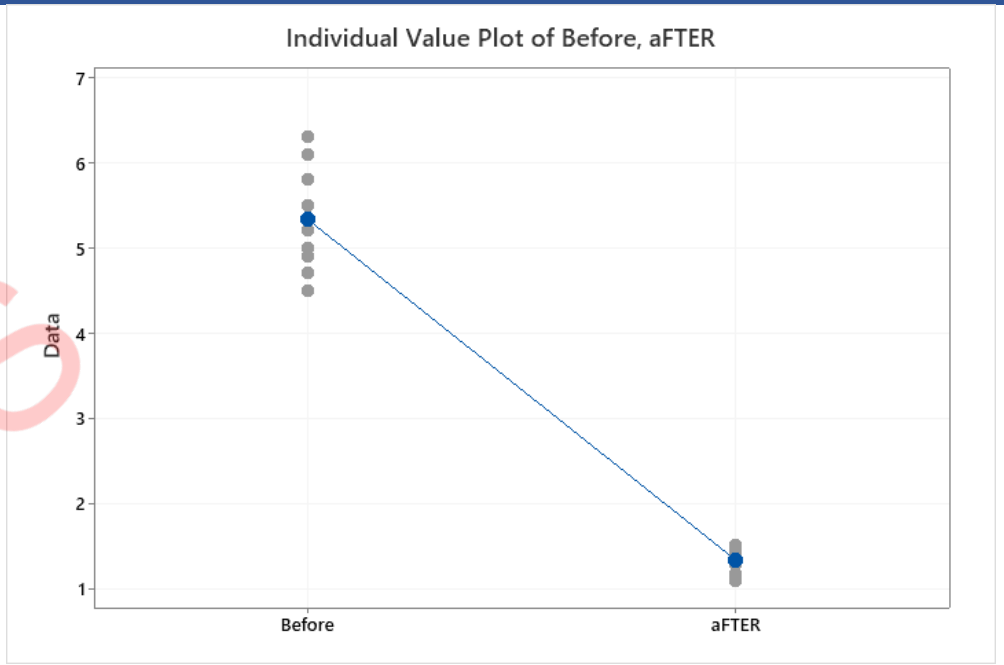
Estimation for Difference

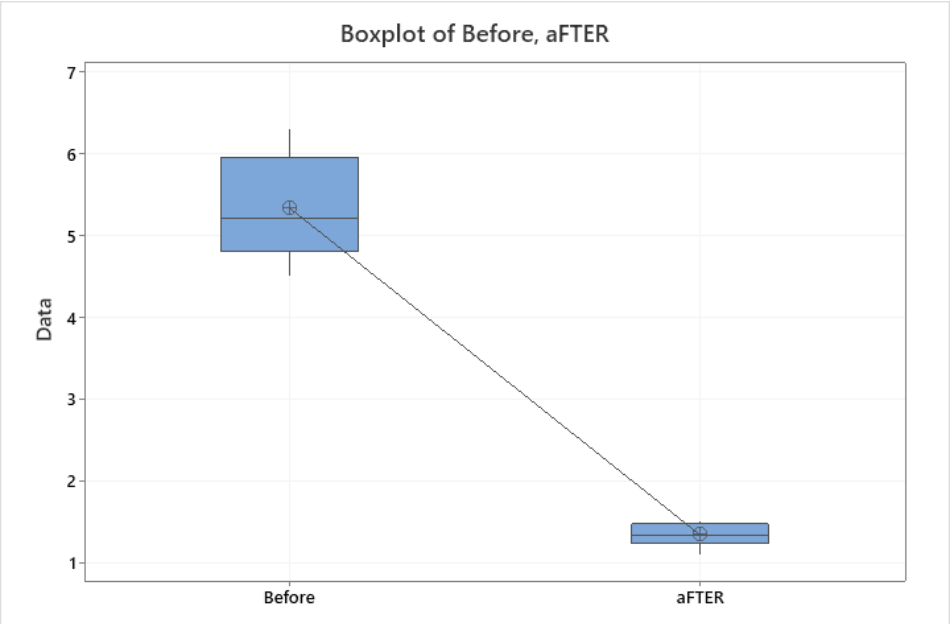
Difference	95% CI for Difference
3.996	(3.499, 4.492)

