Engineering Project Management & Finance

(UESTC 3031 & UESTCHN 3012)

Design For Manufacturing

(Part 2)

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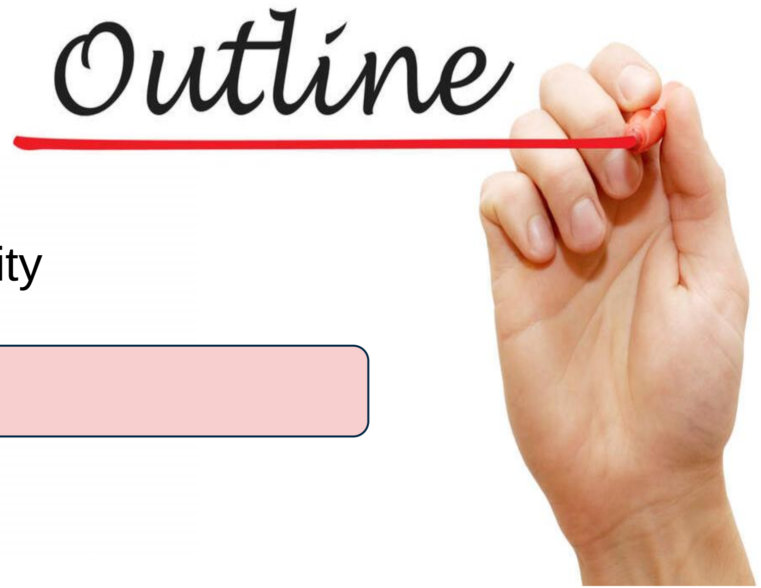


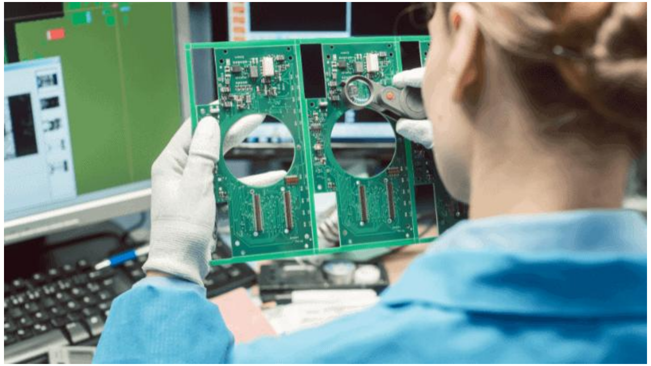
- **Part 1:** Introduction & Design for Sustainability
- **Part 2:** Quality Control & Cost of Quality
- **Part 3:** Robust Manufacturing Design
- **Part 4:** 6-Sigma & Process Capability

Quality Control (QC)

Definition

- Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer.

- QC is similar to, but not identical with, quality assurance (QA).



The goal of QC is to identify any defects after a product is developed, but before it's released.

QC vs QA

- Quality assurance (QA) is a proactive process that focuses on defect prevention by progressively refining manufacturing processes, policies and procedures.
- Quality control (QC) is a reactive process that focuses on effectively identifying defects in completed products before they can be shipped to customers.

Quality Assurance Vs Quality Control

QUALITY ASSURANCE	QUALITY CONTROL
Focus on the prevention of defects	Focus on the identification of defects
Proactive process	Reactive process
Process-based approach	Product-based approach
Manages Quality	Verify the Quality

7-QC Tools

By using seven basic tools of quality, we can manage the quality of our product or process effectively. Known around the world as the seven-quality control (7-QC) tools, they are:

- ✓ Flowchart
- ✓ Check sheet
- ✓ Pareto chart
- ✓ Cause-and-effect diagram
- ✓ Control chart
- ✓ Histogram
- ✓ Scatter diagram

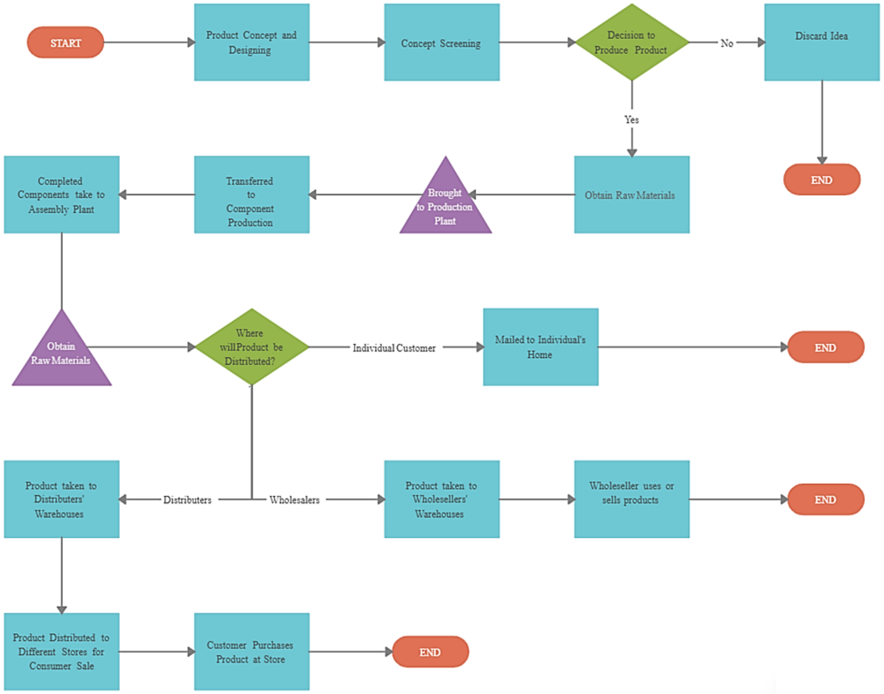
Flowchart

A process flowchart is a diagram that shows the sequential steps of a process and the decisions needed to make the process work. Within the chart/visual representation, every step is indicated by a shape. These shapes are connected by lines and arrows to show the movement and direction of the process.

