Six Sigma Methodologies

Measure Phase Introduction

Measure

Select CTQ Characteristic

- Process Mapping
- Pareto
- Fishbone
- FMEA
- Quality Function Deployment
- CTQ Drill Down Tree

Define Performance Standard

- Develop the Operational Definition
- Define Unit
- Define Opportunity
- Define a Defect / Defective
- DPU /DPMO
- Identify the Target & Specification Limits

Develop Data Collection Plan, MSA, Collect Data

- Data Collection Plan
- Discrete Vs. Continuous data
- Measurement System Analysis
- Sampling

Steps in the Measure Phase:

- **Select CTQ (Critical To Quality) Characteristic**
    - CTQ Drill Down Tree
    - Pareto
    - Fishbone
    - Process Mapping
    - FMEA
    - Quality Function Deployment
- **Define Performance Standards**
    - Operational Definition
    - Unit / Opportunity
    - Target
    - Specification Limits
    - Defect / Defectives
    - DPU / DPMO
- **Develop Data Collection Plan, Measurement System Analyze, Collect Data**
    - Data Collection Plan
    - Discrete Vs. Continuous data
    - Sampling
    - Measurement System Analysis

Select CTQ (Critical To Quality) Characteristic:

What does it entail to select a CTQ (Critical to Quality) characteristic?

The process involves identifying a specific process characteristic that will be the focal point of your project. If the CTQ identified in the Define phase is too broad for a single project, it becomes imperative to narrow the scope by concentrating on a particular factor that significantly influences the CTQ. The extent to which you drill down depends on the desired scope of your project, recognizing that each project is unique. By the conclusion of this step, the aim is to precisely identify the aspect of the product or service that will be measured for your project.

Why is the selection of a CTQ characteristic important?

The significance lies in effectively managing the scope of your project. By drilling down to a sub-process or sub-system, if necessary, you can maintain a connection to the high-level customer metric while simultaneously ensuring that the project scope remains manageable. This approach is crucial for aligning your project goals with customer expectations and optimizing the efficiency of your quality management or project management initiative.

CTQ Tools: There are a variety of tools available to identify the CTQ characteristics:

Process Mapping – improving efficiencies

Pareto – using the 80-20 rule

Fishbone – getting to the root cause

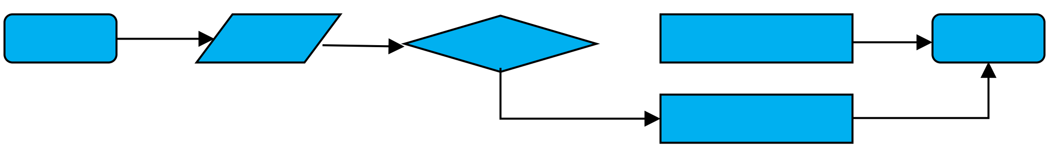
FMEA (Failure Modes and Effects Analysis) – when the process is critical

Quality Function Deployment – when the customer “wants” are not well defined… “Diffused VOC”

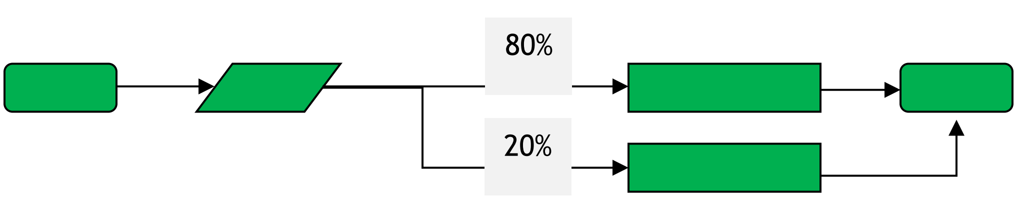
CTQ Drill Down Tree – Alignment with the company’s key goals

Process Mapping: A graphical representation illustrating steps, events, operations, and resource relationships within a given process. Essentially, we visually outline the process, exploring alternative methods to achieve results more efficiently and in less time.

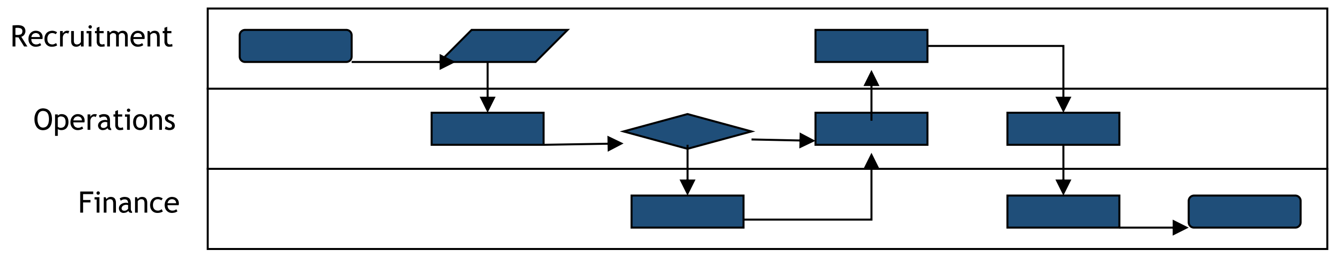
Process Flowchart: Value Add / Non-Value Add Analysis:



Alternate Path Process Map: Designed for complex or extensive processes, this map utilizes alternate paths instead of decision boxes. The inclusion of percentage depictions for alternate paths enhances the informativeness of the map.



