

Philosophies and frameworks for Quality management, 7 QC tools

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Why Quality ?

Share your personal experiences of being annoyed by “poor quality.”

Customer/Quality is King !

Quality is King


“While a top manager should be the ideal customer, he should also be the greatest critic of his company’s products. If the CEO compromises, or is only looking at the margins, then even if he is successful, the company’s success will be short lived.”

—Ratan Tata, Chairman, Tata Group

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Importance of Quality

“No quality, no sales. No sale, no profit. No profit, no jobs.”

Today “quality” is the watchword for the survival and growth of any organization in the global business environment

Things done right 99.9% of the time means: Still

- **One hour of unsafe drinking water per month**
- **Roughly Two unsafe landings at Delhi Airport each day**
- **16,000 lost pieces of mail per hour**
- **20,000 incorrect drug prescriptions per year**
- **500 incorrect surgical operations per week**
- **50 newborn babies dropped each day by doctors**
- **22,000 cheques per hour deducted from wrong accounts**
- **32,000 missed heartbeats per person each year**



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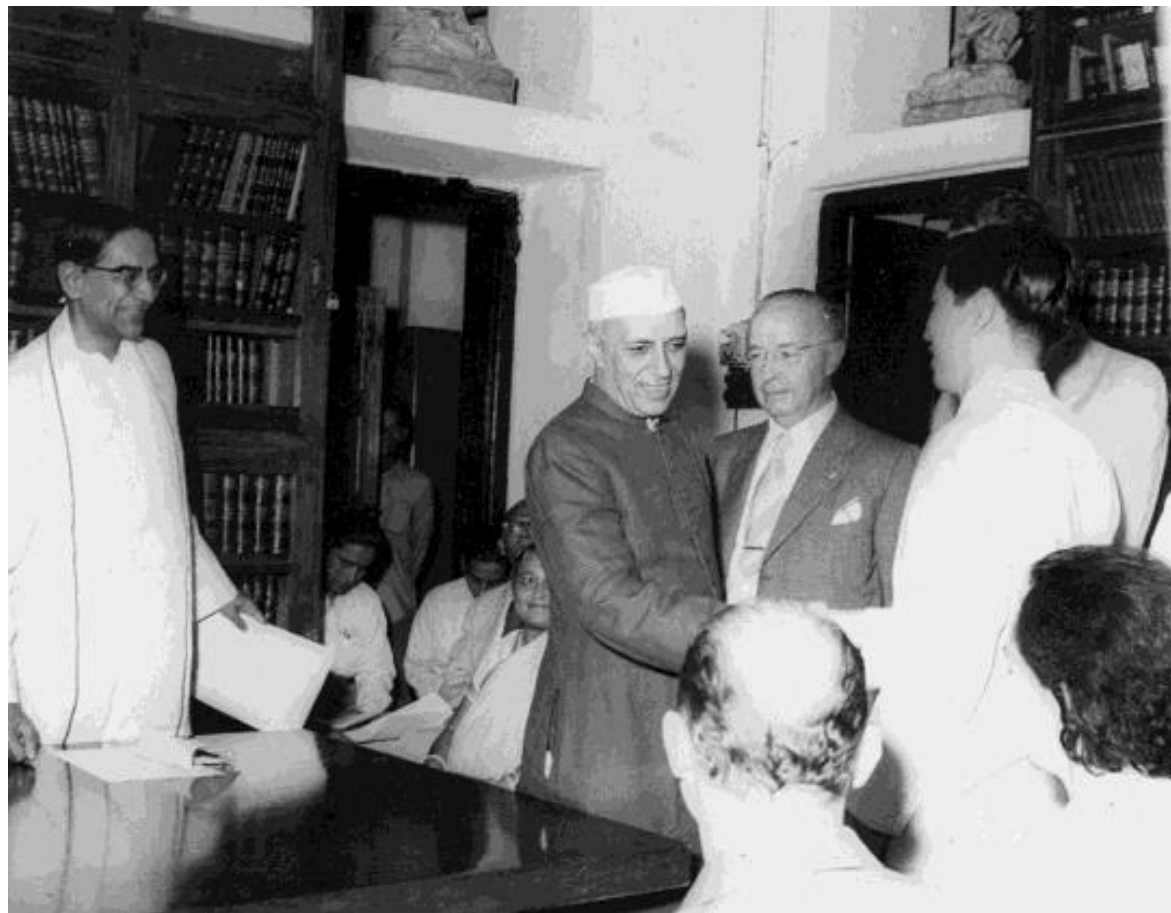
What is Quality ?

What is Quality Management ?

Quality Movement in India



- Prof. P. C. Mahalanobis set up the Statistical Laboratory in the Presidency College sometime in the 1920s. In the year 1931 Indian Statistical Institute was founded.
- Before India gained independence in the year 1947, quality was practiced in quite an informal way
- Dr. Walter Shewhart visited India in 1947-48 under the sponsorship of Prof. Mahalanobis of ISI. During his stay of 3 months, Dr. Shewhart toured the country, held conferences and stimulated interest in statistical quality control among Indian industrialists.
- In 1960s the public sector companies led by Department of Space, Atomic Energy and later followed by Bharat Heavy Electricals (BHEL) and Steel Authority of India Ltd. (SAIL) initiated formal quality measures.



Standing from left to right, P.C.Mahalanobis, Pandit Jawaharlal Nehru (then Indian Prime Minister), Walter A. Shewhart (Known as father of Quality Control) and Genichi Taguchi (Shaking Hands with the Prime Minister) at ISI, Calcutta (now Kolkata), in 1954

Source: Book titled “ THE MAHALANOBIS-TAGUCHI STRATEGY” by GENICHI TAGUCHI , RAJESH JUGULUM

Quality Movement in India

- Quality movement was further consolidated in the 1980s with the efforts of Confederation of Indian Industries (CII). Large scale application of quality tools in private industry sectors was steered through other industry associations like FICCI (Federation of Indian Chambers of Commerce and Industry) and ASSOCHAM.
- Prof. Ishikawa, the founder of quality movement in Japan was invited by CII in year 1986 when he addressed the first National Conference for Top Management on TQC in India.
- Similar seminar was addressed by Dr. Juran in year 1987.
- Year 1987 also brought the ISO 9000 standards into reality and several organizations

❖ Meaning of Quality:

Q = Quest for excellence of knowledge

U = Understanding customer's need

A = Action to achieve customer's demand

L = Leadership quality

I = Involving all people

T = Team spirit to work for a common goal

Y = Yardstick to measure progress

❖ Defining Quality:

- When the expression “**quality**” is used, we usually think in terms of an **excellent product or service** that fulfills our expectations.
- These expectations are based on the intended use and the selling price.
- Companies offering a powerful combination of **low prices and high quality** are capturing the hearts and wallets of consumers.
- They are moving from competing on price to providing quality, service and convenience.

$$Q = \frac{P}{E}$$

Where,

Q = Quality

P = Performance

E = Expectations

- ✓ If Q is greater than 1.0, then the customer has a good feeling about the product or service.

What is Quality?

$$Q = P/E$$

Where P is Performance and E is Expectations

$Q < 1$ Performance does not meet expectations

$Q = 1$ Performance equals expectations

$Q > 1$ performance is better than expectations

What is Quality?

- According to ISO 9000:2015 , "The quality of an organization's products and services is determined by the ability to satisfy customers and the intended and unintended impact on relevant interested parties.
- The quality of products and services includes not only their intended function and performance but also their perceived value and benefit to customer."

❖ **How do you, as a consumer, evaluate quality?**

One approach which consumers use to evaluate quality is to cite attributes of the product or its product delivery process.

Ex. If someone were to ask you to judge the quality of a personal computer, you might reply by citing such thing as: the way it looks, how long it took to set up, how long it takes to boot up, etc.

For the customer – a rightful level of expectation to buy high quality products at the lowest possible cost.

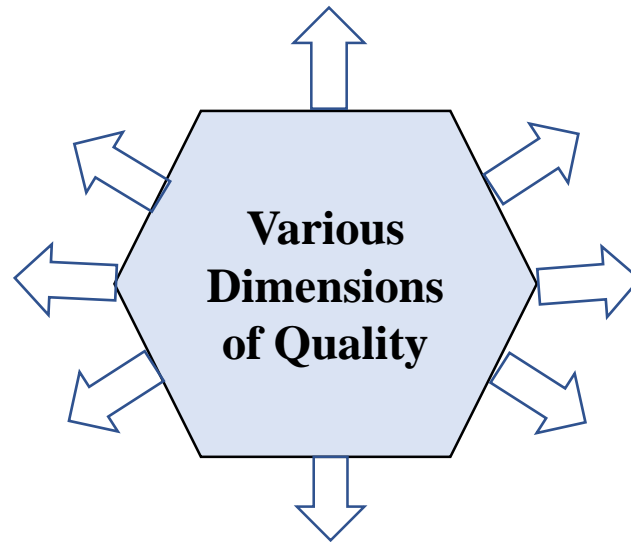
For the provider – a rightful level of expectation to produce quality products at the highest possible profit.

Safety: How much care has the company taken to make the product safe for users before, during or after use? **Ex.** a TV having features to protect the eyes of viewers from harmful radiations.

Customer Service: How is the behavior of the seller with the customer before, during, and after the sale of the product? **Ex.** treatment given by the sales staff may prompt a customer to buy another TV of the same brand from the same dealer.

Appearance: How pleasant is the outward look, smell, taste, feel or sound of the product? **Ex.** super-thin flat TV (which can be hung on a wall like a picture).

Performance: How does the product perform with respect to its intended use? **Ex.** good pictures & sound effects of a TV.



Durability: How long can the product perform well without substantial repair or replacement of parts? **Ex.** performance of a TV for 10 years without needing any repair.

Features: What special features does the product have? **Ex.** 1200 Watt of sound, remote control, picture tube etc.

Reliability: How much is the probability of breakdowns, replacement of parts, etc.? **Ex.** a TV performing well every time it is switched on.

Serviceability: How easily, cheaply, and speedily can the product be repaired and serviced? **Ex.** a company providing on-spot repairs of TVs within 1 hour of customer complaint at nominal charges.

Definition

Quality means fitness for use.

- This is a traditional definition
- Quality of design
- Quality of conformance

Other definitions of quality

1. Conformance to requirements (Crosby, 1979)
2. Fitness for use (Juran, 1979)
3. Continual improvement (Deming, 1982)
4. As defined by the customers (Ford, 1984; 1990)
5. Loss to society (Taguchi, 1987)
6. Six Sigma (Harry and Stewart—Motorola, 1988)
7. Zero defects (Crosby, 1979)
8. Meeting and exceeding present and future requirements of customer on a continuous basis (Charantimath, 2006)

CRITICAL THINKING ACTIVITY

Have We Spoiled Customers?

