“We’re losing money… delivery deadlines… customer trust. Something is wrong in thread rolling”

We are team of Six Sigma Consultants and these are the words of a Plant Manager of **Nut and Bolt Manufacturing unit**

$48,000

Annual Loss

FALLING

Customer Satisfaction

LOSING

OEM Contracts

REPUTATION

At Stake

If nothing is solved

Plant Manager seemed stressed.

We go for a walk

VERTICAL

Manufacturing

PRODUCT

Nuts and Bolts

FUNCTION

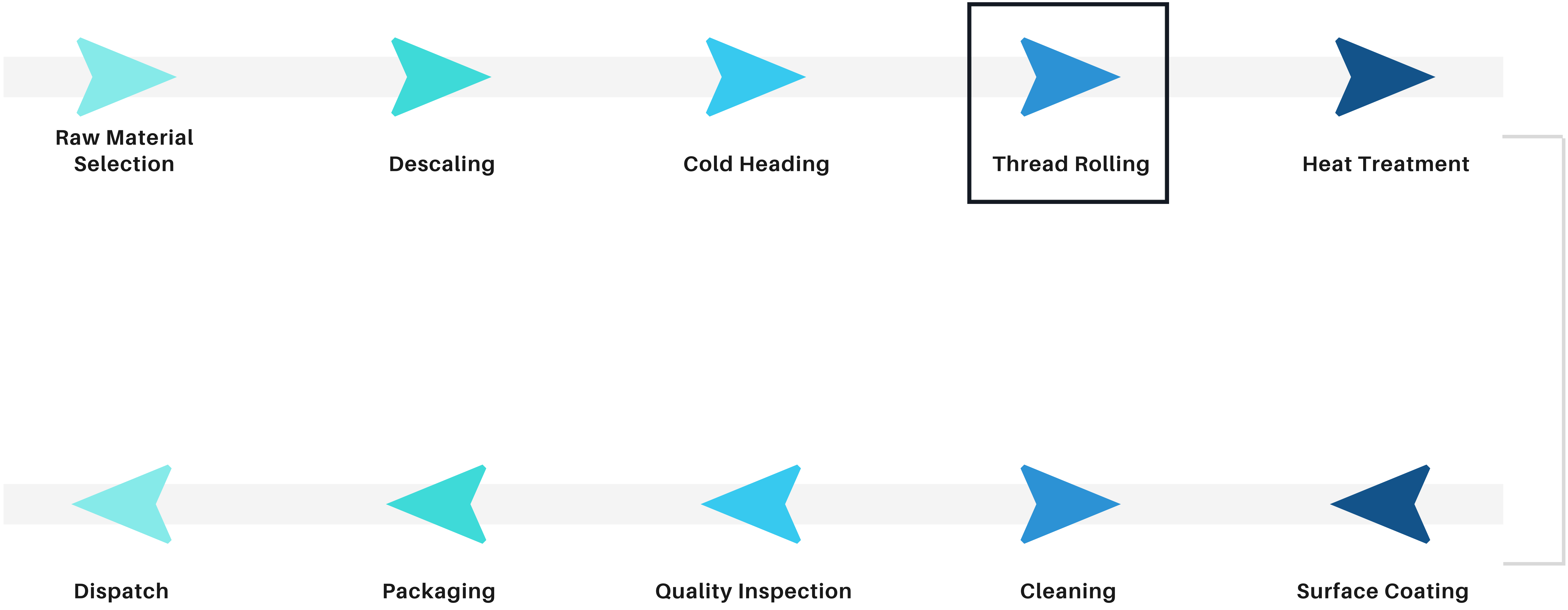
Production

PROBLEM

Dimensional Inaccuracy

First Pass Yield	DPMO
Customer Return	Defect Rate
Rate Cycle Time	Tool Life
Cost of Poor Quality	On TIme Delivery Rate
Overall Equipment Effectiveness	Rework Rate

END TO END PROCESS



VARIATIONS

COMMON CAUSE

- SLIGHT VARIATION IN RAW MATERIAL HARDNESS
- MINOR WEAR ON THREAD ROLLING DIES
- NORMAL FLUCTUATIONS IN LUBRICATION APPLICATION QUANTITY
- AMBIENT TEMPERATURE CHANGES WITHIN ACCEPTABLE LIMIT
- MACHINE VIBRATION AT STANDARD OPERATING LEVELS

SPECIAL CAUSE

- SUDDEN TOOL BREAKAGE OR DAMAGE DURING ROLLING
- LUBRICATION SYSTEM FAILURE
- MISALIGNMENT OF THREAD ROLLING DIES AFTER MAINTENANCE
- RAW MATERIAL BATCH WITH ABNORMAL HARDNESS
- OPERATOR ERROR IN SETTING MACHINE PARAMETERS

Define Phase

CUSTOMERS

INTERNAL

- QUALITY INSPECTION TEAM
- HEAT TREATMENT DEPARTMENT
- ASSEMBLY/PACKAGING DEPARTMENT
- MAINTENANCE TEAM
- PRODUCTION PLANNING & CONTROL

EXTERNAL

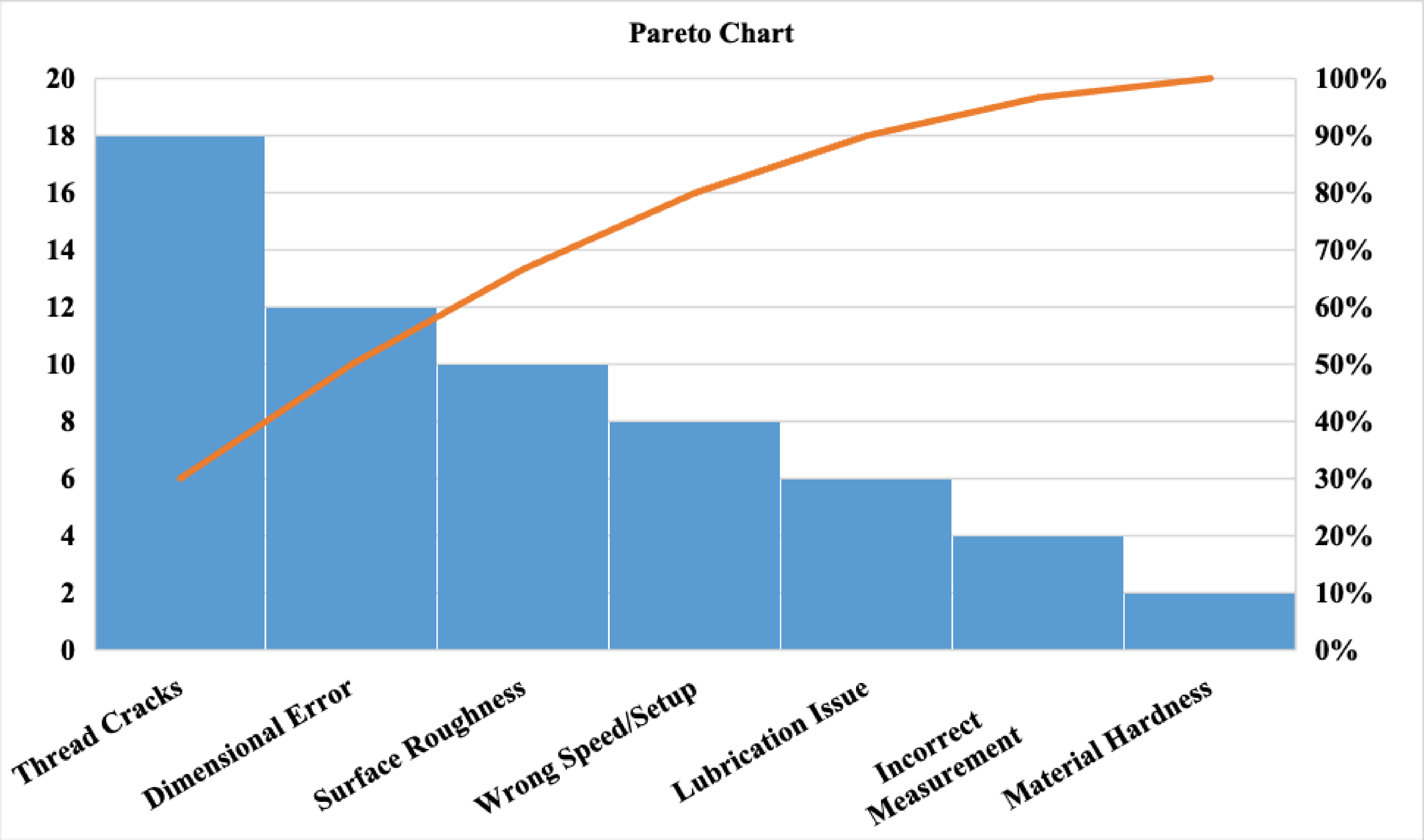
- ORIGINAL EQUIPMENT MANUFACTURERS
- DISTRIBUTORS AND WHOLESALERS
- CONSTRUCTION COMPANIES
- AUTOMOTIVE INDUSTRY
- END USERS

VOICE OF CUSTOMER (VOC):
CUSTOMERS DEMAND BOLTS WITH PERFECTLY FORMED THREADS THAT WITH A TOLERANCE OF ±0.05MM

CRITICAL TO X (CTQ) FACTORS:
1. **DEFECT:** DIMENSIONAL INACCURACY
2. **CTX:** CRITICAL TO QUALITY.
3. **CTX METRIC:** DEFECT RATE %
4. **SPECIFICATION:** <1%.

