الاثنين، 20 نيسان/أبريل 2026

الملتقى السنوي الأول للإحصاء الإيجابي: من الأرقام إلى صناعة الأثر

الأساليب الإحصائية وإدارة الجودة في المنظمات: مقدمة مفاهيمية مع تطبيقات في منهجية ستة سيجما والتحكم في العمليات

Statistical Methods and Quality Management in Organisations: A conceptual introduction with applications in Six Sigma methodology and Statistical Process Control

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Statistical Methods and Quality Management

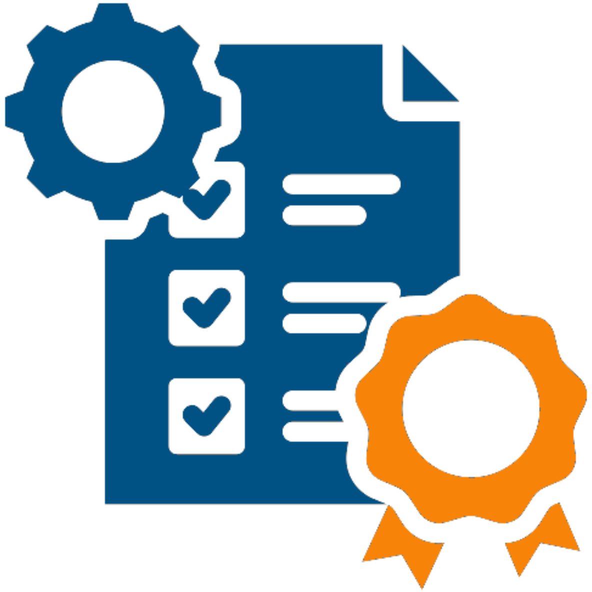
Objectives

- The Conceptual Relationship Between Statistics and Quality Management
- The Core Statistical Methods Used in Quality Management
- The Principles and Structure of Six Sigma Methodology
- the Application of Statistical Process Control (SPC)

Contents

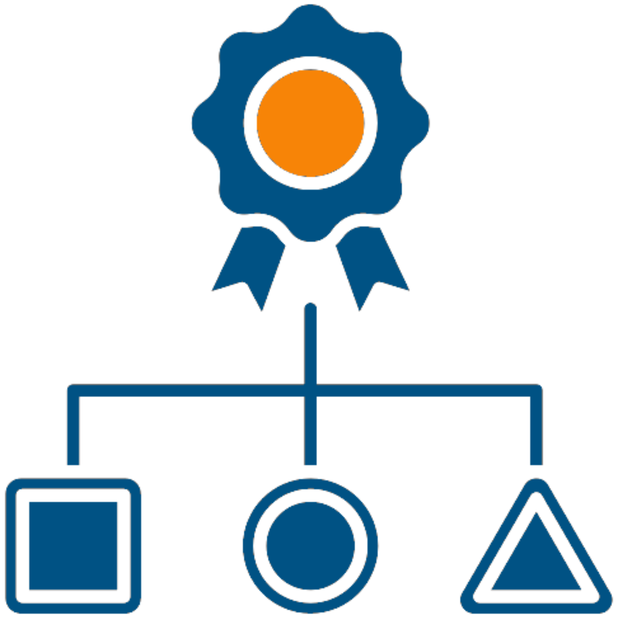
Quality Management

- Quality Management (QM) is essential to ensure products and services consistently meet customer expectations, fostering loyalty and building a strong brand image.
- It drives continuous improvement, reduces operational costs, minimizes waste, and mitigates risks, thereby enhancing efficiency and profitability



Quality Management Systems and Frameworks

- A quality management framework (QMS) is a structured system of processes, procedures, and responsibilities designed to ensure products or services consistently meet customer and regulatory requirements.
- It focuses on improving efficiency, reducing waste, and fostering continuous improvement.
- Core components include planning, control, assurance, and improvement.

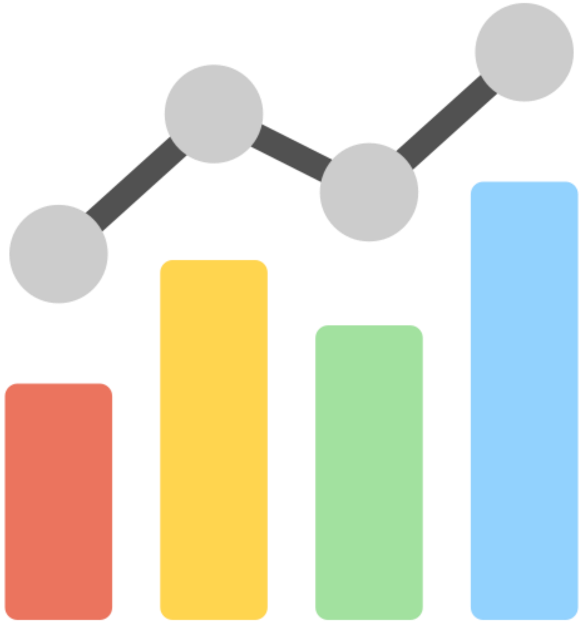


Common Quality Standards and Frameworks

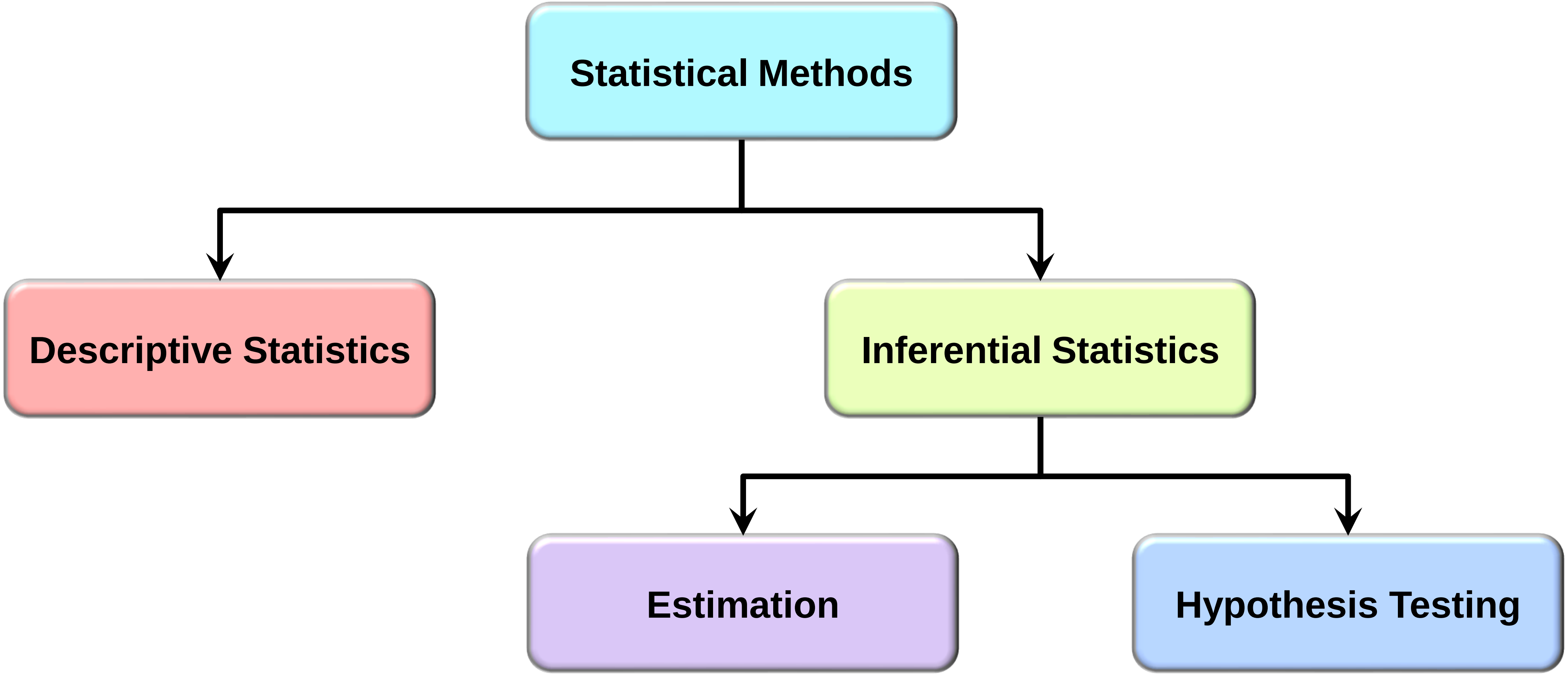
- **ISO 9001:2015** (Quality Management System): The premier global standard for ensuring consistent product/service quality
- **Total Quality Management (TQM)**: A holistic, long-term approach to customer satisfaction and continuous improvement.
- **EFQM Model**: A framework for organizations to manage change and improve performance.
- **Six Sigma**: Uses statistical data to reduce defects and improve process performance

Importance of Statistics

- The field of statistics is the science of learning from data.
- Statistical knowledge helps you use the proper methods to collect the data, employ the correct analyses, and effectively present the results.
- Today, statistics is an important part of the day-to-day activities of any organisation.
- Statistics provide essential insights into economics, health, and social trends, allowing governments, businesses, and individuals to manage risks, predict future trends, and optimise performance.