When to use:

- ✓ To study a process for improvisation
- ✓ To document a process
- ✓ When planning a project

Flowchart
(Examples)



Check Sheet

A check sheet is a structured, prepared form for collecting and analyzing data. This is a generic data collection and analysis tool that can be adapted for a wide variety of purposes and is considered one of the seven basic quality tools.

When to use:

- ✓ When data can be collected and observed by similar location and person
- ✓ When collecting data from a production
- ✓ When collecting data on the pattern of events, problems or defects.

Check Sheet
(Examples)

Tally Sheet

Model	Part Name		Part No:
Operator	Location		Model
S.No	**Defect**	**Frequency**	**Total**
1	Crack	卌 卌 卌 卌 III	23
2	Blow hole	卌 卌 卌 I	16
3	Wrinkle	卌 卌 卌 卌 卌 III	28
4	Rough Surface	卌 卌 卌 III	18
5	Dent	卌 卌 卌 卌 卌 I	26
6	Blister	卌 卌 IIII	14

Project Name: ____________
Name of Data Recorder: ____________
Location: ____________
Data Collection Dates: ____________

Defect Types/ Event Occurrence	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Defect 1								
Defect 2								
Defect 3								
Defect 4								
Defect 5								
Defect 6								
Defect 7								
Defect 8								
Defect 9								
Defect 10								
TOTAL								

Check Sheet

Date:
Verification Stage **Section:**
Product: **Machine:**
Total inspected: **Inspector:**
Batch: **Shift:**

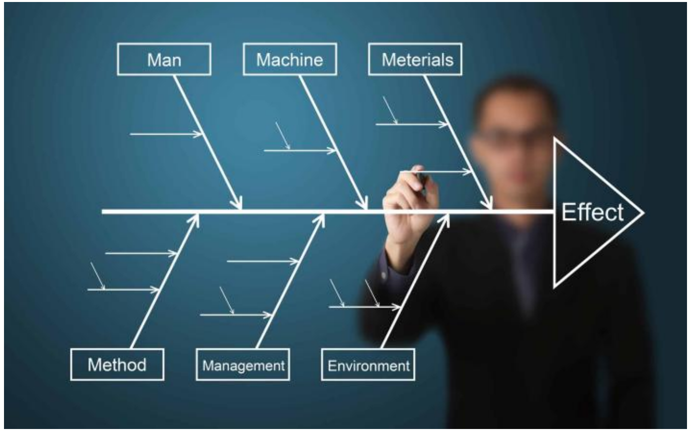
Specification (weight)	Variation	Verifications																						Frequency
	< -0.03	X																						
	-0.03	X																						
	-0.02	X	X	X																				
	-0.01	X	X	X	X	X	X	X	X															
5.20	0	X	X	X	X	X	X	X	X	X	X	X	X											
	0.01	X	X	X	X	X	X	X																
	0.02	X	X	X																				
	0.03	X	X																					
	> 0.03	X																						
																							TOTAL	

Cause-Effect Diagram

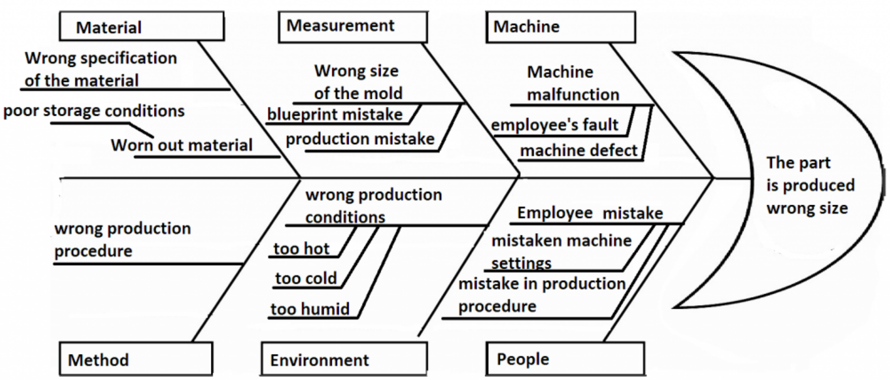
A cause-effect diagram is a visual tool used to logically organize possible causes for a specific problem or effect by graphically displaying them in increasing detail, suggesting causal relationships among theories. A popular type is also referred to as a fishbone or Ishikawa diagram.

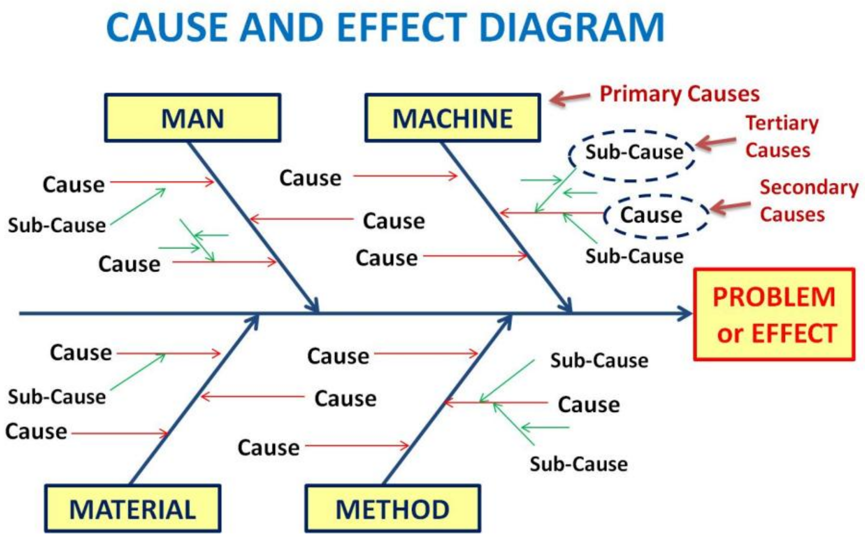
When to use:

- ✓ To study a process for improvisation
- ✓ To document a process
- ✓ When planning a project