PARETO CHART

Defect Category	Defect Rate (%)	Cumulative %
Thread Cracks	18	18
Dimensional Error	12	30
Surface Roughness	10	40
Wrong Speed/Setup	8	48
Lubrication Issue	6	54
Incorrect Measurement	4	58
Material Hardness	2	60



The Pareto Chart shows that Thread Cracks is the most significant defect, accounting for 30% of all reported issues. According to the 80/20 rule principle, focusing efforts on the top three defects, Thread Cracks, Dimensional Error, and Surface Roughness will address approximately 80% of the total problems

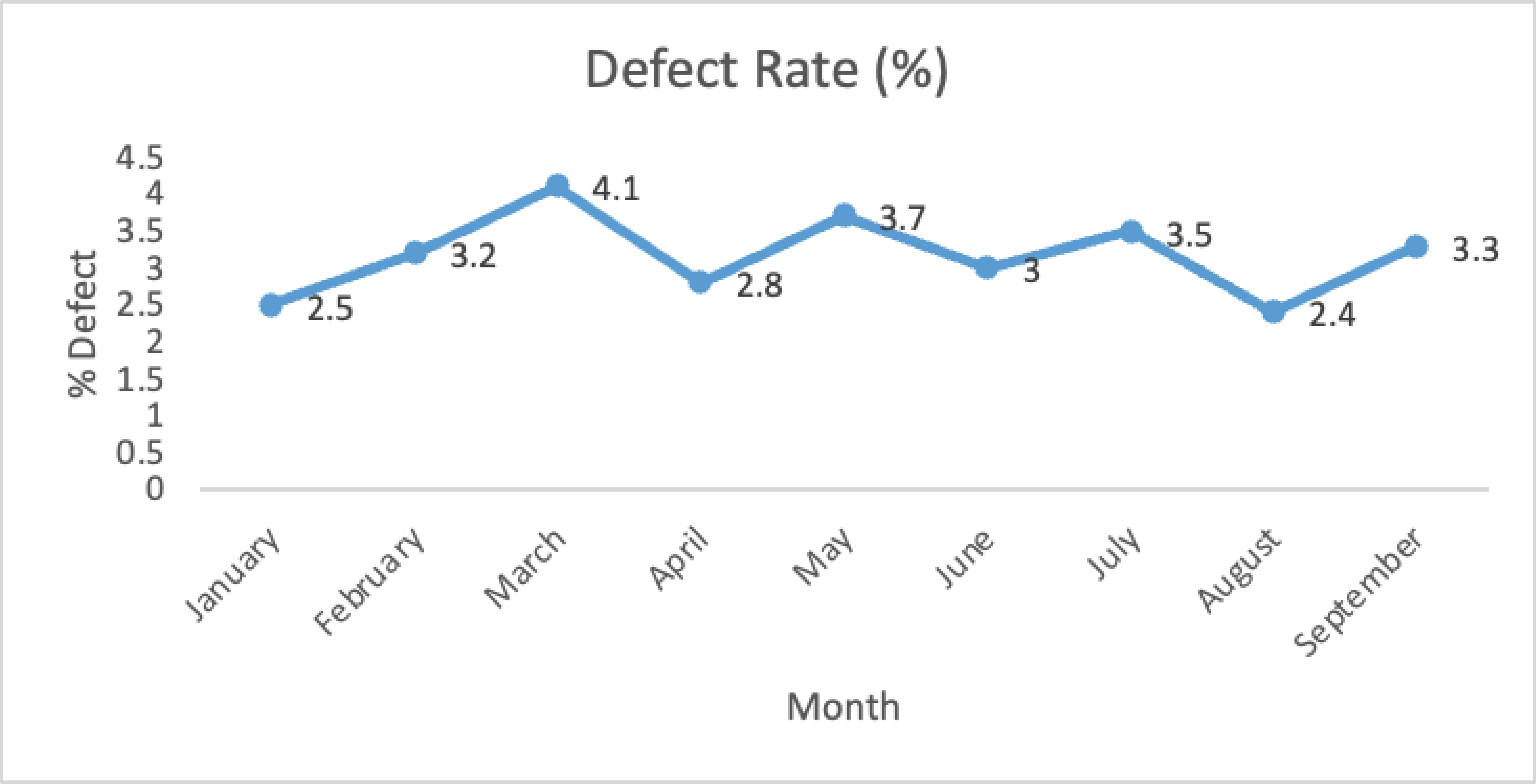
METRIC IDENTIFIED FOR IMPROVEMENT:

DEFECT RATE DUE TO THREAD MISALIGNMENT AND DIMENSIONAL INACCURACY, CURRENTLY AT 3%, TARGETED TO REDUCE TO BELOW 1%.

PRIMARY METRIC:
1. DEFECT RATE (%)

SECONDARY METRIC:
1. FIRST PASS YIELD (FPY)

Month	Defect Rate (%)
January	2.5
February	3.2
March	4.1
April	2.8
May	3.7
June	3
July	3.5
August	2.4
September	3.3



PROJECT CHARTER

PROBLEM STATEMENT

Currently, **3% of bolts** produced in the thread rolling process **exhibit thread misalignment and dimensional inaccuracies**, resulting in an average of 120 defective bolts per 4,000 produced monthly, impacting delivery schedules.

GOAL STATEMENT

Reduce the defect rate due to thread misalignment and dimensional inaccuracies from **3% to ≤1% within 6 months** (by April 30, 2026)

BUSINESS CASE

Thread defects currently cost approximately $48,000 annually in scrap and rework, reduce production efficiency, and cause delays impacting customer satisfaction. Achieving the goal will lower costs by at least $33,000 annually, improve product quality, and strengthen customer relationships.

Benefit Type	Benefit Description	Calculation / Impact	Estimated Annual Value ($)
Tangible	Reduction in Scrap & Rework Costs	(120 - 40) bolts × $33 × 12 months	31,680
	Labor Savings from Improved Efficiency	20% reduction × $833/month × 12 months	2,004
	Savings from Improved On-Time Delivery	$5,000 × ((98%-90%) / 10%)	4,000
	Tooling Cost Reduction	15% of $20,000 tooling cost	3,000
Total Tangible			**40,684**
Intangible	Increased Customer Satisfaction (Repeat	5% increase × $1,000,000 sales	50,000
	Improved Employee Morale (Reduced	2 employees × $2,500 replacement cost	5,000
	Reduced Risk of Non-Compliance	Avoided fines and penalties	2,000
Total Intangible			**57,000**
Overall Total			**97,684**

PROJECT CHARTER

IN-SCOPE

Bolts of sizes M6 to M16 manufactured in the current production line

OUT OF SCOPE

1. Other production lines or product variants outside the specified bolt sizes.
2. Raw material procurement and quality.
3. Cold heading (bolt blank forming) process before threading.
4. Heat treatment and surface treatment processes after threading.
5. Final packaging, storage, and shipping of bolts.
6. Supplier-related quality issues not related to the internal thread rolling process.

Team Member	Role	Power (High/Medium/Low)	Interest (High/Medium/Low)	Influence/ Notes
John Smith	Project Sponsor	High	High	Provides resources, key decision-
Maria Rodriguez	Project Champion	High	High	Aligns project with business
Rahul Kumar	Process Engineer	Medium	High	Leads process improvements
Priya Patel	Quality Engineer	Medium	High	Quality data and defect
Ahmed Khan	Maintenance Lead	Medium	Medium	Equipment and tooling
Sunita Sharma	Operator Representative	Low	High	Provides operational insights
Production Manager	Stakeholder	High	Medium	Oversees overall productio
Finance Manager	Stakeholder	Medium	Medium	Monitors budget and cost

Month	Week	Phase	Activities
Oct 2025	Week 1	Define	Project kickoff and team formation
			Develop project charter
			Define problem, goals, and scope
	Week 2	Define to Measure	Map current thread rolling process
			Identify data requirements and sources
Nov 2025	Week 3	Measure	Create data collection plan
			Begin baseline data collection
	Week 4	Measure	Continue data collection
			Verify data accuracy and completeness
	Week 5	Measure	Complete data collection
			Conduct preliminary statistical checks
	Week 6	Analyze	Analyze data for trends and variation
			Develop initial defect/cycle time metrics
Dec 2025	Week 7	Analyze	Root cause analysis (Fishbone, 5 Whys)
			Validate root causes
	Week 8	Analyze	Prioritize critical X-factors (C&E matrix, FMEA)
			Prepare improvement requirements
	Week 9	Improve	Develop & prioritize improvement ideas
			Design pilot solutions
	Week 10	Improve	Implement pilot improvements
			Train operators
	Week 11	Improve	Monitor pilot performance
			Collect post-improvement data

Month	Week	Phase	Activities
Jan 2026	Week 12	Improve to Control	Analyze pilot results
			Optimize improvemen
	Week 13	Control	Standardize improved
			Update SOPs &
	Week 14	Control	Implement control
			Establish monitoring
	Week 15	Control	Process validation
			Operator competency
Feb 2026	Week 16	Closure	Final performance verification
			Cost savings and impact
	Week 17	Closure	Document lessons learned
			Prepare final project report
	Week 18	Closure	Prepare closure presentation
			Handover to operations
	Week 19	Final Wrap-Up	Management review & sign-off
			Archive documents & officially close project

Measure Phase

SIPOC DIAGRAM

1	2	3	4	5
Supplier	**Input**	**Process**	**Output**	**Customer**
Raw Material Supplier	Bolt Blanks	Machine Setup	Rolled threads on bolt	Quality Inspection

1	2	3	4	5
Supplier	**Input**	**Process**	**Output**	**Customer**
Maintainance Team	Thread Rolling Machines	Thread Rolling Operation	Bolts with accurate threads	End Customers

