

Six-Sigma (DMAIC Methodology) Part II

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MHA623
Healthcare Quality

Lecture 8



Intended Objectives

1. **Explain** the DMAIC methodology and its phases (Define, Measure, Analyze, Improve, Control).
2. **Apply** root cause analysis tools (e.g., Cause & Effect diagrams, Why-Why analysis) to healthcare process issues.
3. **Evaluate** process capability using metrics like DPMO, Sigma Level, and Cp/Cpk indices.
4. **Design** improvement solutions using cost-benefit analysis and PDCA cycles.
5. **Implement** control strategies (e.g., control charts, FMEA) to sustain improvements.

Chapter

DMAIC Methodology

3. Analyze



DMAIC Methodology

➤ *Analyze Phase:*

- The purpose of the Analyze phase is to analyze the data collected related to the **Voice of Customer (VOC)** and the **Voice of Process (VOP)** to identify the **root causes** of the **process problems**, and to develop the **capability of the process**.

Analyze Phase

- The activities performed and tools applied during the **Analyze phase** are:
 1. Develop **cause and effect** relationships.
 2. Determine and validate **root causes**.
 3. Develop **process capability**.

1. Develop Cause and Effect Relationships: (Cause & Effect diagram):

▪ Effect (Problem/Outcome):

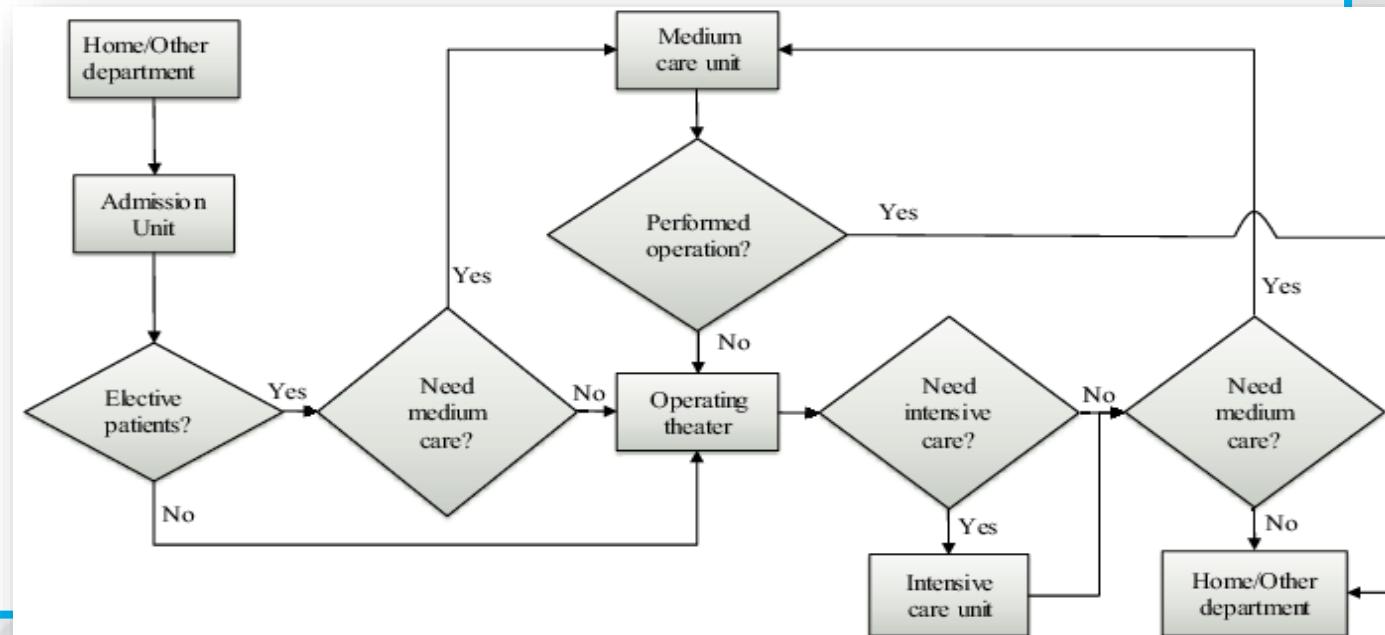
- Clearly define the issue to be analyzed.

▪ Main Cause Categories (Commonly Used):

- **People:** Human errors, training gaps, lack of communication.
- **Machine:** Equipment failures, maintenance issues.
- **Materials:** Defective inputs, supply chain issues, material shortages.
- **Methods:** Inefficient procedures, unclear guidelines.
- **Measurements:** Inaccurate data, lack of monitoring, incorrect metrics.
- **Environment:** External factors, workplace conditions.