Applied Statistical Methods

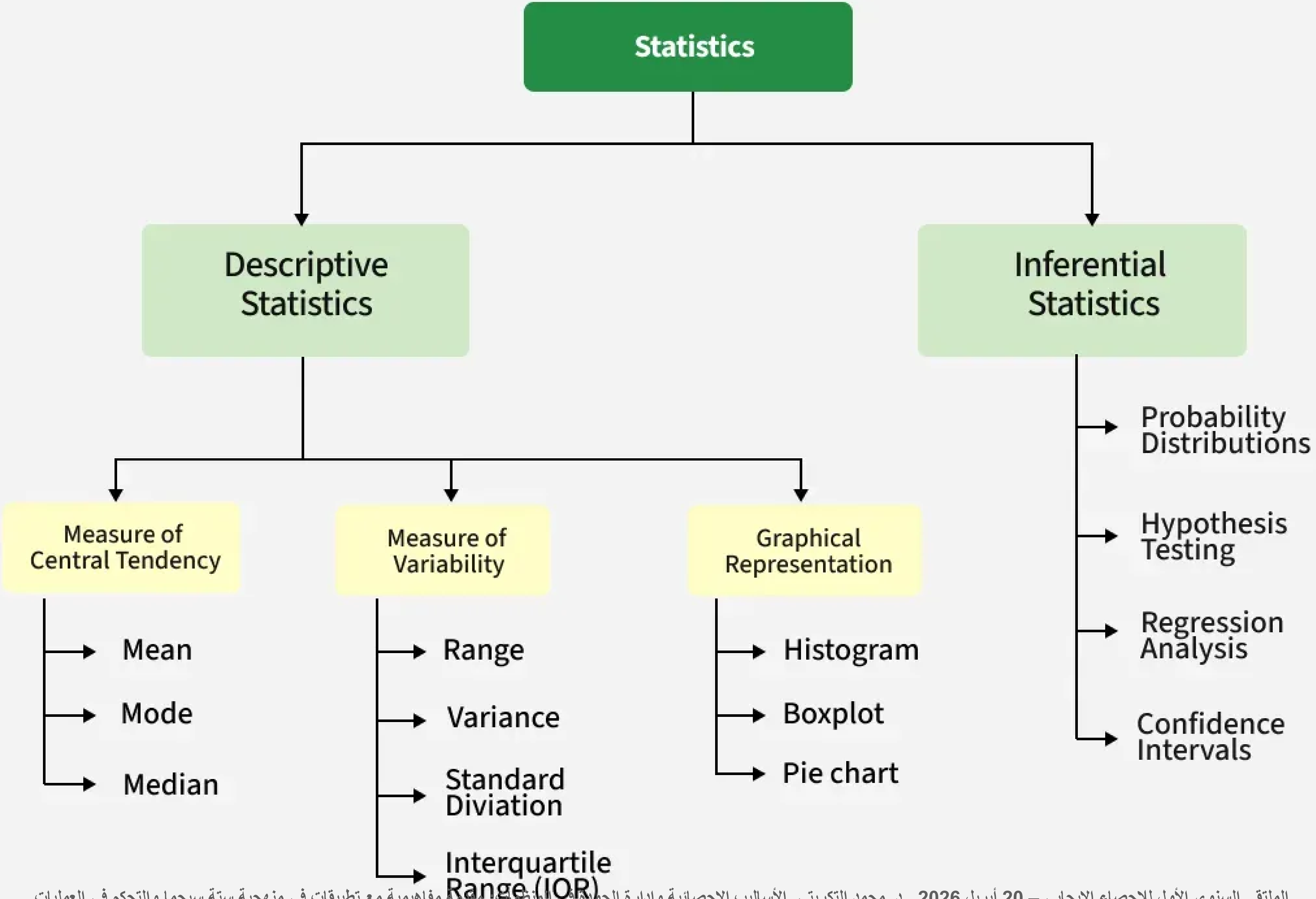


Descriptive and Inferential Statistics

- **Descriptive Statistics** consists of the tools and techniques designed to ***describe data***, such as charts, graphs, and numerical measures
- **Inferential Statistics** consists of techniques that allow a decision-maker to reach a conclusion about characteristics of a larger data set based upon a subset of those data

Describe → **Descriptive Statistics**

Compare Relate → **Inferential Statistics**


Statistics
Descriptive Statistics
Inferential Statistics
Measure of Central Tendency
Measure of Variability
Graphical Representation
Mean
Mode
Median
Range
Variance
Standard Diviation
Interquartile Range (IQR)
Histogram
Boxplot
Pie chart
Probability Distributions
Hypothesis Testing
Regression Analysis
Confidence Intervals

Six Sigma Methodology

Six Sigma

- Six Sigma is a data-driven methodology and set of management techniques designed to improve business processes by reducing defects, minimizing variability, and increasing efficiency.
- It aims for near-perfection, targeting a maximum of 3.4 defects per million opportunities (DPMO).
- It primarily utilises the DMAIC framework—Define, Measure, Analyse, Improve, Control—to enhance existing processes

6σ

DMAIC

- DMAIC is a five-step method for improving processes

DEFINE

Clarify the problem and process

MEASURE

Quantify the problem and map the process

ANALYSE

Determine the root cause

IMPROVE

Confirm the solutions work

CONTROL

Ensure the gains are sustained

The Five Phases of DMAIC

- **Define**: Identify the problem, project goals, and customer requirements.
- **Measure**: Collect data on the current process performance to establish a baseline.
- **Analyse**: Study the data to identify root causes of defects or inefficiencies.
- **Improve**: Develop, test, and implement solutions to address the root causes.
- **Control**: Monitor the improved process to ensure sustained performance and prevent reverting to previous methods.

Statistical Concepts & Metrics Used By Six Sigma

- **Sigma (σ / Standard Deviation)**: Measures the spread or variation in a dataset.
- **Defects Per Million Opportunities (DPMO)**: A standardized metric to calculate process performance, with 6 equals 3.4 DPMO.
- **Mean & Median**: Used to understand the central tendency
- **Process Capability (Cp/Cpk)**: Assesses if a process can consistently produce output within specification limits (USL/LSL).
- **Statistical Process Control (SPC)**: Uses control charts to monitor process stability over time

Statistical Tools & Methodologies Used By Six Sigma

- **Hypothesis Testing**: Used to determine if a process change has a statistically significant effect (e.g. t-tests, ANOVA).
- **Regression Analysis**: Determines the relationship between input variables (x) and process outputs (y).
- **Pareto Charts**: Visualizes the 80/20 rule, helping to focus on the "critical few" causes of defects.
- **Measurement System Analysis** (MSA)
- **Gage R&R**: Validates that the measurement process itself is accurate and precise

Operating at 99 % Quality

Is it Good Enough?

Operating at 99 % Quality

- At least 200,000 wrong drug prescriptions each year
- Two short or long landings at major airports each day
- 5000 incorrect surgical procedures per week;
- Unsafe drinking water for almost 15 minutes each day
- No electricity for almost 7 hours each month
- 50 dropped newborn babies each day

- **Is it Good Enough?**

What Does Six Sigma Really Mean?

3.8 Sigma = 99% Good	→	6 Sigma = 99.99966% Good
▪ 20,000 articles of mail lost each hour	→	▪ 7 articles lost per hour
▪ 15 minutes of unsafe drinking water every day	→	▪ 2 minutes unsafe water per year
▪ 5,000 incorrect surgical operations per week	→	▪ 2 incorrect procedures per week
▪ 2 short or long landings at most major airports each day	→	▪ 1 short or long landing every 5 years
▪ 200,000 wrong drug prescriptions each year	→	▪ 68 wrong prescriptions per year

99% Isn't Always Good Enough

Six Sigma Failure Rates

Sigma Level	Defects per Million Opportunities (DPMO)
1	697,672
2	*308,770*
3	*66,810*
4	6,209
5	232
6	3.4

3.8 Sigma = 99% Good	➔	6 Sigma = 99.99966% Good

Six Sigma Sample Results

Company	Annual Savings
General Electric	$2.0+ billion
JP Morgan Chase	$1.5 billion
Texas Instruments	$600 million
Johnson & Johnson	$500 million
Honeywell	$600 million

What is Six Sigma?