Cross-functional process map: This type of map is used when a process involves multiple handoffs between different departments. It is also commonly referred to as a deployment map.

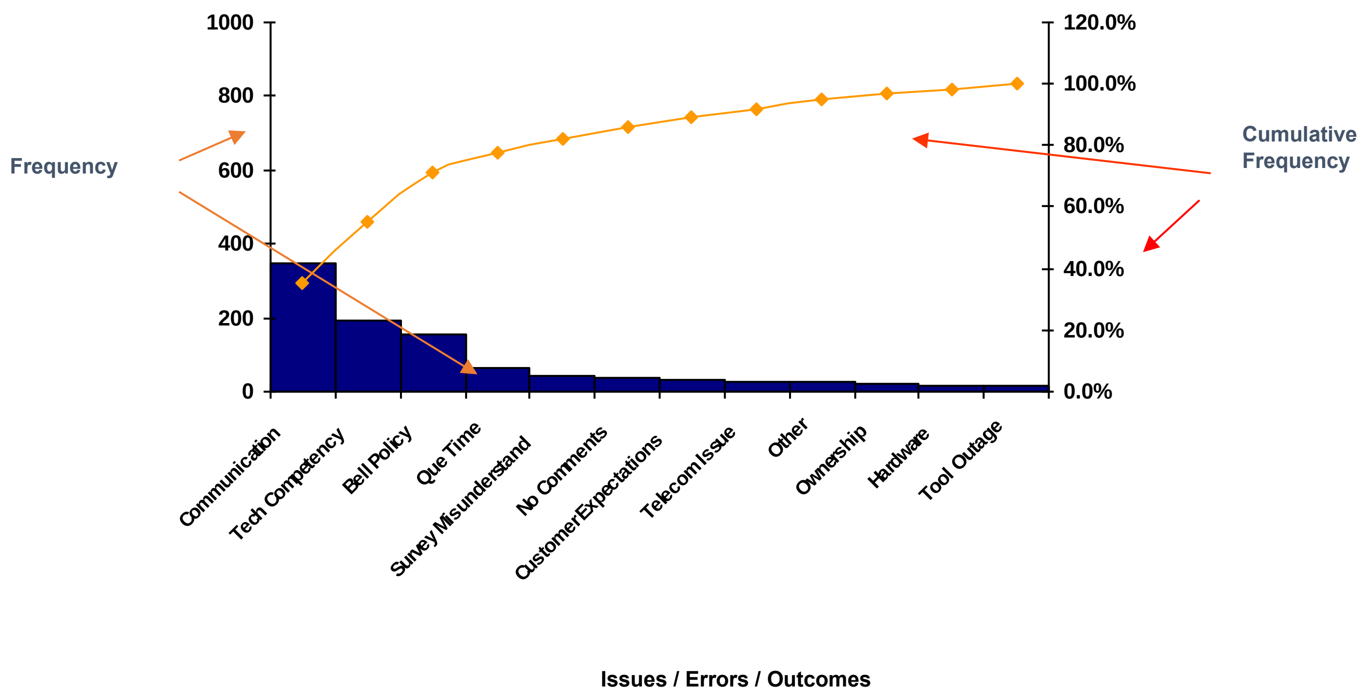


Pareto:

Originating from the Italian economist Vilfredo Pareto, the Pareto Principle states that 80% of wealth is owned by 20% of the population. Applying this principle to problem-solving, we ask:

- What 20% of sources are causing 80% of the problems (80/20 Rule)?

By identifying these key factors, we can strategically focus our efforts where they will yield the greatest improvements.

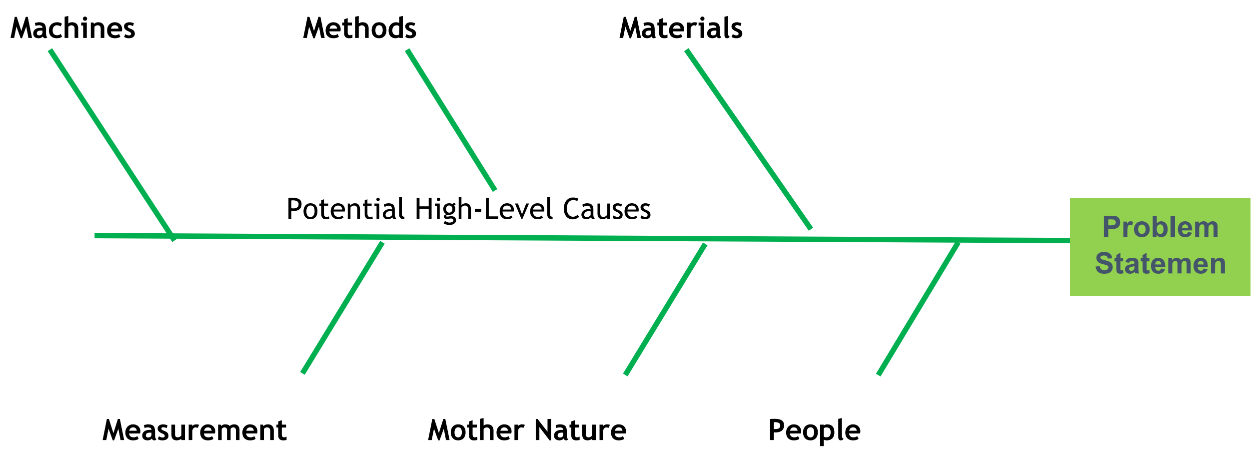


Fishbone:

Originating from Prof. Kaoru Ishikawa in 1943, initially used at Kawasaki Steel Works, the Fishbone Diagram illustrates the hierarchical relationship between causes and the outcome under study. Its application varies across industries:

In the Service Industry, it encompasses the 8Ps: People, Product/Service, Price, Promotion, Policies, Processes, Procedures, and Place/Plant/Technology.

In the Manufacturing Industry, it revolves around the 6Ms: Manpower, Machine, Methods, Measurements, Materials, and Mother Nature (environment).



FMEA (Failure Modes and Effects Analysis)

Originating in the US military in 1949, Failure Mode and Effect Analysis (FMEA) stands as a critical methodology for systematically assessing potential failures in a product or process. This approach involves the meticulous recognition and evaluation of conceivable failure modes and their corresponding effects. The primary objective is to proactively identify actions that could either eliminate or mitigate the occurrence of failures or enhance their detection. An integral part of the FMEA process is the documentation of the entire assessment, creating a comprehensive record that enables tracking changes to the process over time. This systematic and preventive approach aims to safeguard against potential failures by incorporating improvements and adjustments into the existing processes, ensuring a robust and resilient system.

Risk Priority Number	=	<u>Severity</u>	x	<u>Occurrence</u>	x	<u>Detectability</u>
(1-1000)		(1-10)		(1-10)		(1-10)

Severity Scale

Rating	Criteria – A Failure Could:
10	Injure a customer or employee
9	Be illegal
8	Render product or service unfit for use
7	Cause extreme customer dissatisfaction
6	Result in partial malfunction
5	Cause a loss of performance which is likely to result in a complaint
4	Cause minor performance loss
3	Cause a minor nuisance, but be overcome with no performance loss
2	Be unnoticed and have only minor effect on performance
1	Be unnoticed and not affect the performance

Occurrence Scale

Rating	Time Period	Probability
10	More than once per day	> 30%
9	Once every 3-4 days	≤ 30%
8	Once per week	≤ 5%
7	Once per month	≤ 1%
6	Once every 3 months	≤ .03%
5	Once every 6 months	≤ 1 Per 10,000
4	Once per year	≤ 6 Per 100,000
3	Once every 1-3 years	≤ 6 Per Million
2	Once every 3-6 years	≤ 3 Per 10 Million
1	Once every 6-100 years	≤ 2 Per Billion

Detection Scale

Rating	Definition
10	Defect caused by failure is not detectable
9	Occasional units are checked for defect
8	Units are systematically sampled and inspected
7	All units are manually inspected
6	Units are manually inspected with mistake-proofing modifications
5	Process is monitored (SPC) and manually inspected
4	SPC is used with an immediate reaction to out-of-control conditions
3	SPC as above with 100% inspection surrounding out-of-control conditions
2	All units are automatically inspected
1	Defect is obvious and can be kept from affecting the customer

Quality Function Deployment – when the customer "wants" are not well defined:

In 1972, the origin of a transformative concept emerged in Japan through the collaborative efforts of Mitsubishi and the visionary professors Mizuno and Akao. This groundbreaking idea aimed to revolutionize the design of an oil tanker by translating the abstract "wants and needs of the customer" into tangible and measurable parameters. The approach involved a strategic shift, focusing on embedding customer satisfaction directly into the design of a product or process. This innovative method sought to convert subjective preferences into concrete, quantifiable criteria, marking a significant milestone in the evolution of product and process design methodologies.

"How" will you satisfy the wants?

Importance of each to the customer

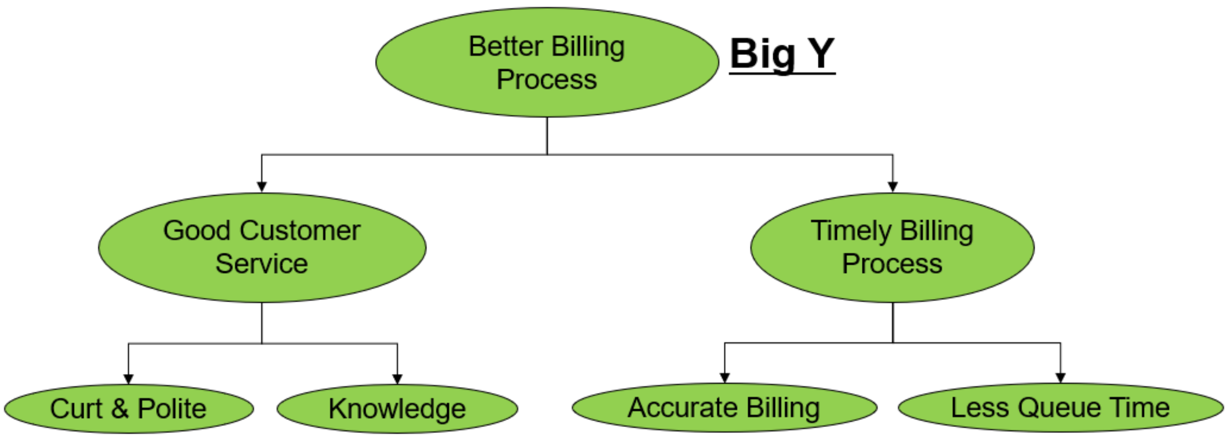
"What" does the customer want?