Cause-Effect Diagram
(Examples)





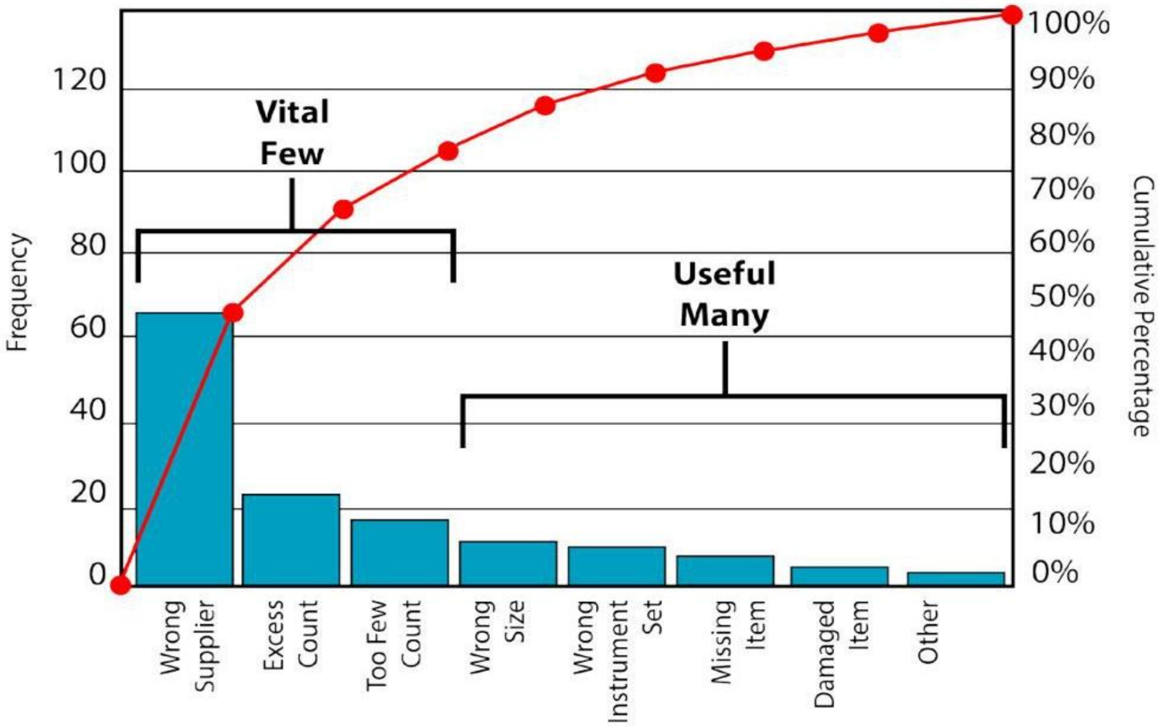
Pareto Chart

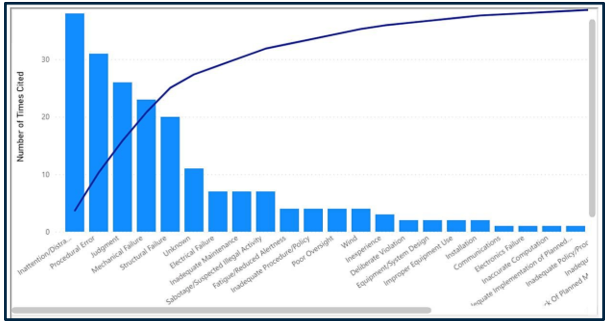
Pareto Chart is a bar chart sorted in descending order from the highest frequency to the lowest frequency from left to right. The height of the bars reflects the frequency or the impact of the problems. Based on the Pareto principle (also known as 80/20 rule), which states that 80% of the effects are caused by 20% of the causes, the Pareto chart is used to determine the most important reasons for a certain effect.

When to use:

- ✓ When analyzing data about the frequency or cause in the process
- ✓ When there are issues or causes, and you want to focus on the important one
- ✓ When analyzing broad causes by looking at the specific parts

Pareto Chart
(Example)





Control Charts

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. It is essentially a statistical chart that helps decide if an industrial process is within control and proficient at meeting the client characterized detail limits. Control graph is also called Shewhart Chart.

When to use:

- ✓ To find or correct issues as they occur in an ongoing process
- ✓ When predicting the specific range of outcomes from a process
- ✓ When determining if a process is stable

Control Charts

A control chart always has a central line for the average, an upper line for the Upper Control Limit (UCL), and a lower line for the Lower Control Limit (LCL). These lines are determined from historical data. Let assume there are N historical data (sample points) from the process, then three parameters including average ($\bar{X}$), UCL and LCL are computed by:

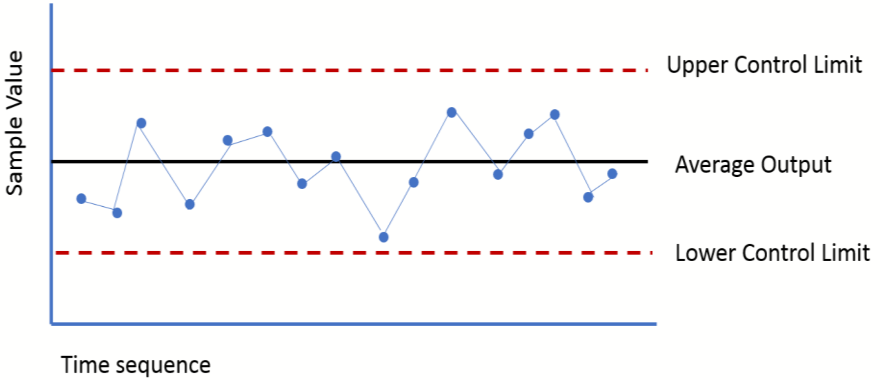
$$\bar{X} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Where x_i shows the value of *ith* historical data.