- Six Sigma is a data-driven methodology and set of management techniques designed to improve business processes by reducing defects, minimizing variability, and increasing efficiency
- Six Sigma is:
  - Philosophy
  - Methodology
  - Approach
  - Goal
  - Vision
  - Culture

6σ

What is Sigma?

- Sigma is another word for standard deviation

Sigma Level	Defects per Million Opportunities (DPMO)
1σ	697,672
2σ	*308,770*
3σ	*66,810*
4σ	6,209
5σ	232
6σ	3.4

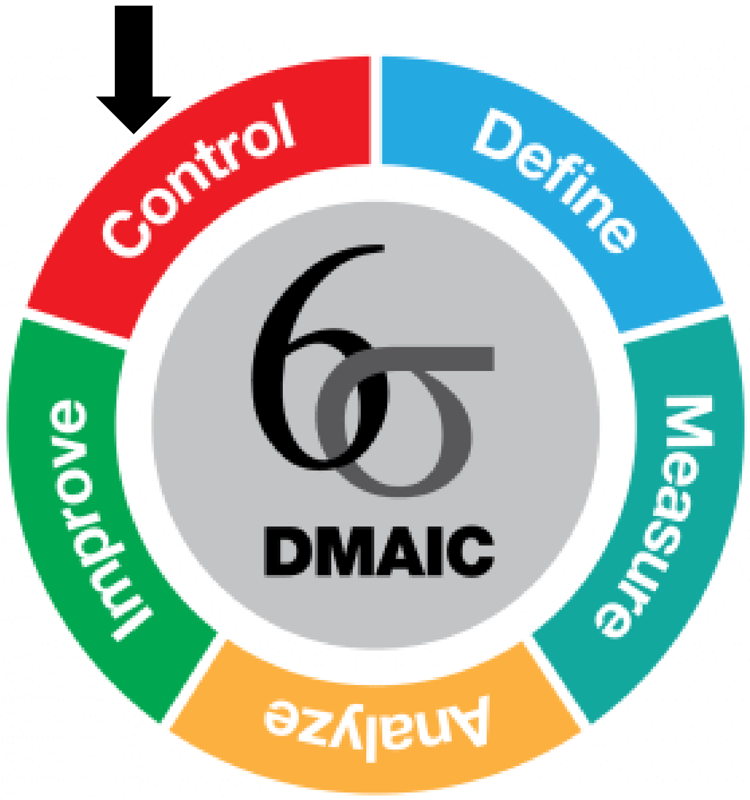
Six Sigma Uses Statistics

- Six Sigma is a methodology that uses statistics as its core, foundational language to measure, analyse, and reduce process variation, aiming for near-perfect quality of 3.4 defects per million opportunities (DPMO).
- Six Sigma utilises statistical tools—such as standard deviation, control charts, and hypothesis testing—to drive data-driven decision-making and continuous process improvement.

Statistical Process Control

DMAIC Phase 5: CONTROL

- How do you sustain the improvement?
- In the Control Phase, the team develops a Monitoring Plan to track the success of the updated process and crafts a Response Plan in case there is a dip in performance.
- Once in place, the Process Owner monitors and continually updates the current best method.



Variation Management and Quality Management

- Variation Management as a Pillar of Quality Management
- The Law of Variation is defined as the difference between an ideal and an actual situation.
- Variation or variability is most often encountered as a change in data, expected outcomes.
- Understand Common and Special Causes
- Understand Accuracy and Precision