➤ **First, draw the process flowchart:**

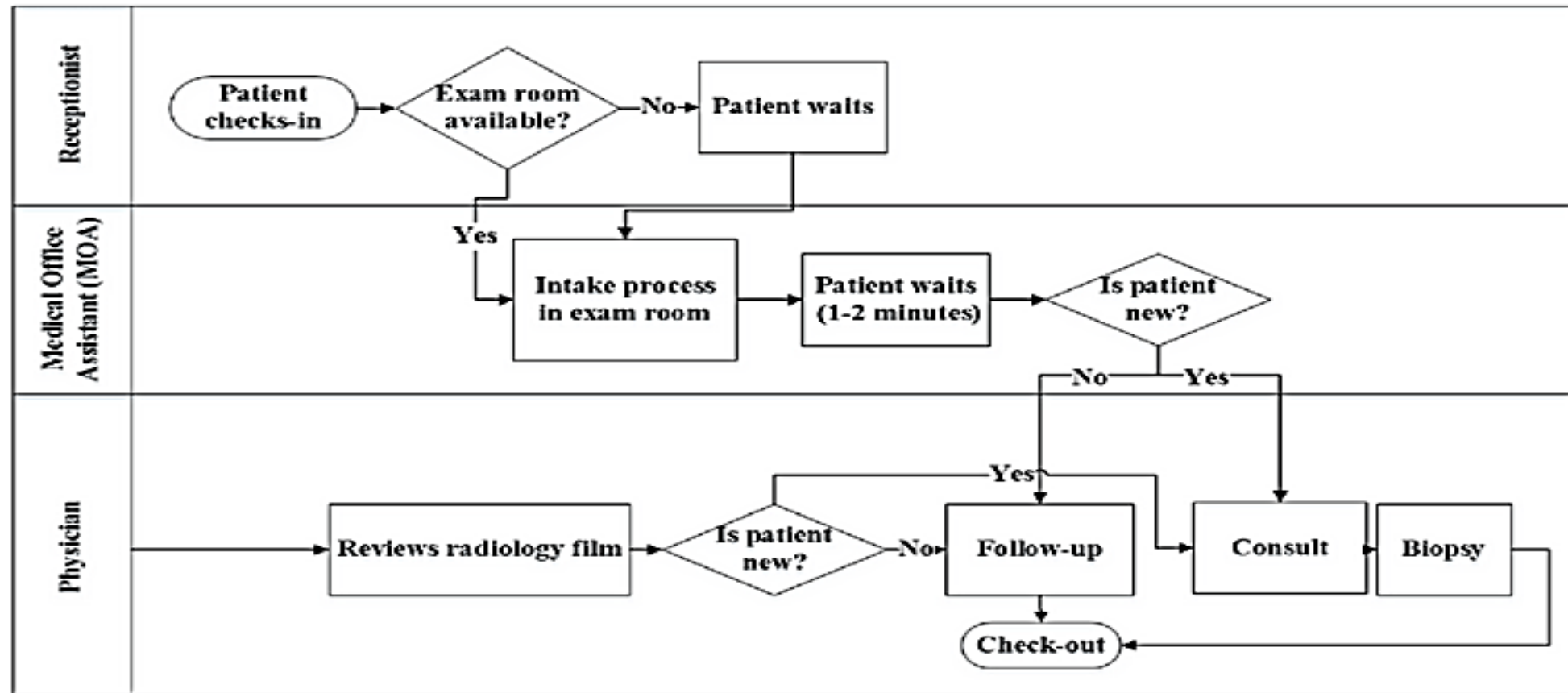
- **Definition:** A flowchart is a visual representation of a process using symbols to show steps, decisions, and flow.
- **Purpose:** Helps in process analysis, troubleshooting, and improvement by identifying inefficiencies.



➤ **First, draw the process flowchart:**

Symbol	Name	Function
	Start/end	An oval represents a start or end point
	Arrows	A line is a connector that shows relationships between the representative shapes
	Input/Output	A parallelogram represents input or output
	Process	A rectangle represents a process
	Decision	A diamond indicates a decision

➤ First, draw the process flowchart:



Swim-lane diagram of breast center.

Environment

High noise level

Location of
medication
room

Equipment

Medication
dispensing
not automated

Leadership

Equipment
needs no met

Budget
constraints

Transcription error

Handwritten
order
illegible

Medication nurse
working overtime

Pharmacist review not
done before dispensing

Order entry not
computerized

Medication
Error

Communication

People

Procedures

1. Develop Cause and Effect Relationships: (Why–Why Diagram):

■ Steps to Apply:

- **State the Problem** → Write it on the left side.
- **Ask "Why?"** → Identify the direct cause of the problem.
- **Ask "Why?" Again** → Determine the cause of the previous cause.
- **Repeat Until Root Cause is Found** → Typically five times but can vary.
- **Verify the Root Cause** → Ensure it's the true underlying issue before taking corrective actions.

2. Determining & Validating Root Causes:

A. Correlation Analysis:

Purpose: Measures the strength and direction of the relationship between two variables.

Formula: $Y = F(X) \rightarrow$ Dependent variable (Y) is a function of independent variable(s) (X).