*“If you want to understand how the worldwide quality movement has benefited consumers, just look at automobiles. **What used to be considered a luxury option is now just standard,**” said one quality manager. “That is precisely the problem,” said another quality manager, **“We have spoiled the consumer. Now customers will never be happy no matter what we do.”** Join this debate. What is your opinion concerning the following questions?*

- 1. Are consumers spoiled and unrealistic in their expectations, or are they finally demanding their rights in the marketplace?*
- 2. How has the worldwide demand for quality driven the concept of innovation? How has innovation changed your life?*

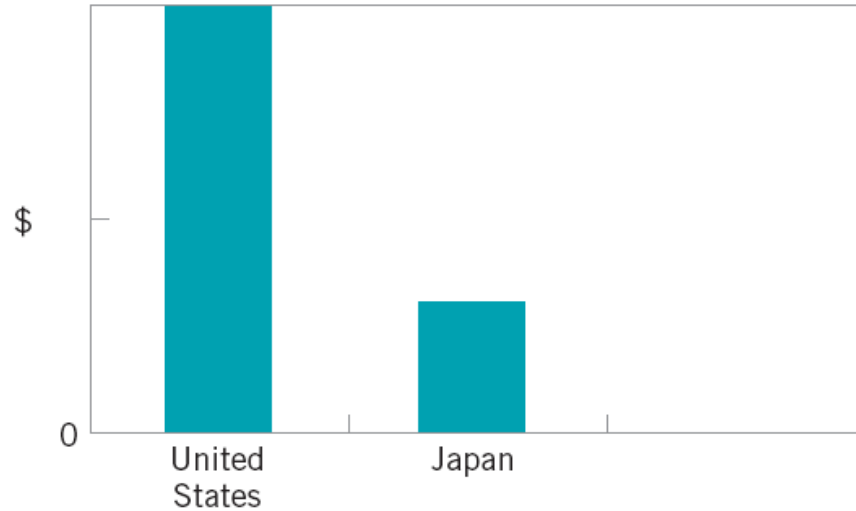


Definition

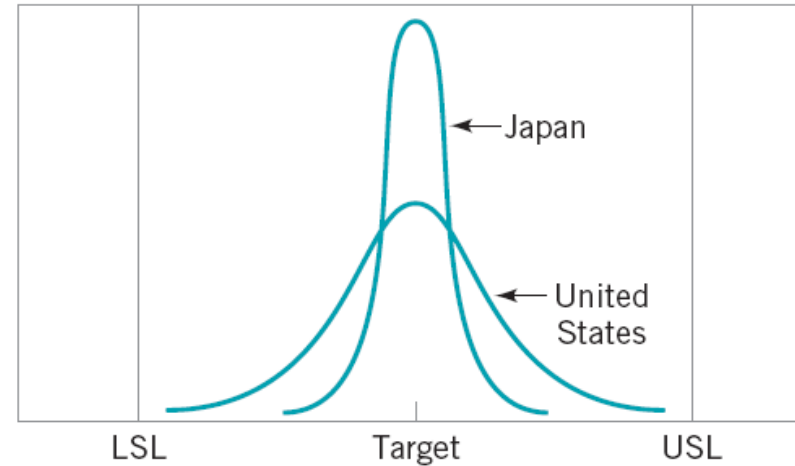
Quality is inversely proportional to variability.

This is a modern definition of quality

The Transmission Example



■ **FIGURE 1.1** Warranty costs for transmissions.



■ **FIGURE 1.2** Distributions of critical dimensions for transmissions.

A few years ago, one of the automobile companies in the United States performed a comparative study of a transmission that was manufactured in a domestic plant and by a Japanese supplier. An analysis of warranty claims and repair costs indicated that there was a striking difference between the two sources of production, with the Japanese-produced transmission having much lower costs, as shown in Fig. 1.1.

Definition

Quality improvement is the reduction of variability in processes and products.

- The transmission example illustrates the utility of this definition
- An equivalent definition is that quality improvement is the **elimination of waste**. This is useful in service or transactional businesses.

Why “Quality Improvement” is Important: A Simple Example

- A visit to a fast-food store: Hamburger (bun, meat, special sauce, cheese, pickle, onion, lettuce, tomato), fries, and drink.
- This product has 10 components - is 99% good okay?

$$P\{\text{Single meal good}\} = (0.99)^{10} = 0.9044$$

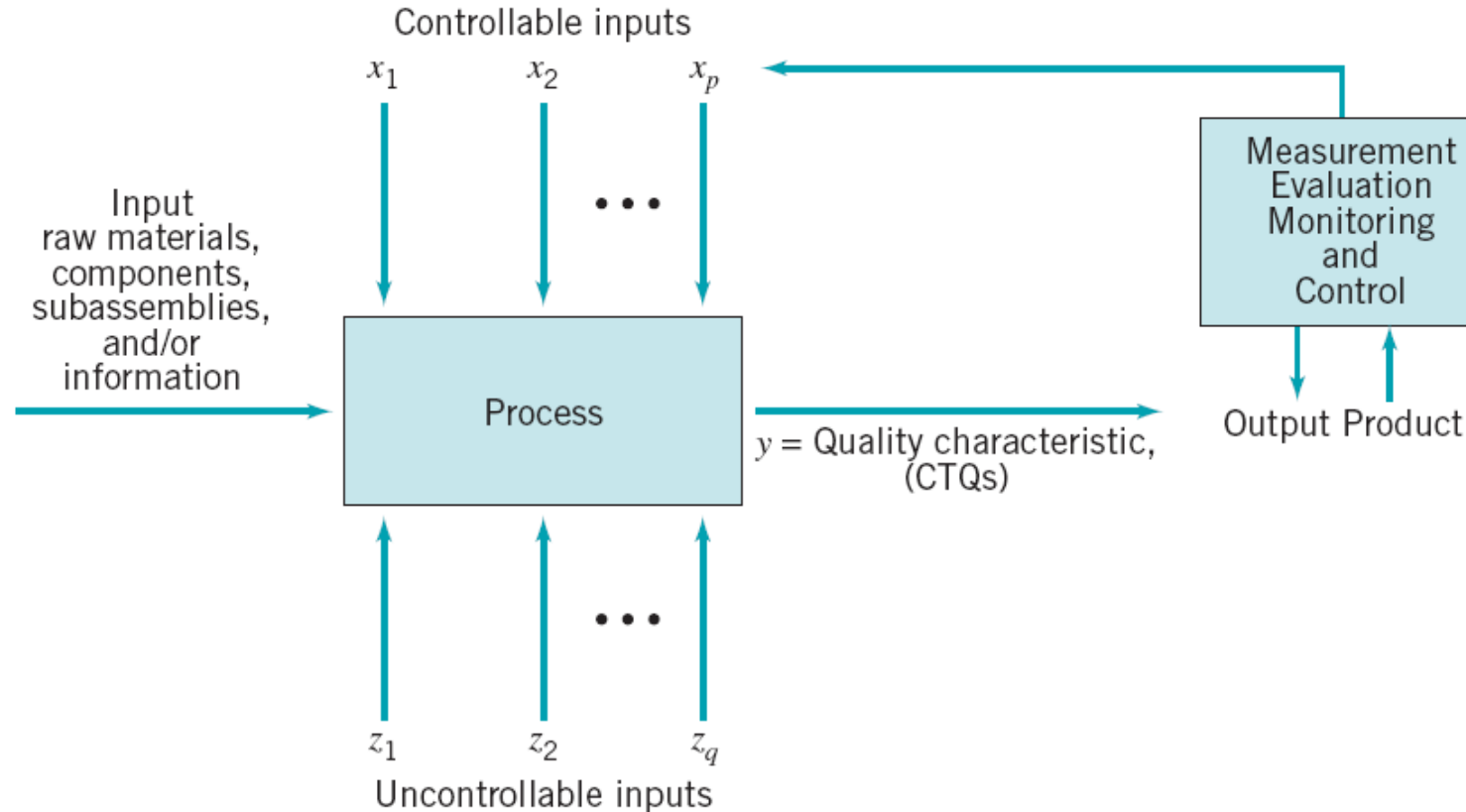
$$\text{Family of four, once a month: } P\{\text{All meals good}\} = (0.9044)^4 = 0.6690$$

$$P\{\text{All visits during the year good}\} = (0.6690)^{12} = 0.0080$$

$$P\{\text{single meal good}\} = (0.999)^{10} = 0.9900, P\{\text{Monthly visit good}\} = (0.99)^4 = 0.9607$$

$$P\{\text{All visits in the year good}\} = (0.9607)^{12} = 0.6186$$

Statistical Methods for Quality Control and Improvement



■ **FIGURE 1.3** Production process inputs and outputs.



❖ Total Quality Management (TQM):

- TQM is the art of managing the whole to achieve excellence. Quality management is a company activity involving various functional departments. **For ex.**
 - Marketing department
 - Purchasing department
 - Store department
 - Manufacturing department
 - Quality control department
 - Packaging department
 - Shipping department
- Therefore, quality is everybody's job in a business.

What is TQM?

- Total Quality Management (TQM) is an enhancement to the traditional way of doing business. It is a proven technique to guarantee survival in world-class competition. Only by changing the actions of management will the culture and actions of an entire organization be transformed.
- Analysing the three words, we have
 - *Total*—Made up of the whole.
 - *Quality*—Degree of excellence a product or service provides.
 - *Management*—Act, art, or manner of handling, controlling, directing, etc.
- Thus TQM is the art of managing the whole to achieve excellence.