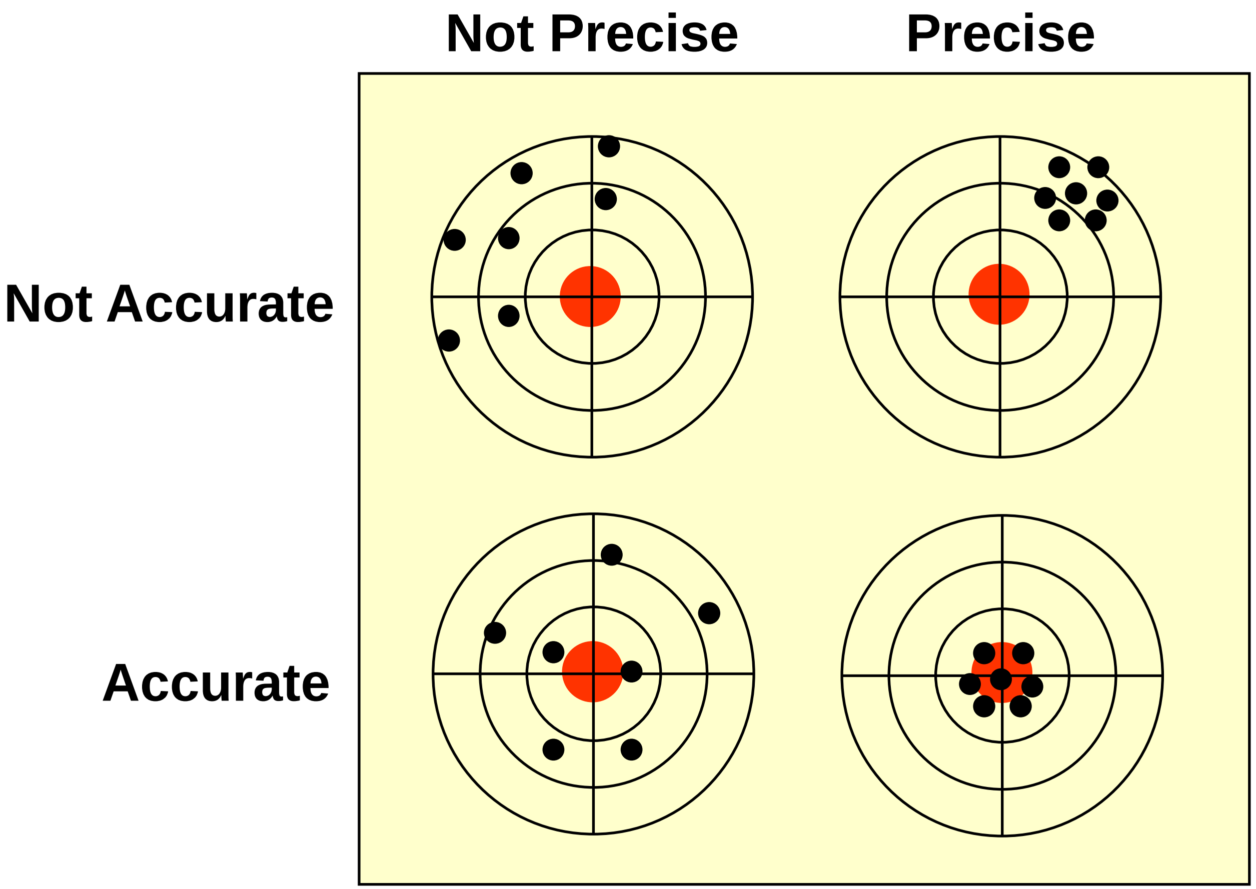
Standard Deviation (Sigma) and Variance

Standard Deviation = σ

Variance = σ^2

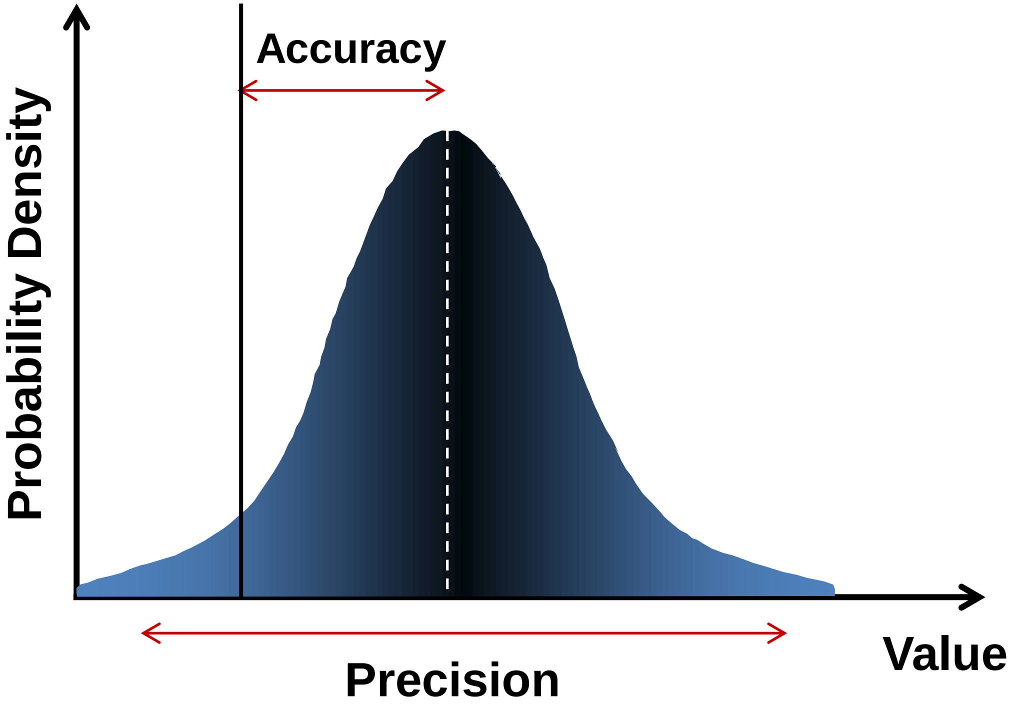
Accuracy and Precision

- We need two numbers,
  - one to measure **accuracy** and
  - one to measure **precision**



Mean and Standard Deviation

- We need two numbers,
  - one to measure accuracy (Mean)
  - one to measure precision (Standard Deviation)
- Mean measures accuracy by indicating how close the average of measurements is to the true or accepted value.
- Standard deviation measures precision by quantifying how spread out or consistent the measurements are relative to the mean.

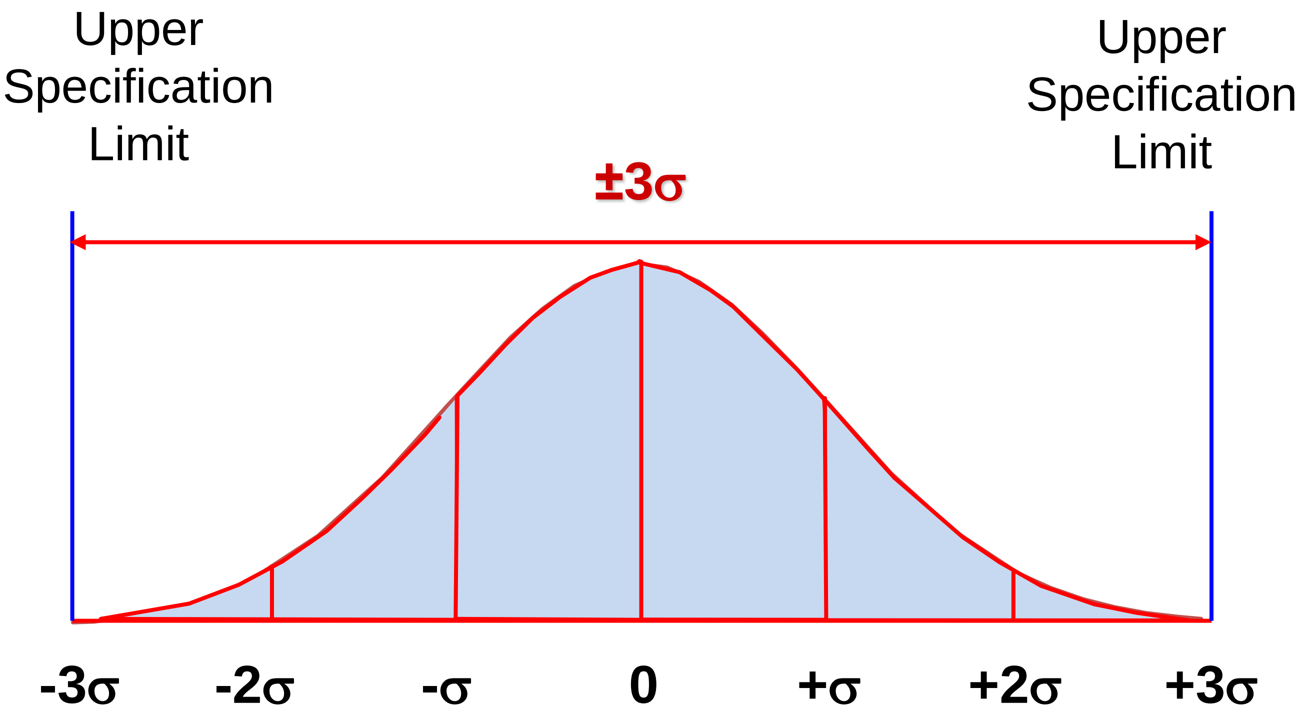


Statistical Process Control

Process Capability

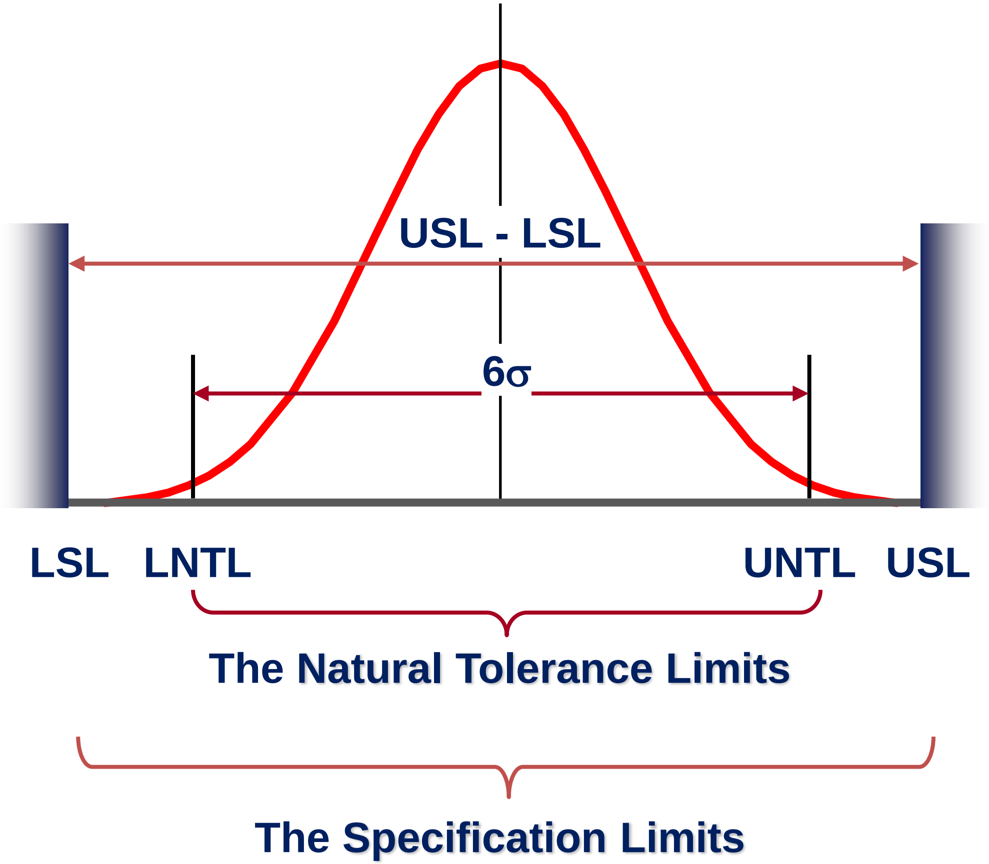
Natural Tolerance Limits

- The Natural Tolerance Limits for a process are defined as being limits positioned at three standard deviations (3σ) on each side of the process mean.
- These are the limits at which the process is marginally capable.
- They represent what the process can do, not what it should



Specification Limits

- The product has a ‘Specification Limits’, or tolerances.
- Limits are imposed on the product by the designer.
- Limits are found on the drawing or in the specification.
- If the product does not conform to these tolerances the product will be rejected.



Process Tolerances

- The specification limits, like the natural tolerance limits, will have two sides – there will be a:
  - Lower Specification Limit (LSL), and
  - Upper Specification Limit (USL).
- These are also often called the process tolerances.
- Example: Car piston diameter specification variation should be less than 20 microns (0.02 mm).