- **Correlation Coefficient (r):**

- +1.0** $\rightarrow$ Perfect positive correlation

- 0** $\rightarrow$ No correlation

- 1.0** $\rightarrow$ Perfect negative correlation

- **Interpretation:** Higher $|r|$ value means a stronger relationship between variables.

2. Determining & Validating Root Causes:

B. Linear Regression Analysis

Purpose: Predicts the relationship between independent (X) and dependent (Y) variables.

Equation: $Y = a + bX$ (where a = intercept, b = slope).

- **Coefficient of Determination (R^2):**

- Measures how well the prediction equation fits the data.
- $0 \leq R^2 \leq 1$ (Higher values indicate better fit).

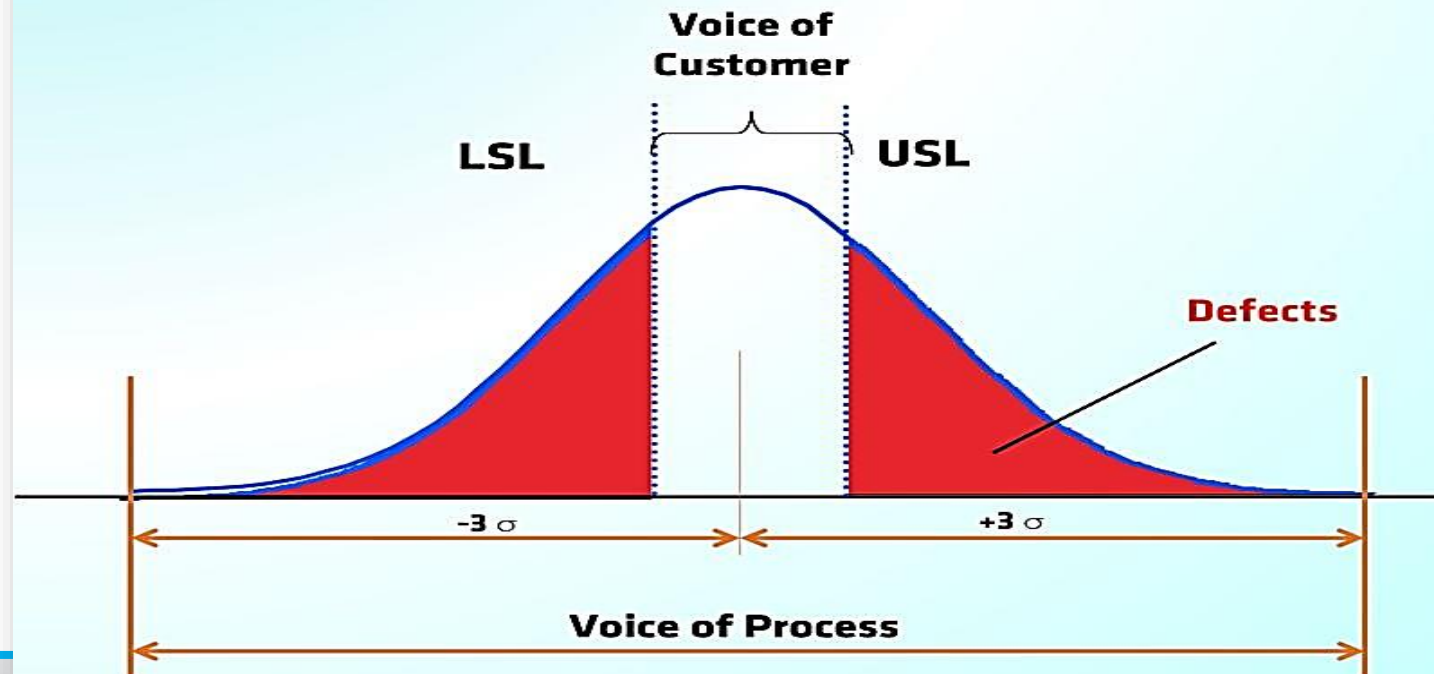
- **Application:** Helps in forecasting and determining key influencing factors.

3. Process Capability Development:

- **VOC (Voice of the Customer):** Specification limits set by customer requirements.
- **VOP (Voice of the Process):** Actual process performance (**variation**).
- **USL (Upper Specification Limit):** Maximum acceptable value (**from VOC**).
- **LSL (Lower Specification Limit):** Minimum acceptable value (**from VOC**).
- **μ (Mu / Process Mean):** Average performance level of the process.
- **σ (Sigma / Standard Deviation):** Measure of process variation (**from VOP**).

3. Process Capability Development:

Voice of customer and Voice of Process



3. Process Capability Development:

➤ Purpose:

- Measures how well a process meets specifications.
- Identifies areas for improvement and defect reduction.

➤ Key Metrics:

A. DPMO (Defects Per Million Opportunities):

- **Formula:**

$$DPMO = \frac{\text{Number of Defects} \times 1,000,000}{\text{Units} \times \text{Opportunities per Unit}}$$

- *Lower DPMO = Higher process capability.*

3. Process Capability Development:

B. Sigma Level (Process Performance):

- Higher sigma level = Fewer defects.
- Common benchmarks:
 - **3 σ (66,800 DPMO)** – Average process.
 - **6 σ (3.4 DPMO)** – World-class quality.