SIPOC DIAGRAM

1 Supplier

Tooling Supplier

2 Input

Thread rolling dies and tools

3 Process

Lubrication application

4 Output

Defect free threaded rolls

5 Customer

Assembly Line

---

1 Supplier

Operators

2 Input

Lubricants, machine settings

3 Process

Visual and dimensional check

4 Output

Reduced scrap and rework

5 Customer

Packaging department

SIPOC DIAGRAM

1. **Supplier**

   Quality Control Department

2. **Input**

   Inspection standards and tools

3. **Process**

   Post process inspection

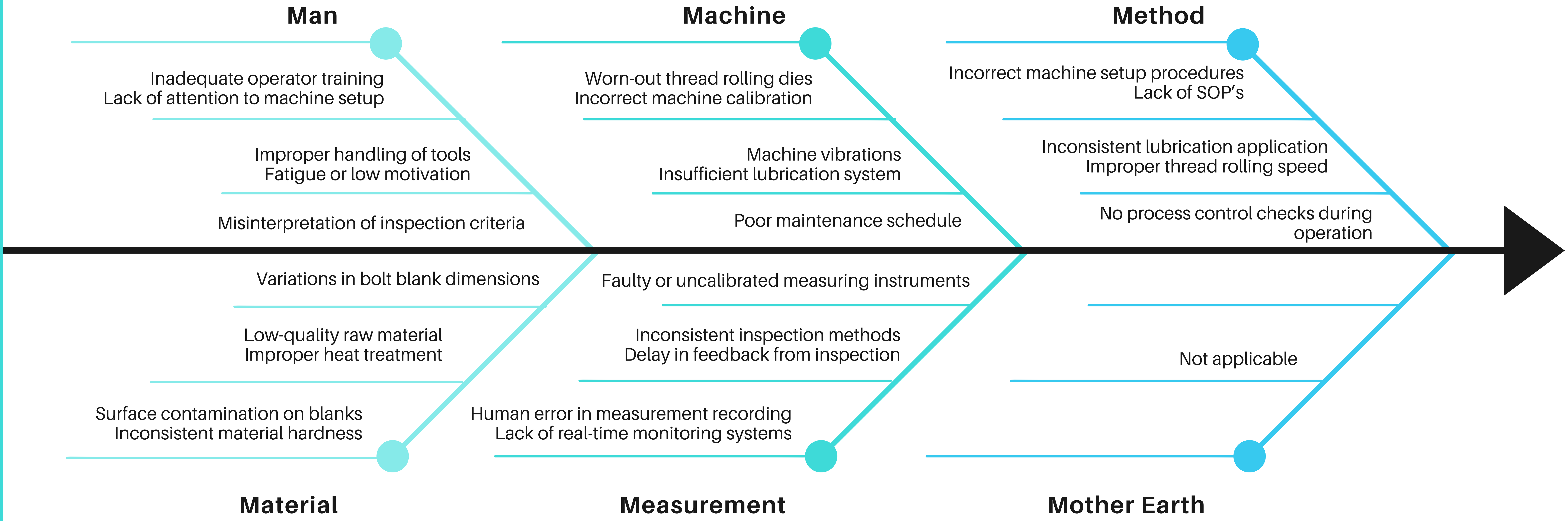
4. **Output**

   On time delivery of quality bolts

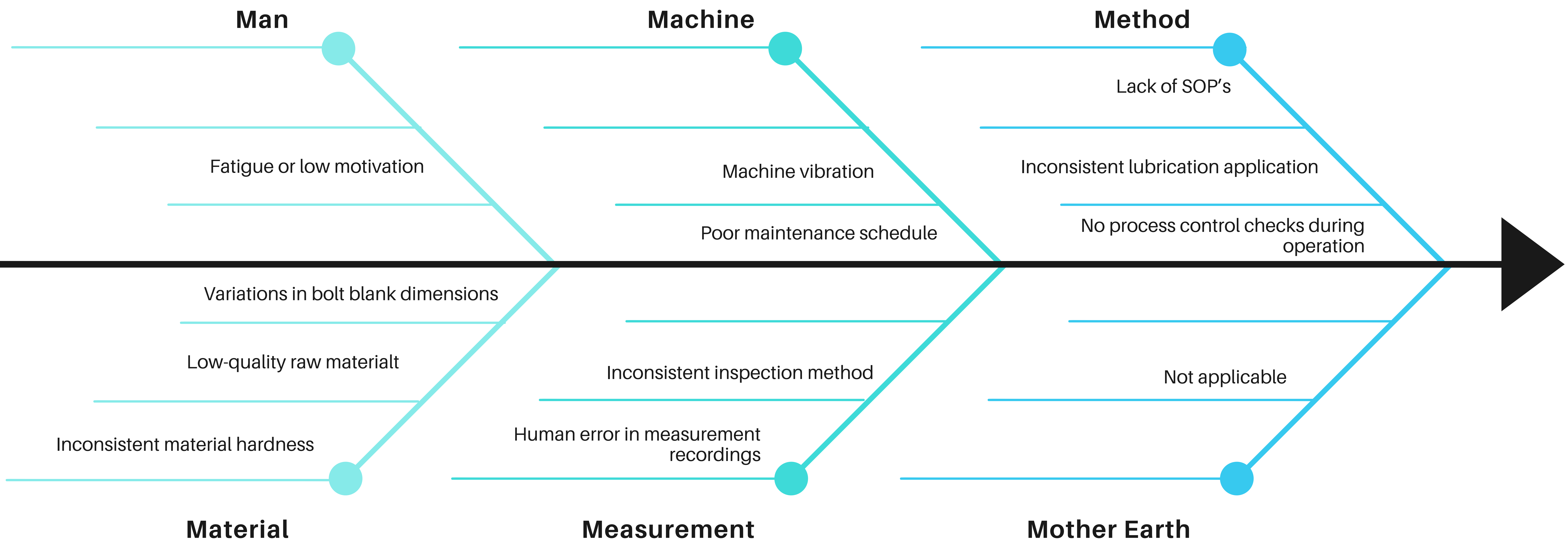
5. **Customer**

   Customers

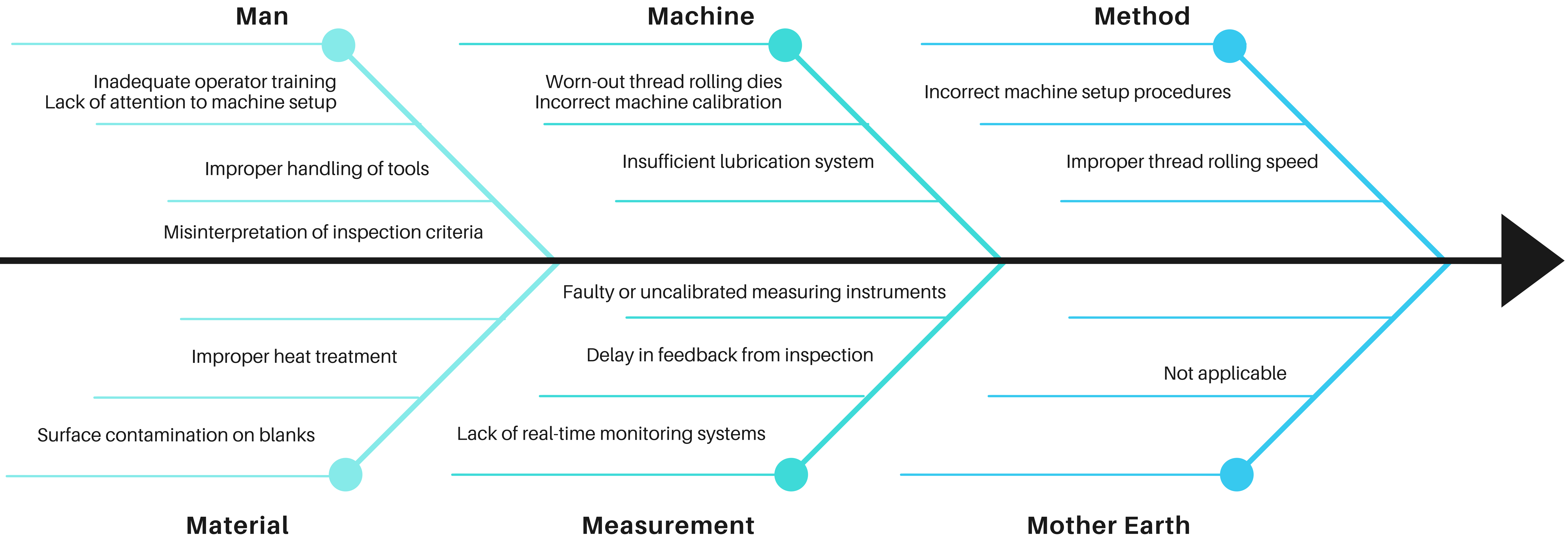
FISH BONE ANALYSIS



FISH BONE ANALYSIS- COMMON CAUSES



FISH BONE ANALYSIS- SPECIAL CAUSES



MUDA, MURA AND MURI

MUDA

- **Rework due to thread defects**
  - Caused by worn-out thread rolling dies or incorrect machine setup.
- **Idle machine time**
  - Waiting for maintenance or inspection feedback delays production.
- **Excess motion by operators**
  - Searching for properly calibrated tools or walking to check measuring instruments not kept at point-of-use.

MURA

- **Inconsistent thread quality**
  - Caused by variations in bolt blank dimensions or inconsistent material hardness.
- **Irregular inspection criteria**
  - Different interpretations of inspection standards among operators/inspectors.
- **Unstable lubrication application**
  - Leads to inconsistent friction and quality during the rolling process.

MURI

- **Operators compensating for lack of SOPs**
  - Leads to decision fatigue and mental strain.
- **Machines running without proper maintenance**
  - Overburdens machines, risking breakdown during thread rolling.
- **Single operator handling multiple machines**
  - Reduces attention per machine, increasing chances of improper setup or missed defects.

EXAMPLES OF WASTES

Waste Type	Description	Thread Rolling Example
D – Defects	Products that are scrapped or	Thread defects due to worn-out
O – Overproduction	Producing more than what's needed or	Producing bolts in advance without
W – Waiting	Idle time when resources are	Waiting for machine
N – Non-Utilized Talent	Underutilizing employee skills and ideas	Operators manually adjusting
T – Transportation	Unnecessary movement of materials	Moving bolt blanks between workstations or
I – Inventory	Excess raw materials or	Stockpiling bolt blanks or
M – Motion	Unnecessary movement by	Operators walking back and
E – Extra Processing	Doing more than necessary	Over-inspecting threads or

ACTION PLAN TO ADDRESS ISSUES

Issue Area	Observation (Special Cause / 3M / Waste)	Lean Tool	Action	Benefit	Low Hanging Fruit?	Monetary Value
Man	Inadequate operator training; misinterpretation of inspection criteria	Standard Work / Visual Aids	Create visual SOPs; retrain on inspection	Reduced inspection errors, improved quality	Yes	$8,000
Machine	Worn-out dies; incorrect calibration; lubrication failure	TPM / Visual Management	TPM checklist; lubrication indicators	Improved machine reliability	Yes	$12,000
Method	Incorrect setup; no SOPs; improper speed	5S / SMED / Standard Work	Standardize setup procedures; label speed settings	Quicker, accurate setups	Yes	$6,000
Material	Surface contamination; variation in hardness	Incoming Quality Control (IQC)	Add hardness & surface check at receiving	Prevents bad material from entering line	Yes	$5,000
Measurement	Faulty instruments; delayed feedback	Gauge Control / Poka-Yoke	Regular calibration; use digital gauges	Faster and accurate inspections	Yes	$4,000
Muda (Waste)	Rework, excess motion, overproduction	5S / Kanban / Visual Management	Organize workspace, introduce Kanban	Less movement, less excess WIP	Yes	$7,000
Mura (Unevenness)	Inconsistent inspection and output	Standard Work / Control Charts	Define inspection frequency, track process variation	More consistent quality	Yes	$3,000
Muri (Overburden)	One operator managing multiple machines	Line Balancing / Cross-training	Reallocate machines; rotate tasks	Reduced fatigue and errors	Yes	$6,000
Defects (D)	Thread cracks, improper size	Poka-Yoke / Root Cause (5 Whys)	Add limit switch or thread depth sensor	Defect prevention	No (may need minor investment)	$10,000
Waiting (W)	Delays in tool changes or decisions	SMED / Visual Management	Prepare toolkits, color code tools	Less downtime during changeovers	Yes	$4,000
Motion (M)	Unnecessary walking to fetch tools	5S / Layout Optimization	Relocate tools to point-of-use	Reduced time and fatigue	Yes	$8,000
Overproduction (O)	Producing excess bolts	Pull System / Kanban	Implement demand-based production	Lower inventory, saves space	Yes	$3,000
Inventory (I)	Excess blanks near thread rolling	FIFO / Supermarket Pull	Install FIFO rack for blanks	Better inventory control	Yes	$8,000
Transportation (T)	Distant movement between stations	Layout Optimization / Spaghetti Diagram	Move related stations closer	Faster workflow	No (may need layout change)	$12,000
Extra Processing (E)	Duplicate inspection & paperwork	VSM / Digital Logs	Eliminate non-value checks; digitize logs	Time-saving, fewer errors		$6,000