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{X})^2}{N}}$$

$$UCL = \bar{X} + A\hat{\sigma}$$

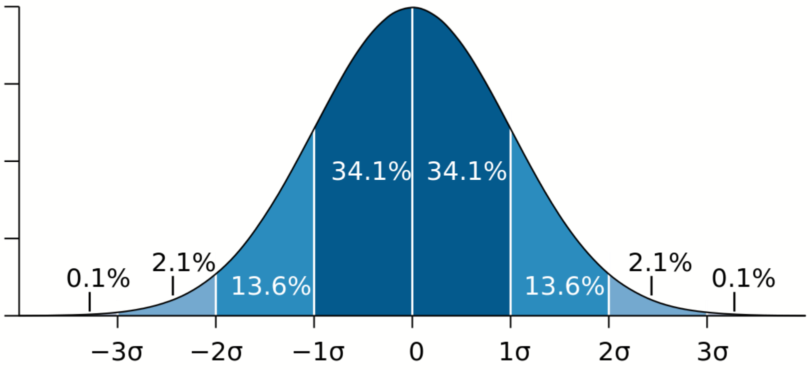
$$LCL = \bar{X} - A\hat{\sigma}$$

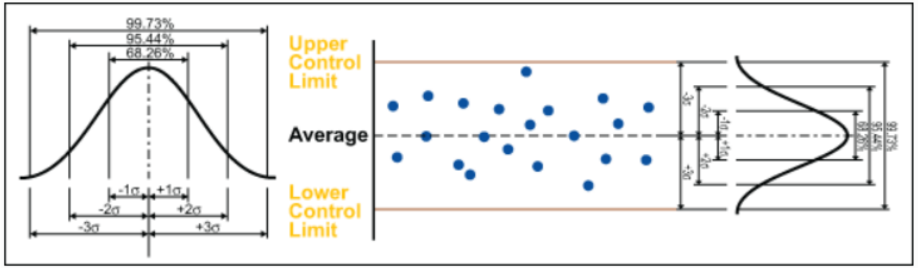


Computing A is discussed in next slide.

Control Charts

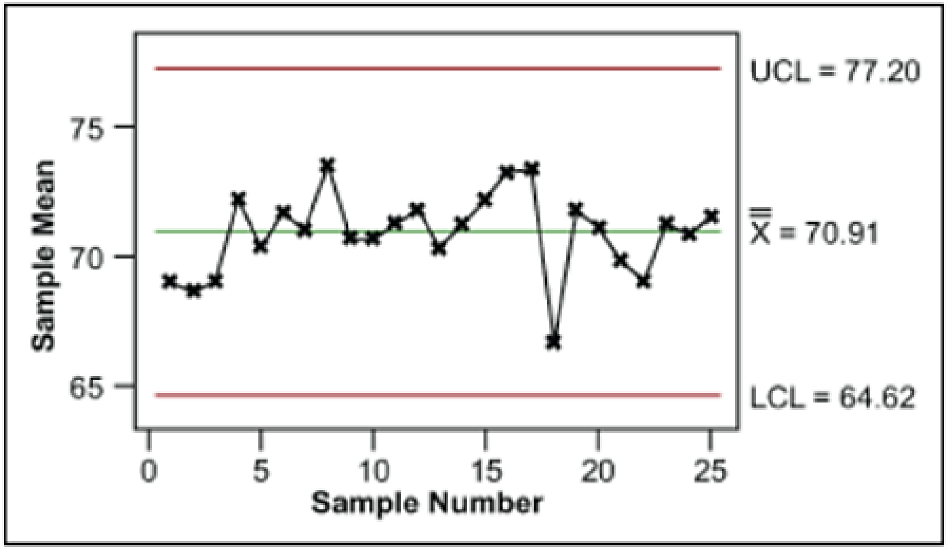
Control rules take advantage of the normal curve in which $A = 1$, then 68.26 percent of all data is within plus or minus one standard deviation from the average, when $A = 2$, then 95.44 percent of all data is within plus or minus two standard deviations from the average, and by $A = 3$, then 99.73 percent of data will be within plus or minus three standard deviations from the average.





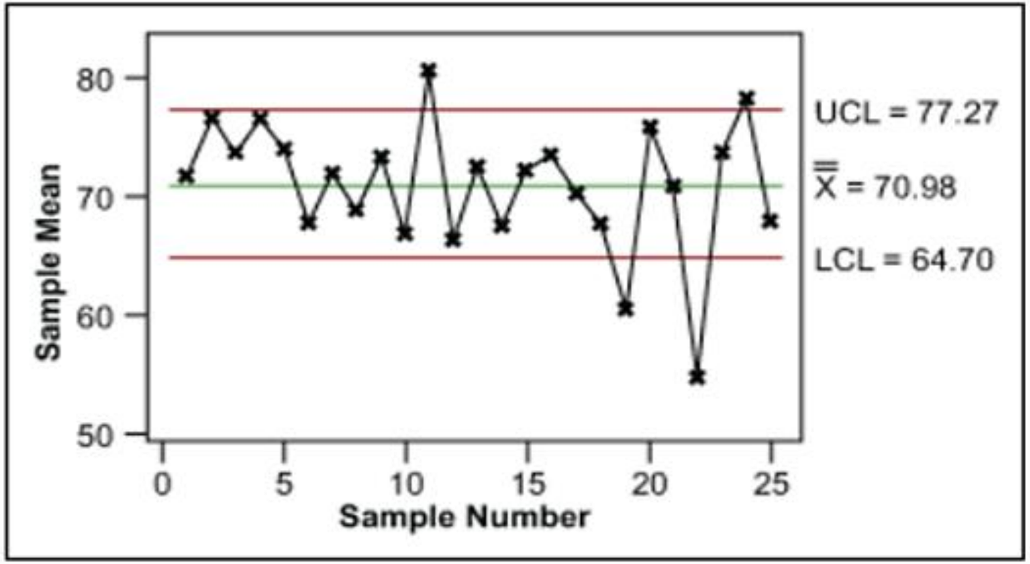
Control Charts

What do you think about this process?



