Methods of Quality Improvement in Automotive Industry I.

Winter semester 2020/2021

Quality???

What is Quality

Quality

- It starts with understanding customer needs and ends when those needs are satisfied.
- It is simply meeting the customer requirements.
- It is the degree to which a set of ***inherent*** characteristics fulfills a need or expectation that is stated, general implied or obligatory.

“Quality” Management System

A management system is a collection of resources comprising *capital, people, processes and procedures* which ensures that customer's requirements for quality are met by the supplier organization.

Quality is conformance to defined specifications in terms of performance, price and delivery. Quality is not goodness, scale or niceness.

The technique used to achieve that conformance is called quality assurance or quality management — hence the term '***quality management system***'.

QCDS paradigm

It expresses the chain „supplier – producer – customer“.

- **Quality** – informs on quality characteristics – usability, operating ability, functionality – accordance with requirements, reliability, safety, durability, design, economy, environment, etc.
- **Costs** - informs on characteristics related to costs and prices – unit costs/loss, productivity, period of cycle, price, row materials, work, unit prices/profit etc.
- **Delivery** – characterizes the produced volume, production time, loading time, transport time, supply time, etc.
- **Services** – express the requirements on safety, failure-free use, possibility of return, user manuals, repair manuals, etc.

Quality planning – process of translating quality policy into processes, procedures, and instructions to achieve measurable objectives and requirements

Quality assurance – planned and methodical activities executed as part of a quality system to provide confidence that process, product, or service requirements for quality are being satisfied

Quality control – act of monitoring, appraising, and correcting a process, product, or service to ensure requirements for quality are being satisfied

Quality improvement – process of analyzing performance and taking methodical, systemic actions to improve it

Quality 4.0

The future of quality and organizational excellence within the context of Industry 4.0.

Quality professionals can play a vital role in leading their organizations to apply proven quality disciplines to new, digital, and disruptive technologies.

It's a new way for ***quality professionals*** to manage quality with the digital tools available today and understanding how to apply them and achieve excellence through quality.

Existing ***processes*** will be broken and the need to educate the next generation of workers to implement new processes and strategies will be vital to not only the quality professional but also business operations.

Quality 4.0

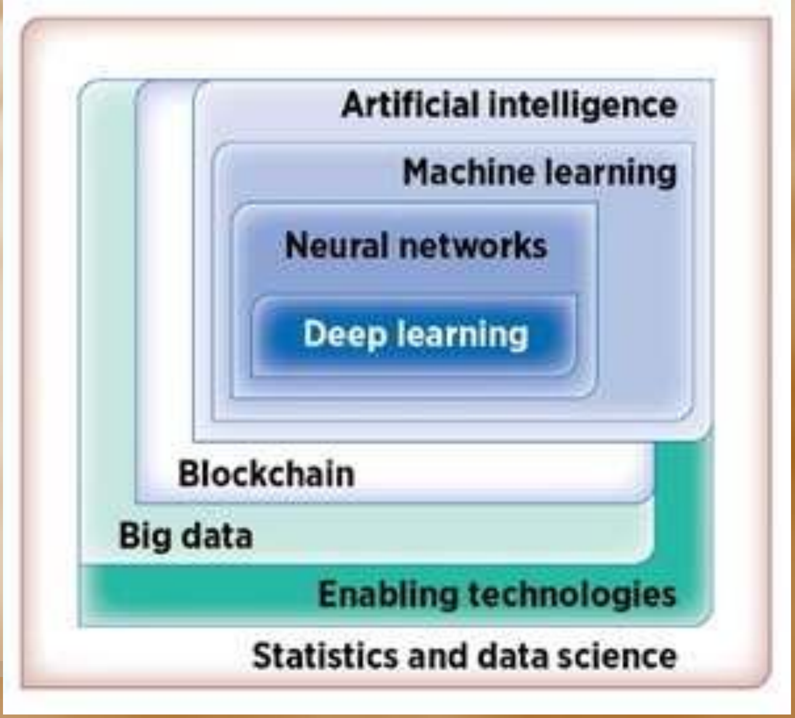
Industry 3.0—1940 to 1995	+ Computer power provided to workers to increase productivity. + Use of information and communication technology drives improvements. + Human participation in workplaces declines. + Stand-alone robotic systems replace manual work.	Quality 3.0	+ Quality is a business imperative. + Meeting customer requirements (customer satisfaction) is emphasized. + Continual improvement is applied. + Gains in productivity occur by stabilizing highly efficient processes, standardizing work and involving all workers in the activities that create quality. + Standardization activities (ISO 9001) and achieving business excellence through organizationwide assessment (such as the *Baldrige Criteria for Performance Excellence*) emerge.
Anticipated changes that will occur during Industry 4.0—1995 to present	+ Integrated cyber-physical interfaces automate working environments. + Automated processes deal with end-to-end systems. + Humans serve only in positions where human judgment cannot be automated and human interactions cannot be simulated. + Machines learn to learn (artificial intelligence).	Quality 4.0	+ Digitization is used to optimize signal feedback and process adjustment, and adaptive learning supports self-induced system corrections. + Quality shifts its control-oriented focus from the process operators to the process designers. + Machines learn how to self-regulate and manage their own productivity and quality. + Human performance is essential; the emphasis shifts from production to system design and integration with the business system.

Quality 4.0 tools

Deep learning: image classification, complex pattern recognition, time series forecasting, text generation, creating sound and art, creating fictitious video from real video, adjusting images based on heuristics.

Enabling technologies: affordable sensors and actuators, cloud computing, open-source software, augmented reality, mixed reality, virtual reality, data streaming, 5G networks, IPv6, IoT.

Data science: the practice of bringing together heterogeneous data sets for making predictions, performing classifications, finding patterns in large data sets, reducing large sets of observations to most significant predictors, applying sound traditional techniques (such as visualization, inference and simulation) to generate viable models and solutions.



Quality 4.0 value propositions

Quality professionals should propose and lead digital transformation initiatives because they will have deep skills in:

- Systems thinking
- Data-driven decision making
- Leadership for organizational learning
- Establishing processes for continuous improvement
- Understanding how decisions affect people: lives, relationships, communities, well-being, health, and society in general

https://videos.asq.org/685a3ddb-e967-4e2c-88e1-069a53e199fd


1. Customer focus
2. Leadership
3. Engagement of people
Quality Management Principles
7. Relationship Management
4. Process approach
6. Evidence-based decision making
5. Improvement

Principle – **Process approach**

Consistent and predictable results are achieved more effectively and efficiently when activities are understood and managed as interrelated processes that function as a coherent system.

Key benefits

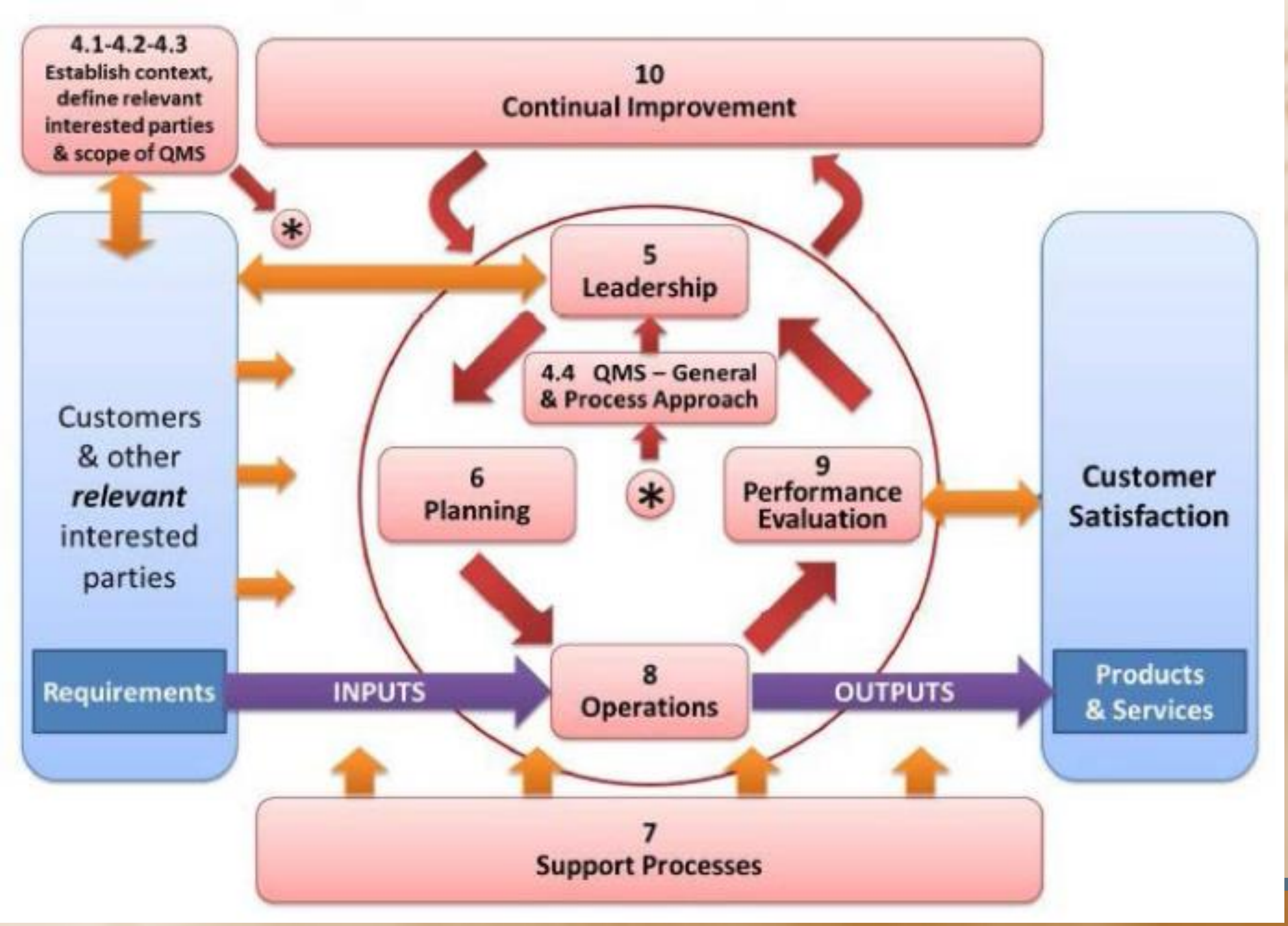
- Enhanced ability *to focus* effort *on key processes and opportunities for improvement*.
- Consistent and predictable outcomes through a system of aligned processes.
- Optimized performance through effective process management, efficient use of resources, and reduced cross-functional barriers.
- Enabling the organization to provide confidence to interested parties as to its consistency, effectiveness and efficiency.

Principle – **Process approach**

Possible actions (ISO 9000:2015) that an organization can take includes:

- it can define the objectives of the system and processes necessary to achieve them;
- it can establish authority, responsibility, and accountability for managing processes;
- it can understand the organization's capabilities and determine resource constraints prior to action;
- it can determine process interdependencies and analyze the effect of modifications to individual processes on the system as a whole;
- it should manage processes and their interrelations as a system to achieve the organization's quality objectives effectively and efficiently;
- it can ensure the necessary information is available to operate and improve the processes and to monitor, analyze and evaluate the performance of the overall system;
- it should manage risks which can affect outputs of the processes and overall outcomes of the QMS.

Model of a process-based quality management system



Process Approach

In order to manage processes, the organization must answer whether it has:

A. Clearly defined objectives and how to measure and review success.

B. Evaluated impacts of objectives on stakeholders.

C. Designed the critical end-to-end process necessary to deliver the objectives.

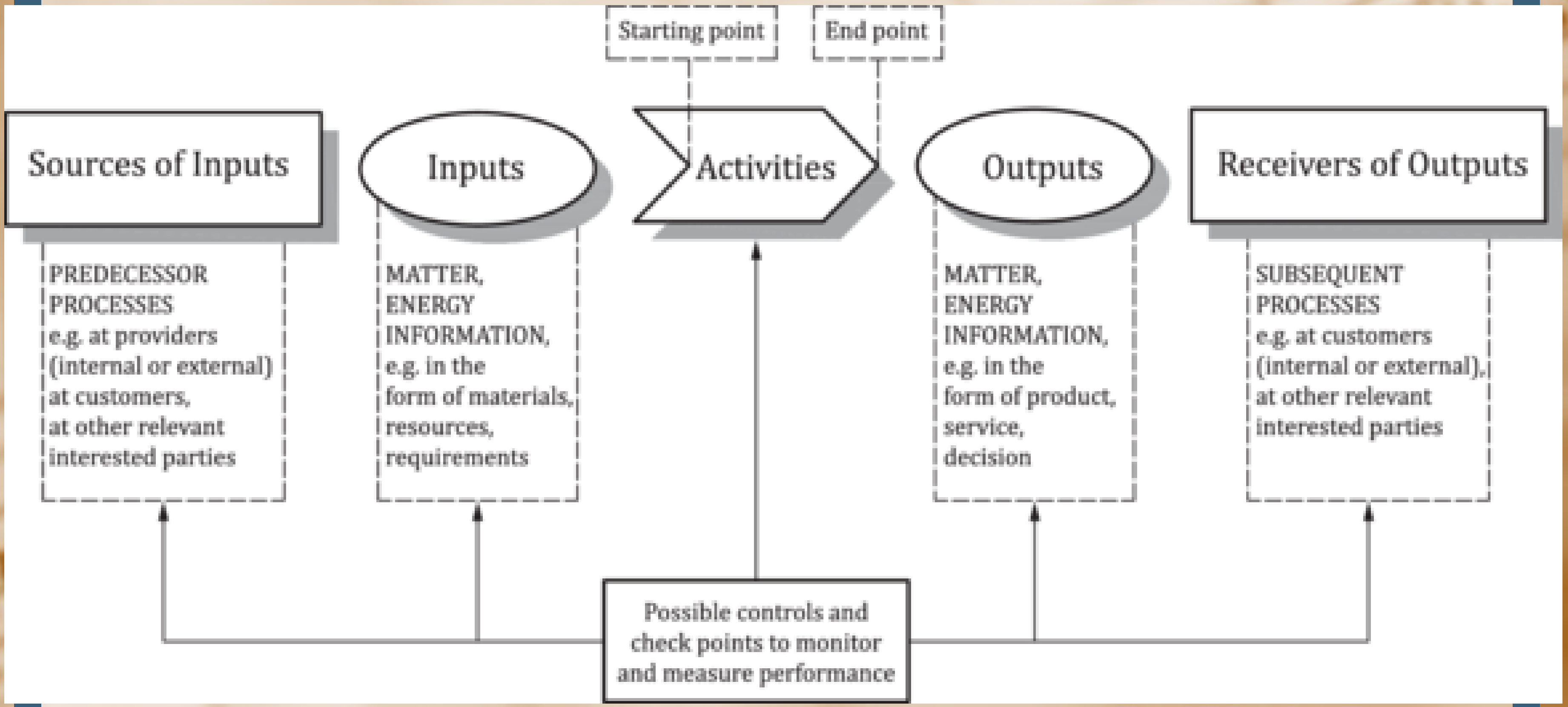
D. Assessed and provided the resources, skills and competence to make it work.