CAUSE AND EFFECT MATRIX

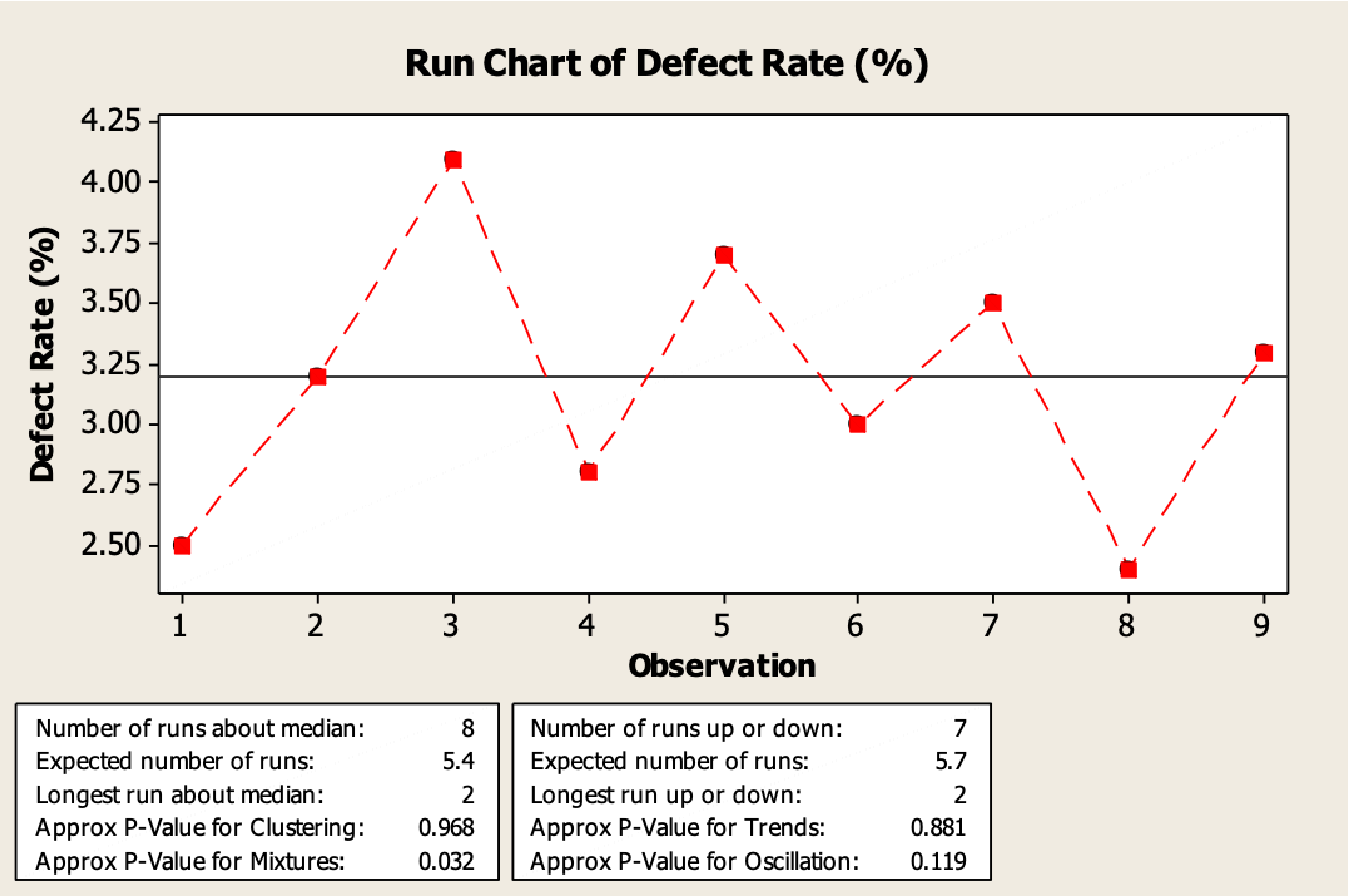
Output (Effect)	Importance Rating (1–
Thread Accuracy	10
Surface Finish	8
Production Rate	7
Scrap Rate	10
Setup Time	6

Rank	Root Cause (Input)	Thread Accuracy (10)	Surface Finish (8)	Production Rate (7)	Scrap Rate (10)	Setup Time (6)	Net Score
1	Incorrect machine	9	9	3	9	3	**266**
2	Worn-out thread rolling dies	9	9	3	9	1	**258**
3	Improper thread rolling speed	9	3	9	9	1	**250**
4	Inadequate operator	9	3	3	9	9	**243**
5	Improper handling of tools	9	3	1	9	9	**234**
6	Surface contamination on blanks	9	9	1	9	0	**234**
7	Lack of SOPs	3	3	9	3	9	**204**
8	No process control checks	9	3	3	9	0	**201**
9	Poor maintenance	3	9	3	9	3	**198**
10	Variations in bolt blank	9	3	1	9	0	**195**
11	Lack of attention to machine	3	1	3	9	9	**180**
12	Insufficient lubrication	3	9	3	9	0	**174**

DATA COLLECTION PLAN

Prioritized Root Cause (Input 'X')	**Data to Collect (Operational Definition)**	**Data Type (Continuous/Discrete)**	**Collection Method & Tool**	**Frequency & Sample Size**	**Responsible Person**
Y: Defect Rate	1. Bolt status (Pass/Fail) 2. Thread pitch/diameter measurement	Continuous & Discrete	1. Inspection checklist 2. Digital caliper, thread gauge	1. 100% of batch 2. 5 bolts per batch, every 30 mins	Quality Inspector
Incorrect machine calibration	Machine pressure/die gap setting vs. a calibration master log.	Continuous & Discrete	Check machine HMI reading against the SOP; Calibration sticker check.	Start of every shift and after every setup change.	Operator / Setup Team
Worn-out thread rolling dies	Number of parts produced since the last die change.	Continuous	Read from the machine's cycle counter and log it.	At the time of each dimensional inspection (every 30 mins).	Operator
Improper thread rolling speed	Machine speed setting (RPM).	Continuous	Read the setting directly from the machine's control panel	At the time of each dimensional inspection (every 30 mins).	Operator
Inadequate operator training	Operator ID / Name assigned to the machine per shift.	Discrete	Check shift log or production worksheet.	Once per batch.	Supervisor
Surface contamination on blanks	Visual check for rust, oil, or debris on blanks (Pass/Fail).	Discrete	Visual inspection checklist before loading blanks.	10 samples from each new bin of blanks.	Operator
Variations in bolt blank dimensions	Diameter of the bolt blank before thread rolling.	Continuous	Digital caliper.	5 samples from each new bin of blanks.	Operator
Insufficient lubrication system	Lubricant flow rate (L/min) or pressure (PSI).	Continuous	Read from the machine's pressure gauge or flow meter.	At the time of each dimensional inspection (every 30 mins).	Operator

RUN CHART TO DETECT SPECIAL CAUSES

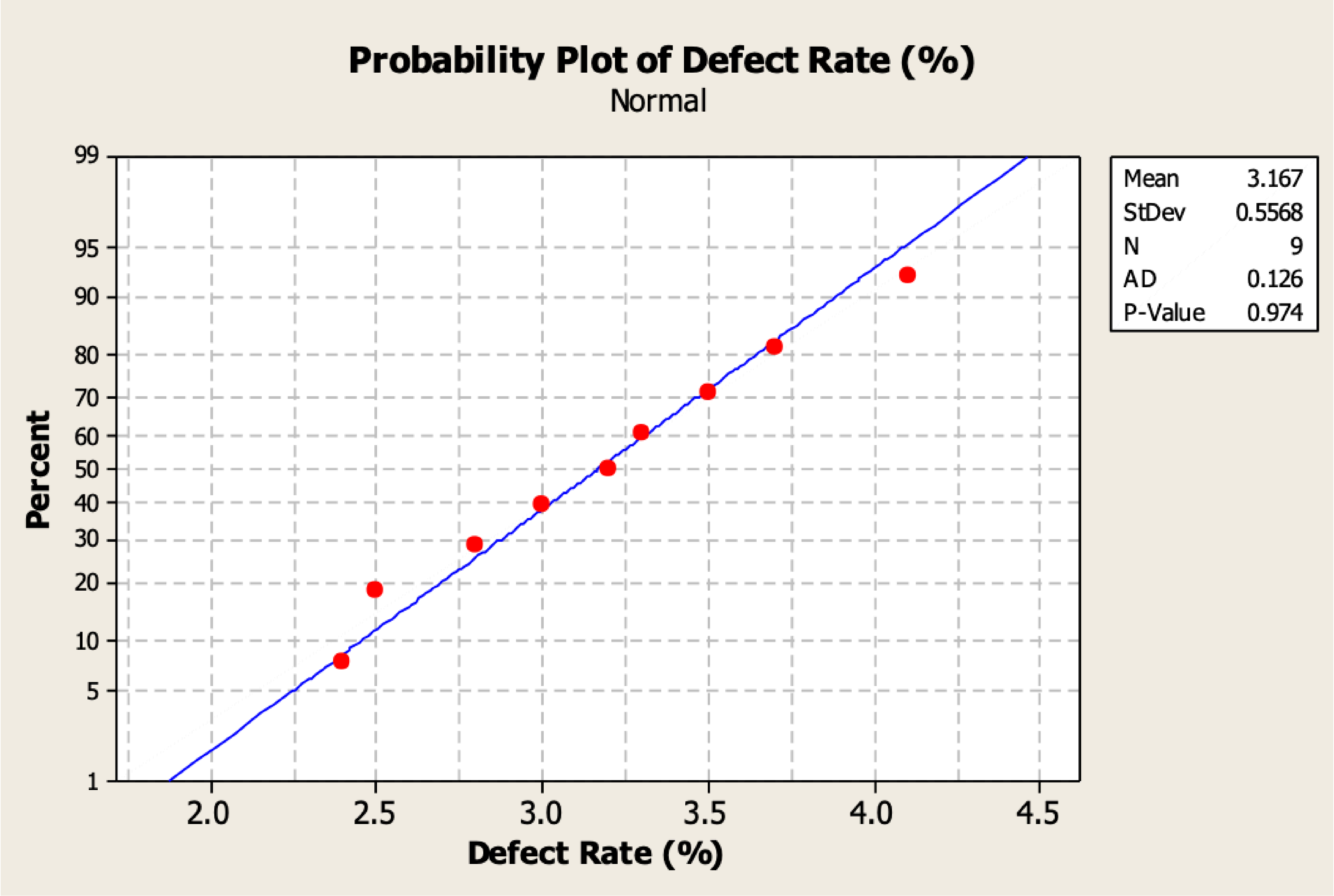


INTERPRETATION

Yes, the process shows evidence of special cause variation. The chart provides P-values to test for non-random patterns. The Approx P-Value for Mixtures" is 0.032.

Since this P-value (0.032) is less than the significance level of 0.05, it indicates that a statistically significant **mixture** pattern exists. This means the data points are abnormally avoiding the center line, suggesting that the data may be coming from two or more different underlying process conditions (e.g., different material batches, different machine setups).