Strength of relationship between the "Whats" & the "Hows"

Customer Needs / Product Requirement	Importance	Weight of portion	Percent nutrition provided	Percent carbohydrate provided	Time to prepare	Number of dishes used	Cost of ingredients	Number of measured ingredients
Fills us up	5	H	M	M				
Is nutritious	4	M	H	L			L	
Tastes good	3			H			L	
Is easy to make	4				H	H		
Is easy to clean up	2				M	H		
Sticks with us	4	H		M				
Is inexpensive	1	L	L	L			M	
Is clean	2				M	M		H
Importance Rating		94*	52	59	48	60	10	18

CTQ Drill Down Tree:

The CTQ (Critical to Quality) drill-down tree tool serves as a valuable aid in selecting a project metric. It effectively illustrates the connection between the chosen project metric and the overarching goals of the company. Once this relationship is established, the tool becomes an instrumental resource in project management, guiding the identification and finalization of pertinent project metrics. Its application extends to projects, where it plays a crucial role in ensuring alignment with company objectives and facilitating the determination of metrics that truly matter to the quality and success of the project.



Define Performance Standards

What does it mean to Define Performance Standards? A performance standard defines:

- The process to be measured
- How it will be measured
- How much variance will be tolerated?

This is the point when you determine the best way to turn what the customer wants into a numeric measurement.

Why is it important to Define Performance Standards?

The performance standard translates customer needs into a precisely defined measure, enabling the collection of performance data. By establishing clear criteria for acceptable and unacceptable performance in your process, you can then define a defect. This definition of a defect serves as the foundation for evaluating performance capability and setting improvement goals for the project.

The Key Steps in "Define Performance Standards" are:

- **Develop the Operational Definition**
- **Define Unit**
- **Define Opportunity**
- **Define a Defect / Defective**
- **DPU /DPMO**
- **Identify the Target & Specification Limits**

Develop the Operational Definition:

An Operational Definition is a precise and explicit description that serves to clarify both what the Critical to Quality (CTQ) is and the methodology for measuring it. It functions as a comprehensive guide, providing a clear understanding of the essential quality parameter and describing the specific steps or criteria for its measurement. By encapsulating the essence of the CTQ and outlining the measurement process, an operational definition becomes a valuable tool in ensuring a standardized and unambiguous interpretation of critical quality aspects within a given context. We need to have an Operational Definition to:

- Remove ambiguity in understanding between team members
- Clearly defines a "standard" way to measure a CTQ
- Ensuring that CTQ representation is correct and independent of different times and operators

Define Unit

Unit: A Unit is a measurable and observable output of your business process. It is the number of parts, sub-assemblies, assemblies, or systems inspected or tested.

Define Opportunity

Opportunity: An Opportunity is the total number of chances per unit to have a defect. It is a characteristic you inspect or test. The total count of opportunities indicates the complexity of a product or service.

Define a Defect / Defective

Defect: A Defect is a characteristic of the Unit that does not meet the customer's requirements.

Defective: A Defective is a unit with one or more defects.

DPU /DPMO

DPU – **D**efects **P**er **U**nit – Always greater than or equal to Zero

DPMO – **D**efects **P**er **M**illion **O**pportunities – value between Zero and One.

DPMO = (Total Defects * 1,000,000) / Total Opportunities

Please refer to the example below to gain a clear understanding of all the terms mentioned above:

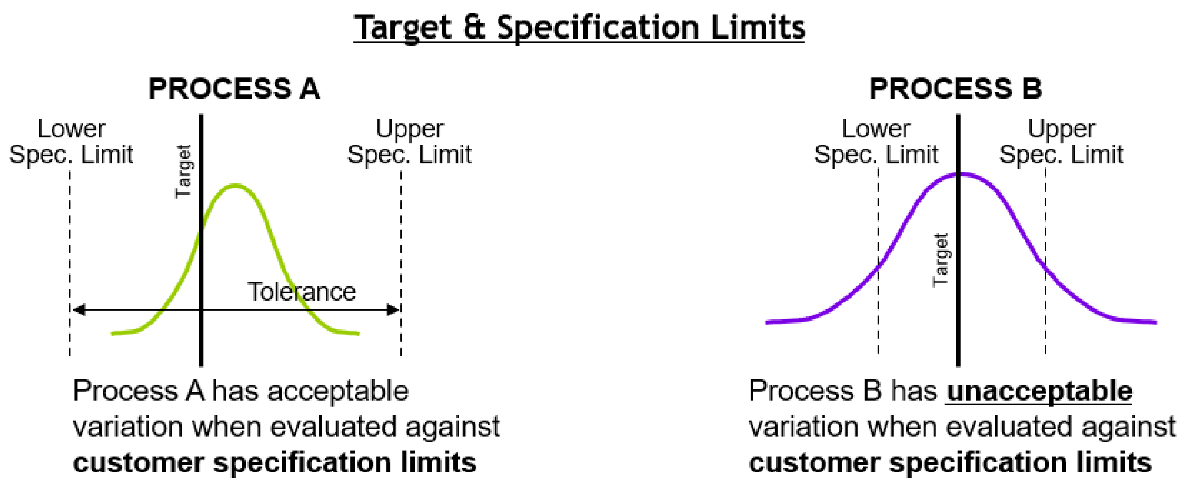
Example: 10 transactions were audited on a program today. Each transaction is audited on 5 parameters. The chart below shows the score on each parameter and the overall score. The pass score for each parameter and the call is 85%.