Control Charts

What do you think about this process?

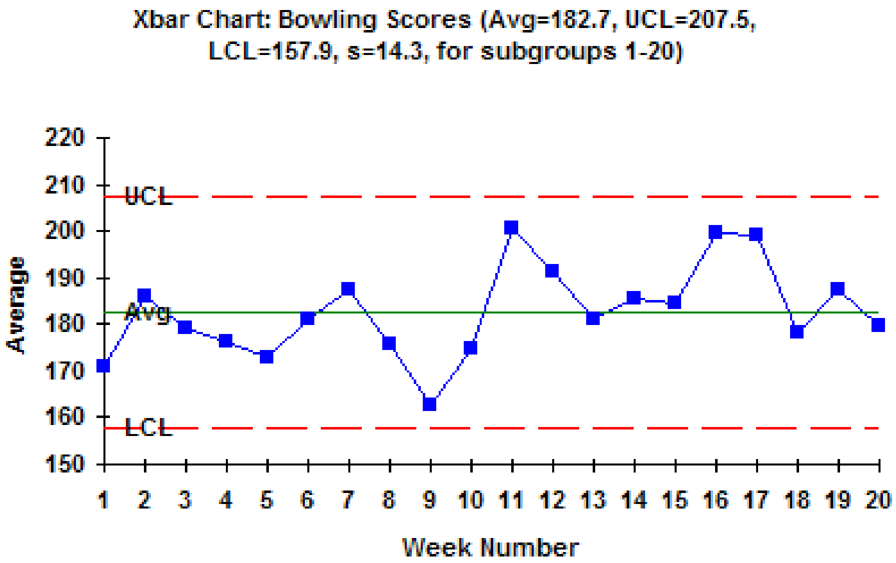


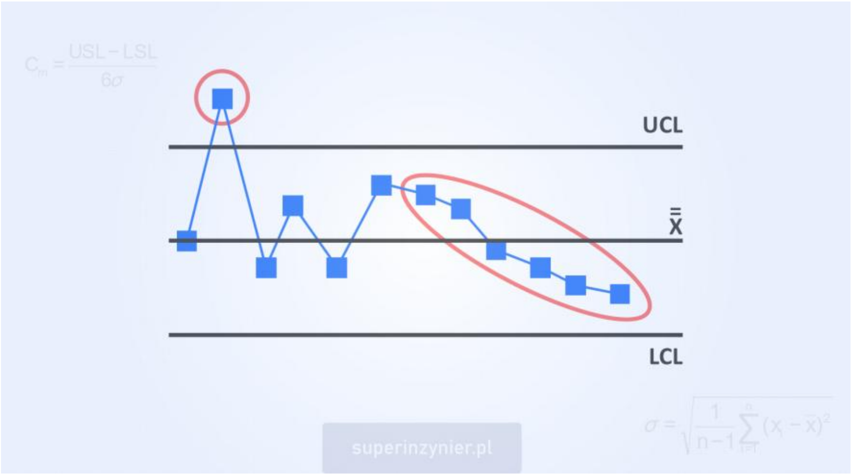
Control Charts

Non-stable control chart example (cont’d):

- **Identify the Cause:** Look for patterns or points outside control limits to understand what's causing the instability.
- **Investigate the Issue:** Check for possible factors like machine problems, material defects, or human error.
- **Implement Corrective Actions:** Fix the issue, such as repairing equipment, improving training, or changing materials.
- **Monitor the Process:** Keep using the control chart to track if the process improves and becomes stable again.
- **Verify Stability:** Ensure that the data points stay within the control limits over time, showing that the process is now stable.

Control Charts
(Examples)





Control Charts

Numerical Example

This data set represents the yield rate (%) for a particular electronic manufacturing process over 15 samples. Using this data set, a control chart can be created to monitor the process and detect any shifts or trends in the yield rate over time.

Sample Number	Yield Rate (%)
1	98.50
2	97.80
3	98.30
4	99.10
5	99.30
6	94.32
7	98.40
8	98.60
9	98.80
10	99.00
11	99.10
12	98.80
13	98.90
14	99.10
15	98.20

Control Charts (Answer)

Sample Number	Yield Rate (%)
1	98.50
2	97.80
3	98.30
4	99.10
5	99.30
6	94.32
7	98.40
8	98.60
9	98.80
10	99.00
11	99.10
12	98.80
13	98.90
14	99.10
15	98.20