NORMALITY TEST

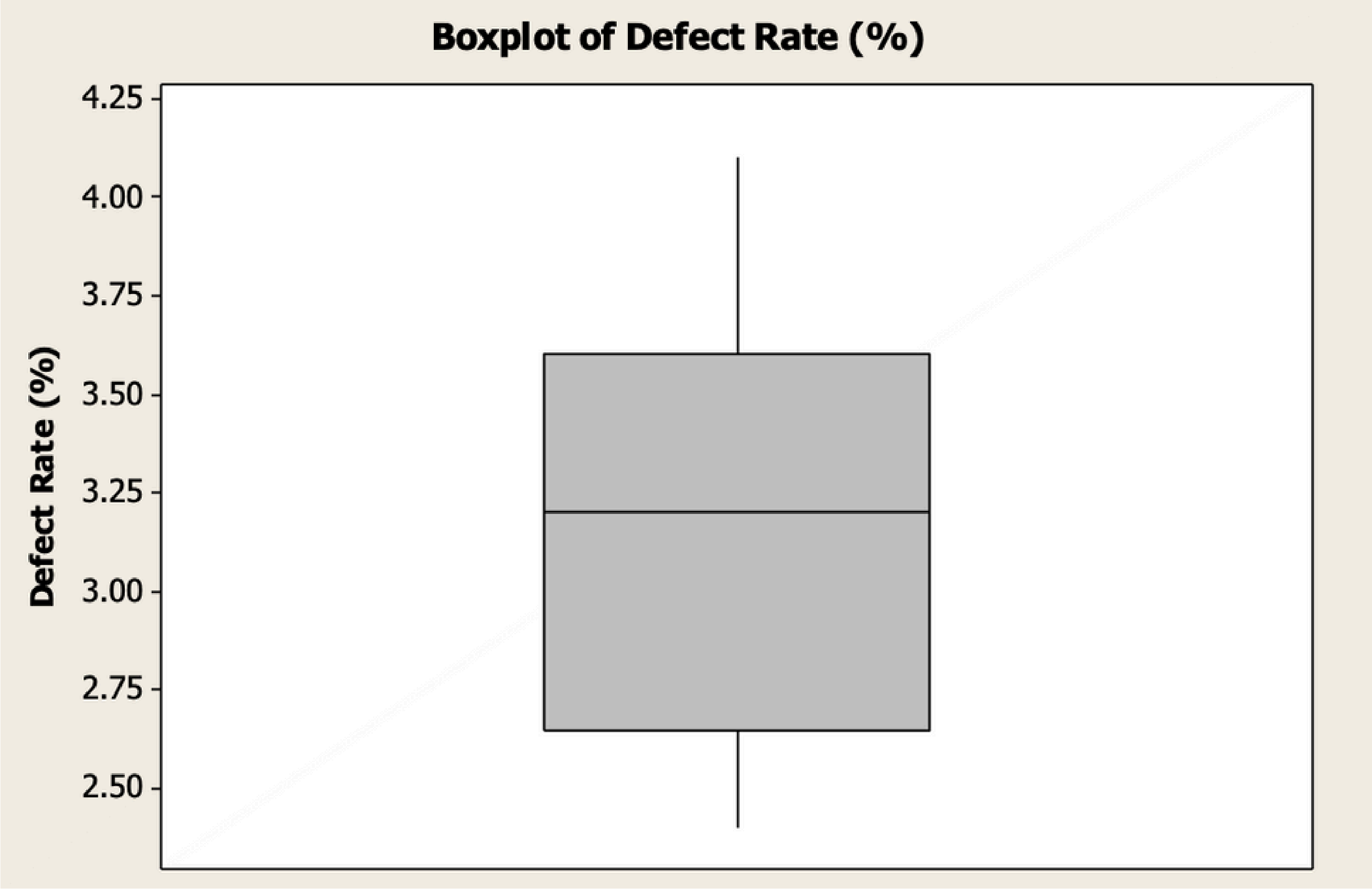


INTERPRETATION

Yes, the data is normally distributed. The Anderson-Darling normality test gives a P-Value of 0.974.

Since this P-value (0.974) is much greater than the significance level of 0.05, we cannot reject the null hypothesis. This means the data fits the normal distribution very well. Visually, the red data points also fall very closely along the straight blue "Normal" line, which confirms this conclusion.

BOX PLOT FOR THE BEFORE IMPROVEMENT DATA



INTERPRETATION

Value of the median is 3.2%. This indicates that half of the months had a defect rate above 3.2%, and half were below.

Spread (Interquartile Range - IQR):

- The bottom of the box (Q1) is at 2.65%.
- The top of the box (Q3) is at 3.6%.
- This shows that the central 50% of the monthly defect rates fluctuate within a range of 0.95% (3.6% - 2.65%).

Total Range (Whiskers):

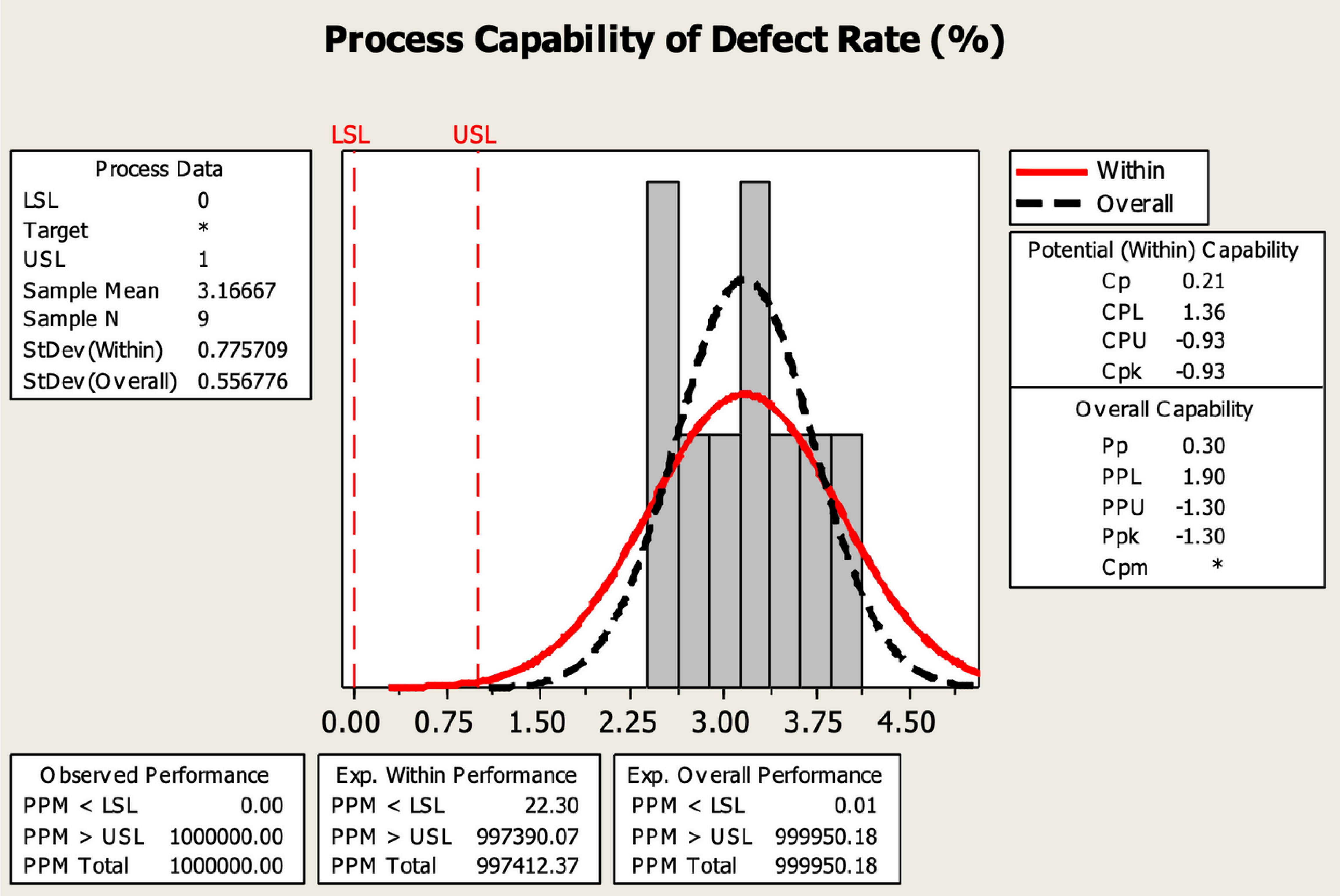
- The minimum defect rate observed was 2.4%.
- The maximum defect rate observed was 4.1%.

Distribution Shape:

- The median line (3.2%) is positioned almost exactly in the middle of the box, which suggests the data is approximately symmetric and not heavily skewed.
- There are no outliers, indicating that all data points, including the high of 4.1%, are considered part of the process's common variation.

CP,CPK FOR THE BEFORE IMPROVEMENT DATA

As we observe above, Cp and Cpk both are less than ‘1’. This means the process is poorly capable, This is generally considered the not acceptable performance and is below the modern target of 1.33 (4-Sigma) for a capable process.



Analyse Phase

IDENTIFY CRITICAL ROOT CAUSES

Based on the Cause & Effect Matrix, the top two root causes are Incorrect machine calibration and Worn-out thread rolling dies. We will use a 2-Sample T-Test to validate if their impact on the defect rate is statistically significant.

Hypothesis Test 1: Incorrect Machine Calibration

Null Hypothesis (H_o): The mean defect rate for correct calibration is equal to the mean defect rate for incorrect calibration $\mu_{correct} = \mu_{incorrect}$

Alternative Hypothesis (H_a): The mean defect rate for correct calibration is less than the mean defect rate for incorrect calibration $\mu_{correct} < \mu_{incorrect}$

Defect Rate (Correct	Defect Rate (Incorrect
1.10%	2.90%
0.90%	3.40%
1.00%	3.10%
0.80%	3.50%
1.20%	2.80%
0.90%	3.00%

```
95% CI for difference:  (-0.02503, -0.01964)
T-Test of difference = 0 (vs not =): T-Value = -20.29  P-Value = 0.000  DF = 6


Two-Sample T-Test and CI: Defect Rate (Correct Cal, Defect Rate (Incorrect C

Two-sample T for Defect Rate (Correct Calibratio vs Defect Rate (Incorrect
     Calibrat

                          N     Mean    StDev  SE Mean
Defect Rate (Correct Cal  6  0.00983  0.00147  0.00060
Defect Rate (Incorrect C  6  0.03117  0.00279   0.0011


Difference = mu (Defect Rate (Correct Calibratio) - mu (Defect Rate (Incorrect
     Calibrat)
Estimate for difference:  -0.02133
95% CI for difference:  (-0.02438, -0.01829)
T-Test of difference = 0 (vs not =): T-Value = -16.58  P-Value = 0.000  DF = 7
```

Result (T-Test):

P-Value: < 0.001

Conclusion: Since the P-Value is less than 0.05, we reject the null hypothesis (H_o). There is a statistically significant difference. This validates that incorrect machine calibration is a critical root cause of higher defect rates.