Process Approach

Identification of processes within an organization

1. Define the purpose of the organization.
2. Define the policies and objectives of the organization.
3. Determine the processes in the organization.
4. Determine the sequence of processes.
5. Define the process ownership.
6. Define the process documentation.

Schematic representation of the elements of a single process



Process Approach

Process identification

1) Delimit the process-determine the starting and final activities.
2) Define the process objective.
3) Identify the sub-processes that contribute to the objective.
4) Determine the process target.
5) Determine the critical success factors.
6) Determine the sub-processes with the biggest improvement potential.
7) Assign responsibilities for the process/sub-processes.

Process Approach

Planning the process

1. Define the activities within the process.
2. Define the monitoring and measurement requirements.
3. Define the resources needed.
4. Verify the process and its activities against its planned objectives.

Process Approach

***Implementation* and measurement of the process**

The organization may develop a project for implementation that includes, but is not limited to:

- Communication.
- Awareness.
- Training.
- Change management.
- Management involvement.
- Applicable review activities.

Process Approach

Analysis of the process

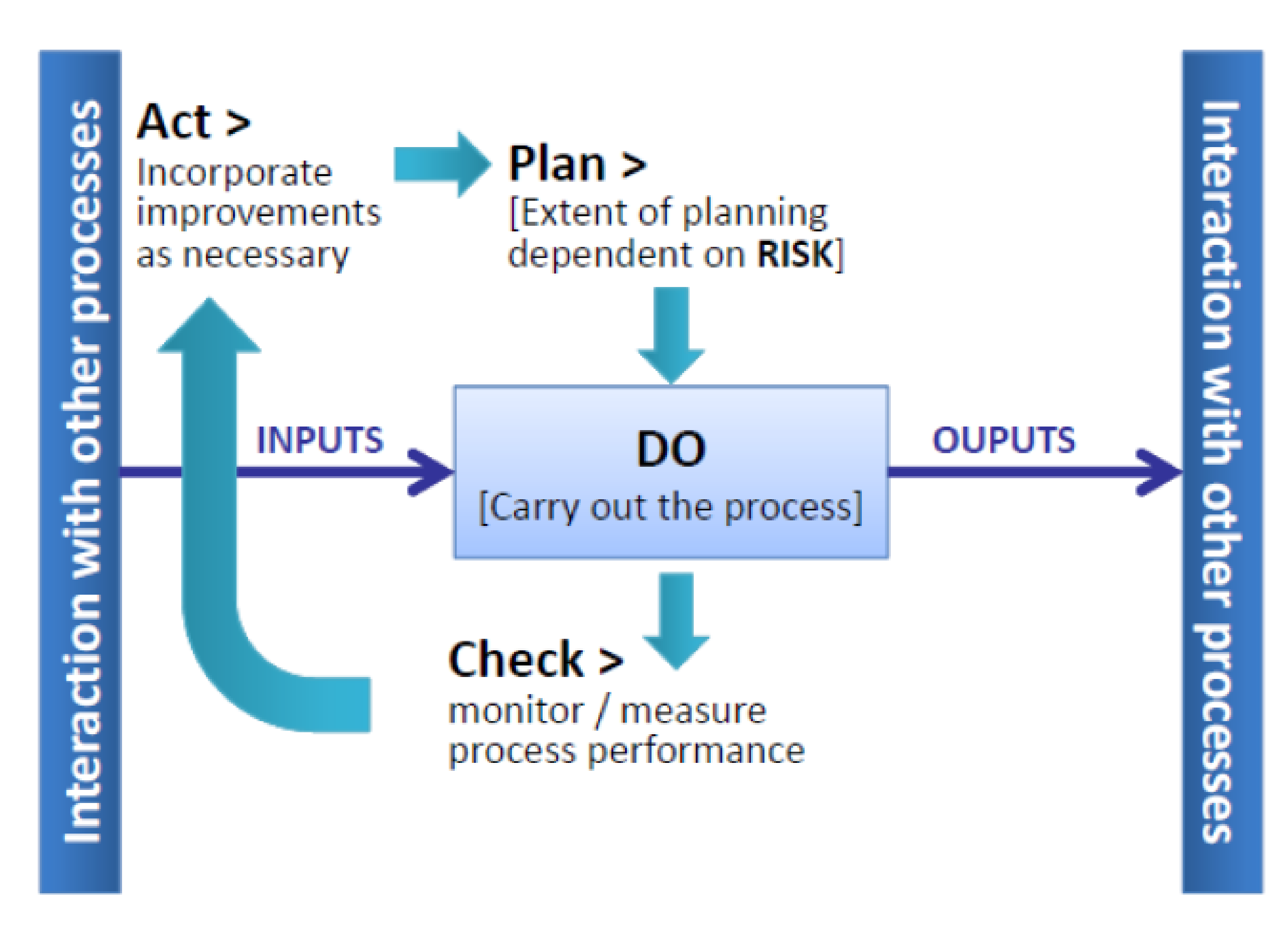
1. Determine and describe the process structure.
2. Measure the process performance.
3. Determine target values.
4. Identify obstacles.
5. Remove obstacles through continuous improvement.
6. Implement the results of the analysis.

Process Approach
Plan-Do-Check-Act (PDCA) cycle

Corrective action and improvement of the process

- ✓ "**Plan**" Establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies.
- ✓ "**Do**" Implement the processes.
- ✓ "**Check**" Monitor and measure processes and product against policies, objectives and requirements for the product and report the results.
- ✓ "**Act**" Take actions to continually process performance.

The PDCA cycle can be applied to all processes and to the quality management system as a whole.


Interaction with other processes
Act >
Incorporate improvements as necessary
Plan >
[Extent of planning dependent on RISK]
INPUTS
DO
[Carry out the process]
OUPUTS
Check >
monitor / measure process performance
Interaction with other processes

Improvement

Successful organizations have an ongoing focus on improvement.

Improvement is essential for an organization to maintain current levels of performance, to react to changes in its internal and external conditions and to create new opportunities.

Improvement

Key Benefits (ISO 9000:2015)

- There are improved process performance, organizational capability, and customer satisfaction;
- There is an enhanced focus on root cause investigation and determination, followed by prevention and corrective actions;
- There is an enhanced ability to anticipate and react to internal and external risks and opportunities;
- There is enhanced consideration of both incremental and breakthrough improvement;
- There is improved use of learning for improvement; There is an enhanced drive for innovation.

Improvement

Possible actions (ISO 9000:2015) that an organization can take includes:

- It can promote the establishment of improvement objectives at all levels of the organization;
- It can educate and train people at all levels on how to apply basic tools and methodologies to achieve improvement objectives;
- It can ensure people are competent to successfully promote and complete improvement projects;
- It can develop and deploy processes to implement improvement projects throughout the organization;
- It can track, review and audit the planning, implementation, completion, and results of improvement projects;
- It can integrate improvement consideration into the development of new or modified products and services and processes;
- It can recognize and acknowledge improvement.

Improvement

To apply the principle of improvement, there is necessary:

- To identify the processes needed for quality management system and their application throughout the organization.
- To determine the sequence and interaction of the processes.
- To determine the criteria and methods needed that both the operation and control of the processes are effective.
- To ensure the availability of resources and information necessary to support the operation and monitoring of the processes.
- To monitor, measure and analyse the processes.
- To implement actions necessary to achieve the planned results and continual improvement of the processes.

Process of Continual Improvement

1. ***Reason for improvement***: a process problem should be identified and an area for improvement selected, noting the reason for working on it.

2. ***Current situation***: the effectiveness and efficiency of the existing process should be evaluated. Data to discover what types of problems occur most often should be collected and analysed. A specific problem should be selected and an objective for improvement should be set.

3. ***Analysis***: the root causes of the problem should be identified and verified.

4. ***Identification of possible solutions***: alternative solutions should be explored. The best solution should be selected and implemented i.e. the one that will eliminate the root causes of the problem and prevent the problem from recurring.

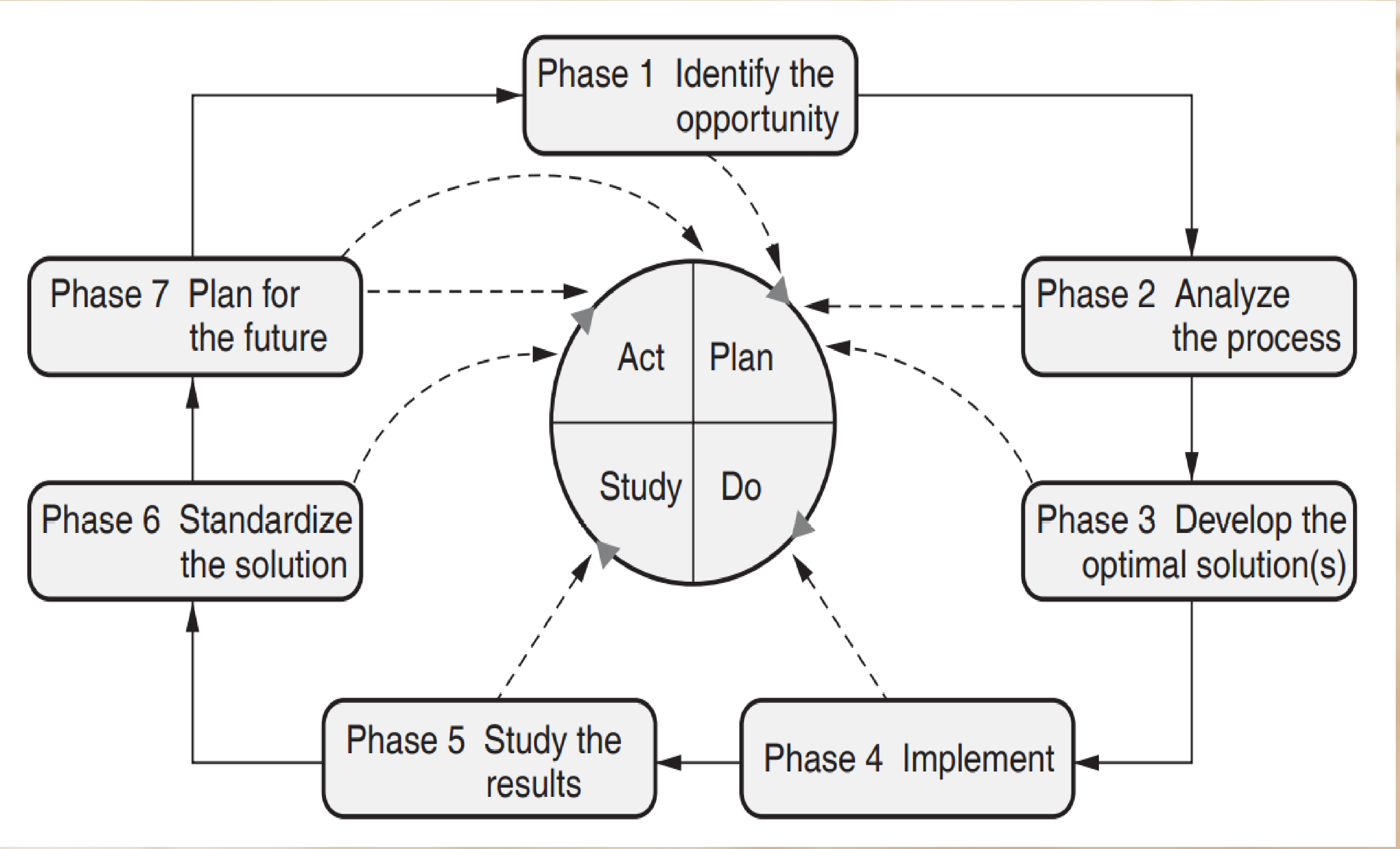
Process of Continual Improvement

5. ***Evaluation of effects***: it should be confirmed that the problem and its root causes have been eliminated or their effects decreased, that the solution has worked out, and the objective for improvement has been met.

6. ***Implementation and standardization of the new solution***: the old process should be replaced with the improved process, thereby preventing the problem and its root causes from recurring.

7. ***Evaluation of the effectiveness and efficiency of the process with the improvement action completed***: the effectiveness and efficiency of the improvement project should be evaluated and consideration should be given for using its solution elsewhere in the organization.

Process of Continual Improvement



Means for the *integrated quality assurance* shall refer to two basic spheres:

- *analysis of processes,*
- *analysis of statistical variability / stability / capability* of processes / products.

Analysis of statistical variability represents the assessment of the quality indicators in terms of quantity, and measurable and comparable parameters.

The methods of statistical control/regulation of quality of processes:

- ***SPC** – Statistical Process Control*
- ***SQC** – Statistical Quality Control*

The statistical methods of control/regulation of quality are classified:

- *simple statistical methods – „**seven old methods**“;*
- *moderately demanding statistical methods;*
- *demanding statistical methods.*

Seven old tools of quality management

- *Flow diagram*
- *Cause–and–Effect Diagram*
  (Ishikawa Diagram, Fishbone Diagram)
- *Pareto chart and Lorentz curve*
- *Check sheet*
- *Histogram*
- *Scatter Diagram*
- *Control Chart*

Data orientation: Focus on numerical data and calculation.