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
18.55	8	0.000





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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

#	Process Step	Function / Requirement	Potential Failure Mode	Effect on CTQs / Y (% scrap)	S	Potential Causes	O	Current Controls (Prev/Det)	D	RPN	Recommended Actions (acceptance criteria)	Owner	Due	Residual S/O/D/RPN
1	Ink prep	Correct viscosity at press	Ink viscosity out of spec	Color shift, smearing → reprints	8	Poor mixing/temperature control; solvent drift	6	Cup/viscometer checks, operator visual	6	288	Inline viscometer + temp control; mixing SOP; SPC on viscosity (±3%); lot hold if OOS	Process Eng	W2	8/3/3/72
2	Infeed/registration	Maintain roller geometry	Roller misalignment	Registration errors, ghosting	8	Setup error, thermal growth	5	Manual alignment, periodic checks	6	240	Laser alignment tool; shim standards; first-article grid check every setup	Maint/PE	W2	8/3/3/72
3	Plate mount	Plate condition maintained	Plate wear / damage	Dot gain, blur, repeats → scrap	7	Plate reuse, harsh cleaning	5	Visual inspection	6	210	Plate wear index & life log; approved cleaning SOP; quarantine worn plates	QA / Sup	W3	7/3/3/63
4	Web handling	Stable web tension	Web tension variation	Stretch, skew, wrinkles	7	Brake drift, sensor noise	4	Operator setting, occasional check	6	168	Closed-loop tension control; CV≤2% alarm; daily sensor calibration	Maint	W3	7/2/3/42
5	Ink system	Clean ink delivery	Ink contamination	Specks/fish-eyes → print defects	6	Dirty buckets/filters, backflow	4	Filter change weekly	5	120	Inline filtration + change counters; sealed lids; 5S at ink room	QA	W2	6/2/3/36
6	Substrate	GSM consistency	Paper GSM inconsistency	Mottle, pressure variation	6	Supplier variability, storage	4	COA review, incoming check	5	120	Tighten AQL; moisture conditioning racks; quarantine OOS rolls	SCM / QA	W4	6/2/3/36
7	Drying	Proper solvent evaporation	Ink under/over drying	Offset/blocking or brittle	6	Dryer temp/airflow drift	4	Temperature setpoint check	5	120	PID tune; airflow verification; run cards with temp–speed matrix	Process Eng	W3	6/2/3/36
8	Setup & run	Operator consistency	Operator skill variation	Setup scrap, slow recovery	5	Inadequate training	5	Buddy checks	6	150	Skill matrix; standardized setup checklist; certification & refreshers	HR / Sup	W4	5/3/3/45
9	Handling	Cap/roll handling	Improper handling damage	Edge dents, creases	5	Rough transport, stacking	4	Visual checks	6	120	Poka-yoke trolleys; FIFO lanes; visual standards	Sup	W3	5/2/3/30
10	Measurement	Gauge system	Viscosity gauge error	Missed OOS → hidden scrap	7	Poor MSA/calibration	3	Annual cal only	6	126	MSA (GRR ≤10%); monthly cal check; dual-cup verification	QA	W4	7/2/3/42