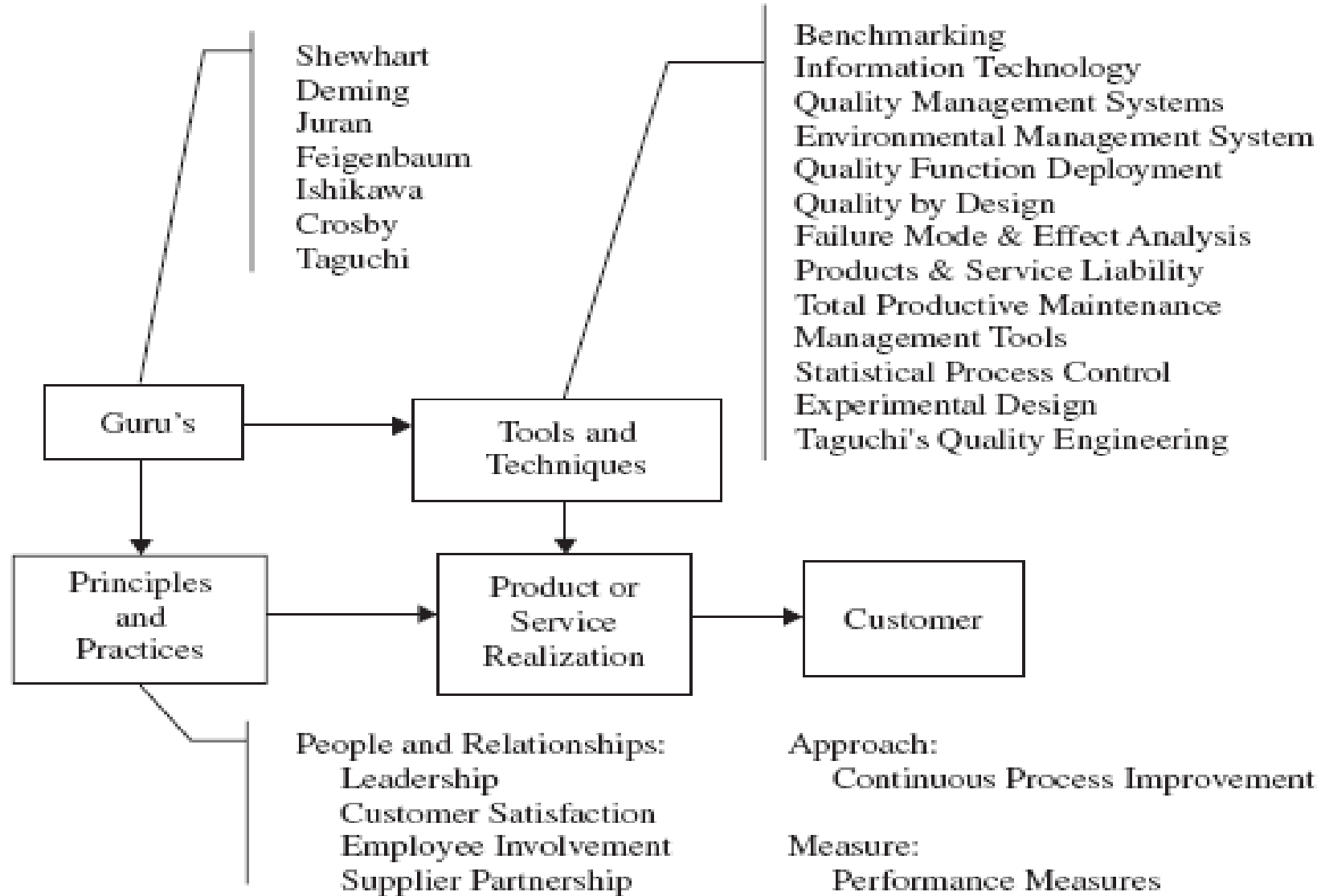
❖ TQM Six Basic Concepts:

1. A committed and involved management to provide long-term top-to-bottom organizational support.
2. An unwavering focus on the customer, both internally and externally.
3. Effective involvement and utilization of the entire work force.
4. **Continuous improvement of the business and production process.**
5. Treating suppliers as partners.
6. Establish performance measures for the processes.

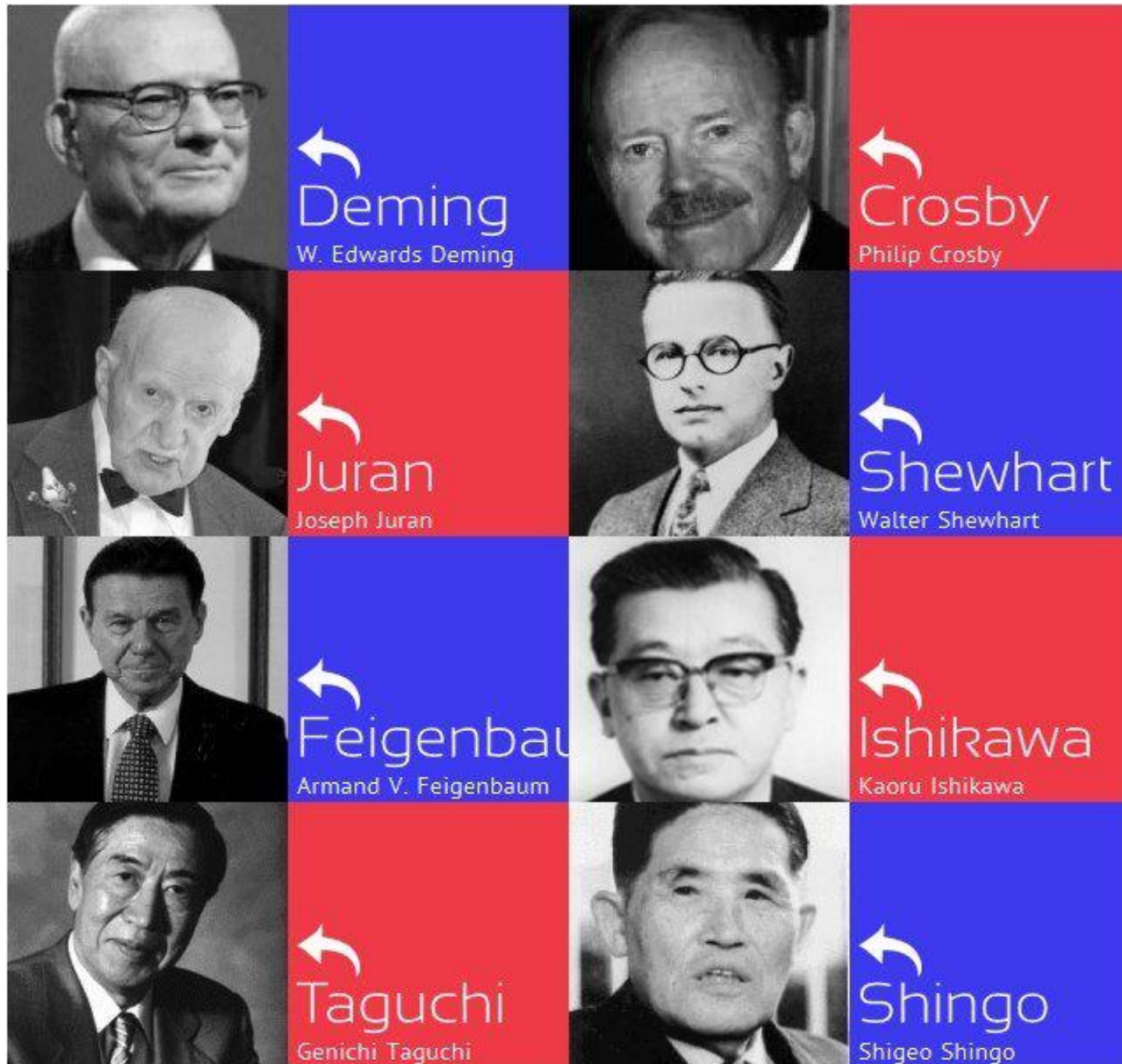
❖ **New and Old Cultures:**

Quality Element	Previous State	TQM
Definition	Product -oriented	Customer-oriented
Decisions	Short-term	Long-term
Emphasis	Detection	Prevention
Errors	Operations	System
Responsibility	Quality control	Everyone
Problem solving	Managers	Team
Manager's role	Plan, assign, control, and enforce	Coach, facilitate, and mentor

TQM Framework



❖ Quality Gurus:



Quality Gurus and their major contribution

Shewhart	Statistical Process Control
Ronald Fisher	Design of Experiments
Deming	14-points for Management
Juran	Juran Trilogy
Taguchi	Robust Design
Ishikawa	Quality Tools, Fishbone Diagram
Crosby	Zero Defect, "Quality is Free", Cost of Poor Quality

Benefits of TQM

- Improved quality and productivity
- Better employee participation and teamwork
- Better customer and employee satisfactions
- Increase in market share and profitability
- Improved communication
- TQM is a good investment according to study by Hendricks and Singhai
 - They studied 600 organizations and showed that there is strong linkage between TQM and financial performance

❖ Obstacles or Barriers of TQM:

- **Lack of management commitment:** In order for any organizational effort to succeed, there must be a substantial management commitment of management time and organizational resources. The purpose must be clearly and continuously communicated to all personnel.

- **Inability to change organizational culture:** Changing an organization's culture is difficult and will require as much as five years. Management must understand and utilize the basic concepts of change. They are –
 - People change when they want to and to meet their own needs.
 - For change to be accepted, people must be moved from a state of fear to trust.

- ✓ It is difficult for individuals to change their way of doing things; it is much more difficult for an organization to make a cultural change.

- **Improper planning:** All constituents of the organization must be involved in the development of the implementation plan and any modifications that occur as the plan evolves. Of particular importance is the two-way communication of ideas by all personnel during the development of the plan and its implementation.
 - Customer satisfaction should be the goal rather than financial or sales goals.
 - Blue Dart Express Ltd. has improved their on-time delivery performance to 99.96% and introduced several value-added services like “full money back guarantee” with their customer focus.

- **Lack of continuous training and education:** Training and education is an ongoing process for everyone in the organization. Needs must be determined and a plan developed to achieve those needs.
 - Training and education are most effective when senior management conducts the training on the principles of TQM.

- **Incompatible organizational structure and isolated individuals and departments:** Differences between departments and individuals can create implementation problems. The use of multifunctional teams will help to break down long-standing barriers.
 - Restructuring to make the organization more responsive to customer needs may be needed.

- **Ineffective measurement techniques and lack of access to data and results:** Key characteristics of the organization should be measured so that effective decisions can be made.
 - In order to improve a process you need to measure the effect of improvement ideas.
 - Access to data and quick retrieval is necessary for effective processes.

- **Paying inadequate attention to internal and external customers:** Organizations need to understand the changing needs and expectations of their customers. Effective feedback mechanisms that provide data for decision making are necessary for this understanding.
 - One way to overcome this obstacle is to give the right people direct access to the customers.

- **Inadequate use of empowerment and teamwork:** Teams need to have the proper training and, at least in the beginning, a facilitator. Whenever possible, the team's recommendations should be followed.
 - Individuals should be empowered to make decisions that affect the efficiency of their process or the satisfaction of their customers.



**TOOLS OF QUALITY- Powerful tools
STATISTICAL PROCESS CONTROL (SPC)**

Seven Magnificent Tools of Quality

Flow chart

Pareto diagram

Cause & effect diagram

Check sheet

Histogram

Scatter diagram

Control charts

❖ Flow Chart:

➤ Purpose –

- How a process works and what it is supposed to do.
- Flow charts are developed by having the people involved in the process – employees, supervisors, managers and customers.
- Whether this process is an administrative or a manufacturing one.
- A facilitator can guide the discussions through questions such as “what happens next?” “who makes the decision at that point? & what operation performed at this point?”
- Every process will require input(s) to complete its task, and will provide output(s) when the task is completed.
- Flow chart can be drawn by using pictures, symbols, or just squares and rectangles.