Moderately demanding statistical methods

- *Statistical inspection*
- *Statistical classification*
- *Test of hypotheses,*
- *Statistical theory of estimate,*
- *Failure theory,*
- *Analysis of Variance (ANOVA),*
- *Design of Experiments (DoE),*
- *Regressive and correlation analysis*
- *Methods of reliability assessment.*

Demanding statistical methods

- *Multi-factor Analysis of Variance,*
- *Combined methods of Design of Experiments (EVOP – Evolution Optimizing),*
- *Multi-dimensional regressive and correlation analysis,*
- *Analysis of time periods (periodogram, frequency analysis),*
- *Cluster analysis,*
- *Sensor methods.*

Seven new tools of quality control and assurance

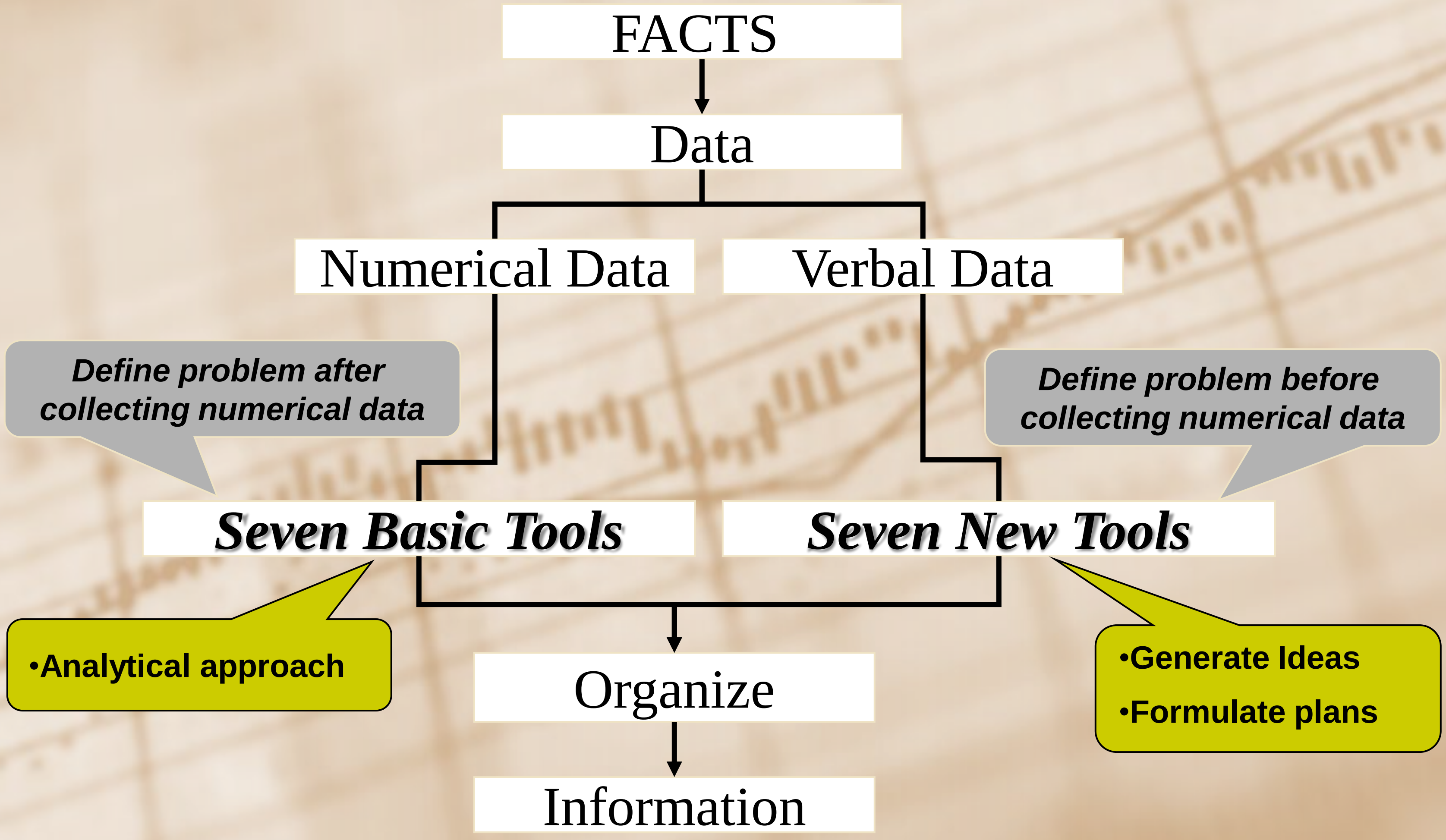
- *Affinity Diagram*
- *Relations Diagram*
- *Tree Diagram*
- *Matrix Diagram*
- *Arrow / Network Diagram*
- *Process Decision Program Charts (PDPC)*
- *Matrix Data Analysis*

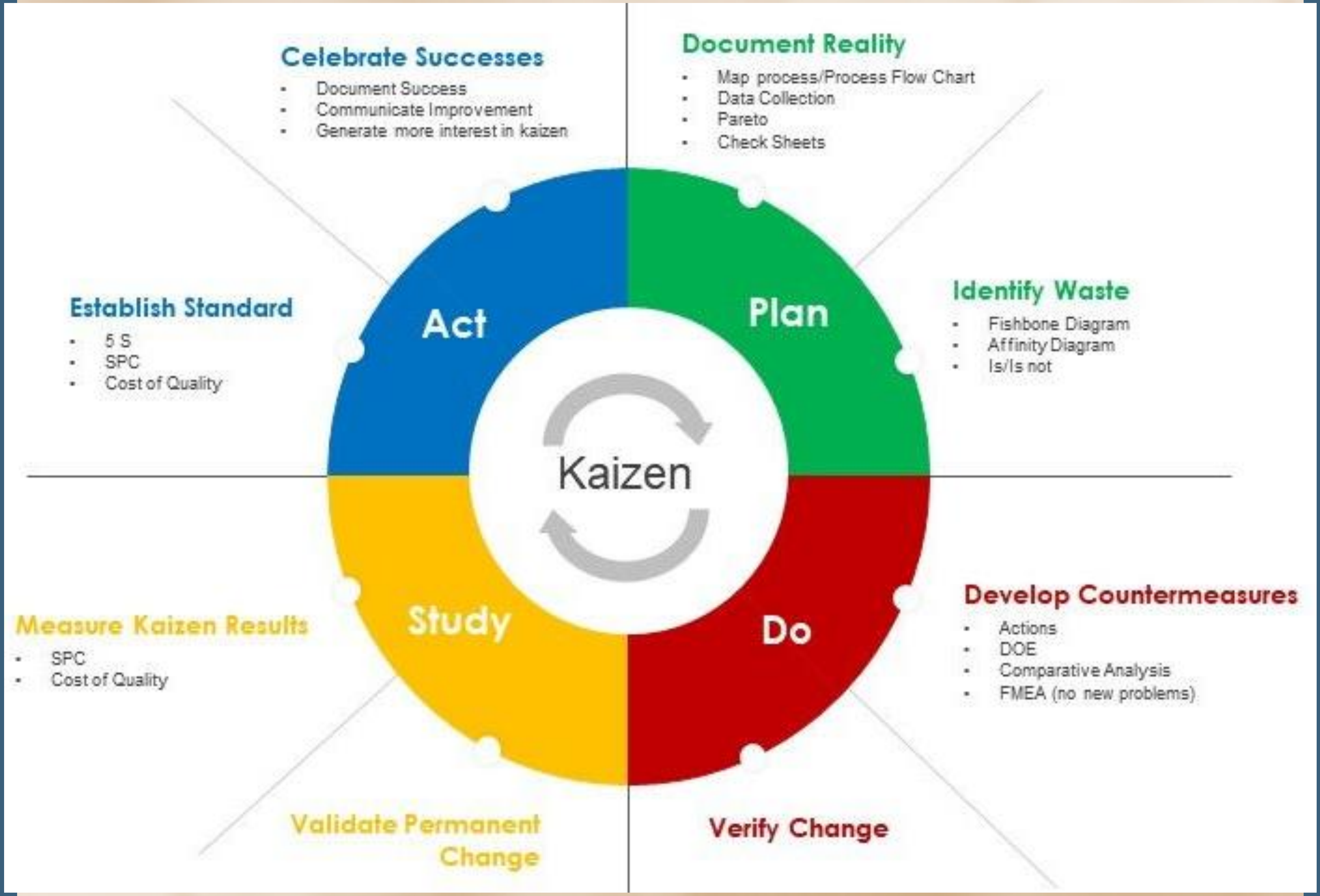
Features:

- combine verbal with numerical data;
- looking for root cause;
- clarify, prioritize goals and schedule;
- involve everyone into full cooperation;
- generate ideas.

METHODS AND TOOLS FOR CONTINUAL IMPROVEMENT

PHASE / TOOL	Reason for improvement	Current situation	Analysis	Identification of possible solutions	Evaluation of effects	Implementation and standardization Ö	Evaluation of the effectiveness Ö
Affinity diagram	AA		A	AA			A
Interrelationship diagram	AA		A	A			A
Systematic diagram	AA		A	A			A
Matrix diagram	A	A	A	A		AA	A
Matrix data analysis	A	A		A	A		A
PDPC diagram	AA			AA		A	A
Arrow diagram	A			A			A
Quality Function Deployment	A	A	A	A			A
Failure Mode and Effect Analysis	A		AA	AA	A		A
Fault Tree Analysis	A		AA	A	A		A
Design of Experiments			AA	AA	A		A
Process Capability Evaluation	A	AA	A	A	A	A	A
Machine Capability Evaluation	A	AA	A	A	A		A
Gage Capability Evaluation	A	AA	A		A		A
Flow Chart	AA	A		A		AA	A
Cause and Effect Diagram			AA		A		A
Data Collection Form		AA	AA	A	A	A	A
Pareto Diagram	AA	A	AA		A		A
Histogram	A	AA	A		A	A	A
Scatter diagram	A		AA		A		A
Control Chart	AA	AA	A	A	A	A	A


FACTS
Data
Numerical Data
Verbal Data
Define problem after collecting numerical data
Define problem before collecting numerical data
Seven Basic Tools
Seven New Tools
•Analytical approach
•Generate Ideas
•Formulate plans
Organize
Information


Celebrate Successes
Document Success
Communicate Improvement
Generate more interest in kaizen
Document Reality
Map process/Process Flow Chart
Data Collection
Pareto
Check Sheets
Establish Standard
5 S
SPC
Cost of Quality
Act
Plan
Identify Waste
Fishbone Diagram
Affinity Diagram
Is/Is not
Kaizen
Measure Kaizen Results
SPC
Cost of Quality
Study
Do
Develop Countermeasures
Actions
DOE
Comparative Analysis
FMEA (no new problems)
Validate Permanent Change
Verify Change

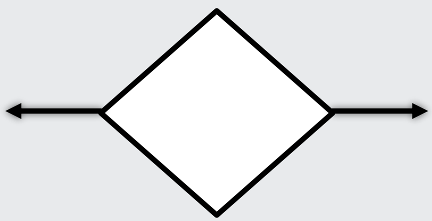
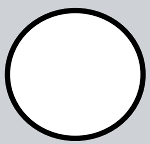
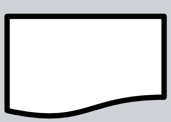
Seven Old Tools of Quality Management

Tools / Phase	Reason for improvement	Current sitation	Analysis	Identification of possible solution	Evaluation of effects	Implementation and standardization	Evaluation of effectivness
Flow Chart	AA	A		A		AA	A
Cause and Effect Diagram			AA		A		A
Check List		AA	AA	A	A	A	A
Pareto Diagram	AA	A	AA		A		A
Histogram	A	AA	A		A	A	A
Scatter Diagram	A		AA		A		A
Control Chart	AA	AA	A	A	A	A	A

Flow Chart

- Flowcharting is typically used to ***map a process flow*** showing the beginning of a process, decision points and the end of process.
- This tool is used when trying to determine where the bottlenecks or breakdowns are in work processes.
- Flow-charting the steps of a process provides a picture of what the process looks like and can shed light on issues within the process.
- Flowcharts are also used to show changes in a process when improvements are made or to show a new work flow process.

Symbols used in Flow Charts

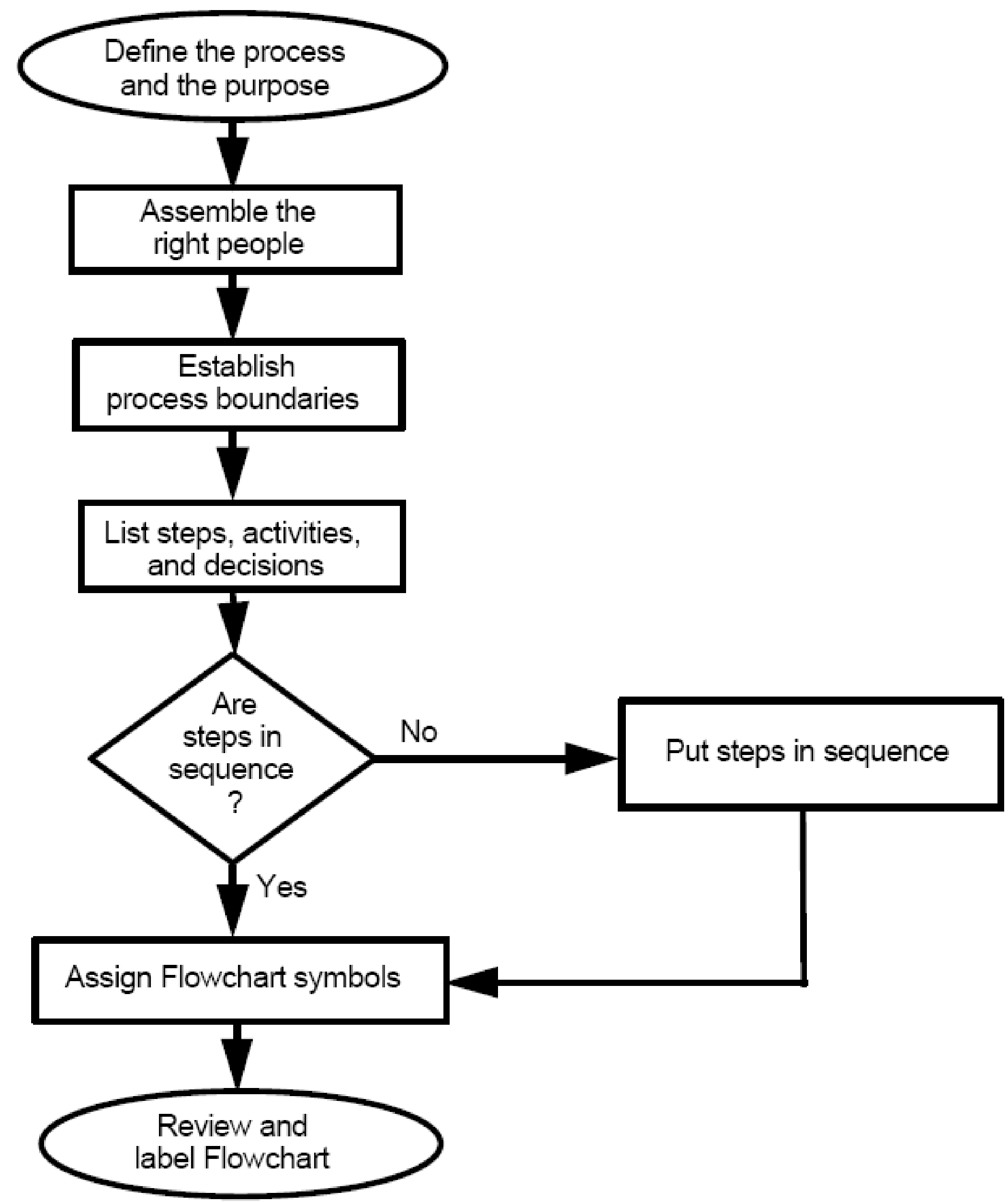
	One step in the process. The step is written inside the box. Usually, only one arrow goes out of the box.
	Direction of flow from one step or decision to another.
	Decision based on a question. The question is written in the diamond. More than one arrow goes out of the diamond, each one showing the direction the process takes for a given answer to the question. (Often the answers are "yes" and "no.").
	Link to another page or another flowchart. The same symbol on the other page indicates that the flow continues there.
	Input or output.
	Document.
	Symbol for start and end points.