Piston Specification Limits

Diameter = 100 mm

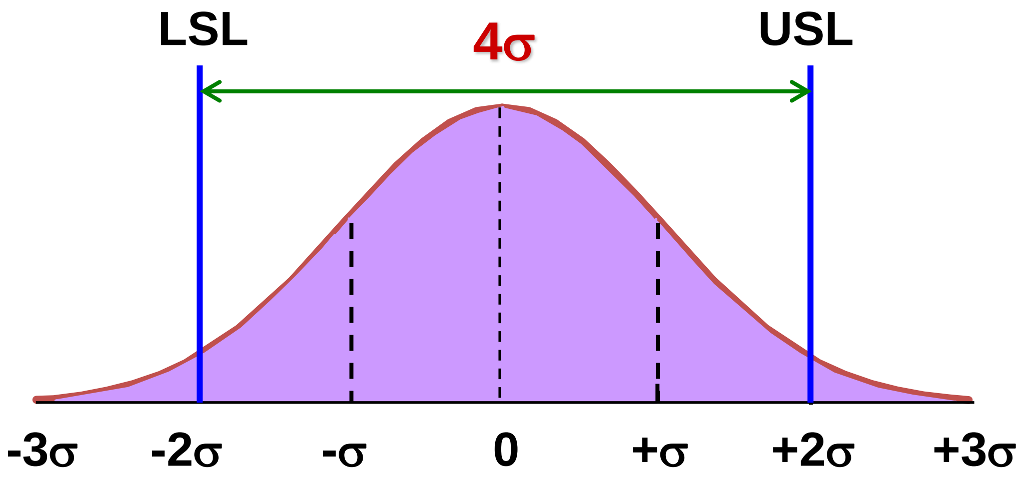
(LSL) = 99.98 mm

(USL) = 100.02 mm

C_p Process Capability Index

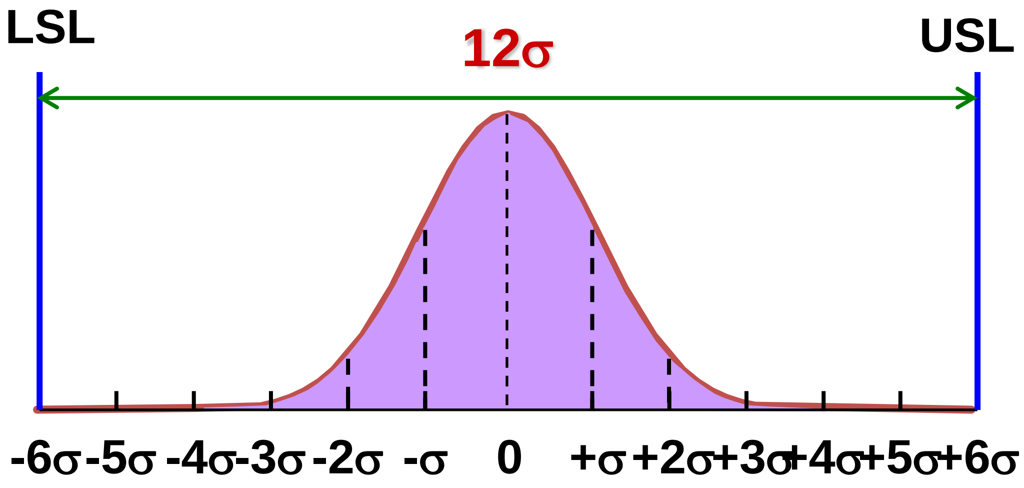
$$C_p = \frac{USL - LSL}{6\sigma} = \frac{4\sigma}{6\sigma} = 0.667$$

Not Capable Process



$$C_p = \frac{USL - LSL}{6\sigma} = \frac{12\sigma}{6\sigma} = 2$$

Capable Process



Potential Capability and Actual Capability Indices

- C_p (**Potential Capability**): Measures if the process spread (6σ) can fit within the specification limits, ignoring centering. Calculated as

$$C_p = \frac{USL - LSL}{6\sigma}$$

- C_{pk} (**Actual Capability**): Accounts for the process mean's position, calculating the distance to the nearest specification limit.

$$C_{pk} = \min\left[\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right]$$