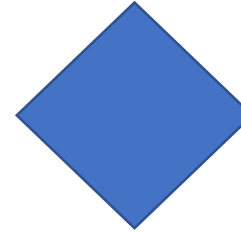
➤ Symbols Used –



Beginning and
ending steps



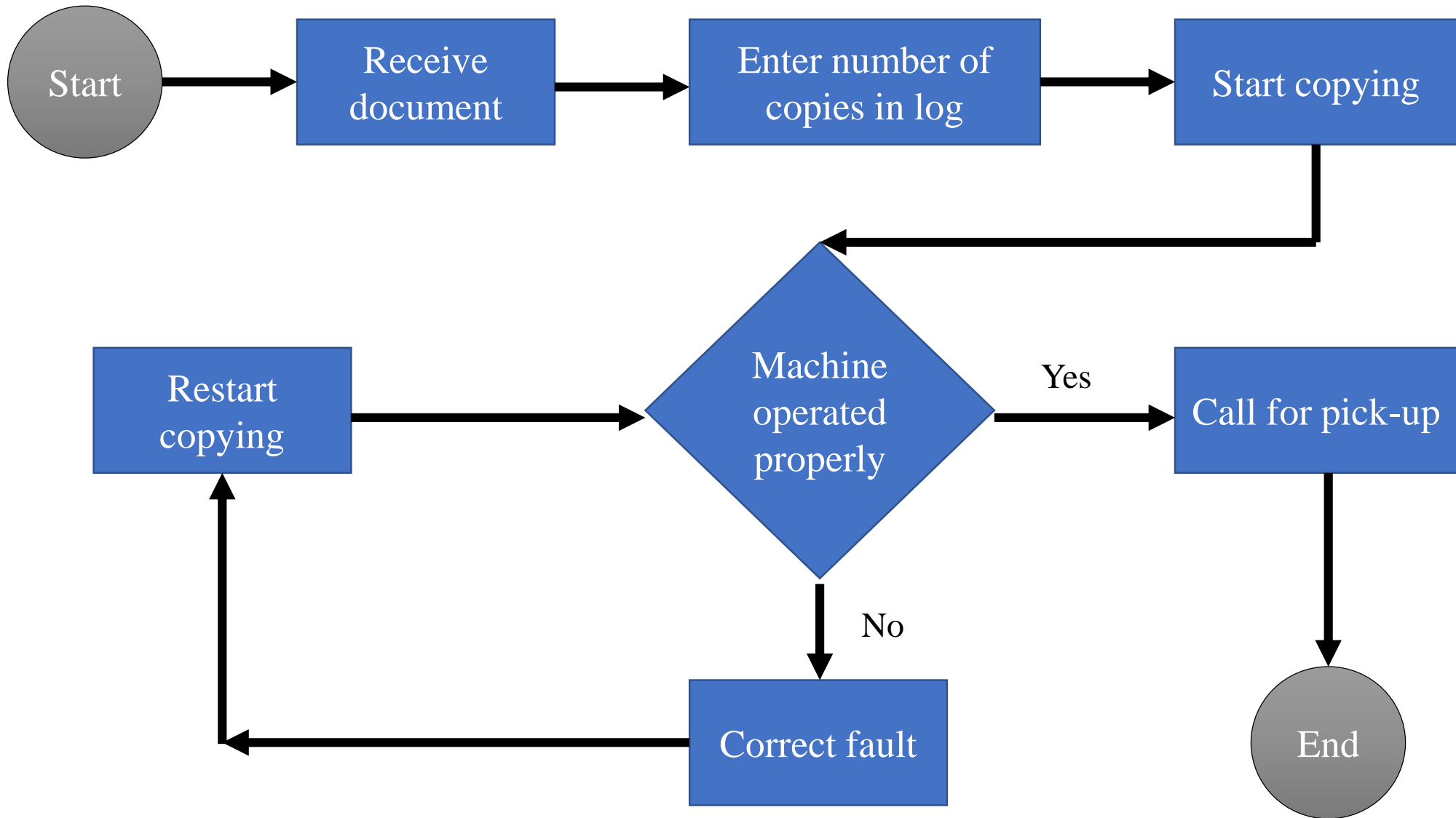
Activity
description



Decision box



To show the direction of flow
from one activity to the next

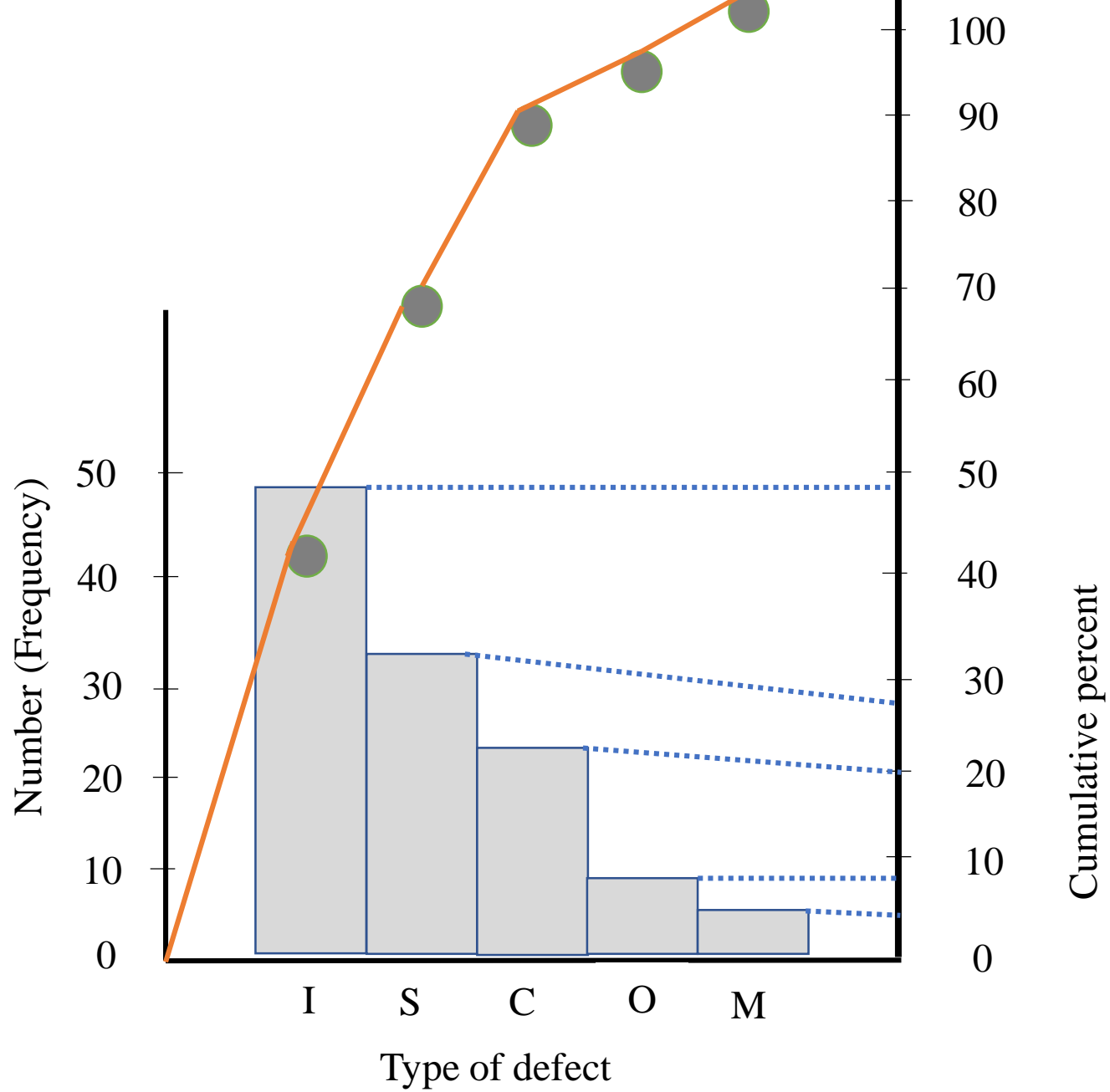


❖ Pareto Diagram:

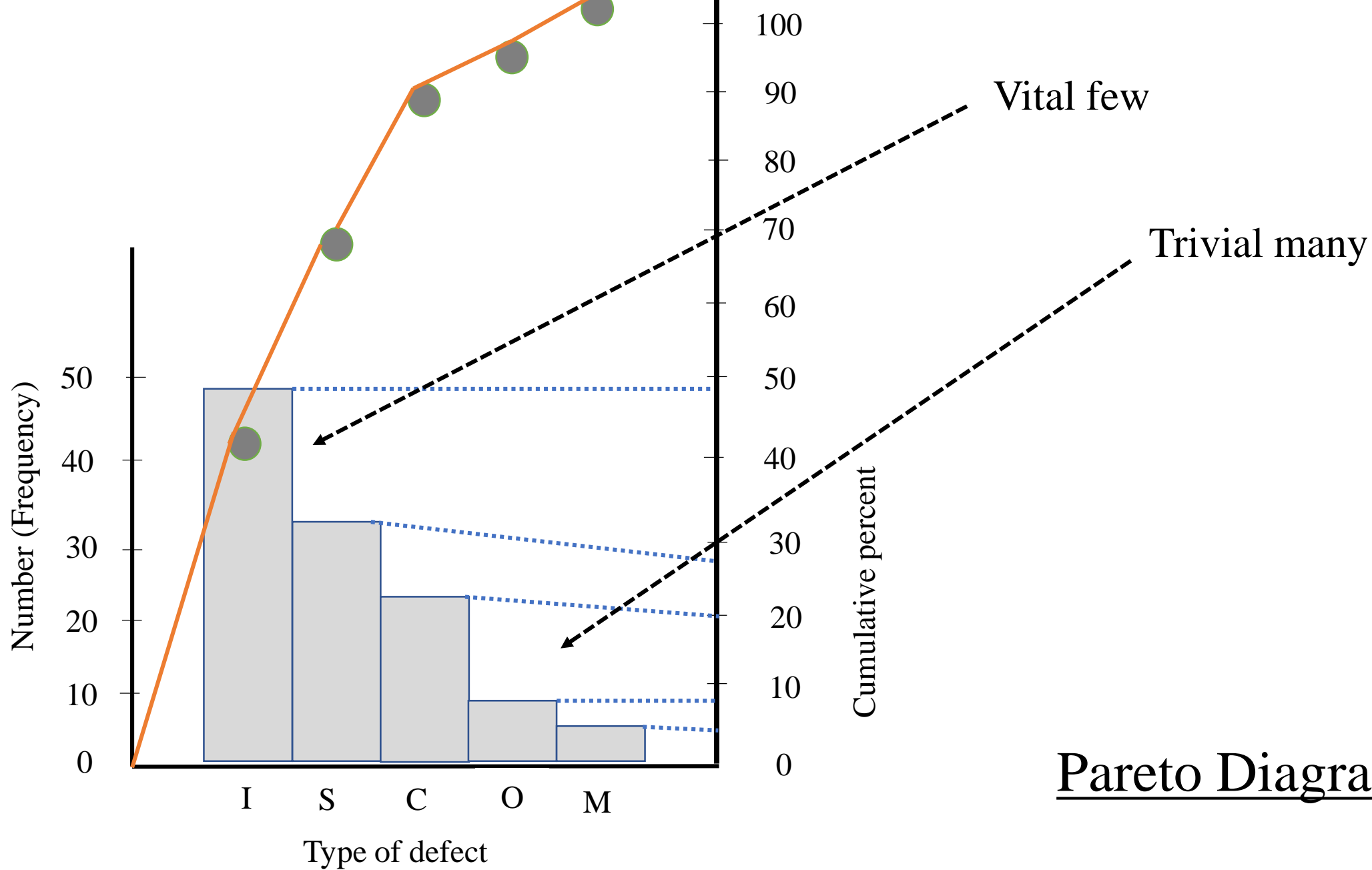
- Pareto released that 80% of the country's wealth was in the hands of 20% of the people.
- This is also called the **80/20** rules.
- Using this theory, we can assume that 80% of problems result from 20% of causes.
- Pareto analysis is a technique based on the Pareto principle of “the **vital few** and **trivial many**.”
- It is a graphical tool for ranking causes from **most significant to least significant** or data classifications in descending order from **left to right**.