Flow Chart

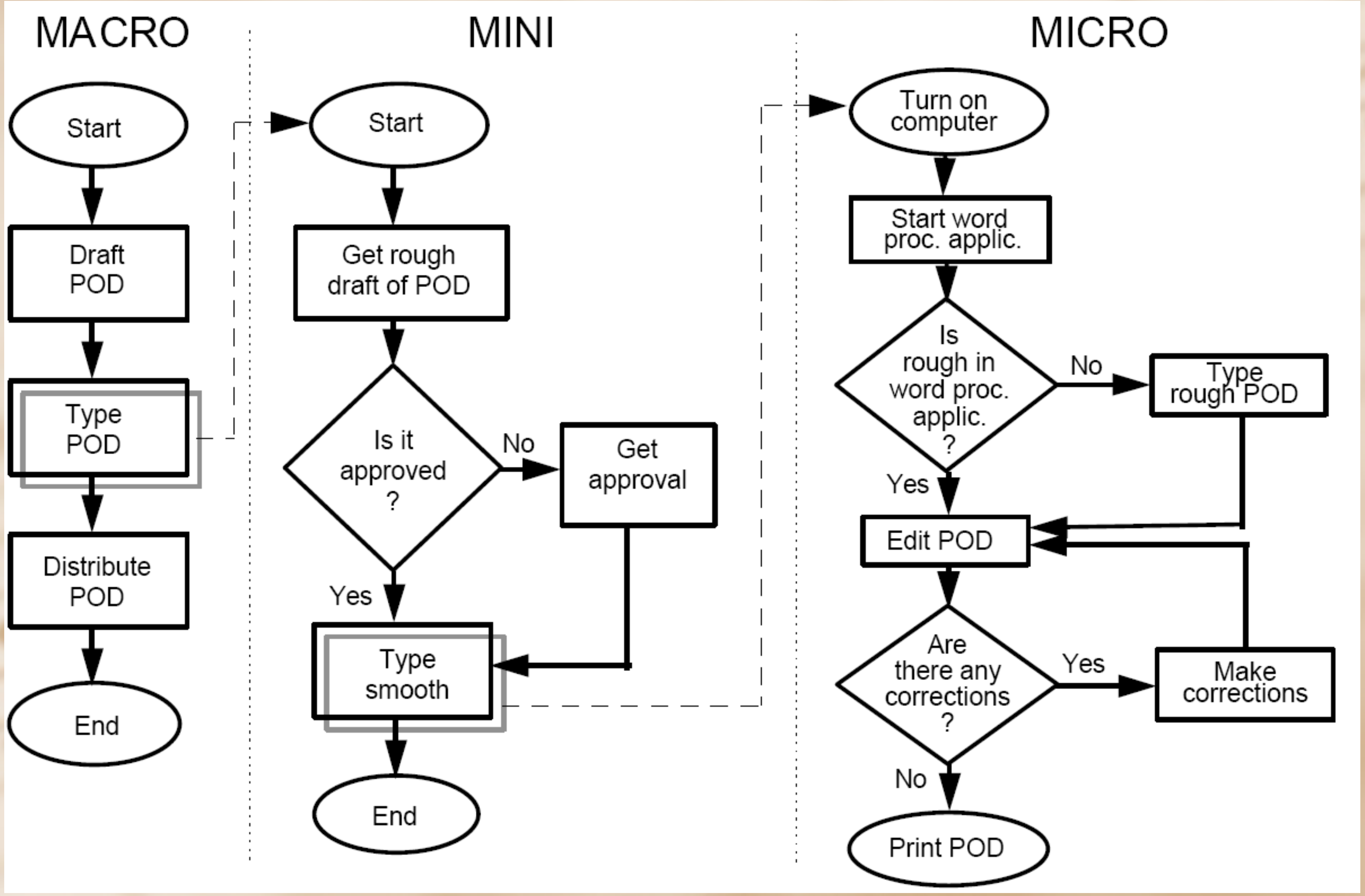
Basic Components of Process Mapping:

1. ***Process***. The overall workflow from a starting point to its successful completion.
2. ***Tasks or Activities***. Something performed by a person or a system.
3. ***Flows.*** This is indicated on the process map by connecting lines and arrows.
4. ***Events.*** These are triggers that cause a process to begin, end, or may redirect a process to a different path.
5. ***Gateways.*** Decisions that can change the path of the process depending on conditions or events.
6. ***Participants.*** Specifically naming the people or systems that perform the tasks or activities.