	Parameter					
Call #	**1**	**2**	**3**	**4**	**5**	**Overall**
1	99	100	x 71	94	x 79	89
2	x 84	x 78	x 70	x 79	85	x 79
3	x 70	91	85	x 72	x 78	x 79
4	85	x 79	x 70	98	x 77	x 82
5	x 77	x 79	100	100	x 79	87
6	94	97	x 78	90	x 76	87
7	95	90	88	x 82	x 76	86
8	88	98	x 72	85	94	87
9	x 72	94	x 77	85	91	x 84
10	x 79	x 78	98	94	91	88

Number of Units,	Opportunities,	Defects,	defectives,	DPU ,	DPMO
10	**50**	**24**	**4**	**2.4**	**480,000**

Identify the Target & Specification Limits

Below is an illustration of the targets and specification limits of two processes based on customer specification limits:



Develop Data Collection Plan, Measurement System Analyze, Collect Data

Key Steps:

- **Data Collection Plan**
- **Discrete Vs. Continuous data**
- **Measurement System Analysis**
- **Sampling and Data Collection**

Data Collection Plan:

Why is this step important?

- Establishing a data collection plan and validating the measurement system are crucial steps as they delineate a coherent strategy for efficiently gathering reliable data.
- The data collection plan aids in guaranteeing optimal resource utilization by focusing solely on gathering data essential for project success.
- Validating the measurement system is imperative as it guarantees that the collected data faithfully reflects the genuine characteristics of your process

Clarify Data		Develop Data Collection Plan										
			Segmentation Factors					Collection Plan				
Measure	Data Type	Operational Definition						Who	When From	To	Quantity	
Number of defective policies	Discrete	Policies identified as defective by the QA resources	Agent	work type	day of week	time of day	error no.	QA team	July 01	Sep 01	100%	
Policies per hour	Continuous	= Total number of policies processed in a shift / time on system (login time - breaks)	Agent	time of day				Ops Manager	July 01	Sep 01	100%	
Upload volumes	Continuous	Number of policies received in a day	time					Ops Manager	July 01	Sep 01	100%	

Discrete Vs. Continuous data

Continuous Data:

- Continuous data encompasses information that can be measured along a continuum or scale.
- It can possess nearly any numeric value and can be meaningfully divided into increasingly finer increments, depending on the precision of the measurement system.
- Continuous data is infinitely divisible.

An example of continuous data is the height of students in a classroom. Heights can be measured along a scale and can take on any numeric value within a certain range. For instance, a student could be 150.5 centimeters tall, and another could be 155.2 centimeters tall. This data is continuous because it can be divided into finer and finer increments, depending on the precision of the measurement device.

Discrete / Attribute Data:

- Discrete data comprises information that can be categorized into distinct classifications.
- It relies on counts, and only a finite number of values is possible.
- The values cannot be meaningfully subdivided.

An example of discrete/attribute data is the number of red apples in a basket. This data is discrete because it consists of distinct categories (red apples) and is based on counts. Each apple can be counted, and the number of red apples in the basket can only be whole numbers (e.g., 0, 1, 2, 3, etc.). The values cannot be further subdivided into smaller increments.

Measurement System Analysis – Attribute Data

Measurement System Analysis (MSA) is a key tool in Six Sigma to assess the accuracy and precision of your measurement process. It helps you identify and reduce the sources of variation that affect your data quality and process capability. These are the measurement attributes:

Accuracy – the disparity between the observed average measurement and a standard.

Repeatability – the variation observed when one person repeatedly measures the same unit with the same measuring equipment.

Reproducibility – the variation observed when two or more people measure the same unit with the same measuring equipment.

Stability – the variation obtained when the same person measures the same unit with the same equipment over an extended period of time.

Linearity – the consistency of accuracy across the entire range of the measurement system.

In order to assess the accuracy and precision of our measurement process, we need to gage the R&R, and its acceptable range.

Gage R&R (Repeatability and Reproducibility) is defined as the process used to evaluate a gauging instrument's accuracy by ensuring its measurements are repeatable and reproducible. The process includes taking a series of measurements to certify that the output is the same value as the input and that the same measurements are obtained under the same operating conditions over a set duration.

For Attribute data, Gage R&R acceptable range is:

- 90% match for Repeatability, Reproducibility, and Accuracy analysis.
- The sample size should be 30-50 if possible.