Quality Percent	DPMO	Sigma Level
93	66,807	3.0
98	22,750	3.5
99	6,210	4.0
99.87	1,350	4.5
99.977	233	5.0
99.9997	3.4	6.0

3. Process Capability Development:

C. Capability Indices (Cp & Cpk):

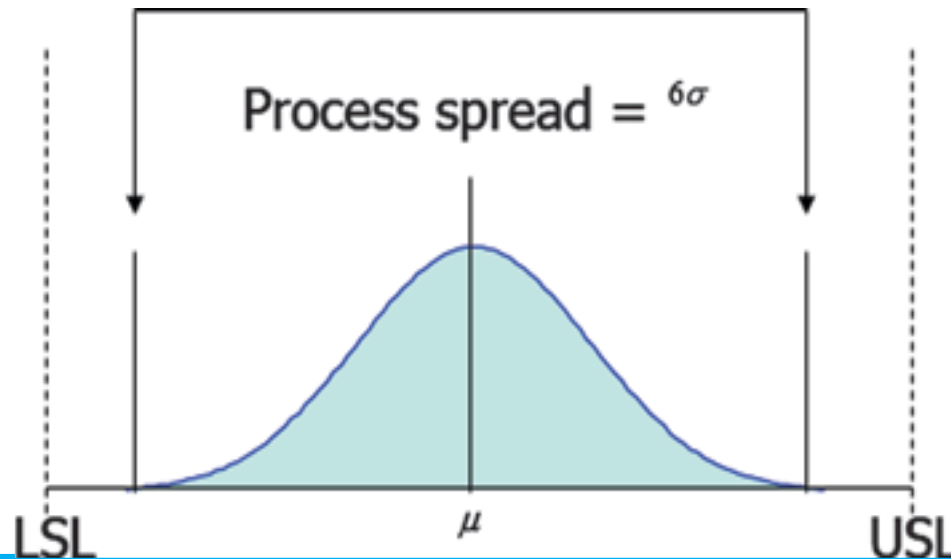
- **Cp:** Measures potential process capability.
- **Cpk:** Accounts for process centering (actual capability).
- **General Formula:**
$$\text{Capability Index} = \frac{VOC}{VOP}$$
- **Interpretation:**
 - **Cp/Cpk ≥ 1.33** → Acceptable process.
 - **Cp/Cpk < 1** → Process needs improvement.

3. Process Capability Development:

- There are typically three scenarios regarding process capability:

A. Process spread is less than the specification spread.

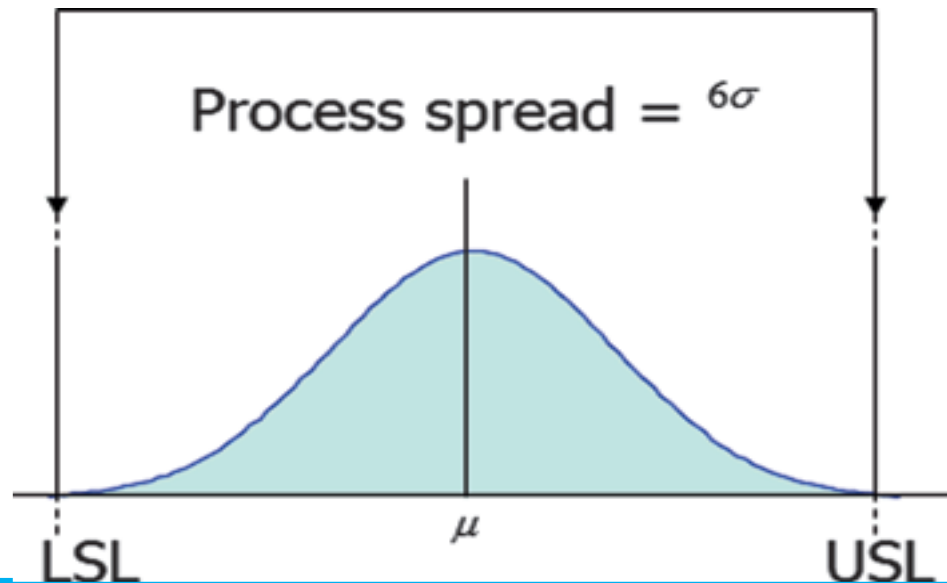
So, The process is quite capable ($C_p/C_{pk} > 1.33$).