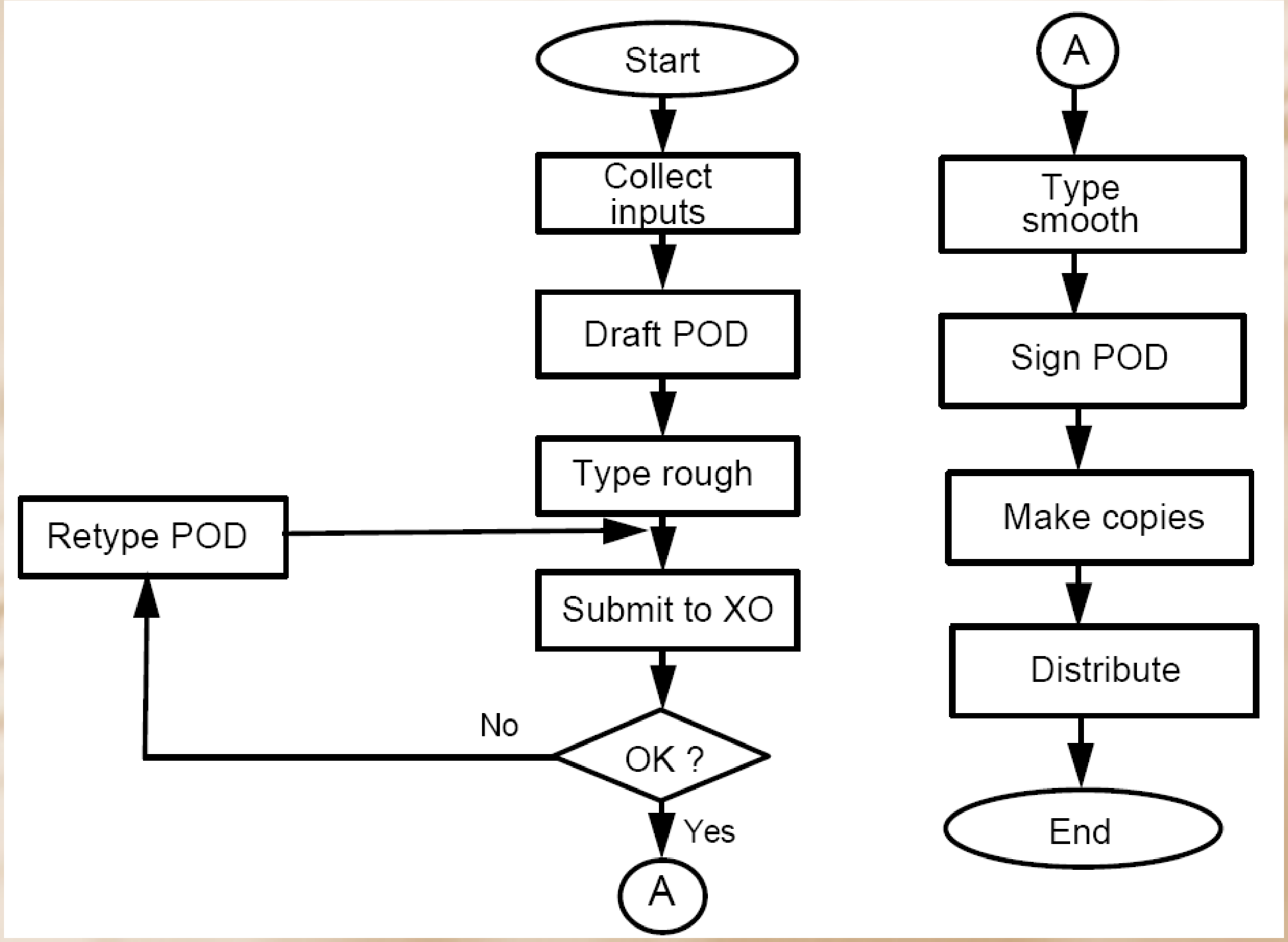
Constructing a flowchart



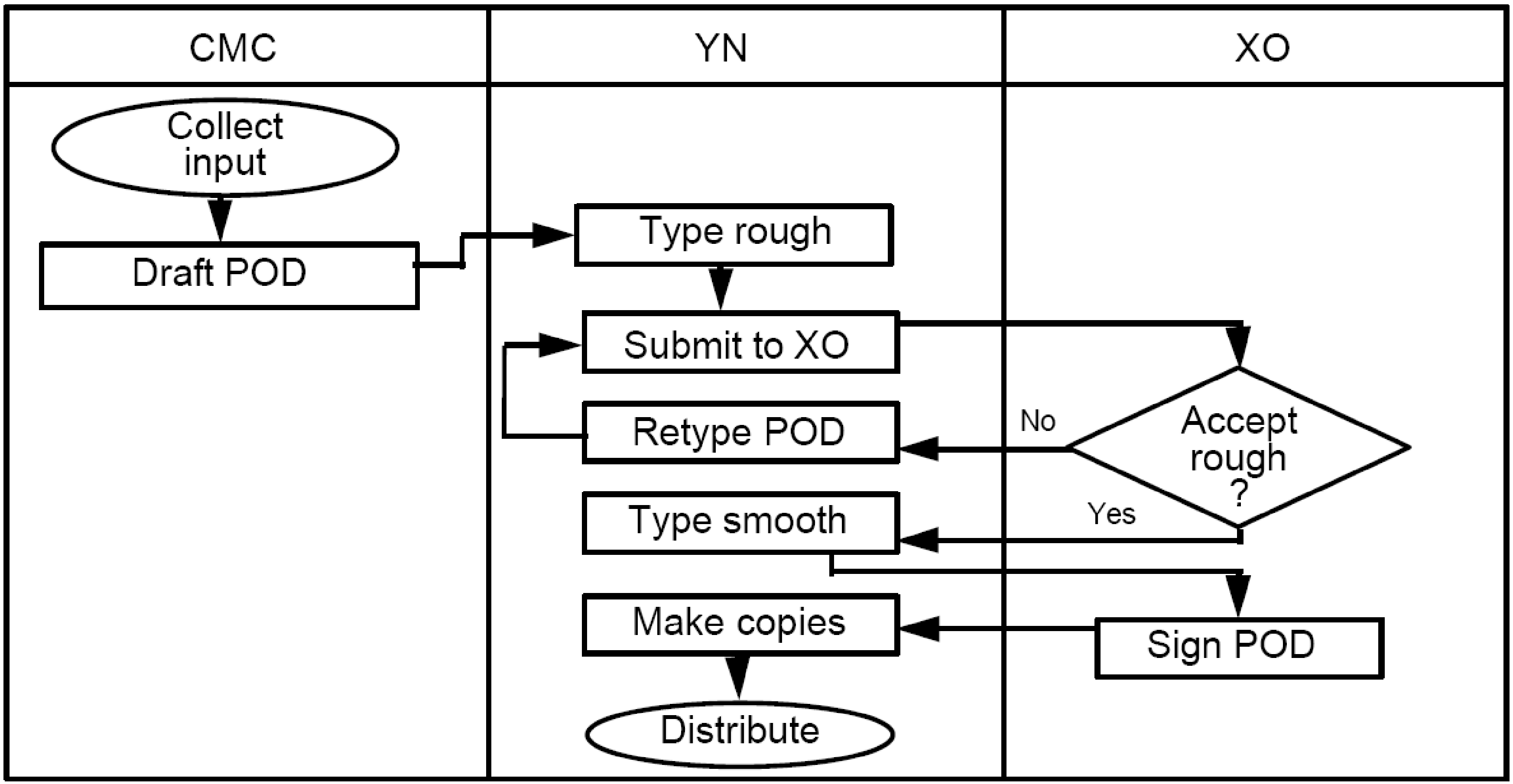
Levels of Flowcharts



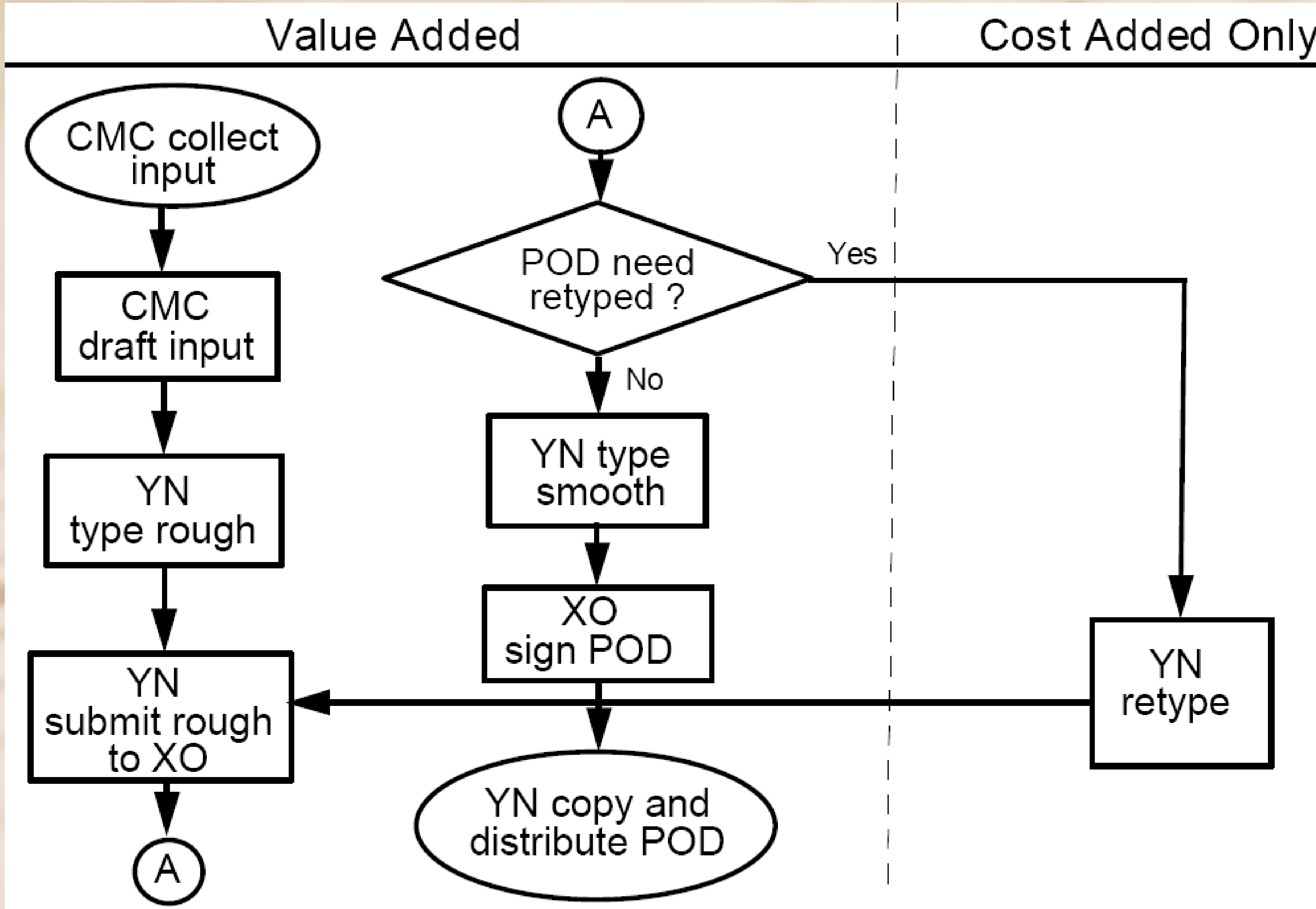
Types of Flowcharts - *linear*



Types of Flowcharts - *deployment*



Types of Flowcharts - *opportunity*



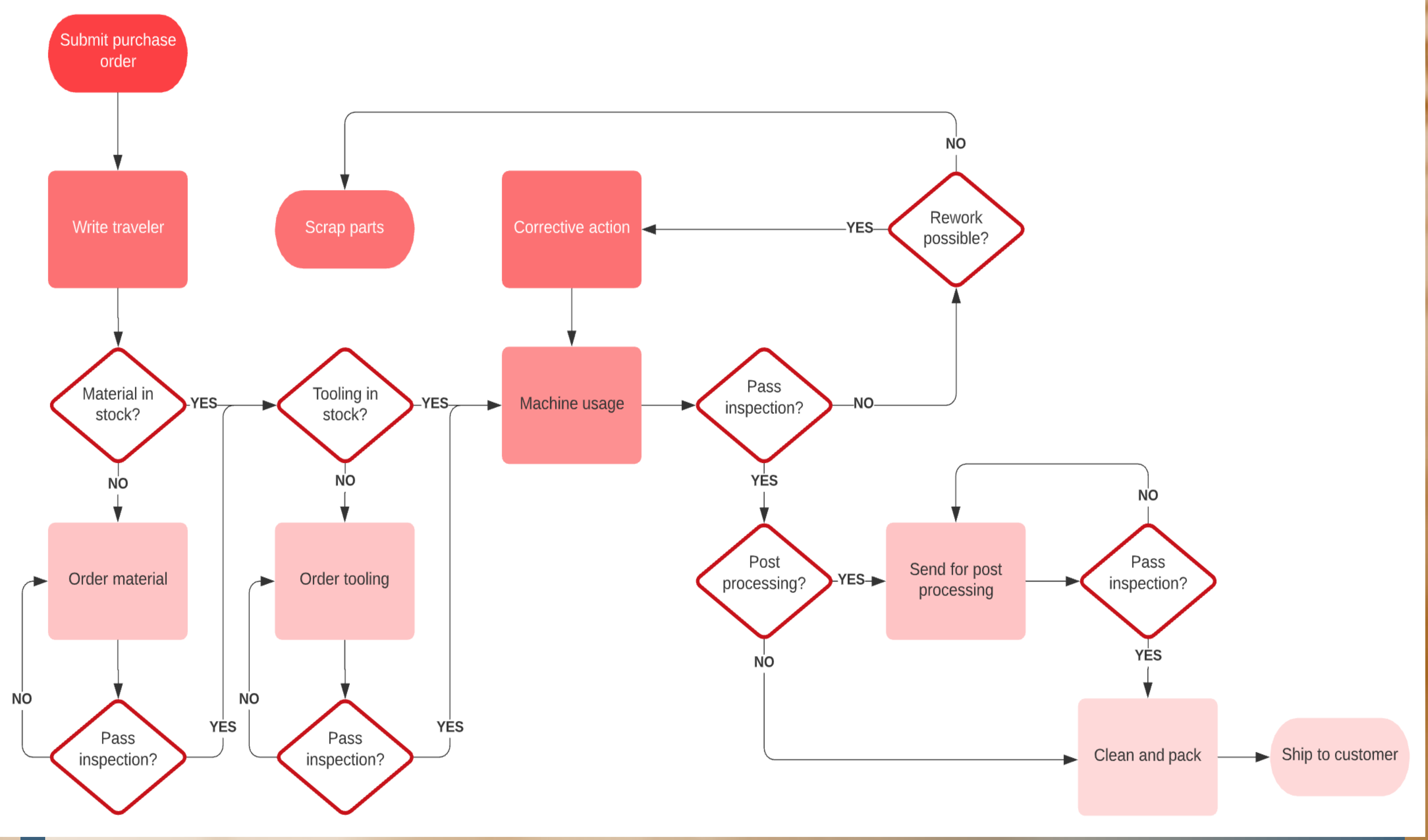
How do we interpret a flowchart?

- Determine who is involved in the process.
- Form theories about root causes.
- Identify ways to streamline the process.
- Determine how to implement changes to the process.
- Locate cost-added-only steps.
- Provide training on how the process works or should work.

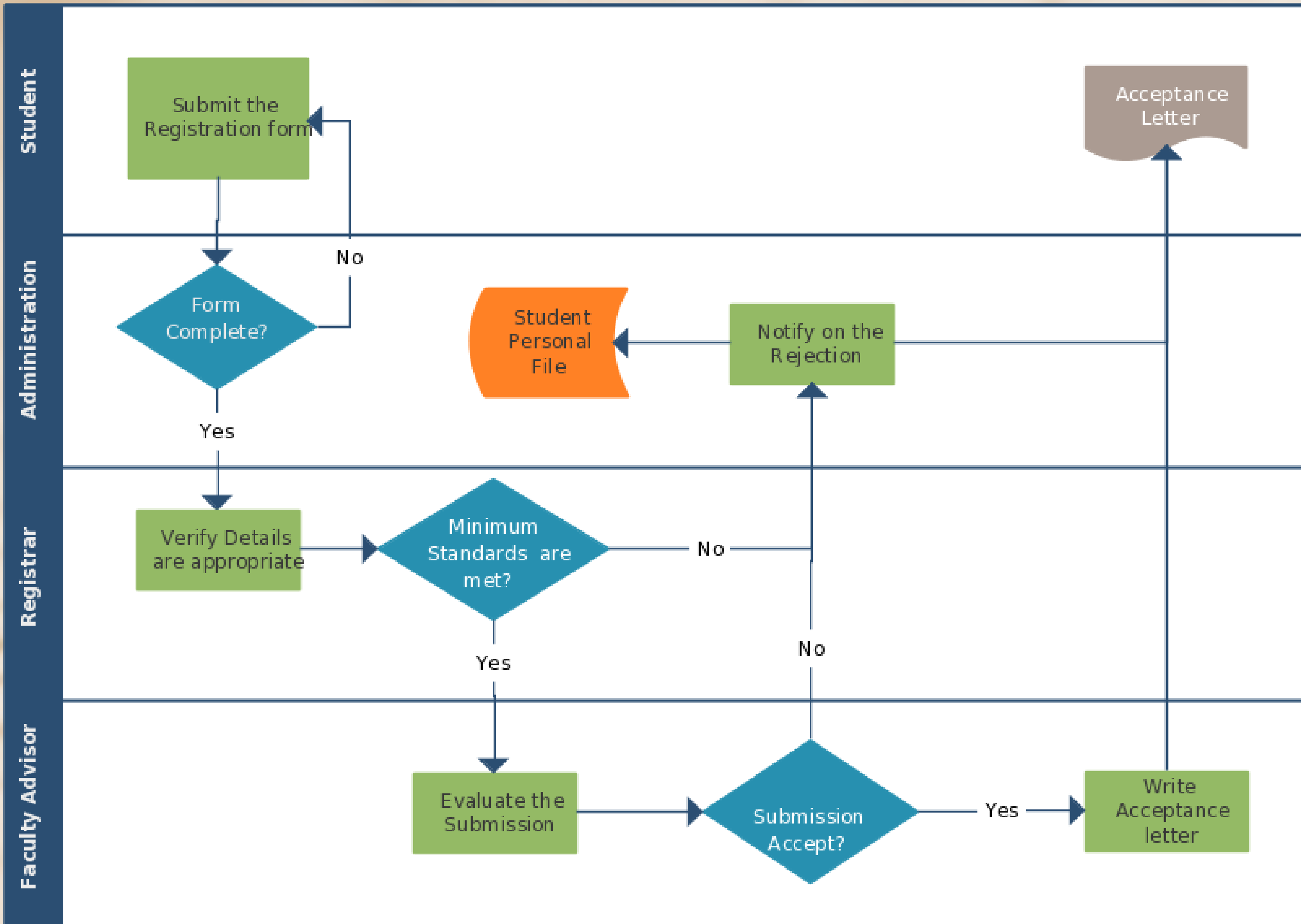
Flow Chart *vs.* Process Mapping *vs.* Value Stream Mapping

- ***Flow chart*** - typically a basic graphical representation of the process using boxes as process steps and connecting arrows.
- ***Process Mapping*** - starts with a flow chart, and typically adds detail such as inputs and outputs of each process step (used in Six Sigma).
- ***Value Stream Mapping*** - starts with a flow chart and adds time for each process step as well as the delay between process steps, including transportation. Also identifies each step as Value-add or Non-value-add (used in Lean).

Flow Chart – *Production Flowchart*

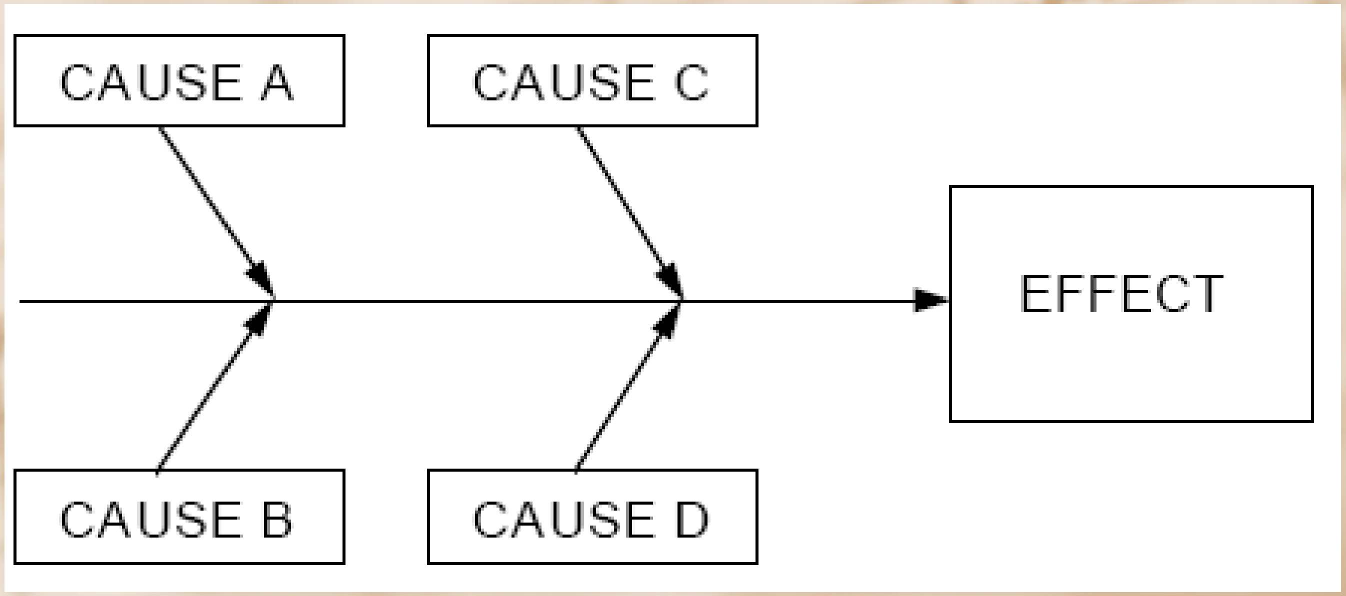


Flow Chart – New Student Application Process



Cause-and-Effect Diagram
(Ishikawa diagram, Fishbone diagram)

A tool that helps identify, sort, and display possible causes of a specific problem or quality characteristic.