$$C_p = \frac{USL - LSL}{6\sigma}$$

$$C_{pU} = \frac{USL - \mu}{3\sigma}$$

$$C_{pL} = \frac{\mu - LSL}{3\sigma}$$

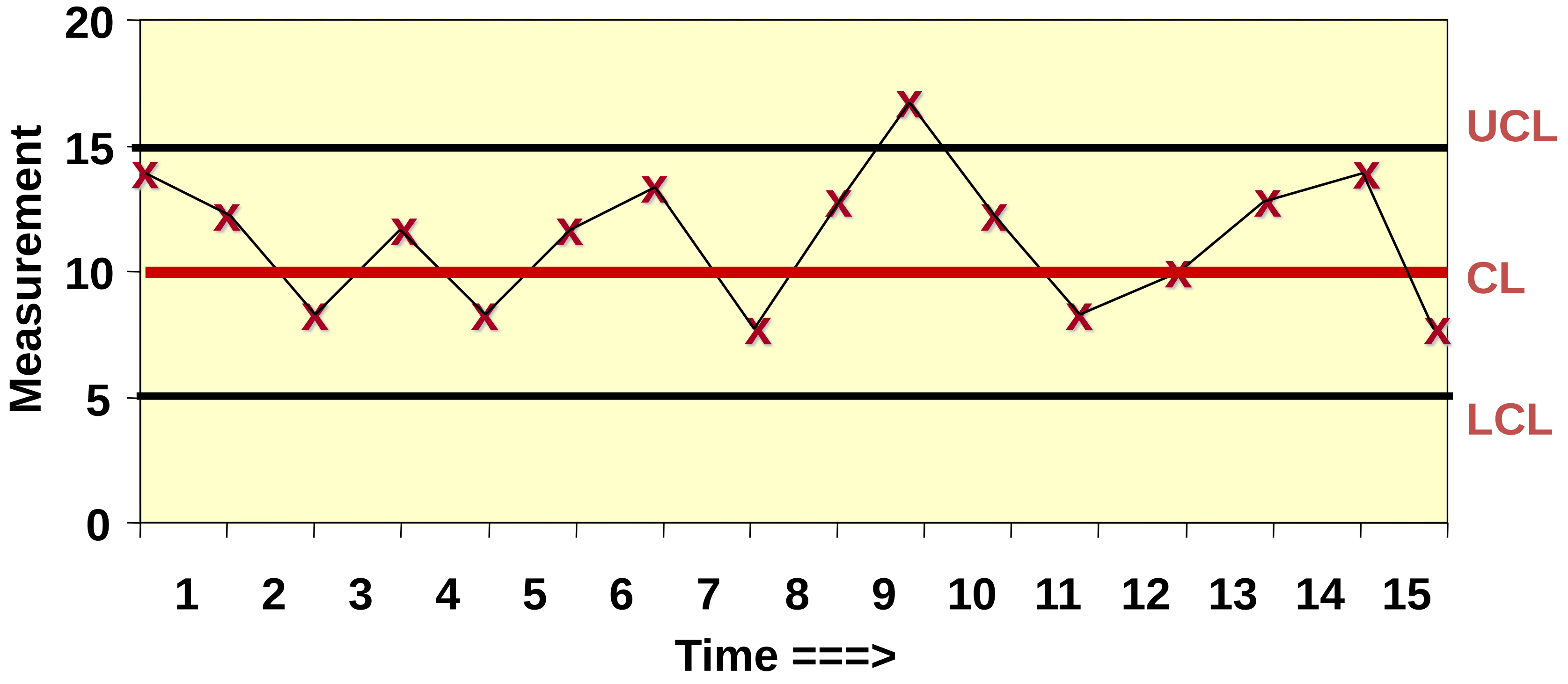
$$C_{pk} = \min\left[CPL, CPU\right]$$

Statistical Process Control

Control Charts

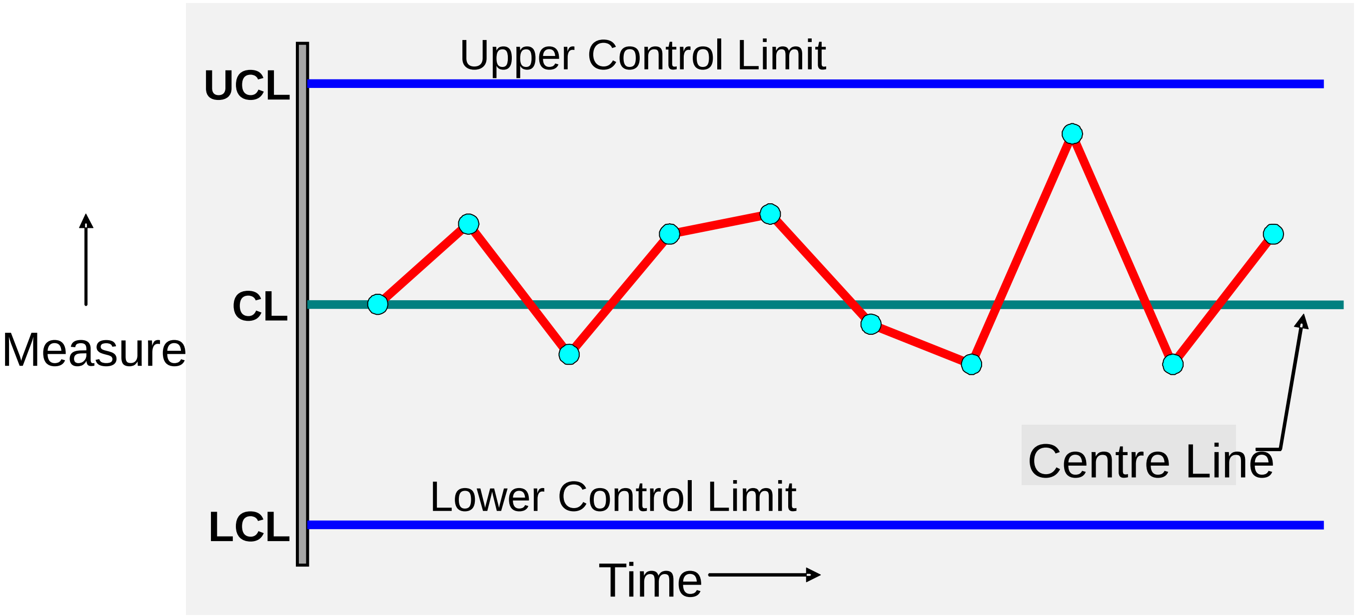
Control Chart

- Once enough measurements have been made, we calculate Average, Highest, Lowest. We add lines that connect the measurements so we can see patterns:



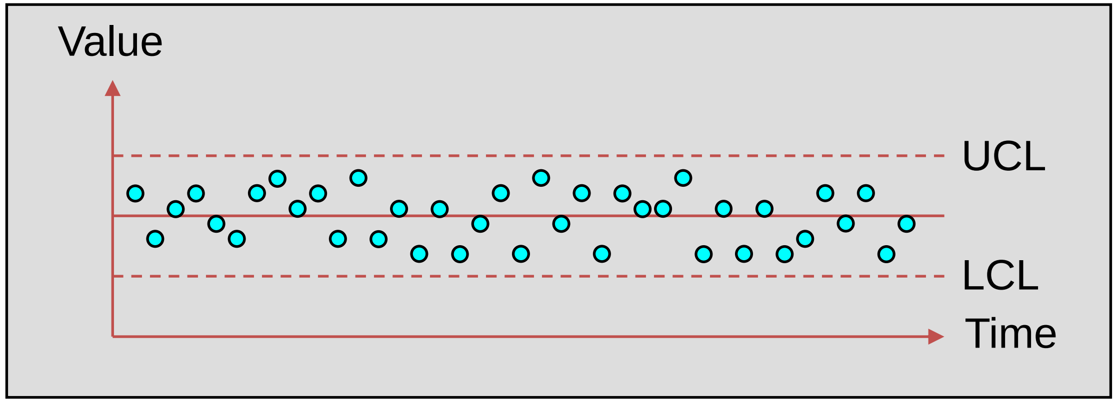
Example: Piston Manufacturing Process

- Diameter = 100 mm Central Line (CL)
- Lower Control Limit (LCL) = 99.98 mm
- Upper Control Limit (UCL) = 100.02 mm