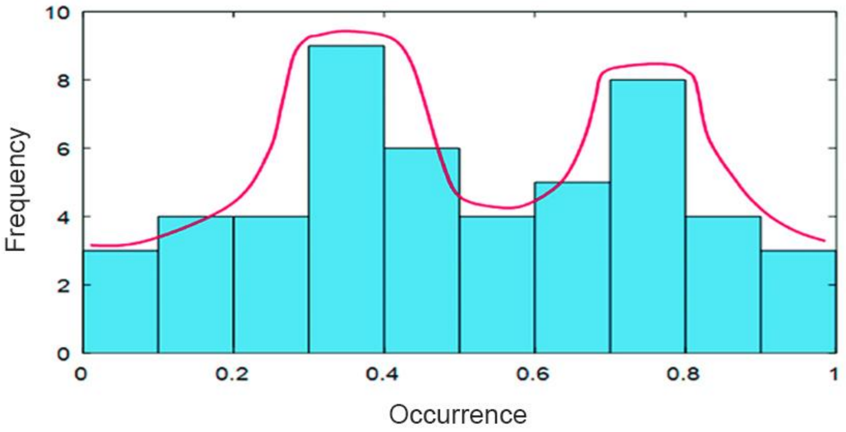
Histogram

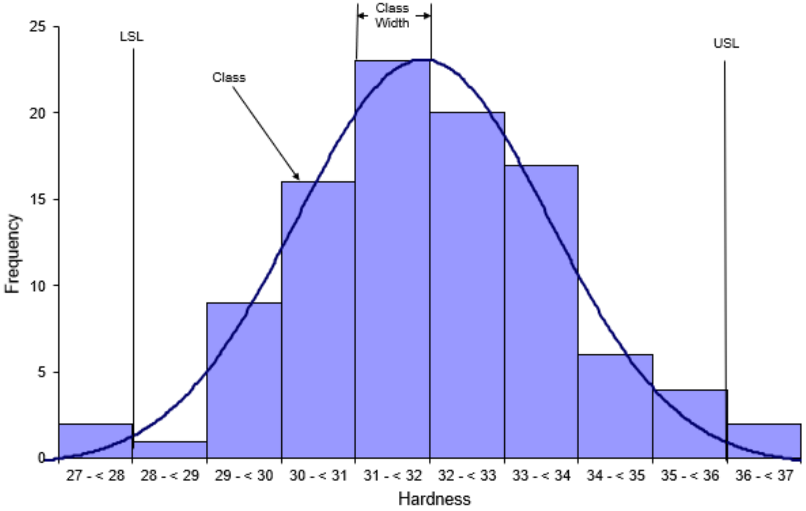
A histogram is essentially a bar chart and allows you to understand at a glance the variation that exists in a process. Although, it creates a "lumpy distribution curve" that can be used to help identify and eliminate the causes of process variation.

When to use:

- ✓ When analyzing if a process can meet customer's requirements
- ✓ When analyzing the numerical data
- ✓ When determining if the outputs of two or more processes are different

Histogram
(Examples)





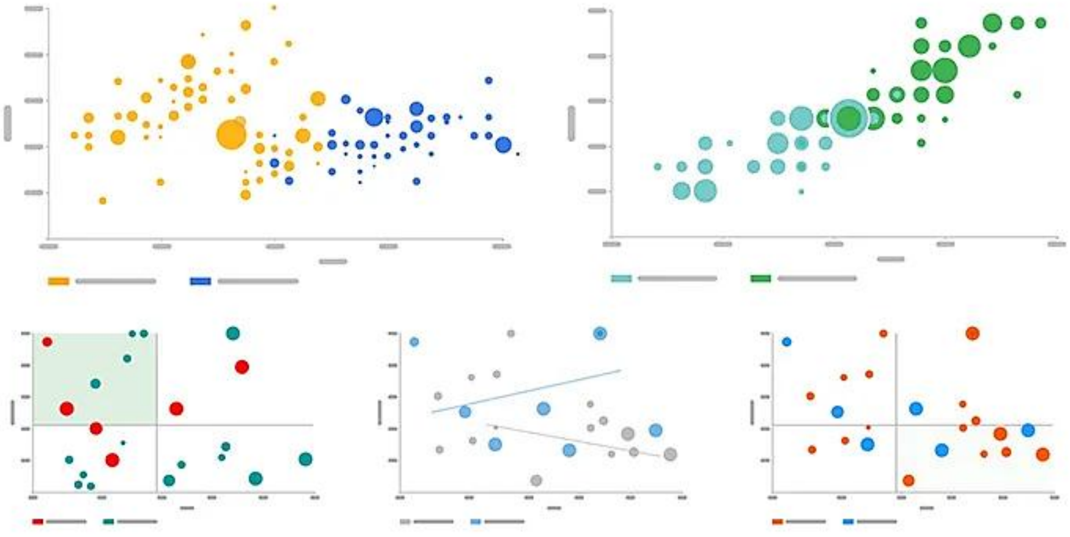
Scatter Diagram

The scatter diagram graphs pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the close-fitting the points will hug the line.

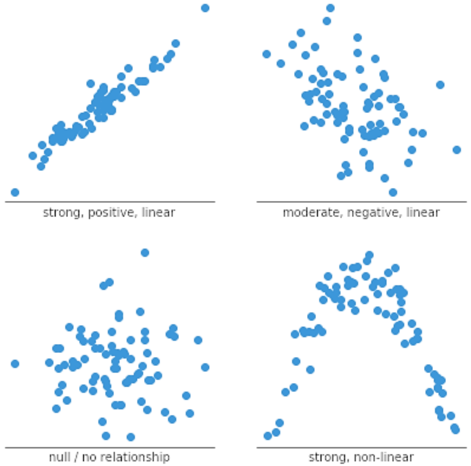
When to use:

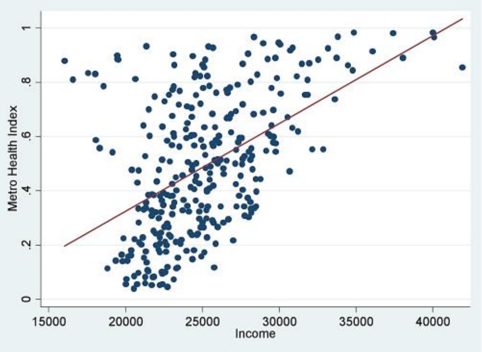
- ✓ When you have a paired numerical data
- ✓ When testing for autocorrelation before constructing a control chart
- ✓ When trying to identify the root causes of issues

Scatter Diagram
(Examples)



Top 5 Scatter Plot Examples to Get You Started with Data Visualization





Scatter Diagram

Numerical Example

This data set represents the temperature (°C) of a production line and the corresponding number of component failures during a certain period. The data can be used to create a scatter diagram to investigate the relationship between temperature and failure rate. The temperature data is plotted on the x-axis, and the number of failures on the y-axis. The resulting scatter plot can be analyzed to determine whether there is a correlation between temperature and failure rates.