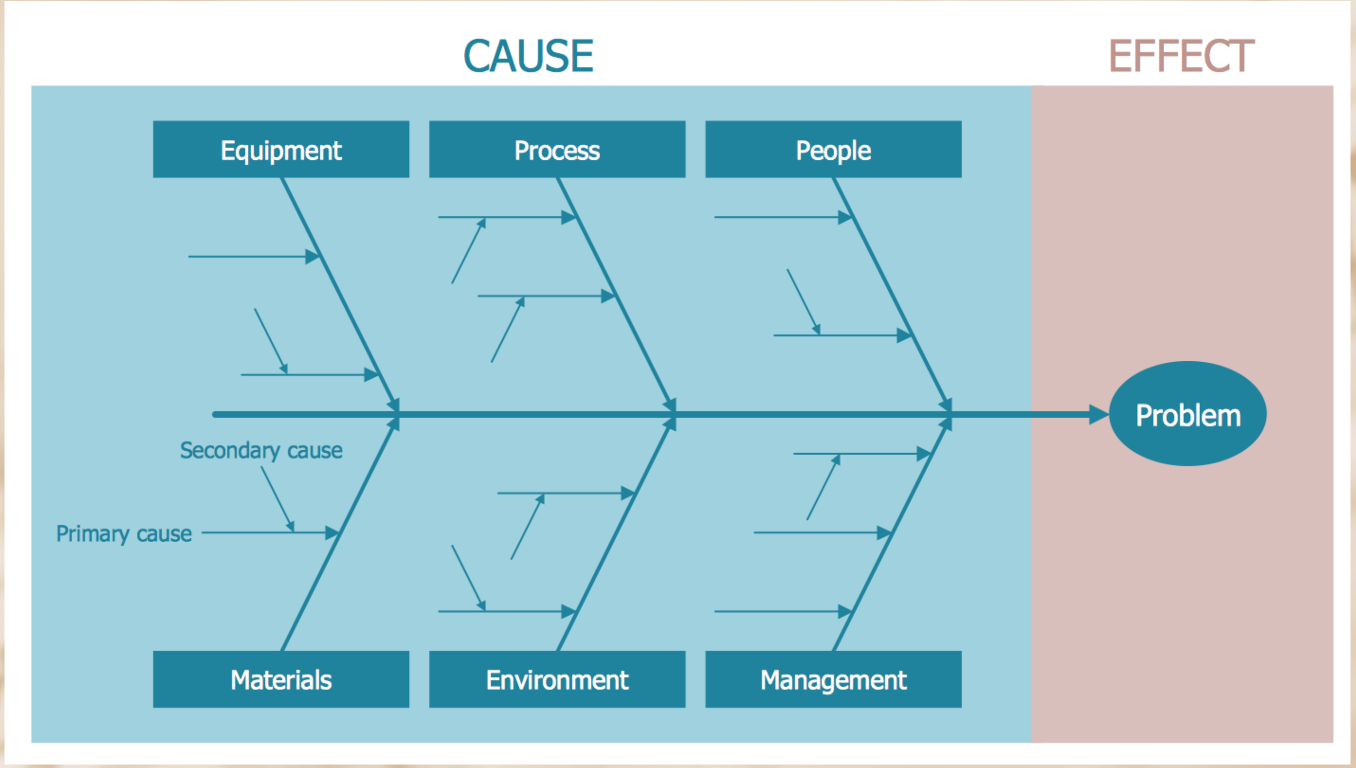


Cause-and-Effect Diagram

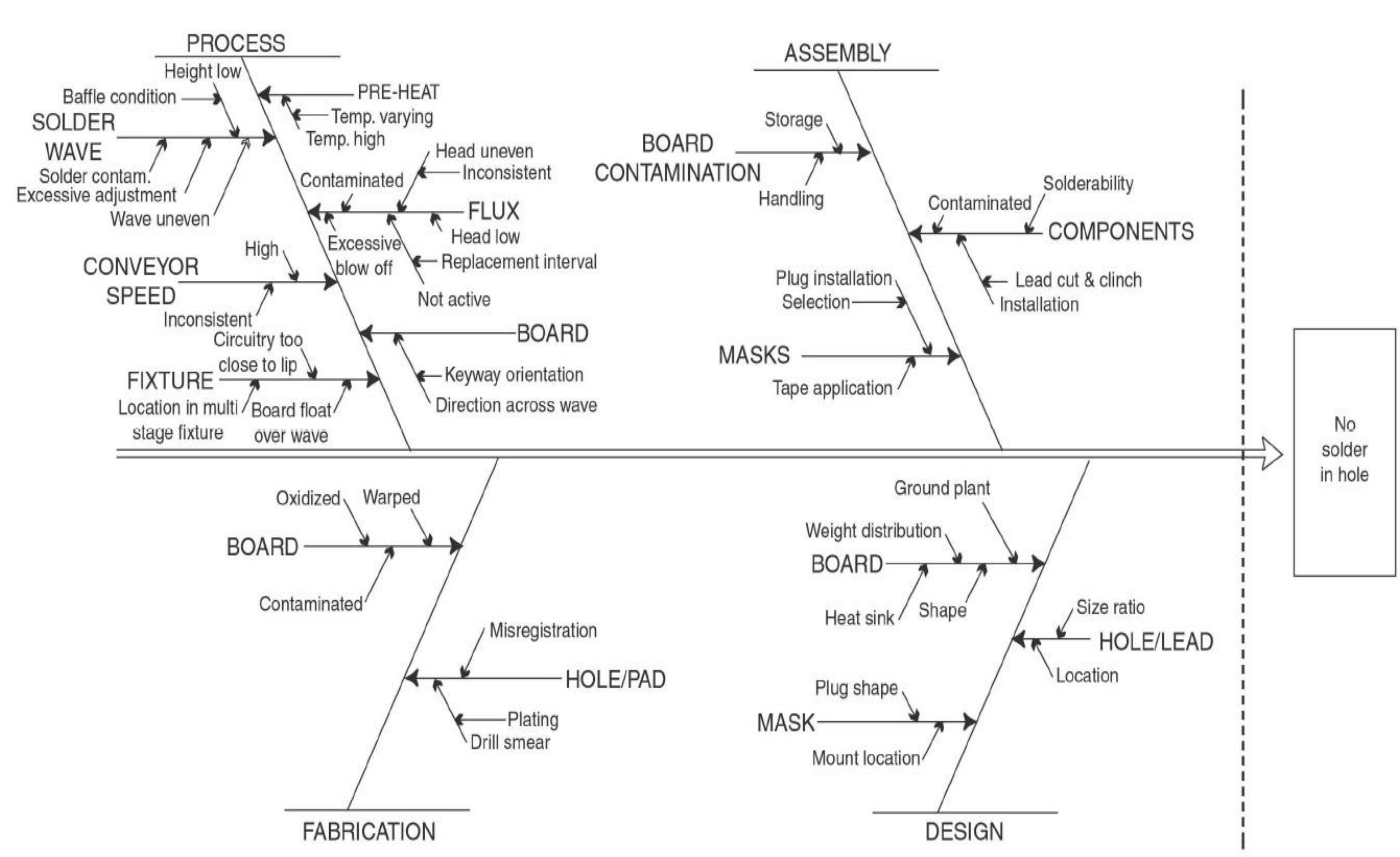
There is a need to:

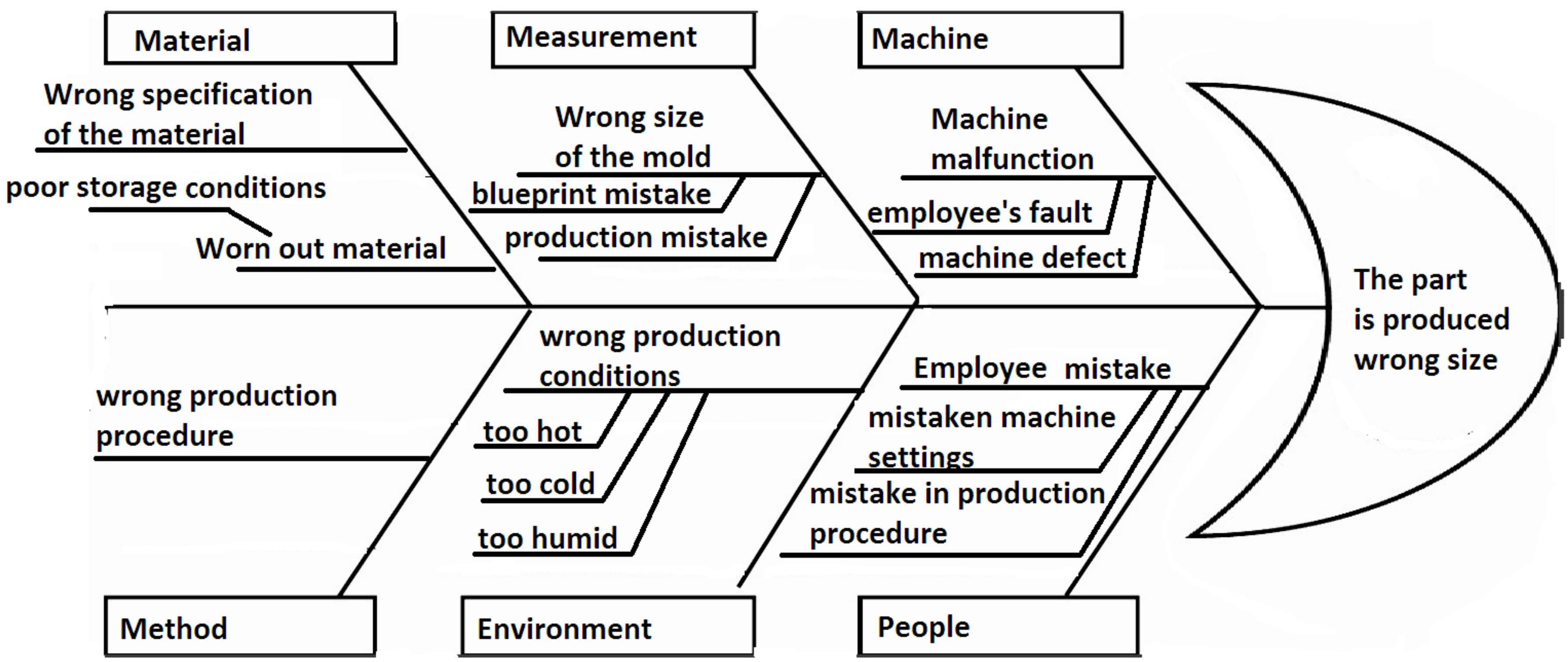
- **identify the possible root causes**, the basic reasons, for a specific effect, problem, or condition.
- **sort out and relate some of the interactions** among the factors affecting a particular process or effect.
- **analyze existing problems** so that corrective action can be taken.

Identification of Main Categories of Causes

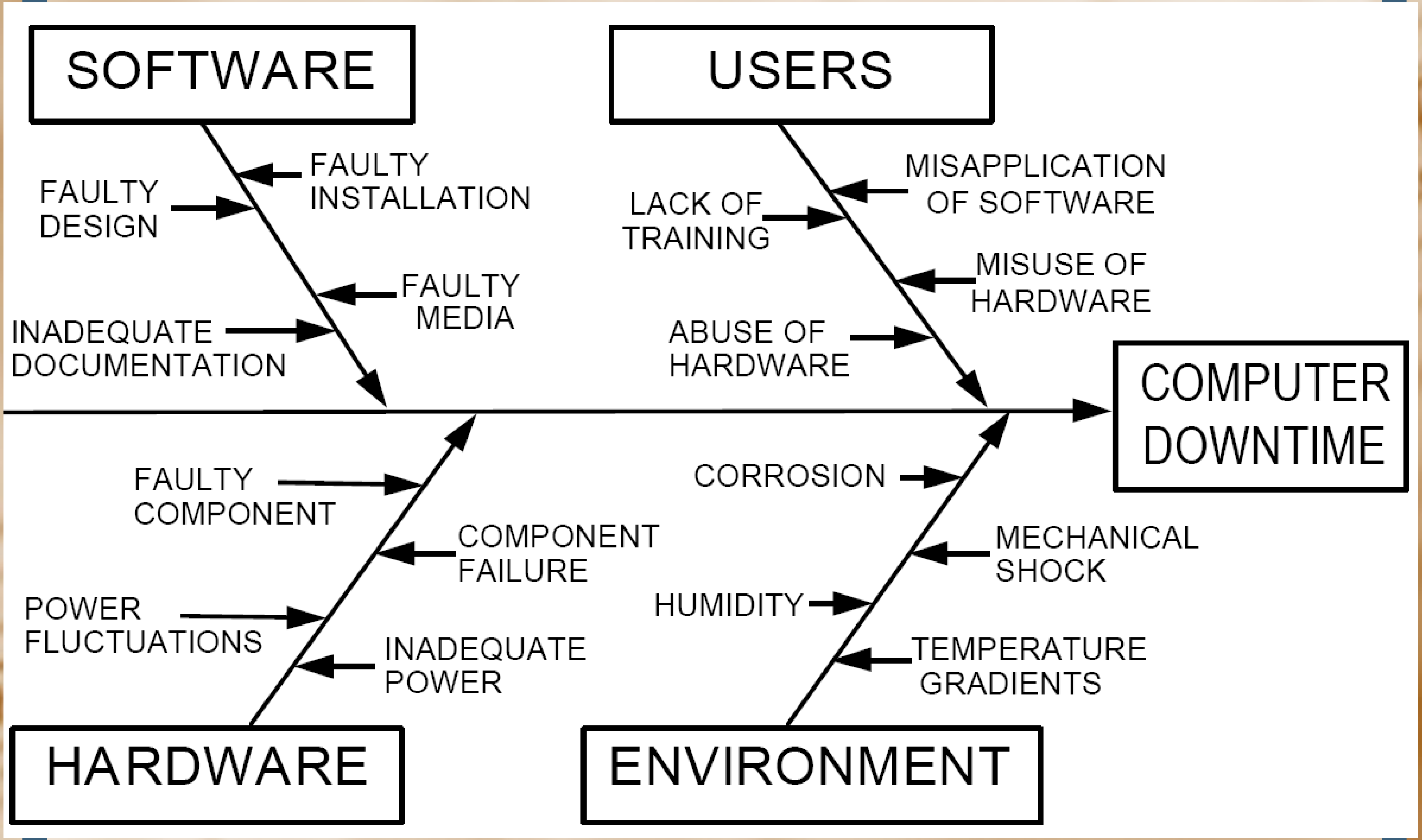


3Ms and P - methods, materials, machinery, and people
5Ms/6Ms – methods, materials, machines (Equipments), measurements, manpower, management,
4Ps - policies, procedures, people, and plant
Environment - a potentially significant fifth category