Example – Pareto analysis of defective items

Type of defect (X-axis)	Number defectives (Y-axis)	Cumulative defectives (Y-axis)	Cumulative % (Right Y-axis)
Incomplete (I)	48	48	41.73
Surface scars (S)	32	80	69.55
Cracks (C)	23	103	89.55
Others (O)	8	111	96.50
Misshapen (M)	4	115	100
Total	115		



Pareto Diagram



Pareto Diagram

Example –

Cause no.	Share in rejection (%)	Cause no.	Share in rejection (%)	Cause no.	Share in rejection (%)
1	0.04	10	0.01	19	0.20
2	0.12	11	0.02	20	1.90
3	0.03	12	6.00	21	0.50
4	0.05	13	0.02	22	0.80
5	0.01	14	0.13	23	1.40
6	5.60	15	0.07	24	0.14
7	0.30	16	0.12	25	0.06
8	0.10	17	0.03		
9	0.05	18	2.30	Total = 25	20.00

Answer –

Cause no.	Share in rejection (%)	Cumulative share	Cause no.	Share in rejection (%)	Cumulative share
12	6.00	6.00	24	0.14	19.14
6	5.60	11.60	14	0.13	19.27
18	2.30	13.90	2	0.12	19.39
20	1.90	15.80	16	0.12	19.51
23	1.40	17.20	8	0.10	19.61
22	0.80	18.00*	15	0.07	19.68
21	0.50	18.50	25	0.06	19.74
7	0.30	18.80	4	0.05	19.79
19	0.20	19.00*	9	0.05	19.84

- Table shows that out of **20%** rejections, **18%** rejections are due to only **6 causes** (No. 12, 6, 18, 20, 22 & 23).
- And **19%** of rejections are due to only **9 causes**.
- Therefore, efforts should be made to eliminate or to minimize the effect of these 6 or 9 causes only.
- If the control department tries to remove the effect of all the causes, it will require much more labour and money.
- To remove the effect of 6 or 9 causes will be much more economical than to remove the effect of 25 causes.

❖ Cause-and-Effect Diagram / Fishbone Diagram / Ishikawa Diagram:

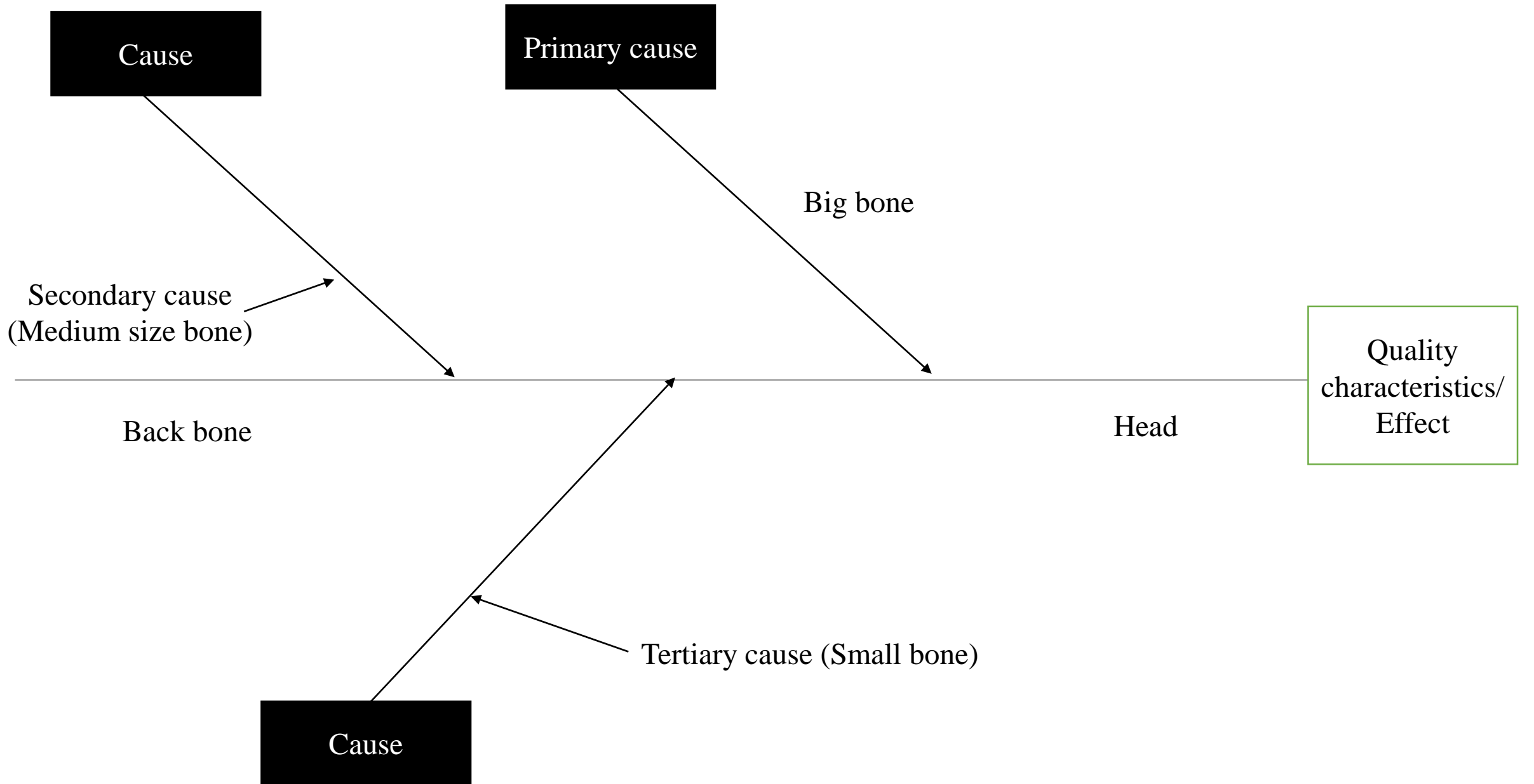
- It is a pictorial presentation in which all possible causes and their effects (problems) are displayed.
- A problem can be due to a variety of reasons or causes.
- The solution to the problem becomes simpler and easier if only true causes for the problem can be identified.
- At the end of the horizontal line, a problem is listed.
- Each branch pointing into the main stem represents a possible cause.

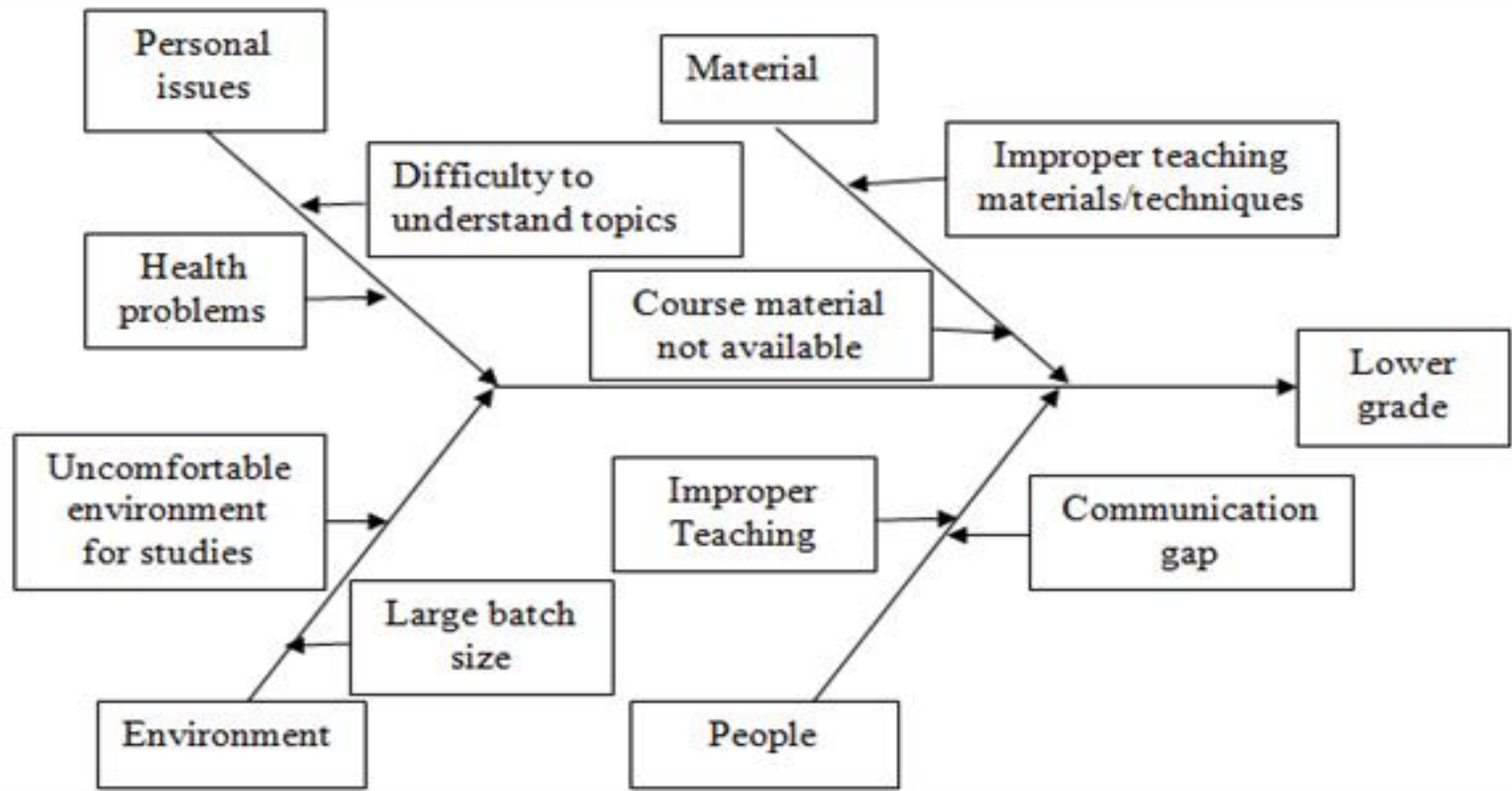
➤ **Construction of Cause-and-Effect Diagram –**

- It is constructed in a brainstorming type of atmosphere.
- Everyone can get involved and feel they are an important part of the problem-solving process.
- Usually small groups drawn from manufacturing or management work with a trained & experienced facilitator.
- The facilitator who listens carefully to the participants can capture the important ideas.