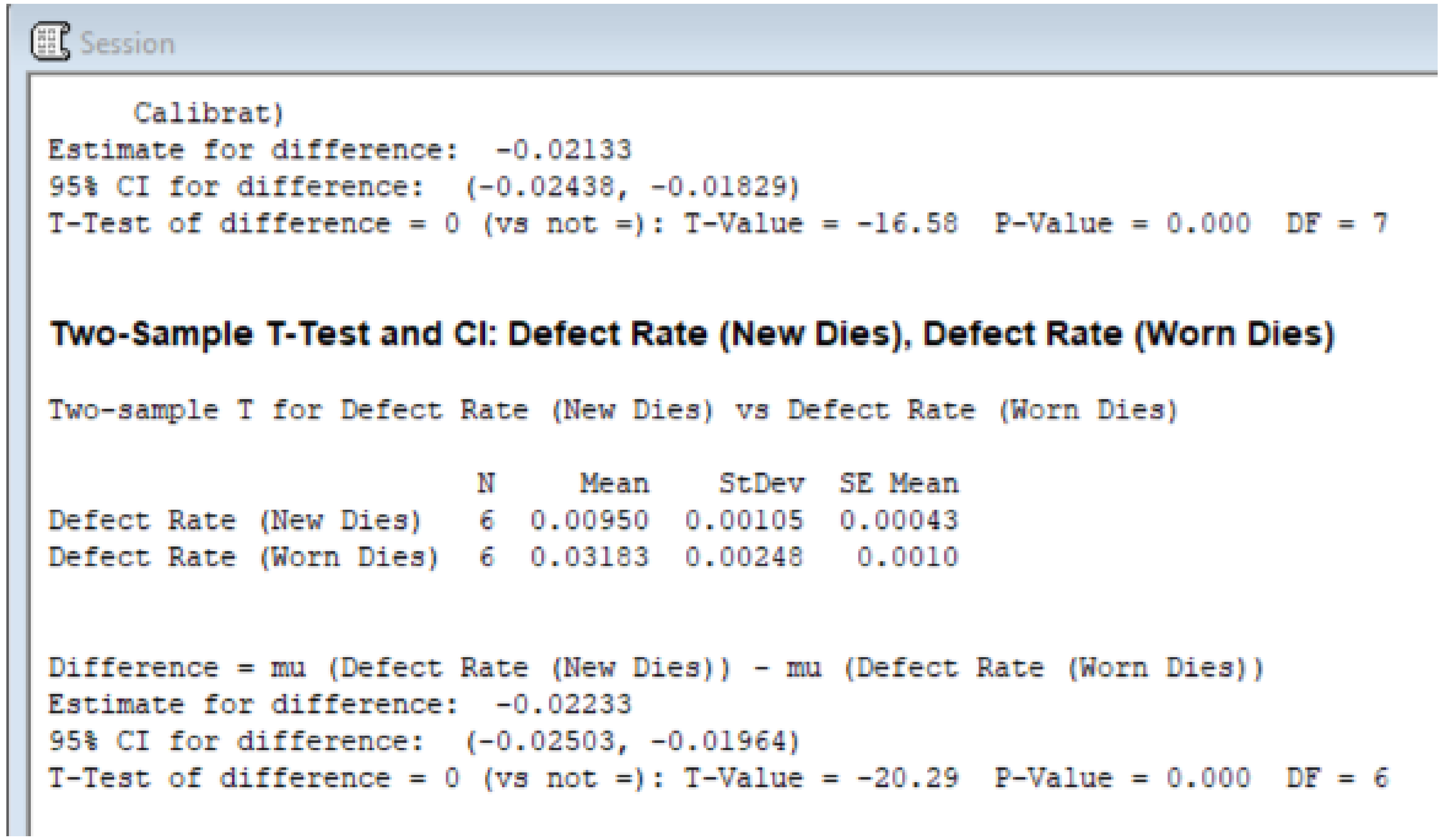
IDENTIFY CRITICAL ROOT CAUSES

Hypothesis Test 2: Worn-out Thread Rolling Dies

Null Hypothesis (H_o): The mean defect rate for new dies is equal to the mean defect rate for worn dies $\mu_{new} = \mu_{worn}$

Alternative Hypothesis (H_a): The mean defect rate for new dies is less than the mean defect rate for worn dies $\mu_{new} < \mu_{worn}$

Defect Rate (New Dies)	Defect Rate (Worn Dies)
0.80%	3.30%
1.00%	3.00%
0.90%	3.60%
1.10%	2.90%
1.00%	3.10%
0.90%	3.20%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    Calibrat)
Estimate for difference:  -0.02133
95% CI for difference:  (-0.02438, -0.01829)
T-Test of difference = 0 (vs not =): T-Value = -16.58  P-Value = 0.000  DF = 7
```

Two-Sample T-Test and CI: Defect Rate (New Dies), Defect Rate (Worn Dies)

```
Two-sample T for Defect Rate (New Dies) vs Defect Rate (Worn Dies)

                         N     Mean    StDev  SE Mean
Defect Rate (New Dies)   6  0.00950  0.00105  0.00043
Defect Rate (Worn Dies)  6  0.03183  0.00248   0.0010