Attribute Data MSA – Repeatability Test

In this test case, we have 120 Opportunities, 13 non-matches, and 107 matches. The Repeatability is calculated as **Repeatability** = 107/120 = **89.17%**

	Operator 1				Operator 2				Operator 3			
Sample	**Tr1**	**Tr2**	**TR3**	**Match?**	**Tr1**	**Tr2**	**Tr3**	**Match?**	**Tr1**	**Tr2**	**Tr3**	**Match?**
1	N	N	N	Y	N	N	N	Y	N	N	N	Y
2	N	N	N	Y	N	N	N	Y	N	N	N	Y
3	N	N	N	Y	N	N	N	Y	D	N	N	N
4	D	D	D	Y	D	D	D	Y	D	D	D	Y
5	D	D	D	Y	D	D	D	Y	D	N	D	N
6	N	N	N	Y	N	N	N	Y	N	N	N	Y
7	N	D	N	N	D	D	D	Y	D	D	D	Y
8	N	N	N	Y	D	N	D	N	N	N	N	Y
9	N	N	N	Y	N	N	N	Y	N	N	N	Y
10	N	N	N	Y	N	N	N	Y	D	N	D	N
11	D	D	D	Y	D	D	D	Y	D	D	D	Y
12	N	N	N	Y	D	D	D	Y	D	D	D	Y
13	D	D	D	Y	D	D	D	Y	D	D	D	Y
14	N	N	N	Y	N	N	N	Y	N	N	N	Y
15	D	D	D	Y	D	D	D	Y	D	D	D	Y
16	D	D	D	Y	N	N	N	Y	N	N	N	Y
17	N	N	N	Y	N	N	N	Y	N	N	N	Y
18	N	N	N	Y	N	N	N	Y	N	N	N	Y
19	N	N	N	Y	D	D	D	Y	N	N	N	Y
20	N	N	N	Y	N	N	N	Y	D	D	N	N
21	D	D	D	Y	D	D	D	Y	D	D	N	N
22	N	N	N	Y	D	D	D	Y	N	N	N	Y
23	N	N	N	Y	D	D	D	Y	N	N	N	Y
24	N	N	N	Y	N	N	N	Y	D	D	D	Y
25	N	N	N	Y	N	N	N	Y	N	N	N	Y
26	D	D	D	Y	D	D	D	Y	D	D	D	Y
27	N	N	N	Y	N	N	N	Y	N	N	N	Y
28	N	N	N	Y	N	N	N	Y	N	N	N	Y
29	N	N	N	Y	N	N	N	Y	N	N	N	Y
30	N	D	N	N	D	D	D	Y	D	D	D	Y
31	D	D	D	Y	D	D	D	Y	D	D	D	Y
32	N	N	N	Y	N	N	N	Y	N	N	N	Y
33	D	N	N	N	D	D	N	N	N	N	N	Y
34	N	N	N	Y	N	N	N	Y	N	N	N	Y
35	N	N	N	Y	N	N	N	Y	N	D	N	N
36	D	D	D	Y	D	D	D	Y	D	D	D	Y
37	N	N	N	Y	N	N	N	Y	D	N	N	N
38	N	N	N	Y	N	N	N	Y	N	N	D	N
39	N	N	N	Y	N	N	N	Y	N	N	N	Y
40	N	N	N	Y	D	D	D	Y	N	N	N	Y
	Operator 1			0.925	**Operator 2**			0.950	**Operator 3**			0.800

Attribute Data MSA – Reproducibility Test

In this test case, we have 40 Opportunities, 19 non-matches, and 21 matches. The Reproducibility is calculated as **Reproducibility** = 21/40 = **52.5%**

	Operator 1			Operator 2			Operator 3			
Sample	Tr1	Tr2	TR3	Tr1	Tr2	Tr3	Tr1	Tr2	Tr3	Match?
1	N	N	N	N	N	N	N	N	N	Y
2	N	N	N	N	N	N	N	N	N	Y
3	N	N	N	N	N	N	D	N	N	N
4	D	D	D	D	D	D	D	D	D	Y
5	D	D	D	D	D	D	D	N	D	N
6	N	N	N	N	N	N	N	N	N	Y
7	N	D	N	D	D	D	D	D	D	N
8	N	N	N	D	N	D	N	N	N	N
9	N	N	N	N	N	N	N	N	N	Y
10	N	N	N	N	N	N	D	N	D	N
11	D	D	D	D	D	D	D	D	D	Y
12	N	N	N	D	D	D	D	D	D	N
13	D	D	D	D	D	D	D	D	D	Y
14	N	N	N	N	N	N	N	N	N	Y
15	D	D	D	D	D	D	D	D	D	Y
16	D	D	D	N	N	N	N	N	N	N
17	N	N	N	N	N	N	N	N	N	Y
18	N	N	N	N	N	N	N	N	N	Y
19	N	N	N	D	D	D	N	N	N	N
20	N	N	N	N	N	N	D	D	N	N
21	D	D	D	D	D	D	D	D	N	N
22	N	N	N	D	D	D	N	N	N	N
23	N	N	N	D	D	D	N	N	N	N
24	N	N	N	N	N	N	D	D	D	N
25	N	N	N	N	N	N	N	N	N	Y
26	D	D	D	D	D	D	D	D	D	Y
27	N	N	N	N	N	N	N	N	N	Y
28	N	N	N	N	N	N	N	N	N	Y
29	N	N	N	N	N	N	N	N	N	Y
30	N	D	N	D	D	D	D	D	D	N
31	D	D	D	D	D	D	D	D	D	Y
32	N	N	N	N	N	N	N	N	N	Y
33	D	N	N	D	D	N	N	N	N	N
34	N	N	N	N	N	N	N	N	N	Y
35	N	N	N	N	N	N	N	D	N	N
36	D	D	D	D	D	D	D	D	D	Y
37	N	N	N	N	N	N	D	N	N	N
38	N	N	N	N	N	N	N	N	D	N
39	N	N	N	N	N	N	N	N	N	Y
40	N	N	N	D	D	D	N	N	N	N
	Operator 1			Operator 2			Operator 3			52.5%