➤ **Steps for Constructing Cause-and-Effect Diagram –**

- 1) Identify what the problem is.
- 2) Draw the backbone from left to right, and write the effect (or problem) in the quality characteristic box (the head of the fish).
- 3) Draw the big bone and write the primary cause.
- 4) Draw the medium size bone & write the secondary cause (sub-cause).
- 5) Draw the small bone & write the tertiary cause.
- 6) Ensure that all causes (factors) which influence the effect (quality characteristic) are displayed in the diagram.





➤ **Solution Finding –**

- The purpose of solution finding is to evaluate ideas that have been proposed and select a method to remove the problem. The following questions are asked –
 - What facilities or equipment are needed?
 - What are the costs?
 - How much time is required for implementation?
 - What is the effect on supervisors and workers?
 - What results are expected?
 - What are the barriers to implementation?

❖ Check Sheets:

- Check sheet is a simple data-recording device.
- The main purpose of check sheets is to ensure that the data is collected carefully and accurately by operating personnel.
- Data should be collected in such a manner that it can be quickly and easily used and analyzed.
- The purpose of collecting data is to either control the production process, to see the relationship between cause-and-effect, or for the continuous improvement of those processes that produce any type of defect.

➤ **Check sheets have the following main functions -**

- Production process distribution checks – where the distribution lies.
- Defective item checks – to determine what kind of defects exist in the process.
- Defective location checks – to determine where the common defects on a part are located.
- Defective cause checks- type of defect and thus validate the cause thereof.
- Check-up confirmation checks – final phase of assembly to check the finished product or work.

- **Data Collection:** There are three primary steps that need to be taken before any data can be collected –
- The first is to establish a purpose for collecting this data. This is based on the quality problem that is going to be investigated.
 - Second, we need to define the type of data that is going to be collected. Data can be collected in two ways: measurable data such as length, height, size, weight, time, etc., and countable data such as the number of defects.
 - The third step is to determine who is going to collect data and when it should be collected.

➤ **Types of Check Sheets –**

1. Defective item check sheet:

- This type of check sheet is used to identify what types of problems or defects are occurring in the process.
- Usually, these check sheets will have a list of the defects or problems that may occur in the process.
- When each sample is taken, a mark is placed in the appropriate column whenever a defect or a problem has been identified.
- The type of data used in the defective item check sheets is countable data.

2. Defective location check sheet:

- This type of check sheets are used to identify the location of the defect on the product.
- Usually, this type of check sheet consists of a picture of the product.
- On this picture, marks can be made to indicate where defects are occurring on the surface of the product.

3. Defective cause check sheet:

- This type of check sheet tries to identify causes of a problem or a defect.
- More than one variable is monitored when collecting data for this type of check sheets.
- For example, we could be collecting data about the type of machine, operator, date, and time on the same check sheet.

		Machine 1	Machine 2
Operator A	Morning	X	X
	Afternoon	XX	XX
Operator B	Morning	X	X
	Afternoon	XX	XX

4. Checkup confirmation check sheet:

- This type of check sheet is used to ensure that proper procedures are being followed.
- These check sheets usually will have a list of tasks that need to be accomplished before the action can be taken.
- Examples of checkup confirmation check sheets are final inspection, machine maintenance, operation checks, and service performance check sheets.

❖ **Histogram:**

- It is used to determine the spread or variation of a set of data points in a graphical form.
- A histogram analyses and graphically displays quantitative data rather than qualitative data.
- Quality practitioners use histograms to display information about process and activity performance.
- Histograms are most effective when they display information with some natural order, such as number of defects found.

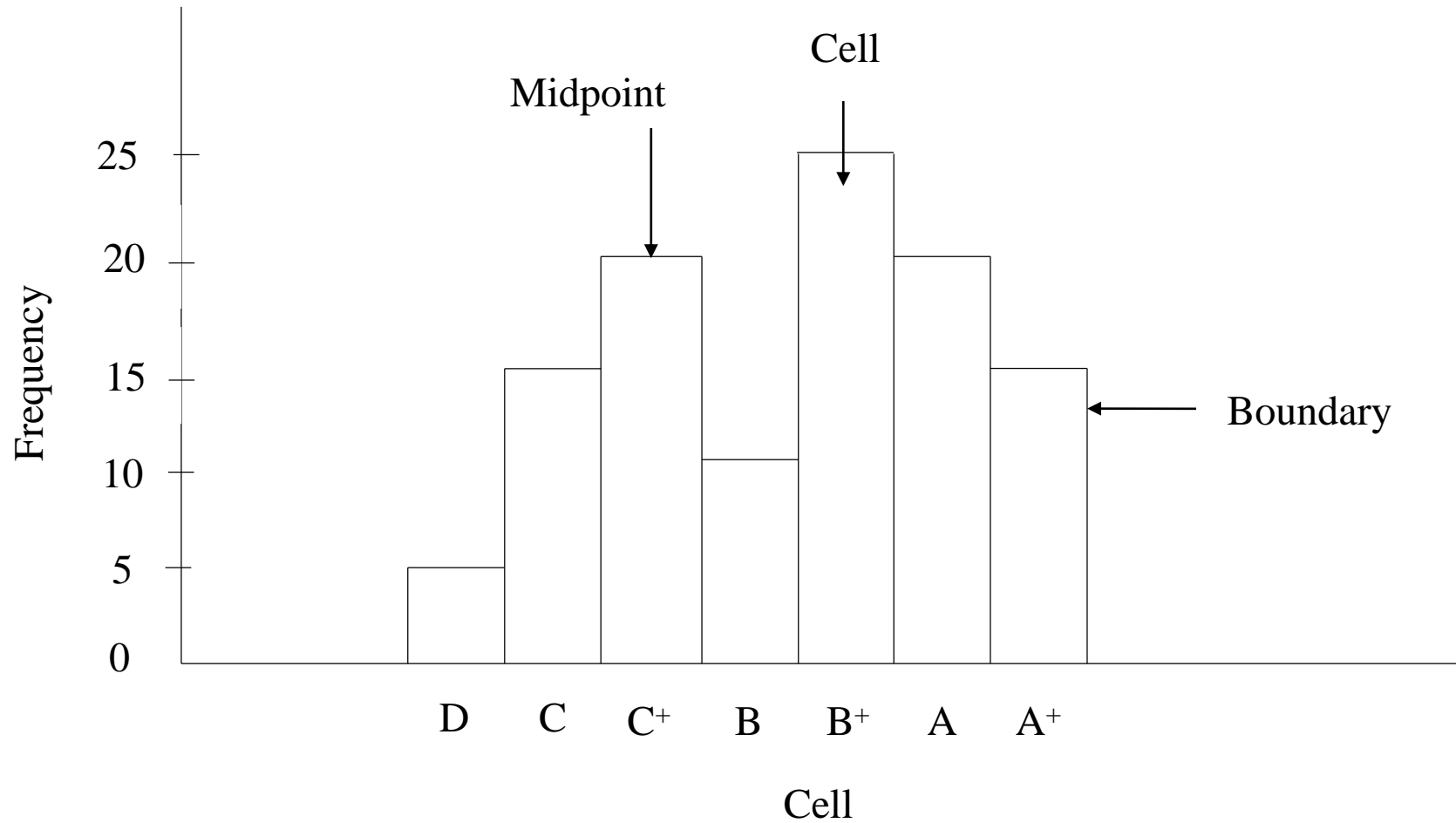
➤ Ungrouped Data:

- Unorganized data are virtually meaningless, a method of processing the data is necessary.
- The first step is to establish an array, which is an arrangement of raw data in ascending or descending order.
- Next step is to tabulate the frequency.

Number of daily defects							
0	1	3	0	1	0	1	0
1	5	4	1	2	1	2	0
1	0	2	0	0	2	0	1
2	1	1	1	2	1	1	
0	4	1	3	1	1	1	
1	3	4	0	0	0	0	
1	3	0	1	2	2	3	

Tally of number of daily defects		
Number nonconforming	Tabulation	Frequency
0		15
1		20
2		8
3		5
4		3
5		1

➤ **Grouped Data:** When the number of categories becomes large, the data are grouped into cells.