Difference = mu (Defect Rate (New Dies)) - mu (Defect Rate (Worn Dies))
Estimate for difference:  -0.02233
95% CI for difference:  (-0.02503, -0.01964)
T-Test of difference = 0 (vs not =): T-Value = -20.29  P-Value = 0.000  DF = 6
```

Result (T-Test):

P-Value: < 0.001

Conclusion: Since the P-Value is less than 0.05, we reject the null hypothesis (H_o). This validates that worn-out thread rolling dies are also a critical root cause of higher defect rates.

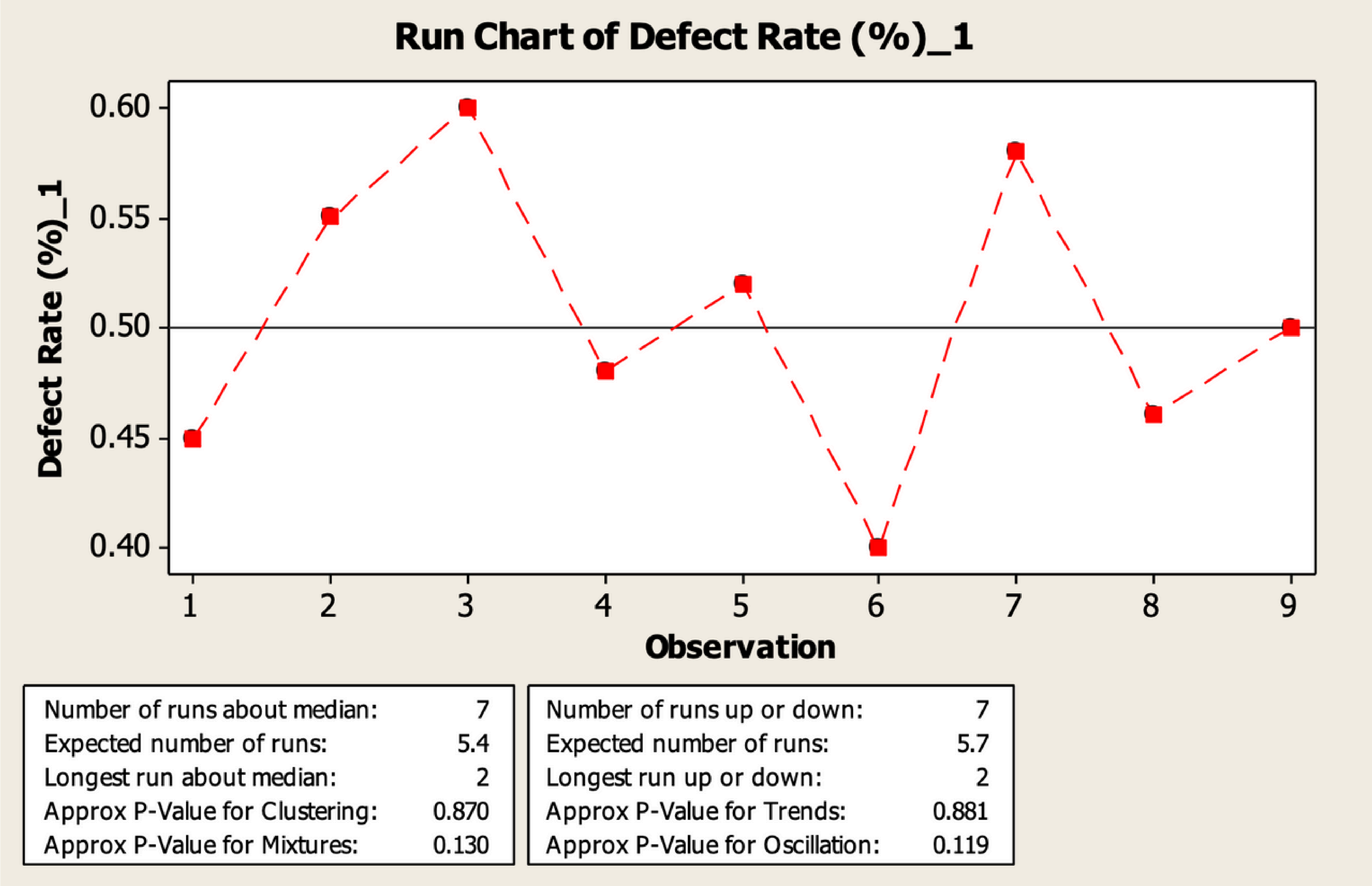
Improve Phase

ACTION PLAN FOR IMPROVEMENT

Validated Root Cause	**Improvement Action**	**Responsibility**
Incorrect machine calibration	1. Develop and implement a mandatory pre-shift calibration checklist. 2. Install "Master Setting" guides on machines for visual confirmation.	Process Engineer
Worn-out thread rolling dies	1. Implement a Total Productive Maintenance (TPM) schedule. 2. Establish a clear "die change" protocol based on a fixed production count (every 50,000 bolts).	Maintenance Lead
Improper thread rolling speed	1. Standardize and lock the optimal speed settings on the machine HMI. 2. Make speed settings part of the new calibration checklist.	Process Engineer
Inadequate operator training	1. Create new visual Standard Operating Procedures (SOPs). 2. Conduct mandatory retraining and certification for all operators on new SOPs and calibration.	Operator Rep

DATA AFTER IMPROVEMENT

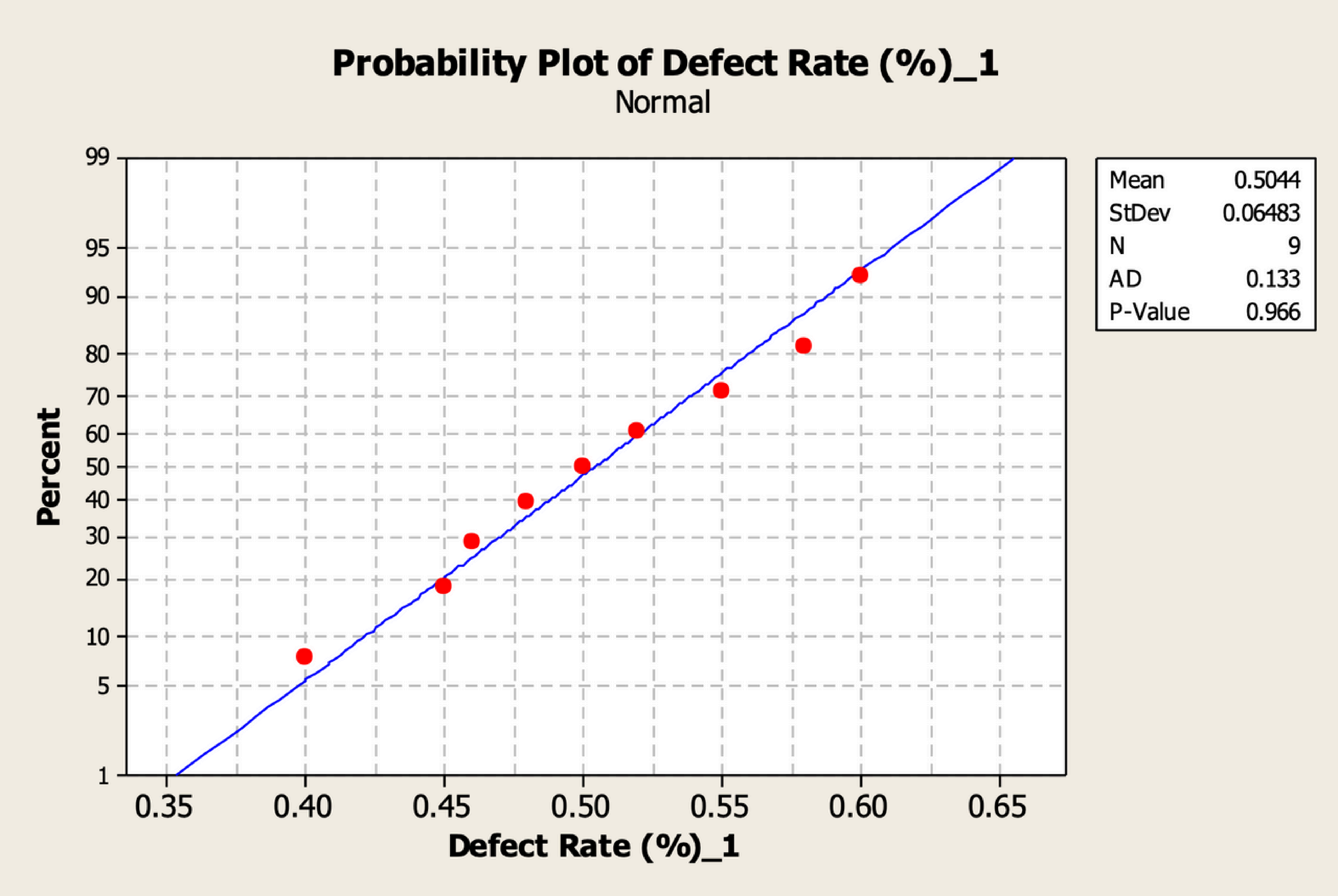
Month	Defect Rate (%)
January	0.45
February	0.55
March	0.6
April	0.48
May	0.52
June	0.4
July	0.58
August	0.46
September	0.5



INFERENCE

There is no special causes and shows randomness in the plot. Approx p value is > 0.05 meaning failed to reject the null hypothesis of non existence of special causes in the after data set

TEST FOR NORMALITY



INFERENCE

The p value is >0.05 indicates failed to reject the null hypothesis of normality. The data is normally distributed

HYPOTHESIS TEST

2 Sample t-test CI: Defect Rate (%)_1, Defect Rate (%)

The p value is <0.05 implying there is significant difference in after data, meaning there is improvement in terms of reduced defect rate.

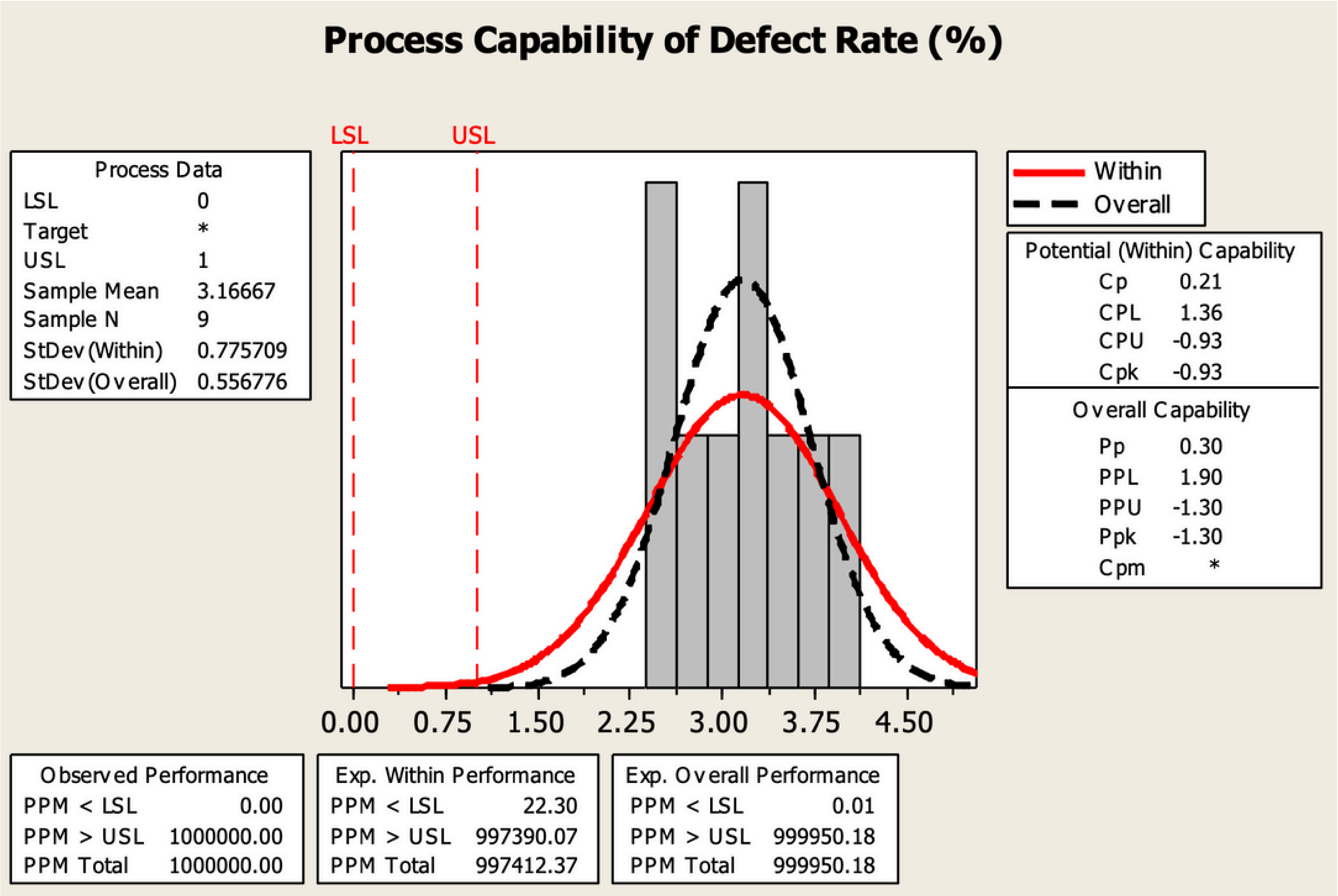
Two-Sample T-Test and CI: Defect Rate (%)_1, Defect Rate (%)

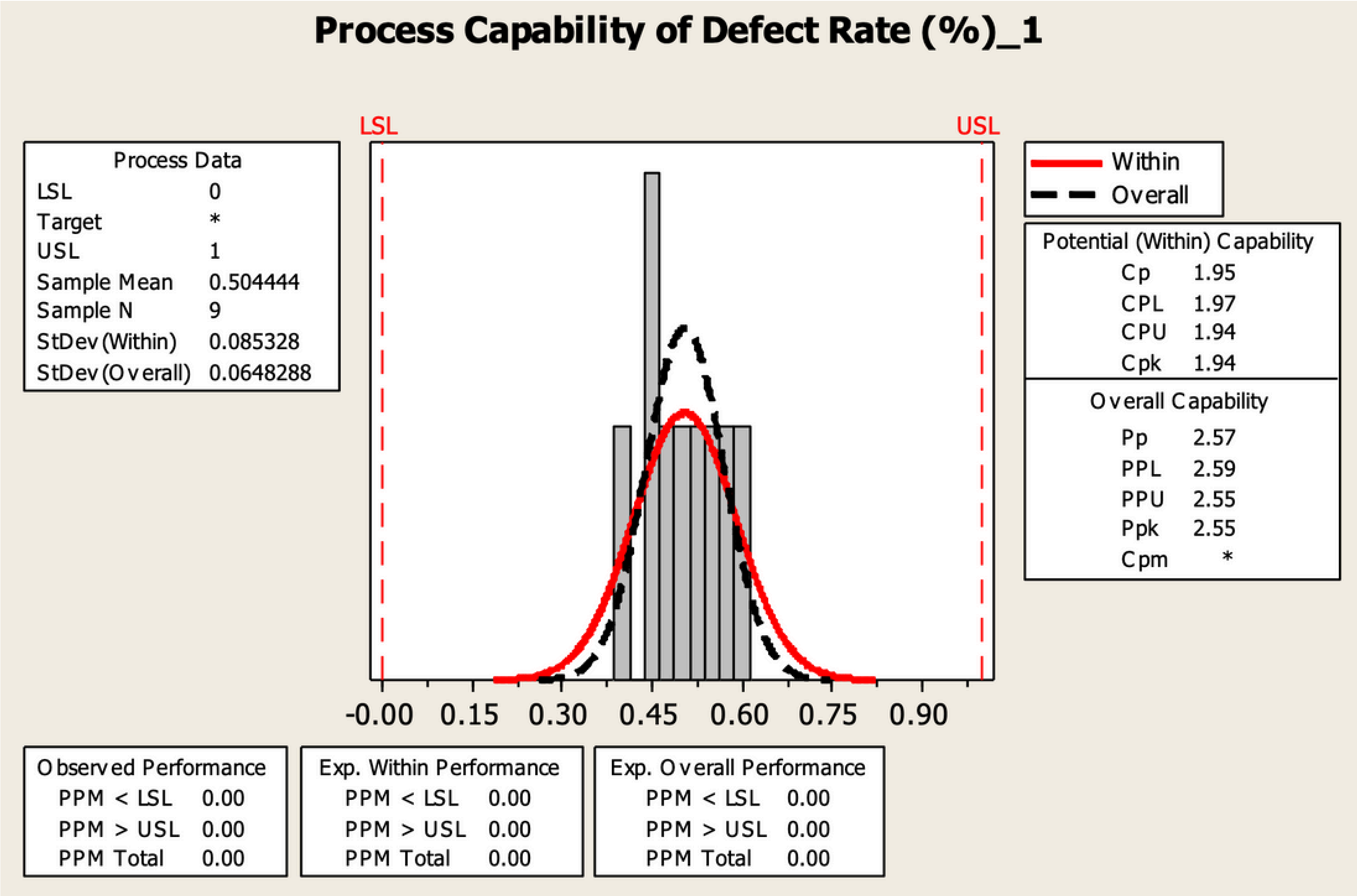
```
Two-sample T for Defect Rate (%)_1 vs Defect Rate (%)

                   N    Mean   StDev  SE Mean
Defect Rate (%)_1  9  0.5044  0.0648    0.022
Defect Rate (%)    9   3.167   0.557     0.19