Attribute Data MSA – Accuracy Test

In this test case, we have 360 Opportunities, 40 non-matches, and 320 matches. The Accuracy is calculated as **Accuracy** = 320/360 = **88.89%**

	Std	Operator 1			Operator 2			Operator 3			Not
Sample	**Value**	**Tr1**	**Tr2**	**Tr3**	**Tr1**	**Tr2**	**Tr3**	**Tr1**	**Tr2**	**Tr3**	**Match?**
1	**N**	N	N	N	N	N	N	N	N	N	***0***
2	**N**	N	N	N	N	N	N	N	N	N	***0***
3	**N**	N	N	N	N	N	N	D	N	N	***1***
4	**D**	D	D	D	D	D	D	D	D	D	***0***
5	**D**	D	D	D	D	D	D	D	N	D	***1***
6	**N**	N	N	N	N	N	N	N	N	N	***0***
7	**D**	N	D	N	D	D	D	D	D	D	***2***
8	**N**	N	N	N	D	N	D	N	N	N	***2***
9	**N**	N	N	N	N	N	N	N	N	N	***0***
10	**N**	N	N	N	N	N	N	D	N	D	***2***
11	**D**	D	D	D	D	D	D	D	D	D	***0***
12	**D**	N	N	N	D	D	D	D	D	D	***3***
13	**D**	D	D	D	D	D	D	D	D	D	***0***
14	**N**	N	N	N	N	N	N	N	N	N	***0***
15	**D**	D	D	D	D	D	D	D	D	D	***0***
16	**N**	D	D	D	N	N	N	N	N	N	***3***
17	**N**	N	N	N	N	N	N	N	N	N	***0***
18	**N**	N	N	N	N	N	N	N	N	N	***0***
19	**N**	N	N	N	D	D	D	N	N	N	***3***
20	**N**	N	N	N	N	N	N	D	D	N	***2***
21	**D**	D	D	D	D	D	D	D	D	N	***1***
22	**N**	N	N	N	D	D	D	N	N	N	***3***
23	**N**	N	N	N	D	D	D	N	N	N	***3***
24	**N**	N	N	N	N	N	N	D	D	D	***3***
25	**N**	N	N	N	N	N	N	N	N	N	***0***
26	**D**	D	D	D	D	D	D	D	D	D	***0***
27	**N**	N	N	N	N	N	N	N	N	N	***0***
28	**N**	N	N	N	N	N	N	N	N	N	***0***
29	**N**	N	N	N	N	N	N	N	N	N	***0***
30	**D**	N	D	N	D	D	D	D	D	D	***2***
31	**D**	D	D	D	D	D	D	D	D	D	***0***
32	**N**	N	N	N	N	N	N	N	N	N	***0***
33	**N**	D	N	N	D	D	N	N	N	N	***3***
34	**N**	N	N	N	N	N	N	N	N	N	***0***
35	**N**	N	N	N	N	N	N	N	D	N	***1***
36	**D**	D	D	D	D	D	D	D	D	D	***0***
37	**N**	N	N	N	N	N	N	D	N	N	***1***
38	**N**	N	N	N	N	N	N	N	N	D	***1***
39	**N**	N	N	N	N	N	N	N	N	N	***0***
40	**N**	N	N	N	D	D	D	N	N	N	***3***
# of N		**5**	**2**	**4**	**6**	**5**	**5**	**5**	**4**	**4**	***40***

MSA Sources of Errors

Repeatability

- Operational definitions
- Maintain stability

Reproducibility

- Operational definitions
- Consistent use of gage
- Training
- Varying work environment
- Human/physical characteristics
- Performance measures
- Unclear requirements

Accuracy

- Instrument used improperly by appraiser
- Operational definition
- Standard not understood

Measurement System Analysis – Continuous Data

In Measurement System Analysis for Continuous Data, it's crucial to ascertain the precision of the system, instrument, device, or gauge. To achieve this, we repeatedly measure the same item under consistent conditions, with the same operator, device, and item location. Each measurement involves fully mounting and dismounting the item, while also subjecting the gage to a full range of normal use.