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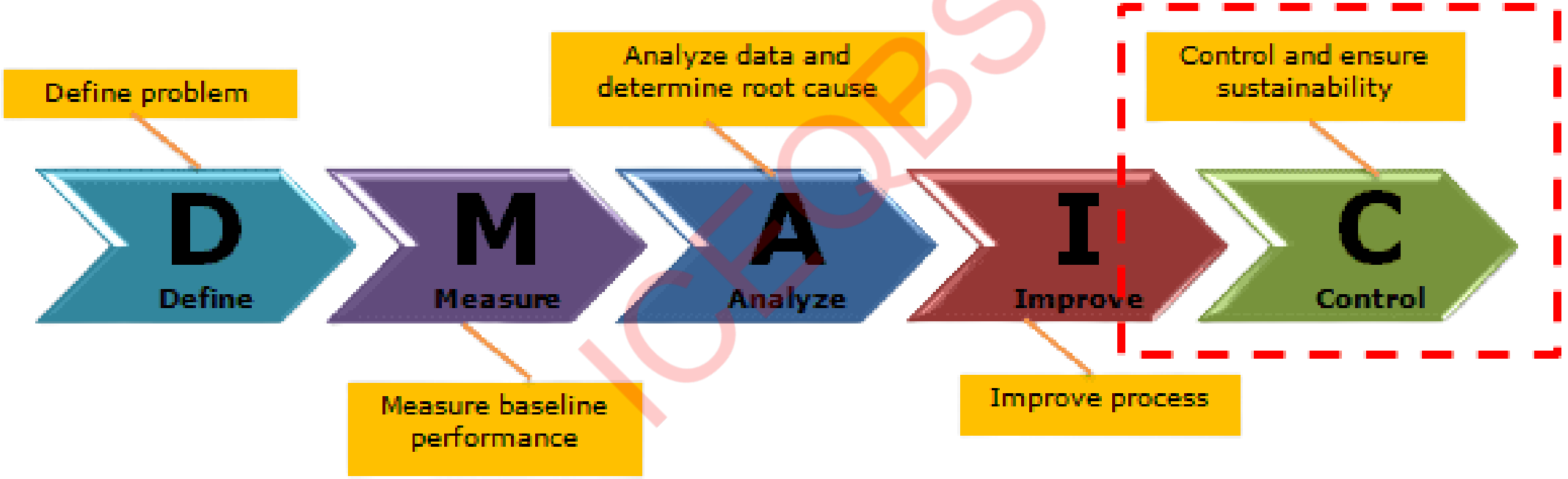
CONTROL PHASE