Difference = mu (Defect Rate (%)_1) - mu (Defect Rate (%))
Estimate for difference:  -2.662
95% CI for difference:  (-3.093, -2.231)
T-Test of difference = 0 (vs not =): T-Value = -14.25  P-Value = 0.000  DF = 8
```

PROCESS CAPABILITY ANALYSIS
FOR THE BEFORE AND AFTER





BEFORE

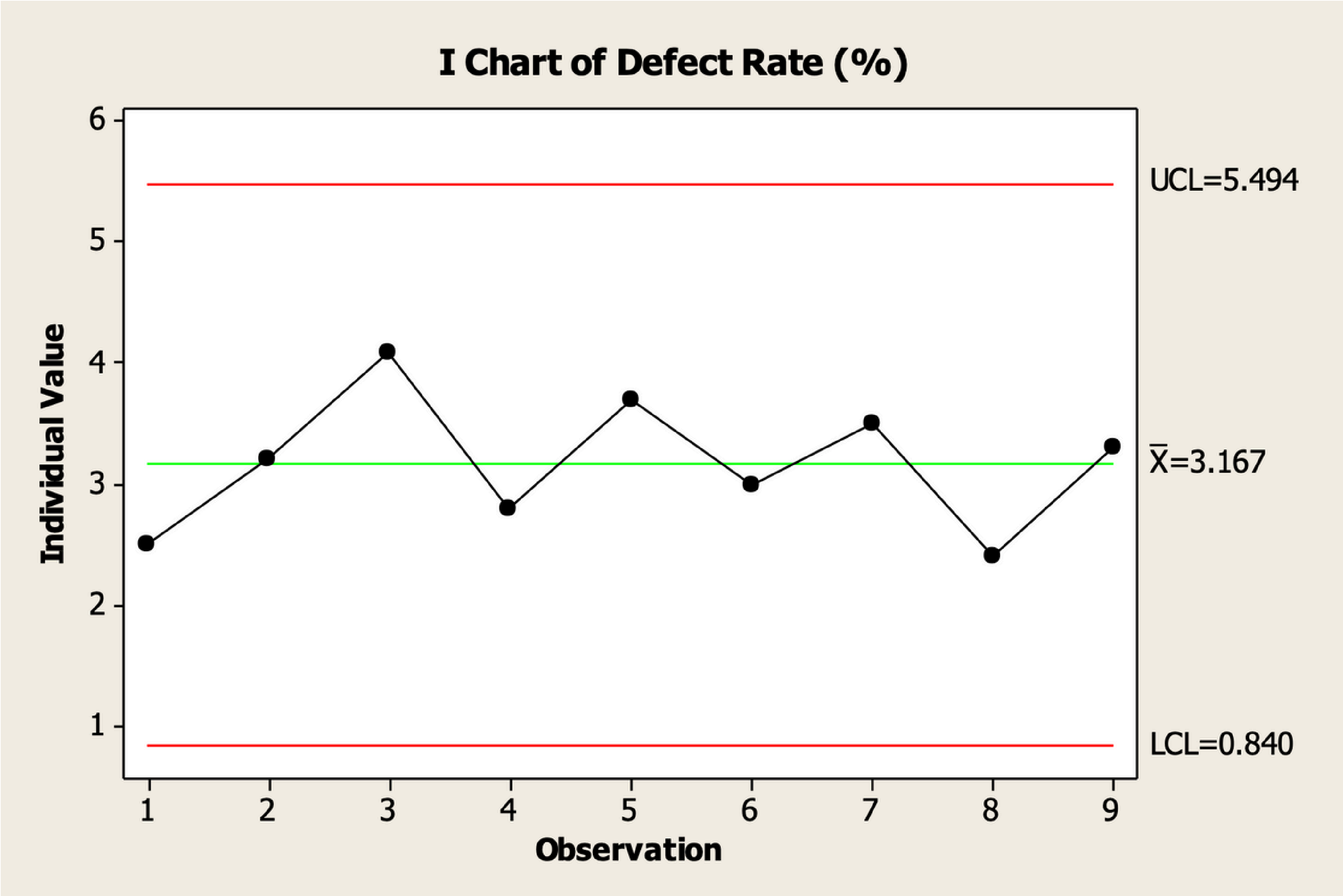
AFTER

From the probability of Defect rates, we get mean = 0.8 and Standard deviation = 0.049725

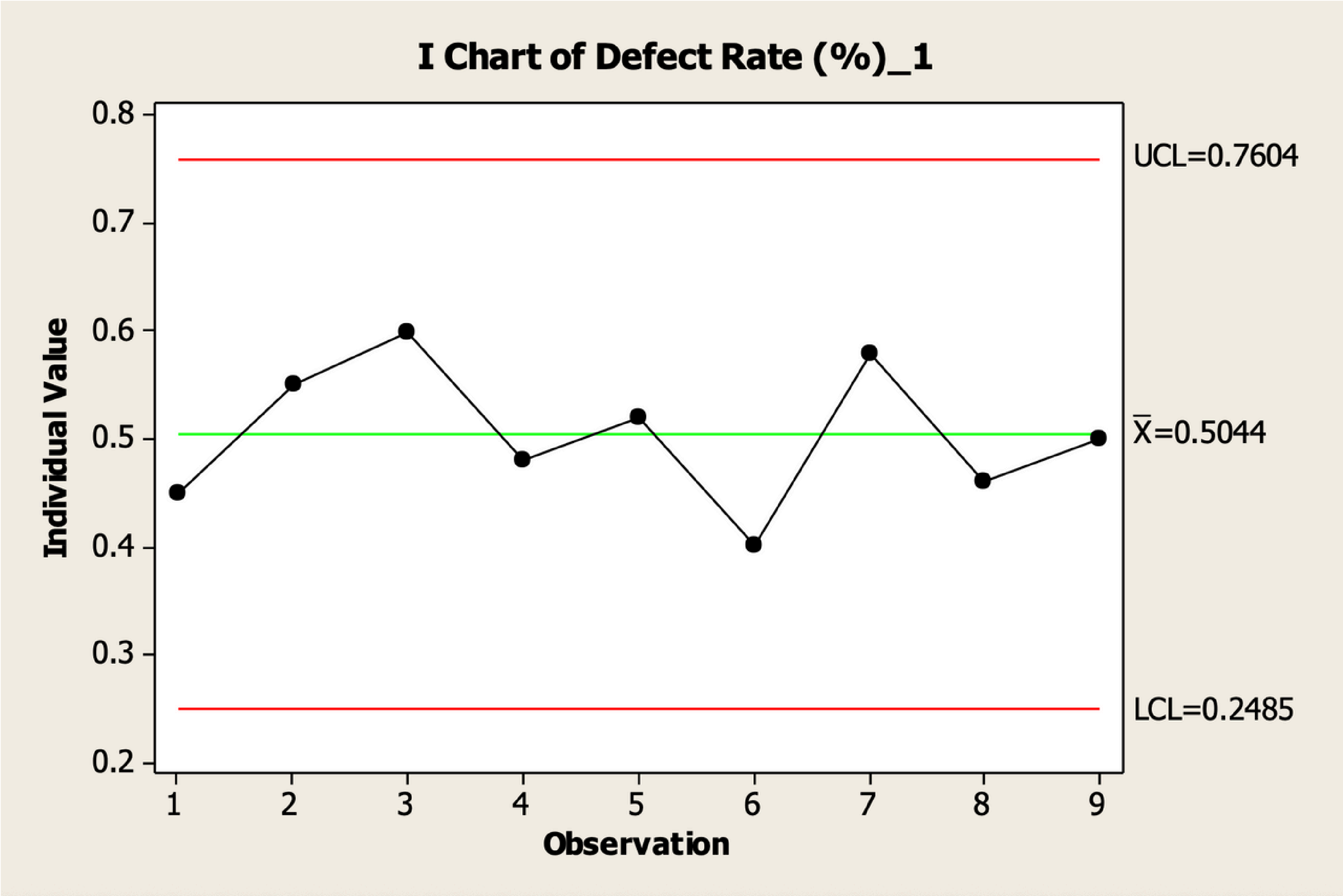
As we observe above, Cp and Cpk both are >2. This means the process is **six sigma capable**

Control Phase

CONTROL CHART FOR BEFORE AFTER COMPARISON



BEFORE



AFTER

5S AND POKA YOKE MECHANISM

Tool	Implementation	Purpose
Sort (Seiri)	Remove old dies and redundant tools	Avoid use of worn-out equipment
Set in Order (Seiton)	Mark calibration gauges and setup tools at point-of-use	Reduce setup time, avoid confusion
Shine (Seiso)	Daily cleaning of thread rolling zone	Detect lubrication leaks early
Standardize (Seiketsu)	Create visual SOPs and setup checklists	Ensure uniform operation
Sustain (Shitsuke)	Monthly 5S audits and recognition program	Maintain discipline and engagement
Poka-Yoke 1	Die-life counter linked to machine stop	Prevent use of worn-out dies
Poka-Yoke 2	Calibration sensor lockout	Machine cannot start without calibration confirmation

FMEA

Process Step	Potential Failure Mode (Caused Even When Step Is Done Correctly)	Cause	Effect on Other Operations / Activities	Sev	Occ	Det	RPN	Action
Machine Calibration	Tight calibration causes downstream machines to compensate more	Calibration improves accuracy but exposes wear/looseness in older machines	Downstream thread rolling machine now shows misalignment → more frequent	6	2	4	48	Synchronize calibration standards across machines; align downstream fixtures
Thread Rolling	Producing perfectly rolled threads increases load on next tool	Correct thread geometry increases torque in next forming/cutting	Downstream cutting or forming tools wear faster due to tighter tolerance fit	5	2	4	40	Adjust downstream tool clearances and lubrication
Lubrication System	Optimal lubrication increases material removal rate upstream	Better lubrication improves rolling but increases chip load upstream	Upstream machining or blanking processes may experience heat	4	2	4	32	Review lubes across all steps; balance lubrication type/viscosity
Inspection	Stricter inspection rejects borderline parts that downstream could still use	Inspection passes only exact parts; borderline parts scrapped unnecessarily	Increases WIP shortages downstream, causing machine idle time	6	3	3	54	Align inspection criteria with downstream process capability
Operator Setup	Perfect speed/feed settings increase cycle time in previous or next	Correct parameters optimize quality but slightly slow throughput	Creates imbalance → bottleneck at setup station → downstream	5	3	4	60	Rebalance cycle time; adjust staffing or parallel stations

CONTROL PLAN TO SUSTAIN IMPROVEMENTS

Parameter	Specification / Target	Control Method	Frequency	Responsible	Reaction Plan
Die Wear (parts produced)	≤ 50,000	TPM log, counter sensor	Every shift	Maintenance	Replace die & record
Calibration	Before start-up	Checklist & digital confirmation	Each shift	Operator	Stop machine if failed
Defect Rate	≤1.0%	Control chart tracking	Weekly	Quality	Root cause analysis if >1%
Machine Speed	Fixed at 900 RPM	Visual verification	Each setup	Supervisor	Recalibrate & lock setting
Lubrication Pressure	2.5–3.0 bar	Gauge reading	Every 2 hrs	Operator	Refill or fix leakage
5S Audit	≥90% score	Checklist audit	Monthly	Quality Head	Retraining if <90%

Thank You