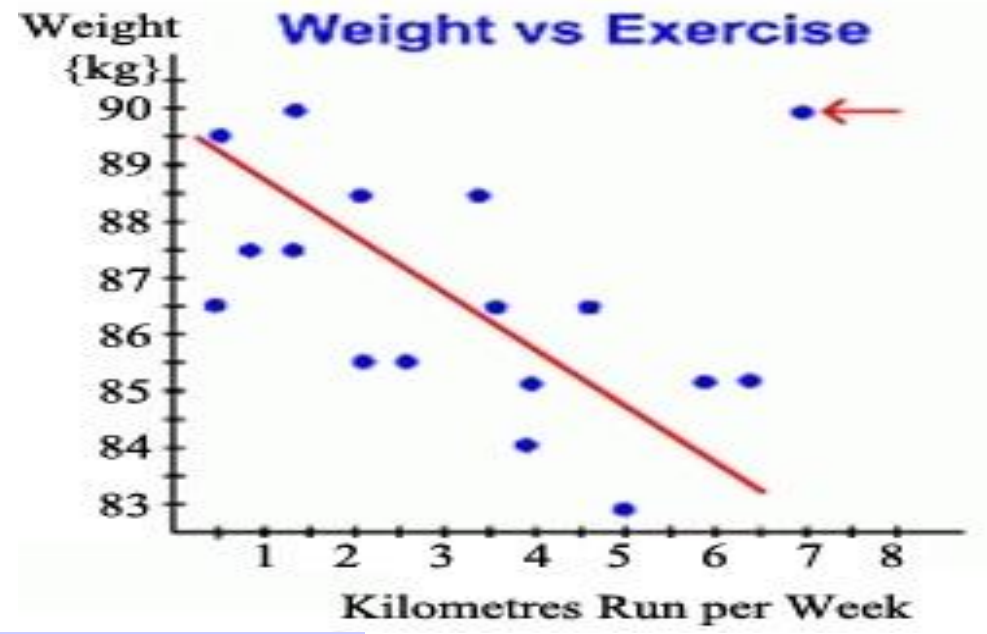
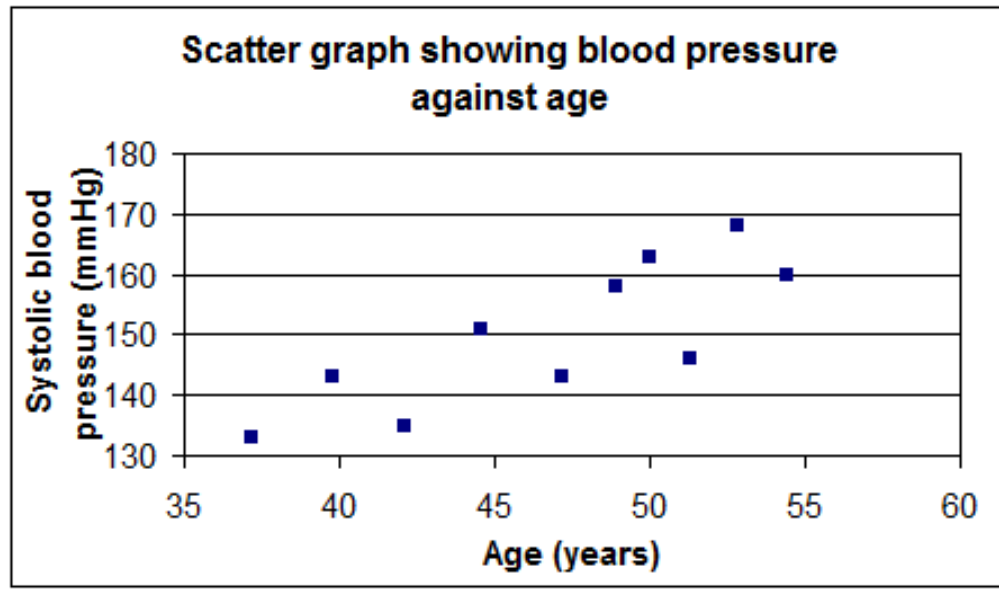


❖ Scatter Diagram:

- The simplest way to determine if a cause-and-effect relationship exists between two variables is to plot a scatter diagram.

Or

- Scatter diagrams are graphical techniques to analyze the relationship between two variables.





Statistical Process Control (SPC)

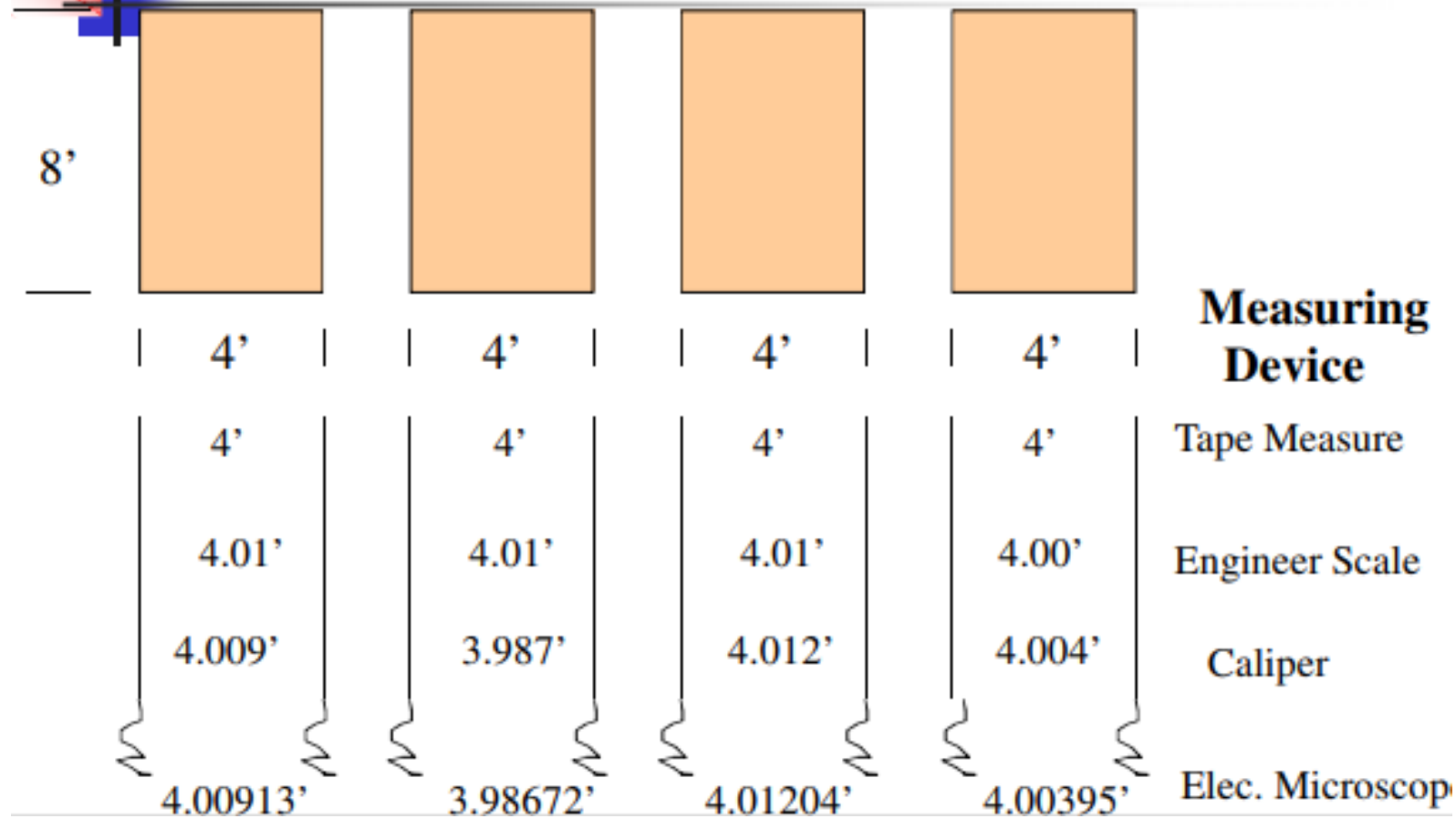
- Need
- Xbar and R charts
- P chart
- C chart
- Applications

Variation



- Variation is natural - it is inherent in the world around us.
- No two products or service experiences are exactly the same.
- With a fine enough gauge, all things can be seen to differ.
- One of the roles of management is work with all employees to reduce variation as much as possible.

The Presence of Variation





Types of Variation

Common Cause Variation: The variation that naturally occurs and is expected in the system

- normal
- random
- inherent
- stable

Special Cause Variation: Variation which is abnormal - indicating something out of the ordinary has happened.

- nonrandom
- unstable



Type of Variation Travel Time to Work - Example

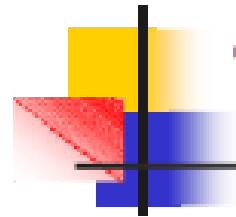
Measurement of Interest: Time to get to work.

Common Cause Variation Sources:

- traffic lights
- traffic patterns
- weather
- departure time

Special Cause Variation Sources:

- accidents
- road construction detours
- petrol refills



Total Product or Process Variation

Total variation = Common Cause + Special Cause

To reduce Total Variation

- First reduce or eliminate special cause variation
- Reduce common cause variation
- Identify the source and remove the causes



Statistical Quality Control

- Measures performance of a process
- Uses mathematics (i.e., statistics)
- Involves collecting, organizing, & interpreting data
- Objective: provide statistical when assignable causes of variation are present
- Used to
 - Control the process as products are produced
 - Inspect samples of finished products



Statistical Process Control (SPC)

- * Statistical technique used to ensure process is making product to standard
- * All process are subject to variability
 - **Natural causes**: Random variations
 - **Assignable causes**: Correctable problems
 - * Machine wear, unskilled workers, poor material
- * Objective: Identify **assignable** causes
- * Uses process control charts

Comparing Distributions

Production Output Example



Plant A	Units Produced	Plant B
99		90
100		90
100		100
100		110
101		110

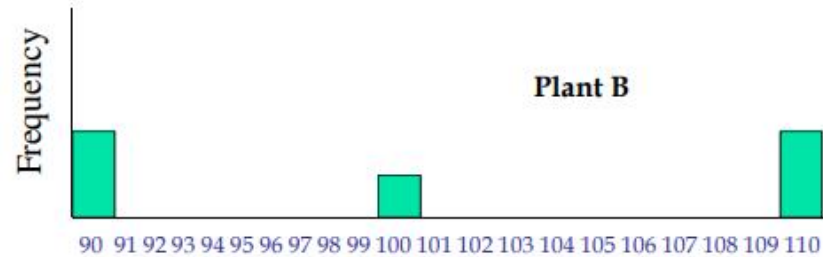
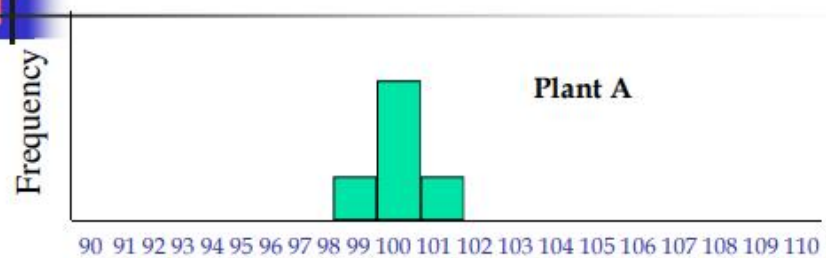
$$\bar{X} = \frac{\sum X}{n} = \frac{500}{5} = 100$$

$$\bar{X} = \frac{\sum X}{n} = \frac{500}{5} = 100$$

No Differences!???

Production Output Distributions

What is the Difference?