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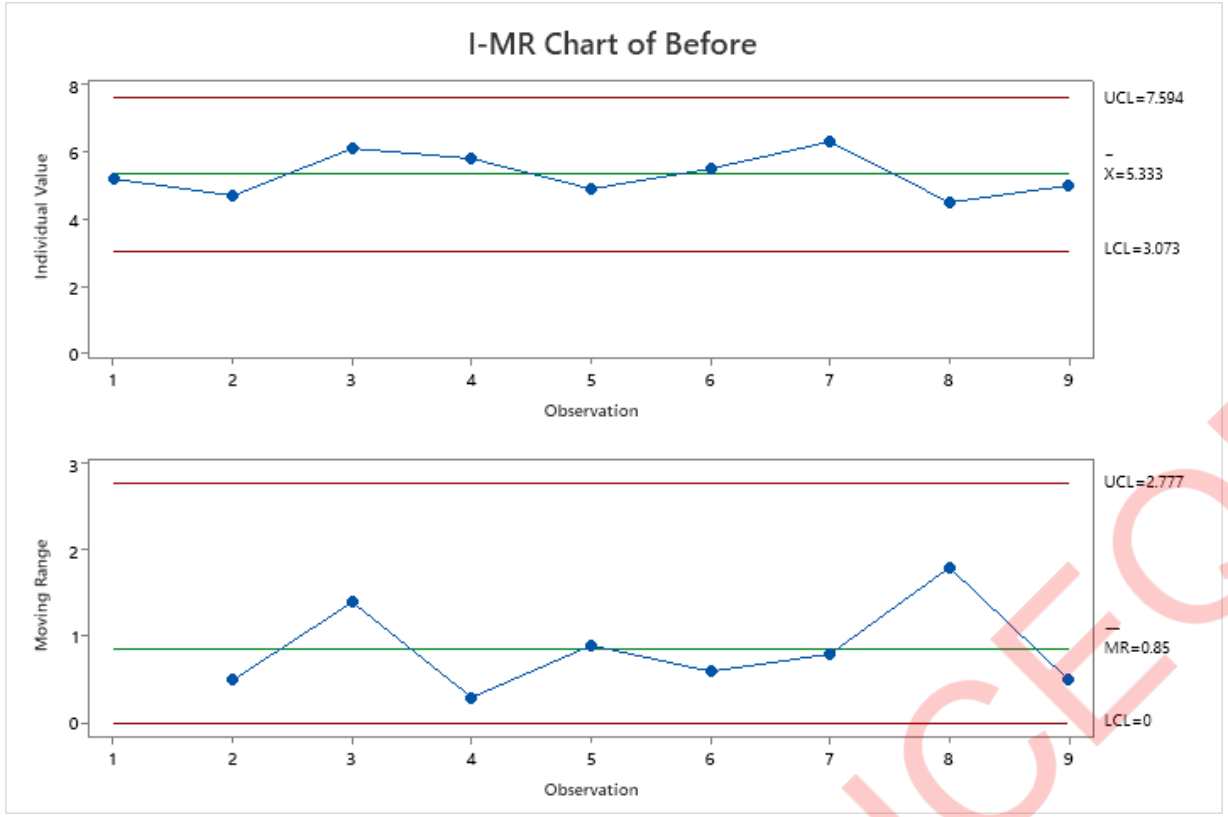
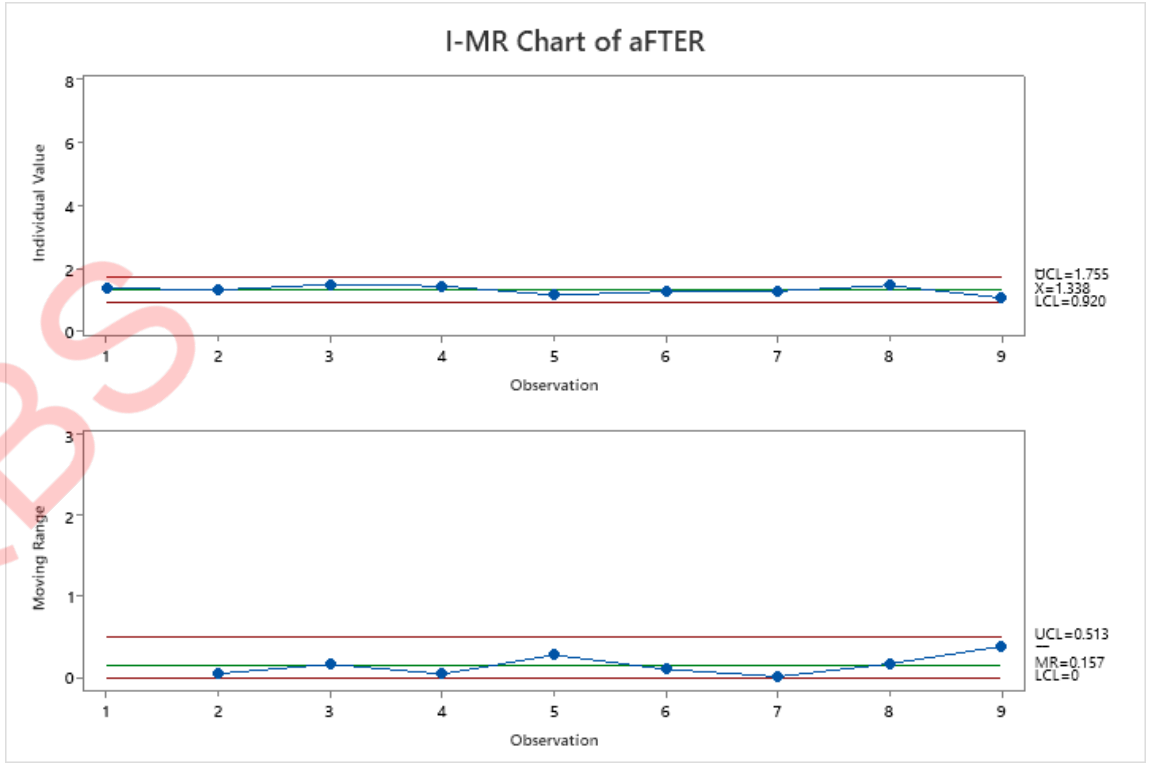
Improve (Statistical validation for Improvement – I-MR Chart)