3. Process Capability Development:

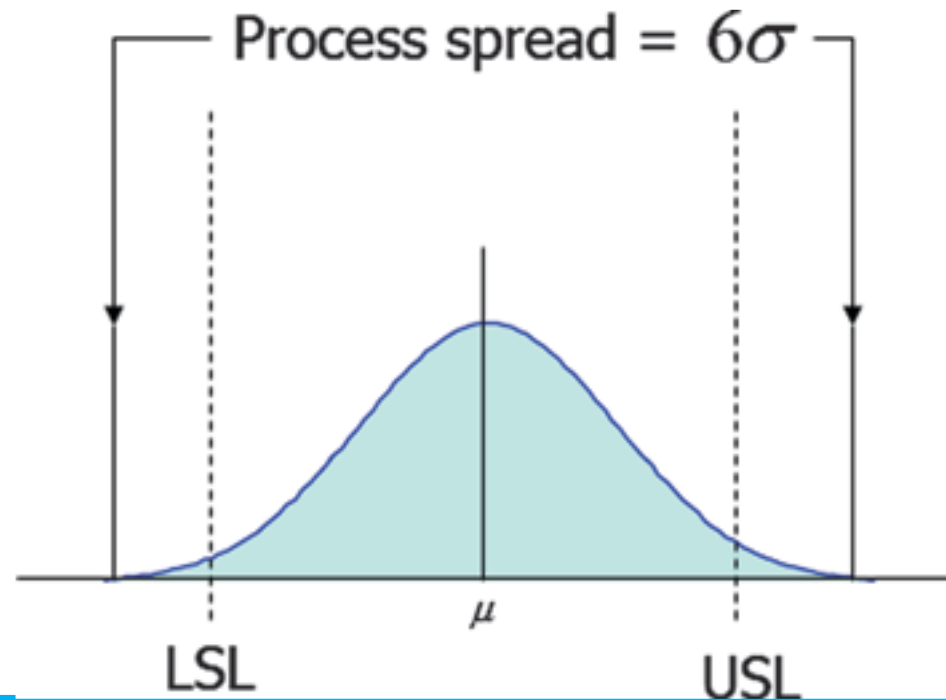
B. Process spread is equal to specification spread, an acceptable situation, but there is no room for error.

If the mean shifts, or variation increases, there will be nonconforming outcomes (Cp/Cpk is between 1.00 and 1.33).



3. Process Capability Development:

C. Process spread is greater than the specification spread. **The process is NOT capable** ($C_p/C_{pk} < 1.00$).



Chapter

DMAIC Methodology

4. Improve



➤ *Improve Phase:*

- The purpose of the **Improve phase** is to **identify improvement recommendations, design the future state, implement pilot projects, train, and document the new processes.**

Improve Phase

➤ **The activities performed and tools applied during the Improve phase are:**

1. Identify improvement recommendations.
2. Perform cost/benefit analysis.
3. Design future state.
4. Establish performance targets and project scorecard.
5. Gain approval to implement, then implement.
6. Train and execute.

Improve Phase

➤ **Improve Phase Roadmap:**

- **Goal:** Implement solutions that eliminate root causes.
- **Key Steps:**
 - Validate solutions with cost/benefit analysis.
 - Design future-state processes.
 - Pilot changes using **PDSA**.
- **Example:** Implementing barcode medication administration (**BCMA**) to prevent wrong-patient and wrong-medication errors in a hospital setting.

➤ Cost-Benefit Analysis Simplified:

▪ Formula:

- **Benefit/Cost Ratio** = (Total Savings × 3 years) ÷ Implementation Cost.

▪ Decision Rule:

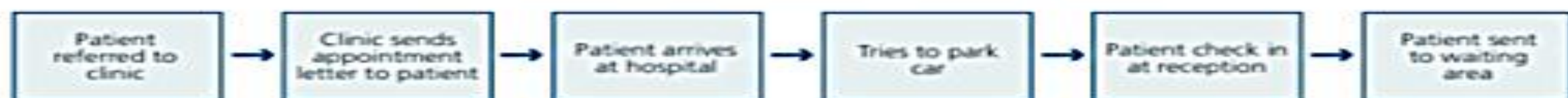
- Resulting value >1.0: Proceed
- Resulting value <1.0: Revise solution

- **Case:** New EHR system saved \$250K/year vs. \$500K implementation cost → $B/C = 1.5$

➤ Future State Process Mapping:

■ What it fixes:

- **Bottlenecks** (e.g., lab result delays).
- **Redundancies** (e.g., duplicate paperwork).
- **Inefficient communication** (e.g., delays in discharge due to waiting for physician approval).
- **Manual data entry errors** (e.g., transcription mistakes when transferring patient information).



30% of appointments have to be rearranged



60% by car
40% by public transport

Car park frequently full

45-65 patients seen per session

Waits 15-30 minutes



Once every hour

Waits between 1 and 1.5 hours for result



15-30 minutes



Negative effect on patient

➤ **PDSA in Action (Hospital Example):**

- **Plan:** Redesign OR turnover checklist.
- **Do:** Test in 1 operating room.
- **Study:** Measure turnover time reduction.
- **Act:** Expand to all ORs after 15% improvement.

➤ Change Management Essentials:

- **Critical for Success:**

- Train *“Improvement Champions”* first (e.g., charge nurses).

- **Address resistance with:**

- Quick wins (show 30-day results).
- Staff feedback sessions.