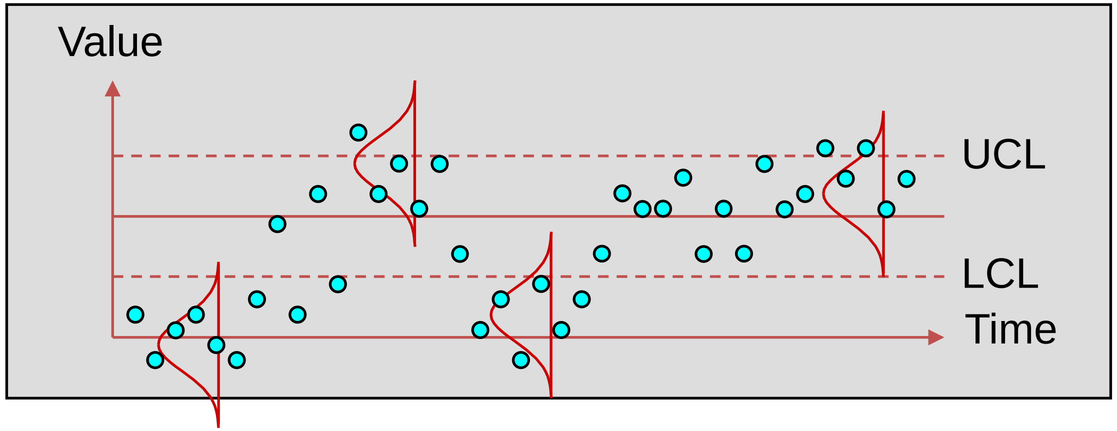


Control Charts - Examples

Process mean is consistent and predictable over time: process is in Control

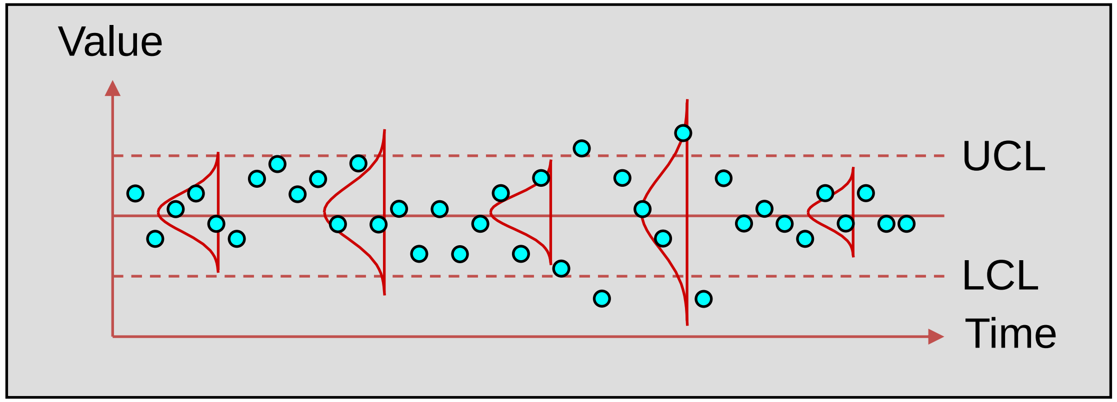


Process mean varies overtime: process out of control

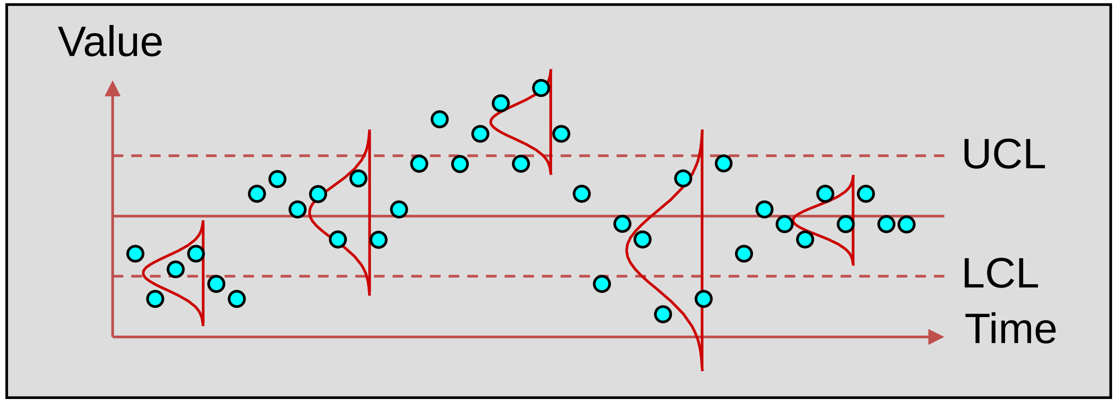


Control Charts - Examples

Process in Control



Process mean and variance change overtime: **process out of control**



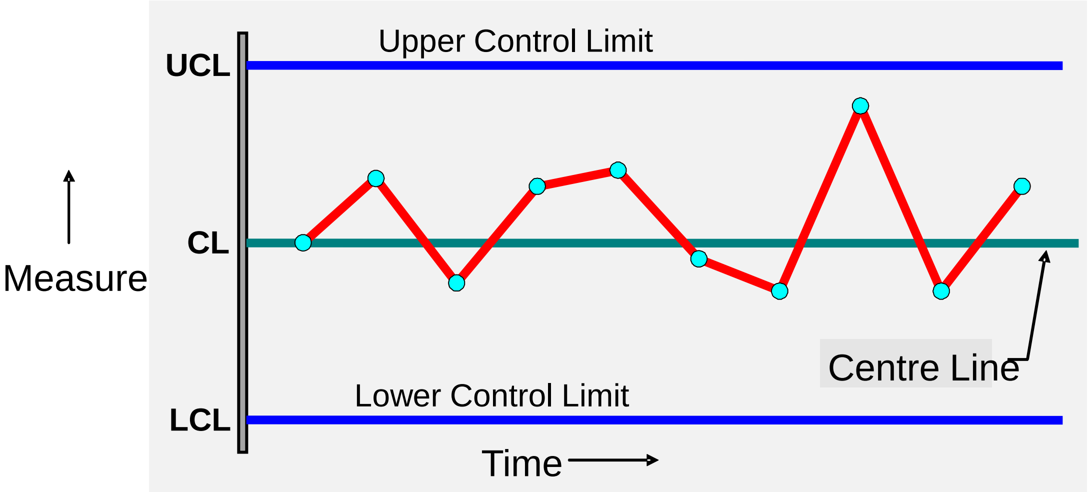
Shewhart Control Limits

- If the mean and the standard deviation of the process are known, the upper and lower control limits are as follows:

$$UCL = \mu + 3\frac{\sigma}{\sqrt{n}} \quad \text{Upper Control limit}$$

$$\mathrm{CL} = \mu$$

$$LCL = \mu - 3\frac{\sigma}{\sqrt{n}} \quad \text{Lower Control limit}$$



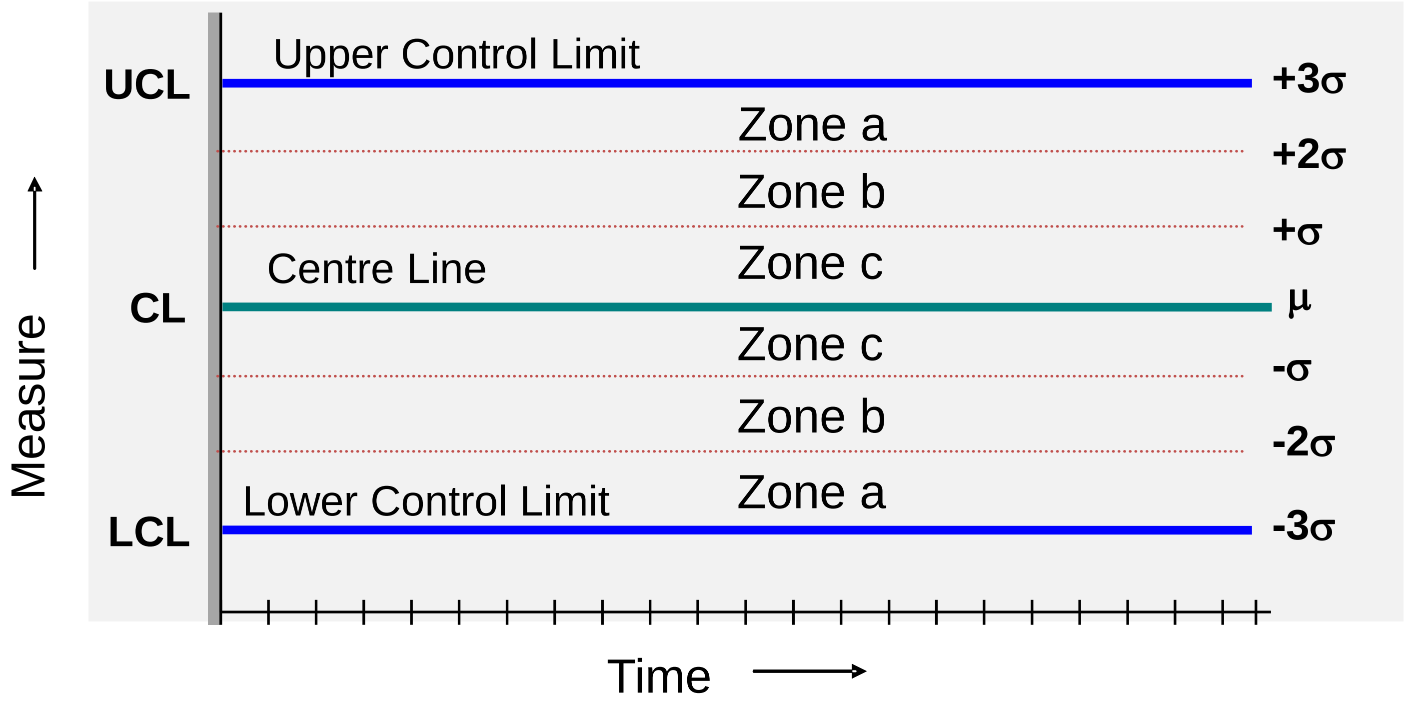
μ = process mean

σ = process standard deviation

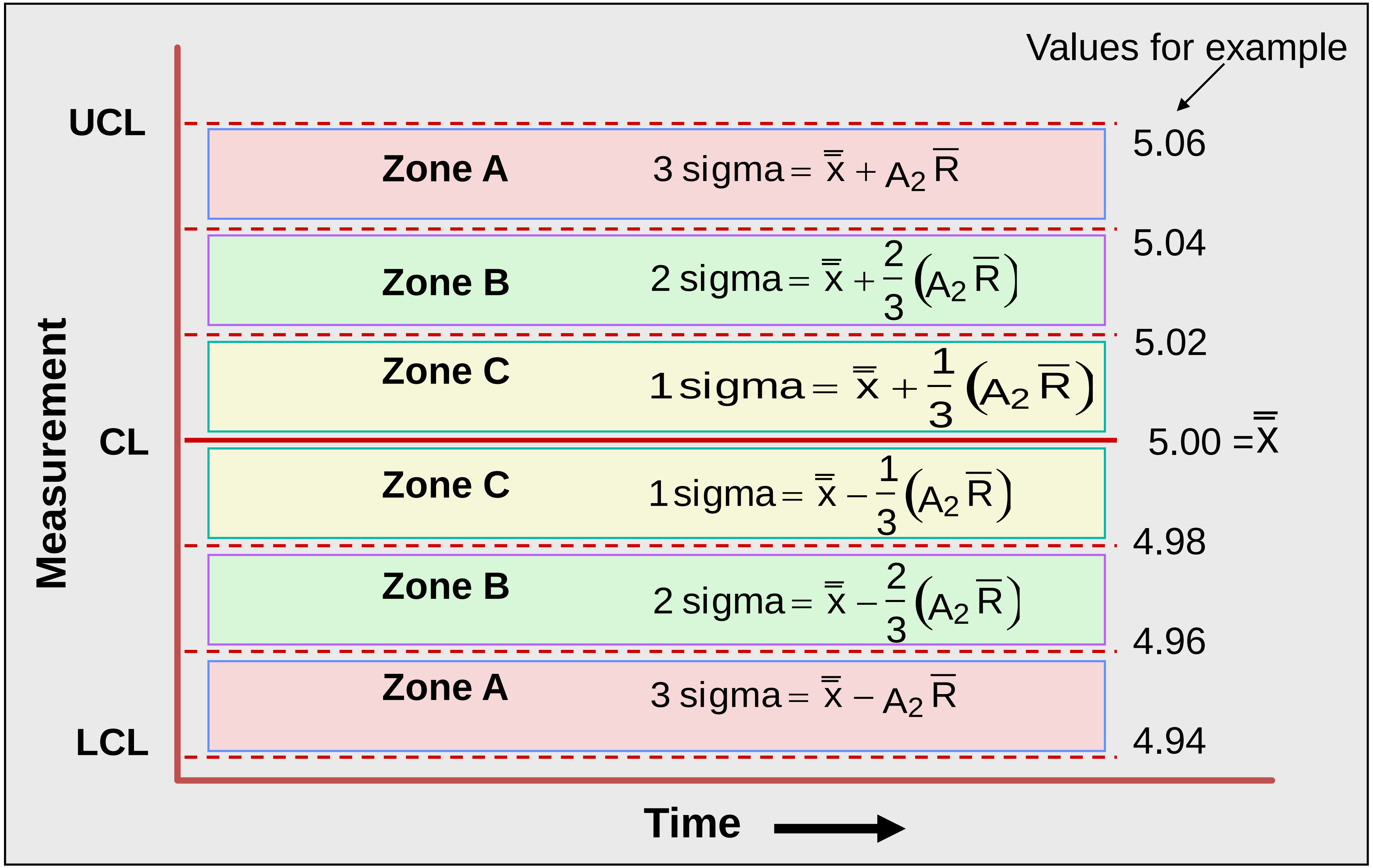
n = sample size

Control Chart Zones

- Control charts can be broken into three zones, a, b, and c on each side of the process centre line
- By default, **Zone a** is defined as the area between 2 and 3 times sigma above and below the centre line;
- **Zone b** is defined as the area between 1 and 2 times sigma, and
- **Zone c** is defined as the area between the centre line and 1 times sigma