Sample Number	Temperature (°C)	Failure Rate in Component A	Failure Rate in Component B
1	22	3	7
2	29	6	7.4
3	25	4	6
4	28	8	6
5	30	10	7.5
6	21	2	6.5
7	26	5	7
8	24	4	5
9	27	7	6.3
10	23	3	7

Scatter Diagram (Answer)

Sample Number	Temperature (°C)	Failure Rate in Component A	Failure Rate in Component B
1	22	3	7
2	29	6	7.4
3	25	4	6
4	28	8	6
5	30	10	7.5
6	21	2	6.5
7	26	5	7
8	24	4	5
9	27	7	6.3
10	23	3	7

Cost of Quality (COQ)

Definition

- Armand V. Feigenbaum first described the concept of the cost of poor quality in a 1956 Harvard Business Review article.
- Cost of quality (COQ) refers to costs incurred while ensuring that you get high-quality deliverables. It also includes the cost of dealing with any defects in your work. This is different from the cost of production, which refers to the total amount spent on labour and materials.

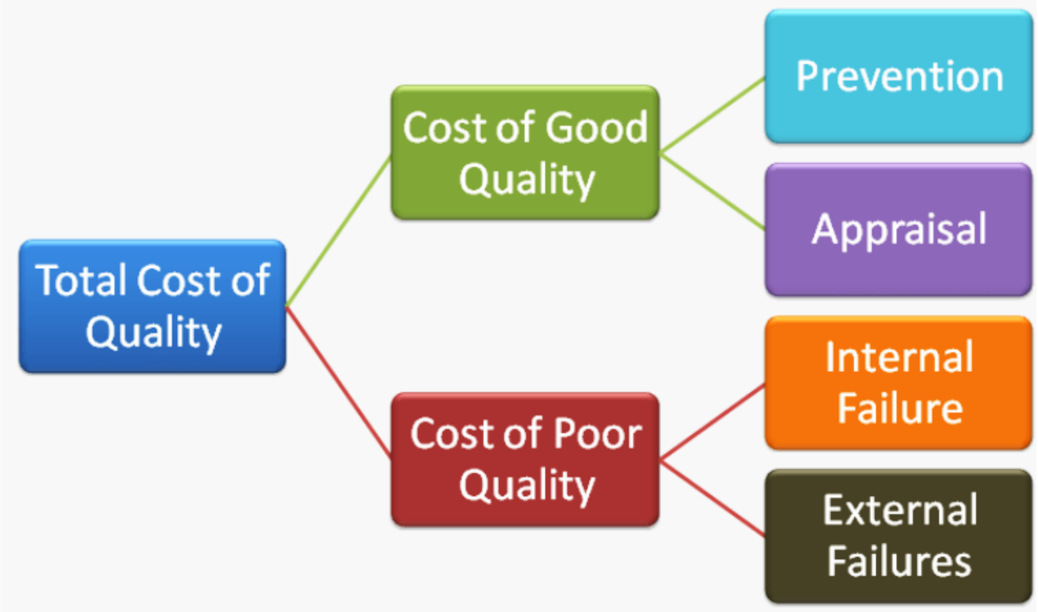
Quality Cost Curve

In 1999, Juran published the 5th addition of Juran’s Quality Handbook where he included the following depiction of the Quality Cost Curve.

Classification

The cost of quality can be categorized into four categories:

- Prevention Cost
- Appraisal Cost
- Internal Failure Cost and
- External Failure Cost



Prevention Costs

Prevention costs associated with activities specifically designed to prevent poor quality in products. The examples of the prevention costs include:

- Quality planning
- Education and training
- Conducting design reviews
- Supplier reviews and selection
- Process planning and control
- Product modifications
- Equipment upgrades

Appraisal Costs

Appraisal costs associated with activities specifically designed to measure, inspect, evaluate or audit products to assure conformance to quality requirements. The examples of the appraisal costs include:

- Test and inspection (receiving, in-process and final)
- Supplier quality control
- Process Audits
- Calibration

Internal Failure Costs

Internal Failure Costs are the costs that are associated with defects found within the organization before the customer receives the product or service. The examples of the internal failure costs include:

- In-process scrap and rework
- Troubleshooting and repairing
- Design changes
- Inventory required to support poor process yields and rejected lots
- Re-inspection / retest of reworked items

External Failure Costs

External Failure Costs are the costs that are associated with defects found after the customer receives the product or service. The examples of the external failure costs include:

- Sales returns and allowances
- Replacing defective products
- Service level agreement penalties
- Service labor and costs incurred due to warranty obligations
- Product recalls / Legal claims
- Lost customers and opportunities
- Downgrading
- Processing of customer complaints

Examples (Classification of the Cost of Quality)

1- Cost of getting company certified to ISO 9001

2- The cost of quality-related training

3- Review of drawings

Examples (Classification of the Cost of Quality)