“Culture eats strategy for breakfast” ***Peter Drucker***

Chapter

DMAIC Methodology

5. Control



➤ ***Control Phase:***

- The purpose of the Control phase is to **measure the results of the pilot projects, and manage the change on a broader scale.**

Control Phase

- **The activities performed and tools applied during the Control phase are:**
 1. Monitor & Control Performance.
 2. Scale Validated Improvements.
 3. Sustain & Advance.

1. Monitor & Control Performance:

- **Confirm Proper Execution:** Verify training and implementation were done correctly.
- **Gather Performance Data:** Collect metrics after changes are implemented.
- **Compare with Baseline:** Check if improvements meet targets.
- **Identify Gaps:** Detect deviations and take corrective actions.

➤ Control Charts:

■ Definition:

- Graphical tools in SPC to monitor process stability over time.
- Plot data points with a central line (**average**), upper/lower control limits.

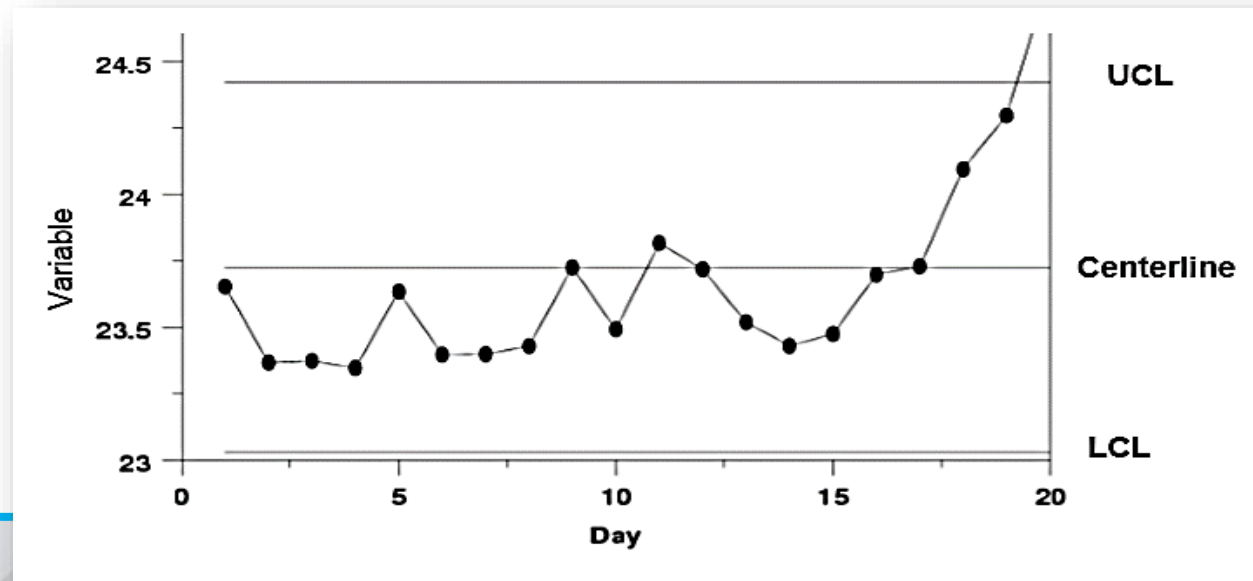
■ Purpose:

- Distinguish between common cause (**expected**) and special cause (**unexpected**) variations.
- Ensure consistent quality in healthcare (e.g., patient wait times, infection rates).

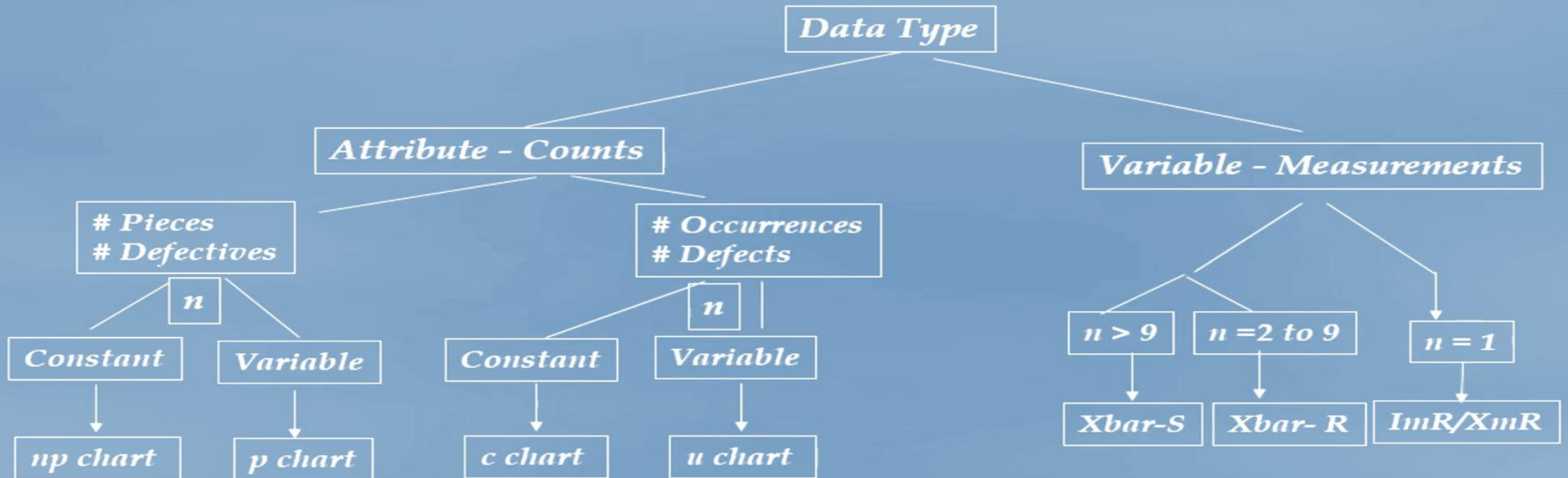
➤ Control Charts:

▪ Key Components:

- **Central Line (Mean):** Process average.
- **Control Limits (UCL/LCL):** ± 3 standard deviations from mean.



Types of Control Charts



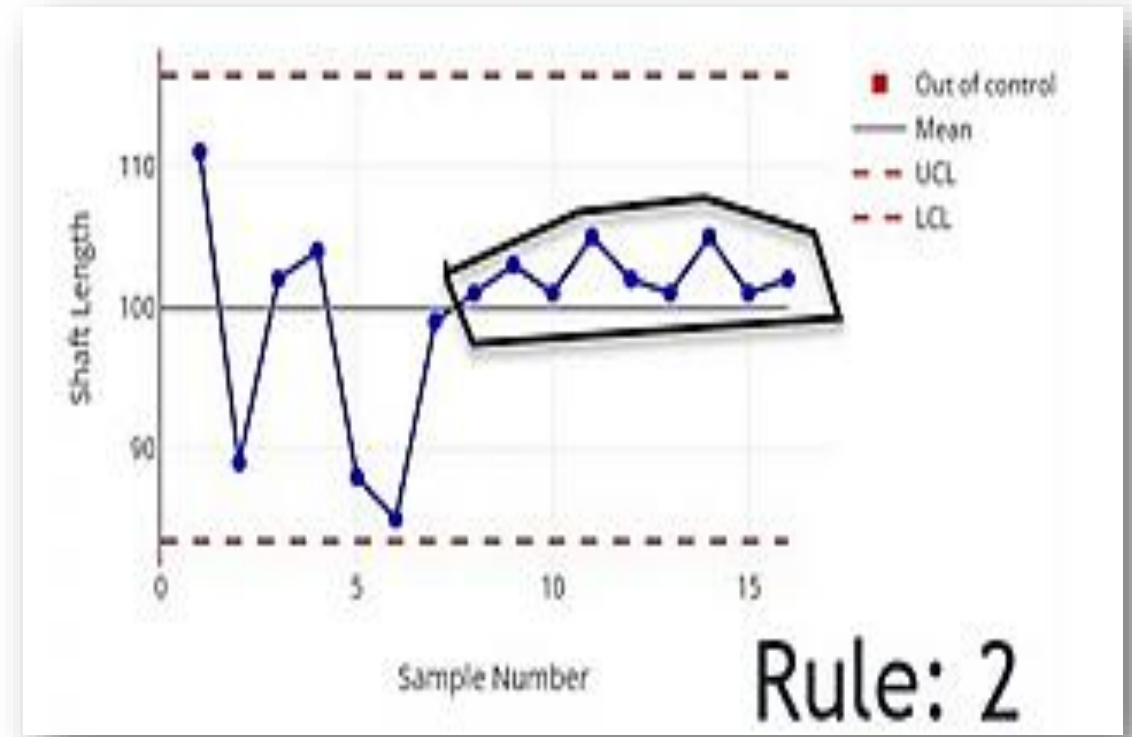
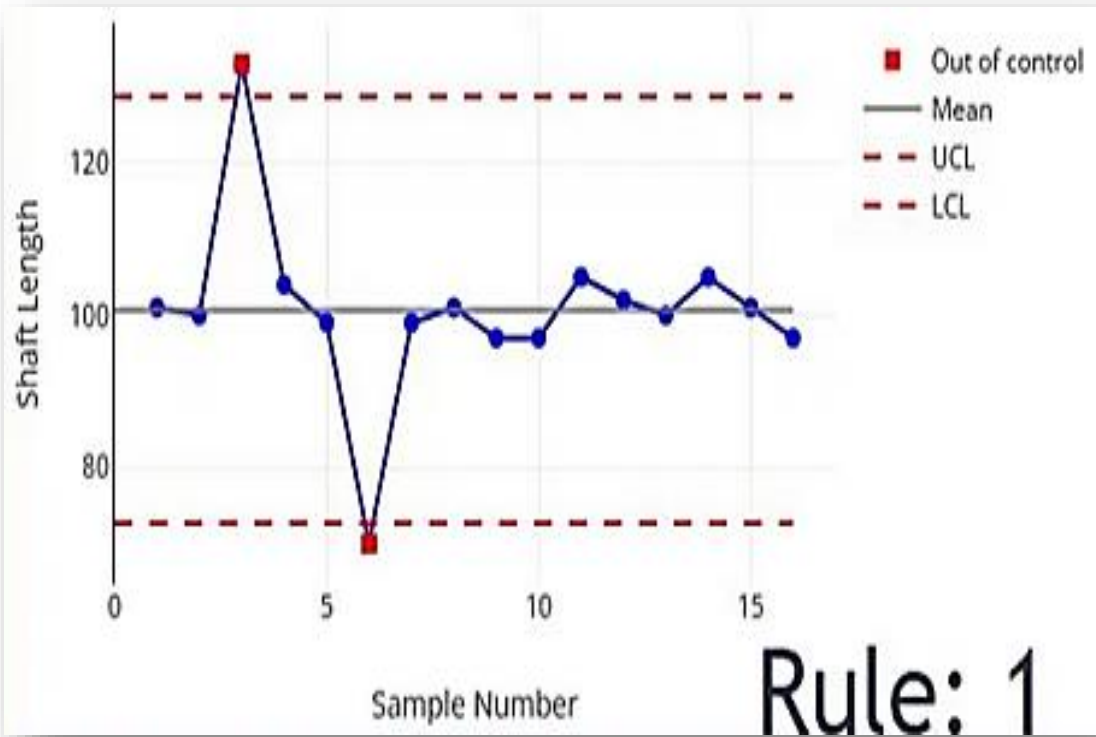
n: sample/ subgroup size