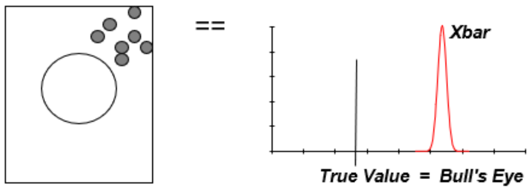
A sample size of 25 or more measurements is generally considered adequate to capture the variability in the measurement process. However, it's important to note that the more samples taken, the better the understanding of the measurement system's behavior.

For this test we calculate the mean – $\bar{x}$, and the standard deviation – s

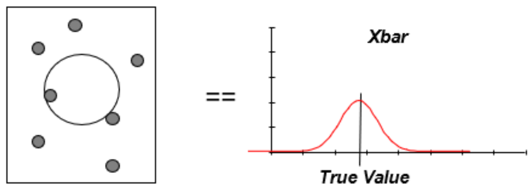
Device precision should ideally be less than 1/10 of the tolerance ($s < 1/10 \times$ tolerance). If the standard deviation (s) exceeds 1/10 x tolerance, the measurement system is deemed unacceptable due to a lack of precision. In such instances, it's imperative to identify and rectify sources of error, which may involve replacing the device

Device accuracy can be estimated by comparing the measured values to the true value of the test unit. The inaccuracy, or bias, can be calculated as (Inaccuracy (Bias) = Measured Value - True Value)

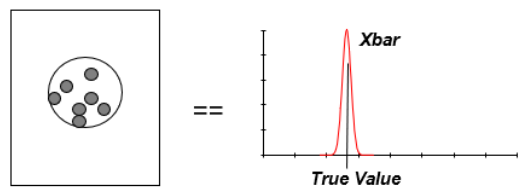
<u>Precision Vs. Accuracy - Target Analogy</u>



I. Precise, not accurate



II. Accurate, not precise



III. Precise and accurate

Sampling:

What is Sampling:

- Sampling involves the selection of units from a population.
- The aim is to ensure that the sample accurately represents the population.
- Sampling helps save time, money, and effort by reducing the amount of data needed.

Population:

- The population refers to the complete set of data, the universal set, often denoted by the symbol "N".
- The population mean is represented by "μ"
- Standard deviation is represented by the symbol "σ"

Sample:

- A sample is a part or subset of a population.
- The sample mean is represented by the symbol "$\bar{x}$".
- The standard deviation is represented by the symbol "s".

When do we sample:

- When the cost associated with data collection is high.
- When the time required to collect all the data is significant.
- When measuring a high-volume process.
- If there's doubt that a sample may not truly represent the process – DO NOT SAMPLE.

To make sure that a sample represents the population:

- Understand the nature of the process thoroughly.
- Familiarize yourself with the characteristics of the population.
- Employ a sampling strategy that aligns with the process.

Suggestions:

- It's preferable to collect a small sample spread over a longer time period than to gather one large sample over a shorter time period.
- Sample more frequently for unstable processes and less frequently for stable processes.
- Sample more frequently for processes with short cycle times and less frequently for processes with long cycle times.

Sample Size Calculation

Continuous / Variable Data:

$$n = \frac{1.96 \times \sigma}{\Delta}$$

- σ - standard deviation.
- Δ - error/precision required in truly representing the population.
- n - sample size
- This equation is for a 95% confidence interval

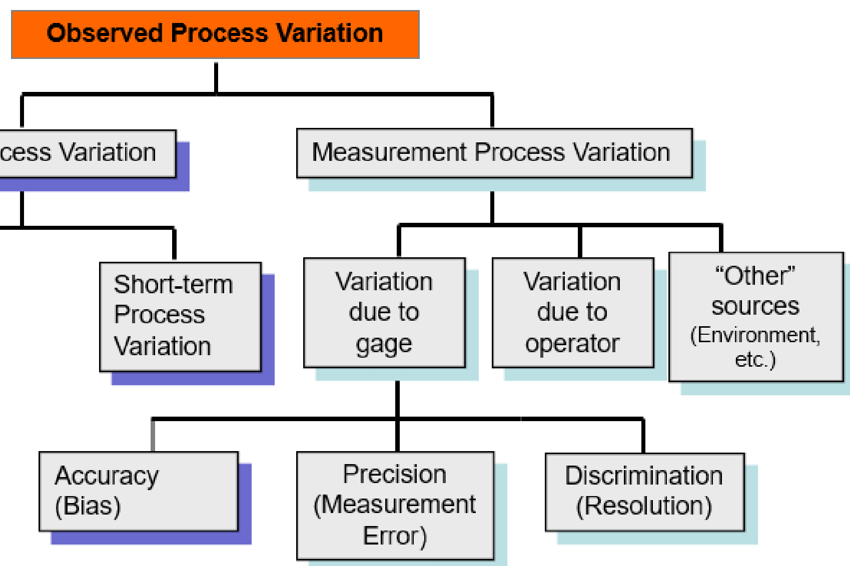
Discrete / Attribute Data:

$$n = \frac{1.96}{\Delta} \times P \times (1-P)$$

- P - proportionate defective.
- Δ - error/precision required in truly representing the population.
- n - sample size
- This equation is for a 95% confidence interval

As the final point, the observed variation of a product or process comprises:

- The inherent variation of the product/process itself.
- The variation introduced by the measurement system.



This article brings the Measure phase to a close at a high level.