4- Preparation of quality management system and inspection procedures

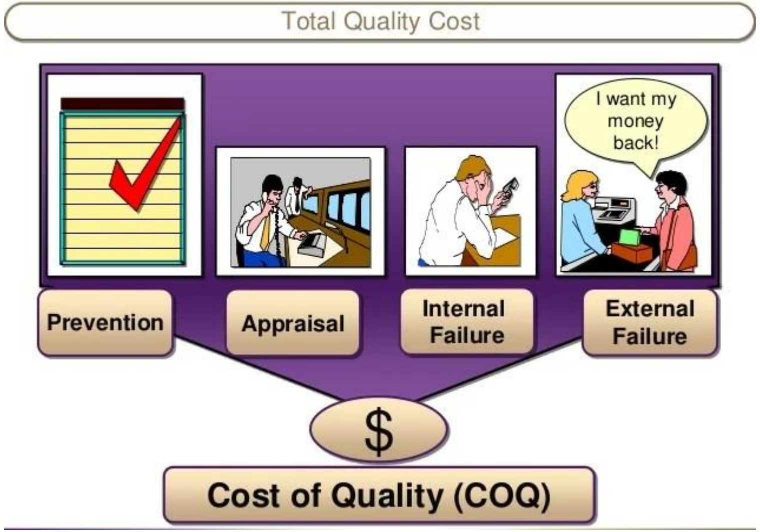
5- Product recall and warranty repairs

6- Defects found by customers after receiving the product

7- Inspection and re-inspection of the repaired product

Visible vs Invisible Cost of Quality

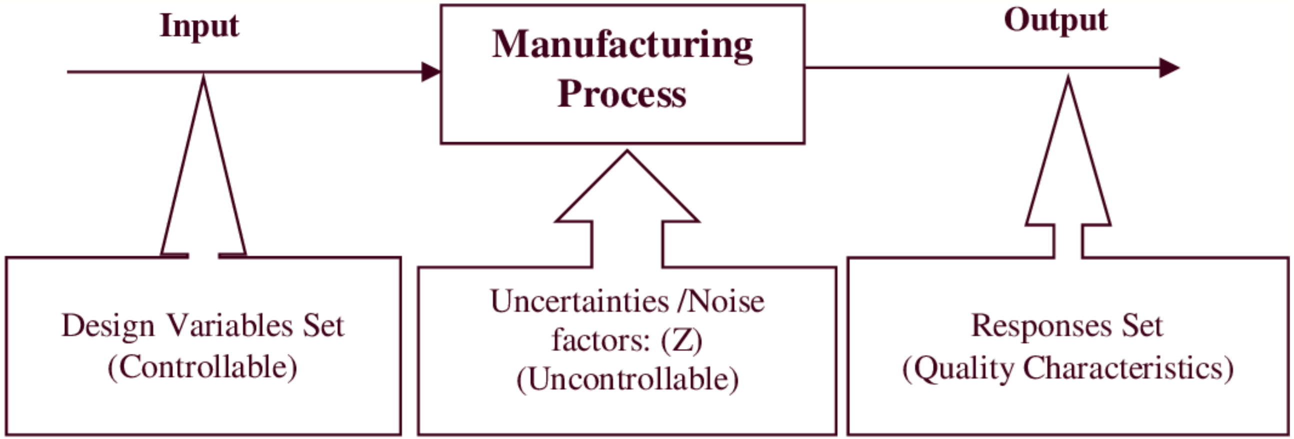
Summary



- COQ is important for companies to understand what they need to do to reduce their overall cost of quality. This will help them improve their business processes and operations, which ultimately lead to better profitability.
- The worst type of cost out of these four categories of the cost of poor quality is the external failure costs. Organizations should make their best effort to reduce the external failure cost.
- Spending more on prevention and appraisal costs usually leads to a reduction in internal and external failure costs.

In the Next Lesson:

Part 3: Robust Manufacturing Design




Q
A

?

When analyzing broad causes by looking at the specific parts, the Pareto chart is one of the applicable tools for the control of quality. Which of the following statements about a Pareto chart is true?

✓ A – It is a bar graph that displays the relative frequency or size of problems in descending order of importance.

B – It is a line graph that shows the cumulative percentage of problems plotted against the total number of occurrences.

C – It is a scatter plot that indicates the correlation between two variables.

D – It is a pie chart that breaks down the total number of problems into categories.

E – None of the above statements.

?

Which of the following statements best fits with the definition of the control charts?

✓ A. Control charts are used to determine whether a process is stable and predictable over time.

B. Control charts are used to determine whether a process is profitable or not.

C. Control charts are used to determine whether a process is meeting customer demand or not.

D. Control charts are used to determine whether a process is efficient or not.

E. None of the above statements is correct.

The goal of Quality control (QC) is to identify any defects after a product is developed, but before it's released to production. By using seven basic tools of quality, we can manage the quality of our product or process effectively. Known around the world as the seven-quality control (7-QC) tools. List any four of these tools.

Accept any four of the below:

- Flowchart
- Check sheet
- Pareto chart
- Cause-and-effect diagram
- Control chart
- Histogram
- Scatter diagram

A company that produces electronic devices is experiencing a high rate of product returns due to defects. How might a cause-effect diagram be used to identify the root causes of these defects?

- A cause-and-effect graph, also called a fishbone diagram, shows the numerous potential reasons for a problem. When a quality-related issue is characterized, the factors prompting the cause of the issue are recognized. We further continue recognizing the sub-factors prompting the causal of distinguished factors until we can distinguish the issue's underlying cause.

Also, any example for the application of a cause-and-effect graph, in this case, can be acceptable, for example:

- A cause-effect diagram, also known as a fishbone diagram or Ishikawa diagram, can be a helpful tool for identifying the root causes of defects in an electronic industry. The diagram can be constructed by identifying the major categories that could contribute to the problem, such as materials, machinery, methods, people, and the environment. The categories are represented as the "bones" of the fish, with the problem or defect at the head of the fish. For example, the problem, in this case, could be a "high rate of product returns due to defects", and the major categories might include design, manufacturing process, materials, human error, and environmental factors.

The cost of quality can be categorized into four categories including Prevention Cost, Appraisal Cost, Internal Failure Cost, and External Failure Cost. Classified two types of costs accordingly, first the cost of quality-related training, and second product recall and warranty repairs.

The cost of quality-related training: This will be a prevention cost, as the training is being delivered to avoid or prevent poor quality.

Product recall and warranty repairs: This will obviously be an external failure cost.

?

Let's say you are a manufacturer of printed circuit boards (PCBs) for electronic devices. You want to monitor the defect rate of your PCBs to ensure that they meet the required quality standards. You decide to monitor the defect rate of your PCBs. After collecting data for a period of time, you plot the data and check the trend of the defect rate over time. Which quality tool is used?

Control Chart (or X-chart as called in the SPC)

?

In the schematic quality tool that you mentioned in previous question, what exactly do you see if noticed that the process is unstable?

We see that there are several data points that are outside the control limits or there is a significant upward or downward trend in the defect rate over time. This indicates that the process is not stable and there are variations in the defect rate that are not under control.

?

The cost of quality can be categorized into four categories: Prevention Cost, Appraisal Cost, Internal Failure Cost, and External Failure Cost. Which item below is not classified as an appraisal cost?

A. Test and inspection (receiving, in-process, and final)

B. Supplier acceptance sampling

C. Product Audits

✓ D. Equipment upgrades

E. Calibration


thank you