Zones for Pattern Tests (Variables data)



Types of Variable Data

- Variables data
  - are quantitative data that can be measured: Length, size, weight, height, time, velocity.
  - Variables data are usually represented as X-bar and R-charts and X-bar and s-charts.
- Attributes data
  - are qualitative data that can be counted: count of scratches per item or a count of acceptability for a go/no-go gauge.
  - Attributes data are usually represented as nonconforming units and are analysed by using p, np, c, or u control charts.

Types of Control Charts in SPC

- **Variable Control Charts** (For Continuous Measurement Data)
  - X-bar and R Chart (Mean & Range)
  - X-bar and S Chart (Mean & Standard Deviation)
  - Individuals and Moving Range Chart (I-MR or XmR)
  - Three-way chart: Used for complex process observations
- **Attribute Control Charts** (For Discrete Count/Attribute Data)
  - p-Chart (Proportion Defective)
  - np-Chart (Number Defective)
  - c-Chart (Count of Defects)
  - u-Chart (Units of Defects)

Data Type	Defective Definition	Sample Size	Chart
Attribute Data - Counted as Discrete Events	Defective Data - Number of defects, not number of defective units	Constant Sample Size	c Chart Number of Defects
		Variable Sample Size	u Chart Defects per Unit
	Defective Unit Data	Constant Sample Size, Usually ≥ 50	np Chart Number of Defective Units
		Variable Sample Size, Usually ≥ 50	p Chart Fraction of Units Defective
Variable Data - Measured on a Continuous scale		Sample Size = 1	X and Rm Moving Range
		Sample Size < 10	Xbar and R
		Sample Size ≥ 10	Xbar and s

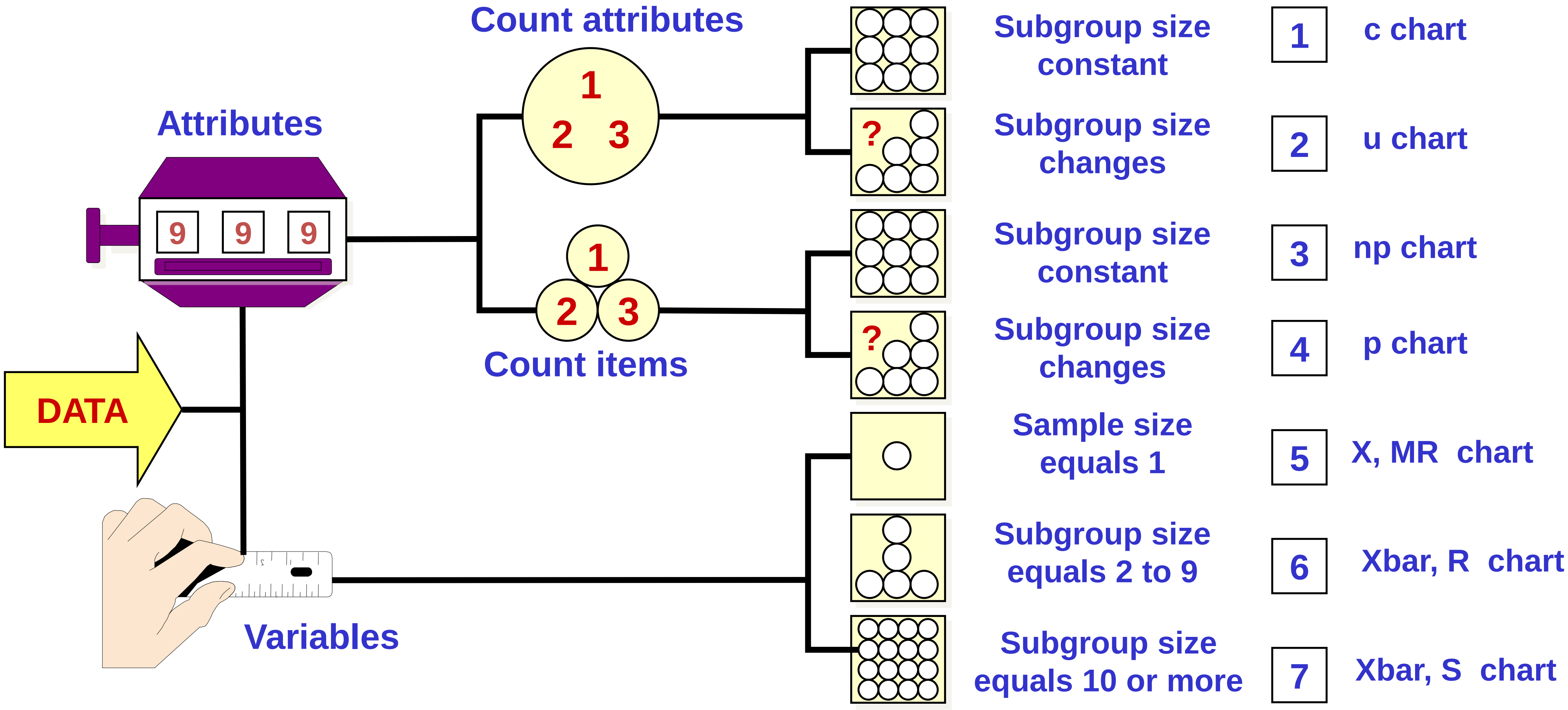
Variable Data Charts

Chart Type	Sample Size	Control Limits
X-bar and R Average and Range Chart	< 10 Usually 3-5	$\bar{X}\ \ Central\ Line: \bar{\bar{x}} = \frac{(\bar{x}_1 + \bar{x}_2 + \cdots \bar{x}_k)}{k}$ $\bar{X}\ UCL = \bar{\bar{x}} + A_2\bar{R}$ $\bar{X}\ LCL = \bar{\bar{x}} - A_2\bar{R}$ $R\ \ Central\ Line: \bar{R} = \frac{(R_1 + R_2 + \cdots R_k)}{k}$ $R\, UCL = D_4\bar{R}$ $R\, LCL = D_3\bar{R}$
X and mR Individuals and Moving Range Chart Note: mR = Median Moving Range	1	$X\ \ Central\ Line: \bar{X}\ \frac{(x_1 + x_2 + \cdots x_k)}{k}$ $X\ \ UCL = \bar{X} + (3.14 \times m\tilde{R})$ $X\ \ LCL = \bar{X} + (3.14 \times m\tilde{R})$ $mR\ \ Central\ Line: Median$ $Moving\, Range$ $mR\ \ UCL = 3.87 \times m\tilde{R}$

The Family of Attribute Charts

- **np-Chart**: for monitoring the number of times a condition occurs, relative to a constant sample size, when each sample can either have this condition, or not have this condition
- **p-Chart**: for monitoring the percent of samples having the condition, relative to either a fixed or varying sample size, when each sample can either have this condition, or not have this condition
- **c-Chart**: for monitoring the number of times a condition occurs, relative to a constant sample size, when each sample can have more than one instance of the condition.
- **u-Chart**: for monitoring the percent of samples having the condition, relative to either a fixed or varying sample size, when each sample can have more than one instance of the condition.

Types of Statistical Control Charts



Summary

- Statistical Methods and Quality Management
- Statistical Quality Control (SQC)
- Six Sigma Methodology
- Statistical Process Control (SPC)
- Process Capability Indices
- Control Charts

Questions

Thank you