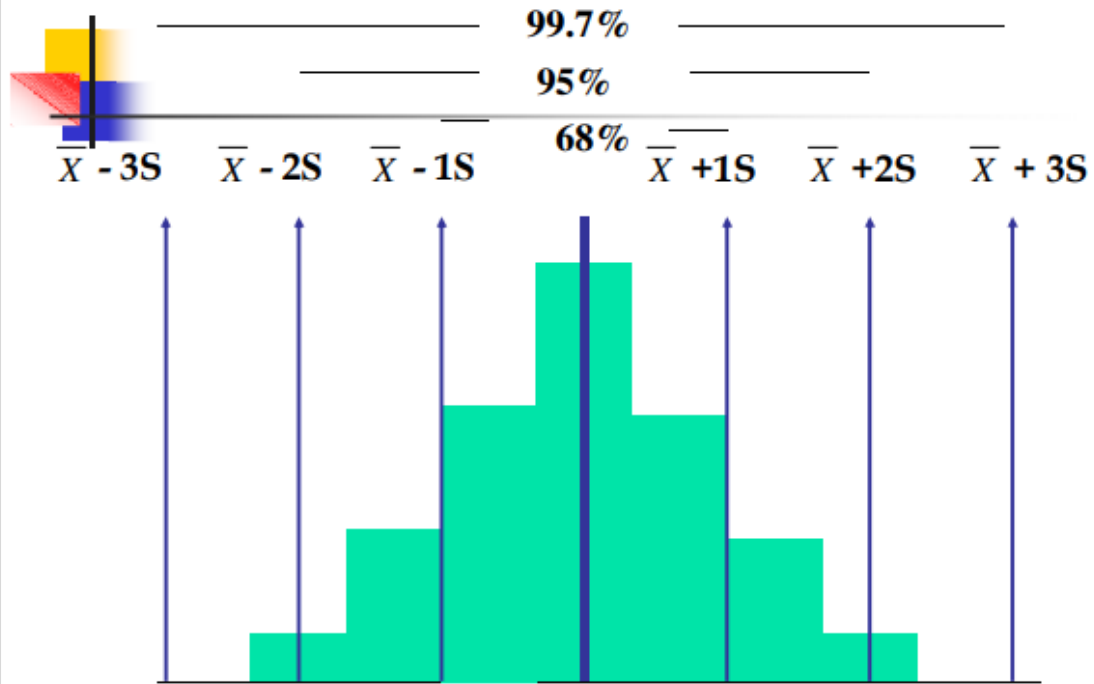
Measure of Variation (Sigma)

S = Standard Deviation

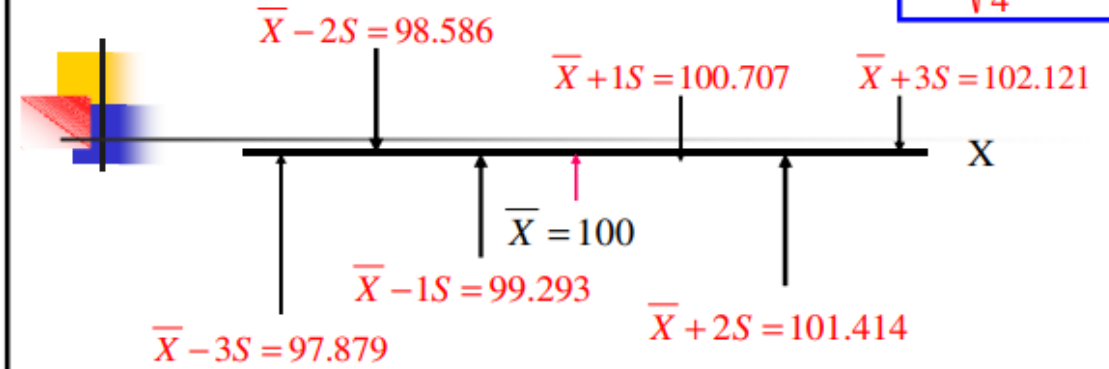
$$S = \sqrt{\frac{\sum (X - \bar{X})^2}{n-1}}$$

Plant A			Plant B		
X	(X - \bar{X})	(X - \bar{X}) ²	X	(X - \bar{X})	(X - \bar{X}) ²
99	99-100 = -1	1 ² = 1	90	90-100 = -10	-10 ² = 100
100	100-100 = 0	0 ² = 0	90	90-100 = -10	-10 ² = 100
100	100-100 = 0	0 ² = 0	100	100-100 = 0	0 ² = 0
100	100-100 = 0	0 ² = 0	110	110-100 = 10	10 ² = 100
101	101-100 = 1	1 ² = 1	110	110-100 = 10	10 ² = 100
$\sum = 0$		$\sum = 2$	$\sum = 0$		$\sum = 400$
$S = \sqrt{\frac{2}{4}} = .707$			$S = \sqrt{\frac{400}{4}} = 10$		

The Concept of Stability



$$S = \sqrt{\frac{2}{4}} = .707$$

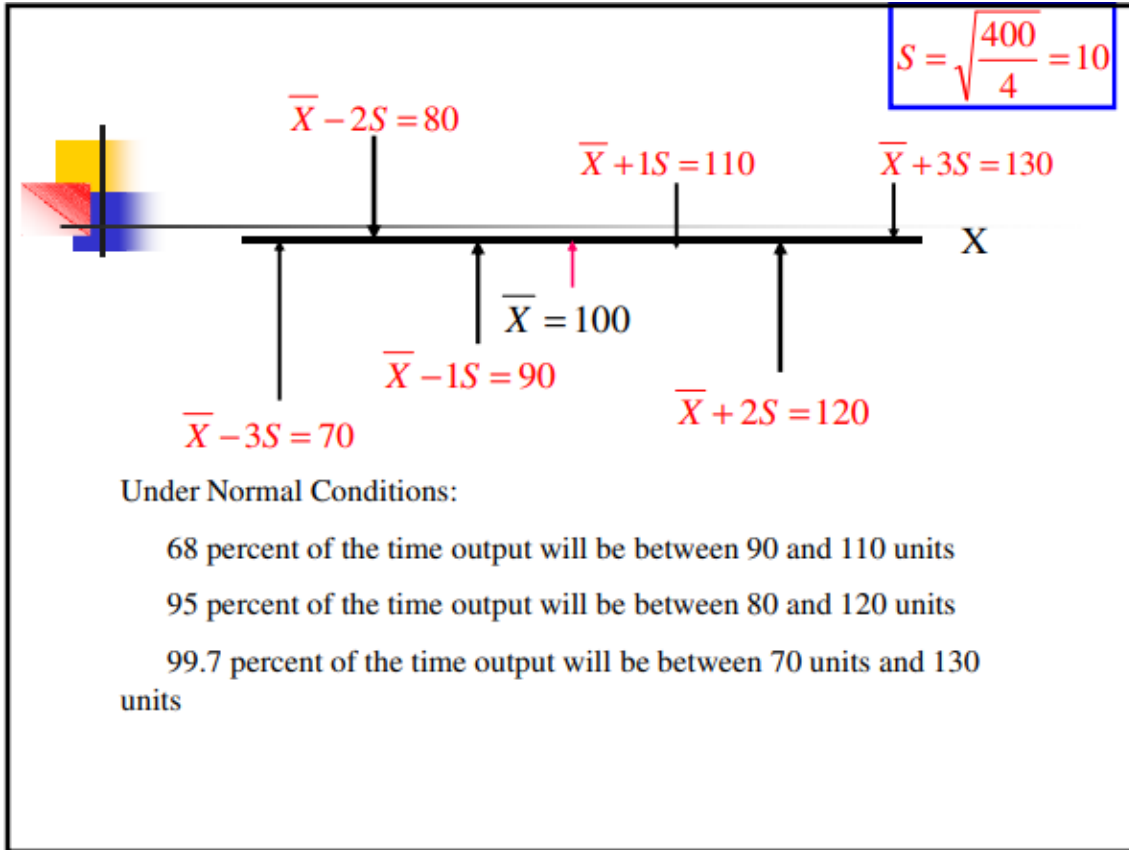


Under Normal Conditions:

68 percent of the time output will be between 99.293 and 100.707 units

95 percent of the time output will be between 98.586 and 101.414 units

99.7 percent of the time output will be between 97.879 units and 102.121 units



Control Limits

Control Limits are the statistical boundaries of a process which define the amount of variation that can be considered as normal or inherent variation

3 sigma control limits are most common

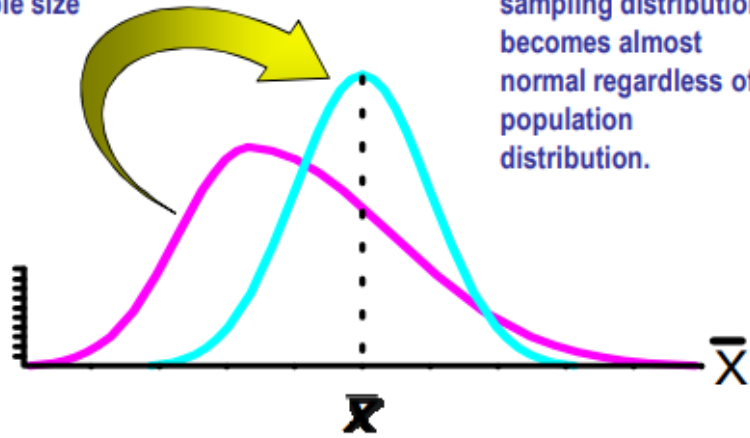
$\pm 3S$ from the mean

If the process is in control, a value outside the control limit will occur only 3 time in 1000 ($1 - .997 = .003$)

Theoretical Basis of Control Charts

Central Limit Theorem

As sample size gets large enough,



Theoretical Basis of Control Charts

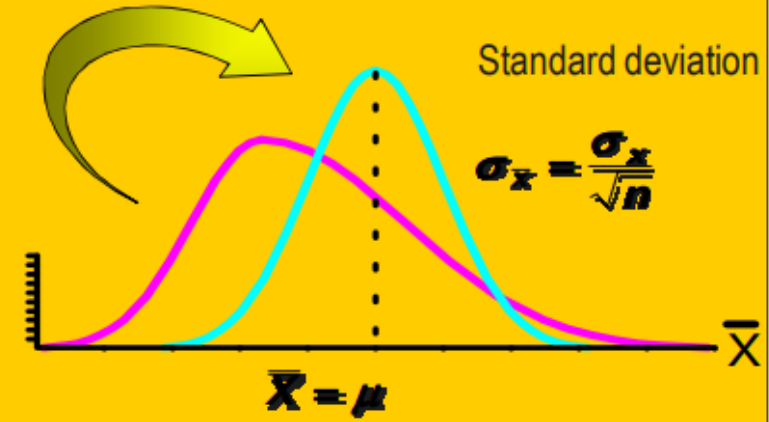
Central Limit Theorem

Mean

$$\bar{\bar{X}} = \mu$$

Standard deviation

$$\sigma_{\bar{X}} = \frac{\sigma_x}{\sqrt{n}}$$



Control Chart Purposes

- * Show changes in data pattern
 - e.g., trends
 - * Make corrections *before* process is out of control
- * Show causes of changes in data
 - Assignable causes
 - * Data outside control limits or trend in data
 - Natural causes
 - * Random variations around average

Control Chart Types