Control Phase

Rule Number	Rule Category	Nelson Rule Description
1	Points beyond 3σ	One point is more than 3 standard deviations from the centerline.
2	Consecutive points on one side of the centerline	Nine or more consecutive points fall on the same side of the centerline.
3	Points beyond 2σ	Two out of three consecutive points fall more than 2 standard deviations from the centerline (on the same side).
4	Points beyond 1σ	Four out of five consecutive points fall more than 1 standard deviation from the centerline (on the same side).
5	Trending	Six or more consecutive points are continually increasing or decreasing.
6	Oscillation	Fourteen or more consecutive points alternate in direction (up and down).
7	Reduced Variation	Fifteen or more consecutive points fall within 1 standard deviation of the centerline (on either side).
8	Increased Variation	Eight or more consecutive points fall outside 1 standard deviation from the centerline (on either side).

Control Phase

Chapter



2. Scale Validate Improvements:

- **Rollout:** Deploy proven solutions to new areas with phased implementation.
- **Engage:** Mobilize champions and address concerns through targeted communication.
- **Standardize:** Embed successful methods in Standard Operating Procedures (**SOPs**) and digital systems.

➤ Failure Mode & Effects Analysis (FMEA):

▪ **Definition:** A systematic method to:

- Identify potential failures in products/processes.
- Evaluate their risks (**Severity, Occurrence, Detection**).
- Prioritize and mitigate high-risk failures.

- **Failure Mode & Effects Analysis (FMEA):**
 - **Risk Evaluation & RPN Calculation:**
 - **Rating Scales:**
 - **Severity (S):** 1 (minor) → 10 (catastrophic)
 - **Occurrence (O):** 1 (rare) → 10 (inevitable)
 - **Detection (D):** 1 (easily detected) → 10 (undetectable)
 - **Calculate RPN (Risk Priority Number) = $S \times O \times D$**
 - **Prioritize & act on high-RPN failures.**

Process Step	Potential Failure Mode	Potential Effects of Failure	S E V E R I T Y	Potential Causes of Failure	O C C U R R E N C E	Current Process Controls	D E T E C T I O N	R P N	Recommended Action

Fig. 2.27 Failure mode and effect analysis form

3. Sustain & Advance:

- **Monitor:** Track performance via control charts and regular audits.
- **Reinforce:** Link to KPIs and recognize adoption.
- **Evolve:** Continuous refinement through PDSA cycles.

Wrap Up

1. **DMAIC** is a structured framework for quality improvement, grounded in data-driven decision-making.
2. **Root causes** are identified through tools like flowcharts, correlation analysis, and regression.
3. **Process capability** is measured via VOC/VOP alignment, Sigma Levels, and capability indices (C_p/C_{pk}).
4. **Improvements** require validation through pilots, cost-benefit analysis, and change management.

Wrap Up

5. **Control tools** (e.g., control charts, FMEA) ensure stability and scalability of solutions.
6. **RPN (FMEA)** prioritizes risks by scoring Severity, Occurrence, and Detection.
7. **Sustained success** depends on monitoring (KPIs, audits) and iterative refinement (PDSA).
8. **Culture** is critical—engage stakeholders early and celebrate quick wins to drive adoption.



Thank You