PROCESS
Height low
Baffle condition
SOLDER WAVE
Solder contam.
Excessive adjustment
Wave uneven
PRE-HEAT
Temp. varying
Temp. high
Head uneven
Inconsistent
Contaminated
FLUX
Excessive blow off
Head low
Replacement interval
Not active
CONVEYOR SPEED
High
Inconsistent
BOARD
Keyway orientation
Direction across wave
FIXTURE
Circuitry too close to lip
Location in multi stage fixture
Board float over wave
ASSEMBLY
BOARD CONTAMINATION
Storage
Handling
COMPONENTS
Contaminated
Solderability
Lead cut & clinch
Installation
MASKS
Plug installation
Selection
Tape application
No solder in hole
FABRICATION
BOARD
Oxidized
Warped
Contaminated
HOLE/PAD
Misregistration
Plating
Drill smear
DESIGN
BOARD
Ground plant
Weight distribution
Heat sink
Shape
HOLE/LEAD
Size ratio
Location
MASK
Plug shape
Mount location



Material
Measurement
Machine
Wrong specification of the material
poor storage conditions
Worn out material
Wrong size of the mold
blueprint mistake
production mistake
Machine malfunction
employee's fault
machine defect
The part is produced wrong size
wrong production procedure
wrong production conditions
too hot
too cold
too humid
Employee mistake
mistaken machine settings
mistake in production procedure
Method
Environment
People


SOFTWARE
FAULTY INSTALLATION
FAULTY DESIGN
FAULTY MEDIA
INADEQUATE DOCUMENTATION
USERS
MISAPPLICATION OF SOFTWARE
LACK OF TRAINING
MISUSE OF HARDWARE
ABUSE OF HARDWARE
COMPUTER DOWNTIME
FAULTY COMPONENT
COMPONENT FAILURE
POWER FLUCTUATIONS
INADEQUATE POWER
HARDWARE
CORROSION
MECHANICAL SHOCK
HUMIDITY
TEMPERATURE GRADIENTS
ENVIRONMENT

Checksheets

The structured forms that enable you to collect and organize data systematically.

Uses for checksheets:

- ***Record information on the key quality characteristics*** of your process for the analysis using tools such as a Pareto charts, Histograms, and Run Charts.
- ***Provide a historical record of the process*** over time.
- ***Introduce Data Collection methods*** to workers and supervisors who may not be familiar or comfortable with collecting data as a regular part of their jobs.

Data Collection

It is needed to define the following:

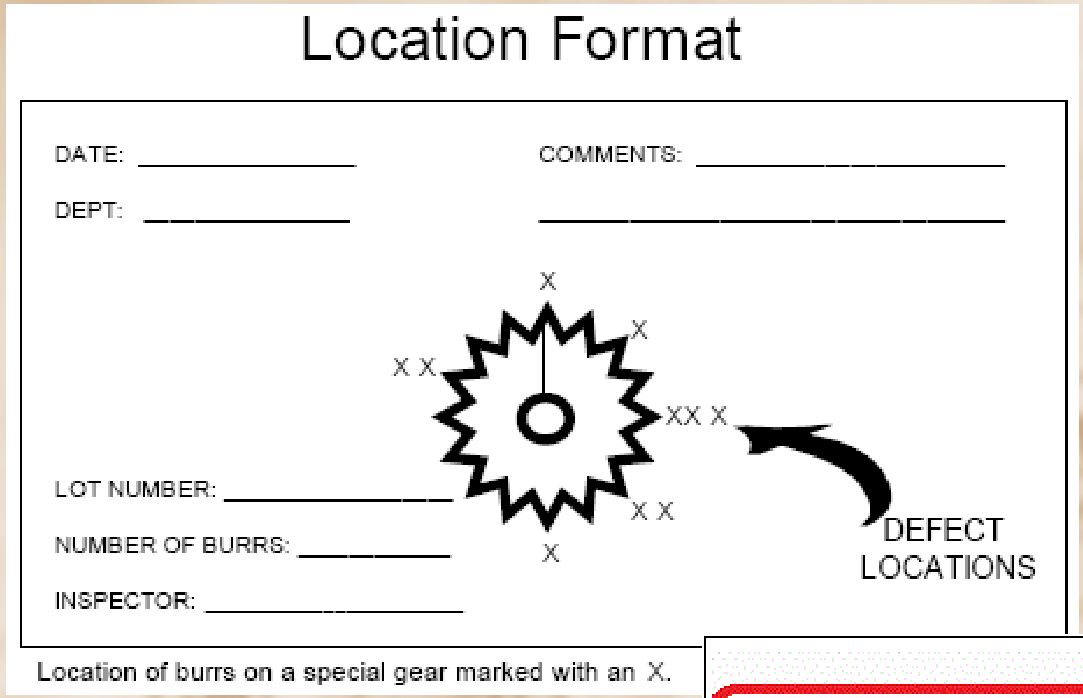
- When and how often you will collect the data
- How you will collect the data
- Units of measurement you will use in collecting the data
- The criteria for defects
- How you will handle multiple defects on single products

Types of Checksheets – *tabular format*

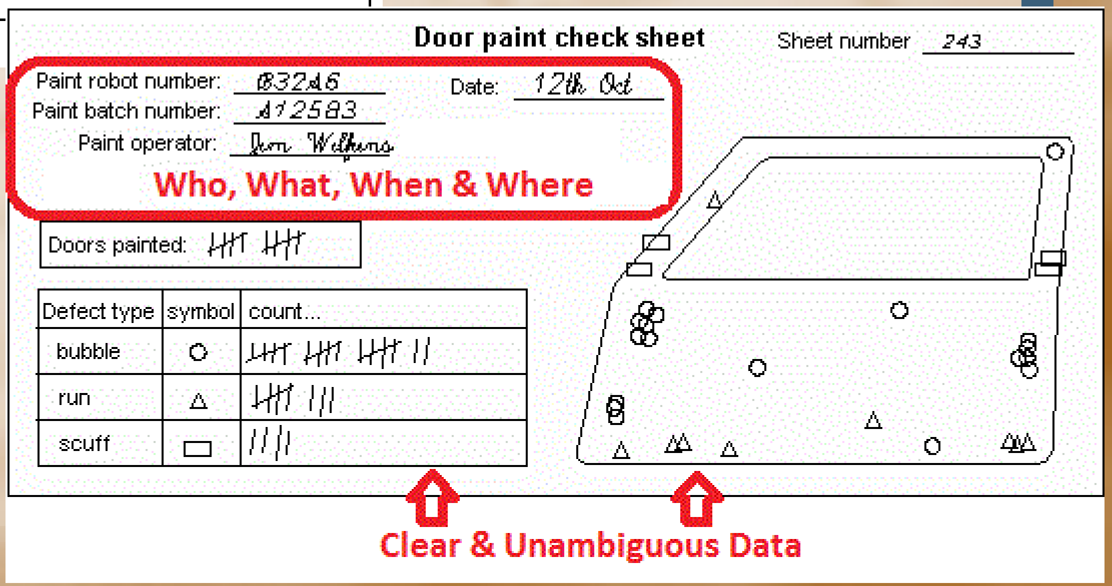
GEAR DEFECT DATA

Defect Category	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	TOTAL
I.D. Size Wrong	I			I	II					I		5
O.D. Size Wrong		I										1
Nicks		II			II	II	II		I	I	II	12
Burrs			I	I	I		I	I	I	I	II	9
Tooth Geometry	I							I				2
Blemishes	I	II		I		I		I			II	8
Other			I									1
Total	3	5	2	3	5	3	3	3	2	3	6	38

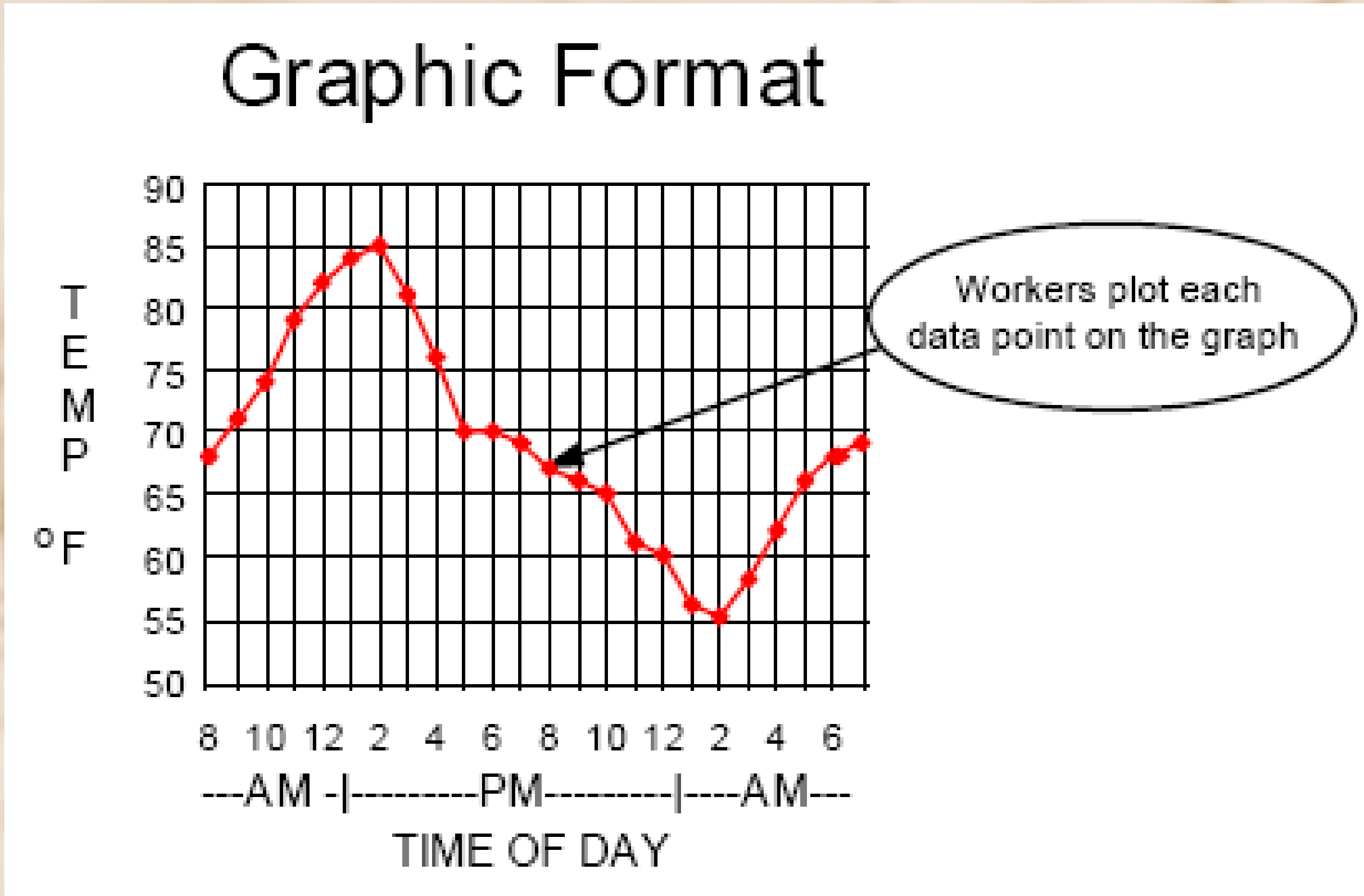
Types of Checksheets



Location of burrs on a special gear marked with an X.



Types of Checksheets



Pareto analysis

The Pareto analysis is used when there are several opportunities to choose one from.

For example, one project may have to be chosen as the first one from several project opportunities, or one defect category may have to be addressed first from among many defect categories.

The Pareto analysis is used in these situations as it separates the ***vital few from trivial many*** opportunities.

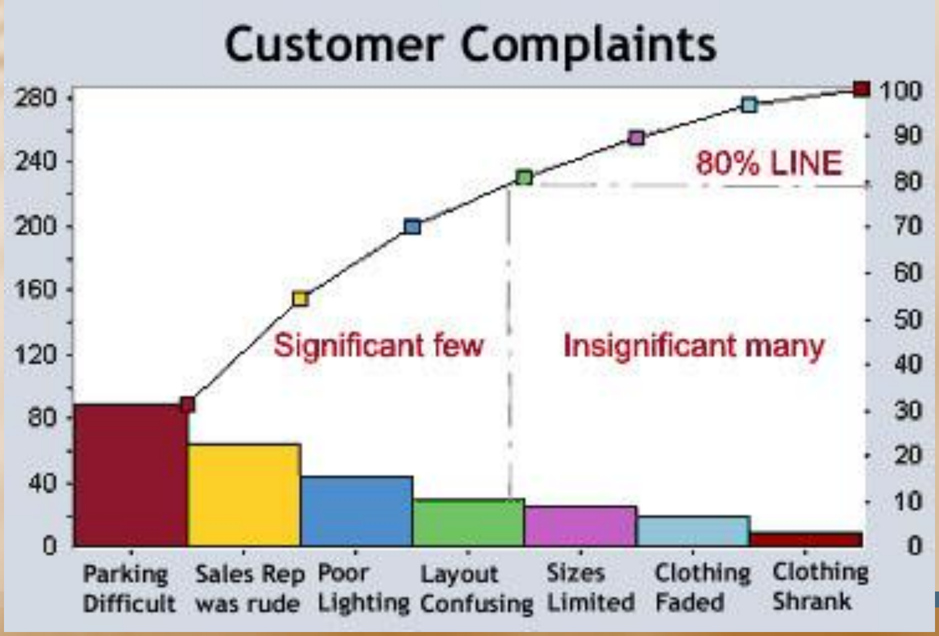
The method is based on a distribution proposed by the Italian researcher Wilfredo Pareto (1848–1923) to describe how a small proportion of people in the free Western societies controlled a large proportion of the total wealth.