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Inference:

- As seen in control chart, before improvement mean was high and there was high variability process and after improvement, it has achieved to target.
- There is a significant reduction in variation

Control Plan

#	Process / CTQ	Characteristic (X or Y)	Target / Spec (after improve)	How to Measure (gage/method)	Sampling / Frequency	Control Method (SPC/Check)	Owner	Reaction / OCAP
1	Final quality	**Y: % Scrap_Print**	**Target ≤ 1.0%** (alarm > 1.5% shift avg)	Line reject log → QA confirm	Per roll + hourly roll-up	**p-chart** by hour; Pareto of defect codes	Supervisor / QA	Point beyond UCL or 2 consecutive hours > 1.5% → stop, isolate WIP, run cause checklist (viscosity/roller/plate), corrective action before restart
2	Ink prep	**X: Ink_Viscosity_Dev_%**	**±3%** vs setpoint @ 25 °C	Zahn/Brookfield (temp-controlled) or inline viscometer	First-off, every **30 min**, and at batch change	**I-MR chart** (or $\bar{X}$-R if subgrouping) + spec check	Process Eng / Operator	Any reading outside ±3% or SPC rule breach → adjust solvent/temperature, re-test; if 2 breaches/shift → hold lot, PE review
3	Registration	**X: Roller_Misalignment_mm**	**≤ 0.30 mm** (lateral/parallel)	Laser alignment/dial indicator	At setup + **every changeover**	Setup checklist + go/no-go record	Maintenance / PE	>0.30 mm → realign before run; repeat within 1 week → escalate to PM on mounts/bearings
4	Plate mount	**X: Plate_Wear_Index_%**	**≤ 8%** (retire ≥12%)	Microscopy / wear index chart	Each plate at mount & end of shift	**I-MR chart** on wear index	QA / Supervisor	≥12% or trending up 3 points → quarantine plate set, replace; log life count
5	Web handling	**X: Web_Tension_CV_%**	**≤ 2% CV** steady-state	Tension transducer trend	First-off + **hourly** glance; alarmed online	**Run chart** with hi/lo alarm	Operator / Maint	>2% CV for >5 min → check brake/sensor, recalibrate; if unresolved → call Maint, hold product until visual OK
6	Substrate	**X: GSM_SD_gm2**	**SD ≤ 2.0 g/m²**	COA + random cross-roll check	Incoming lot + **one roll/lot**	AQL check; record sheet	Incoming QA / SCM	OOS → quarantine lot, inform supplier; allow controlled use only with PE waiver
7	Ink system	**X: Ink_Contam_PPM**	**≤ 50 ppm** particles/gels	Filter patch/PPM test	Each batch + **weekly** line check	Checksheet + acceptance	QA	>50 ppm → change filters, re-mix; re-sample before release
8	Drying	**X: Drying_Time_Dev_s**	**±0.5 s** vs run card	Draw-down test / inline timer	First-off + **every changeover**	Spec check + record	Process Eng	Out of spec → adjust temp/airflow per matrix; re-verify before release
9	People	**X: Operator_Errors_perShift**	**≤ 1/shift**	Error log (setup/adjustment)	Per shift	Weekly trend & Pareto	Supervisor	>1 for 2 shifts → refresher on SOP; LPA focus next week

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Conclusion

Results after improvement

- **Project has achieved its intended results**

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