Juran saw similar phenomenon in the quality area, *where a small number of causes **„vital few“** are responsible for a large proportion of losses*.

Pareto analysis

Such separation helps in prioritizing improvement opportunities and in concentrating on the ***vital few*** causes rather than spreading effort among the many trivial causes.

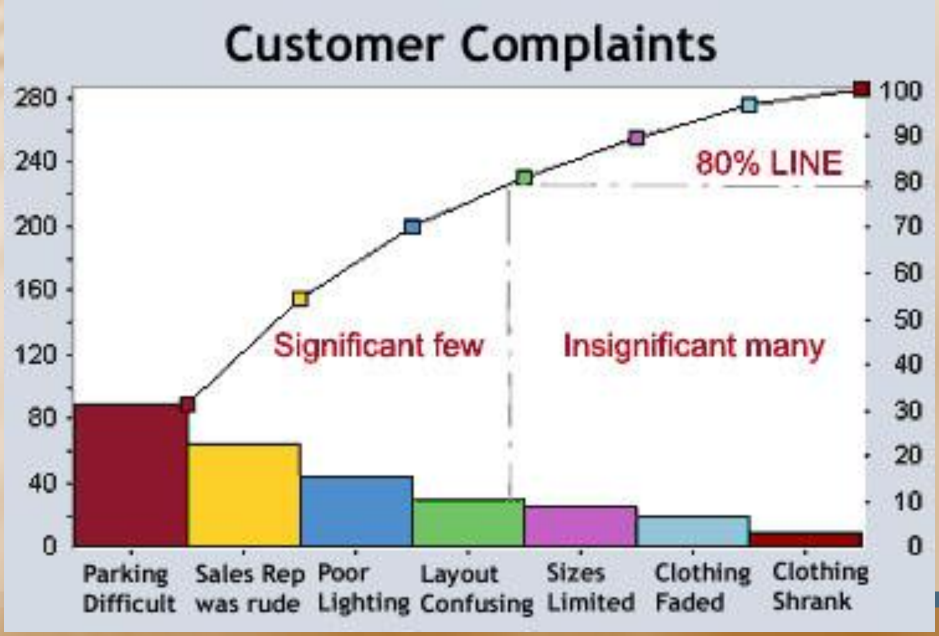
A quality engineer will find this method to be useful in many situations when he should decide which project to select or product-defect to address first.



Pareto analysis

The Pareto analysis consists of obtaining data on the frequency at which the different causes have been occurring, in recent history, in creating the problem.

A Pareto chart is a **bar graph**. The length of the bars represent frequency or cost (money or time), and they are arranged in order from longest on the left to shortest on the right. Therefore, the chart visually shows **which situations are more significant.**



Pareto chart

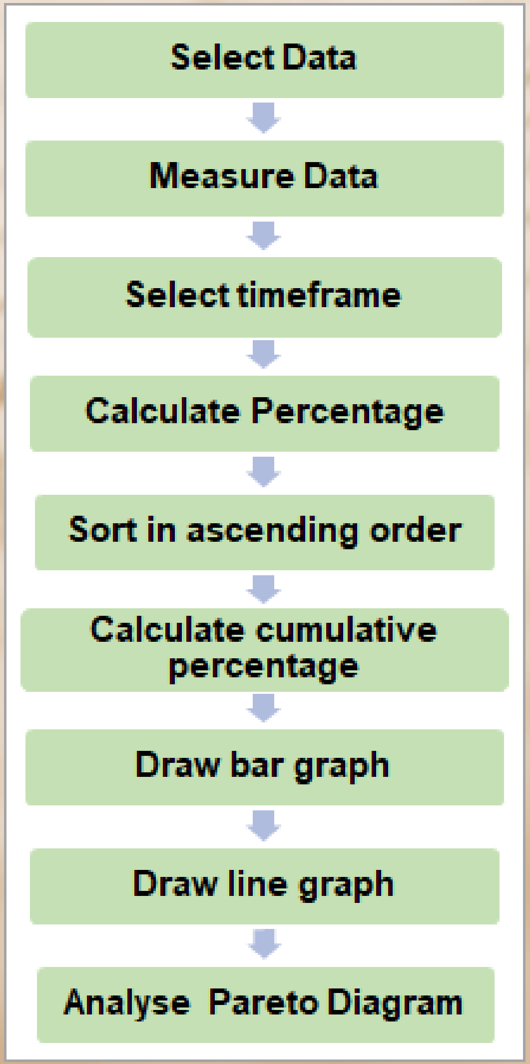
1 - *Record the raw data*. List each category and its associated data count.

2 - *Order the data*. Prepare an analysis sheet, putting the categories in order and placing the one with the largest count first (*in ascending order*).

3 - *Arrange the bar chart in descending order* of cause importance that is, the cause with the highest count first.

4 - *Calculate the cumulative count* for each cause in descending order.

5 - *Calculate the cumulative count percentage* for each cause in descending order.



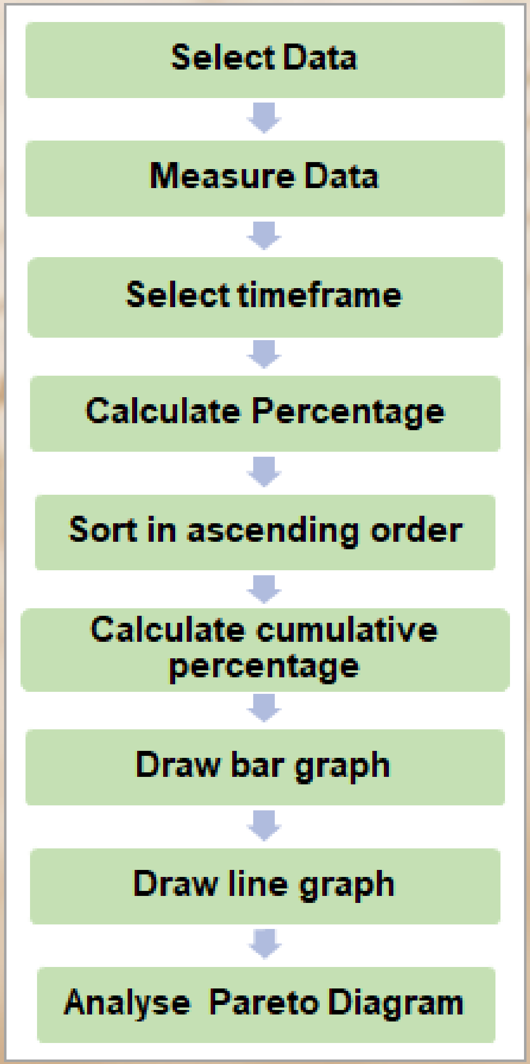
Pareto chart

6 - *Create a second y-axis with percentages* descending in increments of 10 from 100% to 0%.

7 - *Plot the cumulative count percentage* of each cause on the x-axis.

8 - *Draw* a line at 80% on the y-axis running parallel to the x-axis. Then drop the line at the point of intersection with the curve on the x-axis.

This point on the x-axis separates the important causes on the left (vital few) from the less important causes on the right (trivial many).

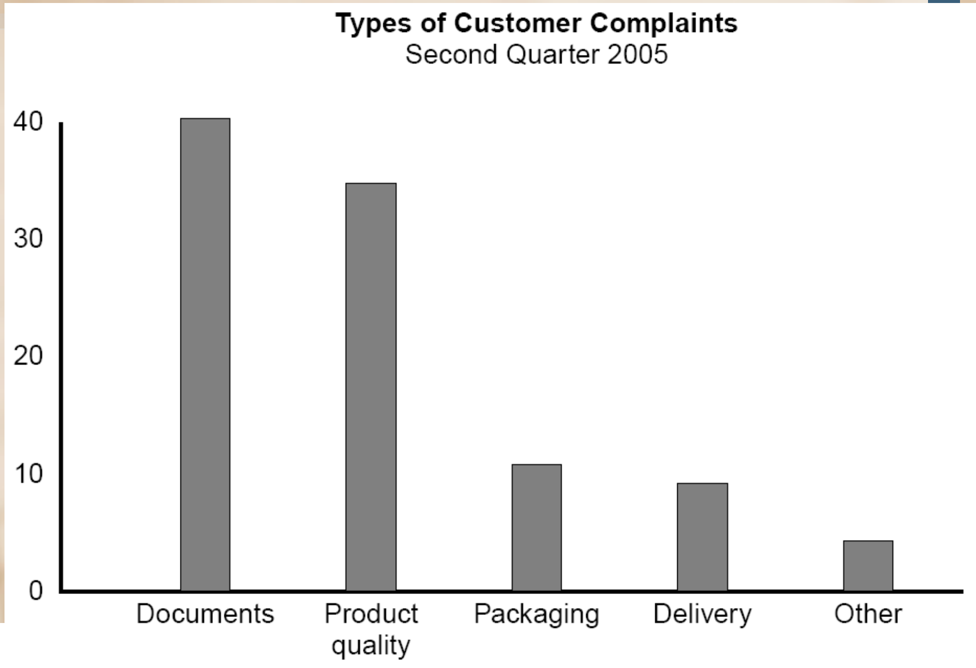


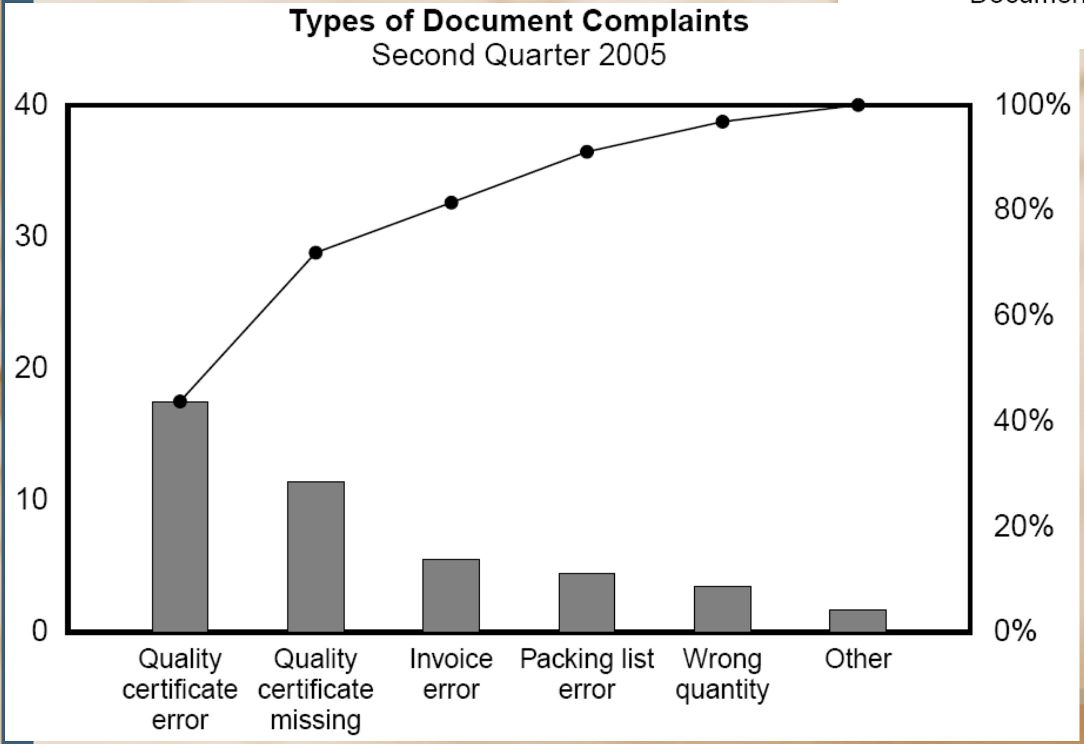
Pareto chart

When to Use:

- When analyzing data about the *frequency of problems or causes in a process*, and . . .
- When there are many problems or causes and you want *to focus on the most significant*, or . . .
- When analyzing *broad causes to their specific components*, or . .
- When communicating with others about your data

Pareto chart



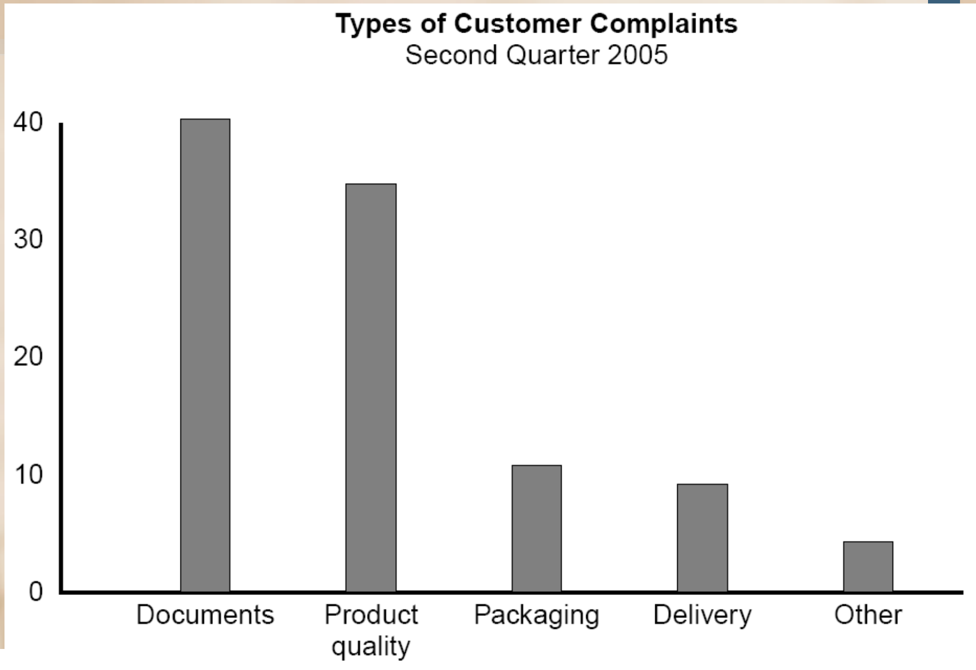


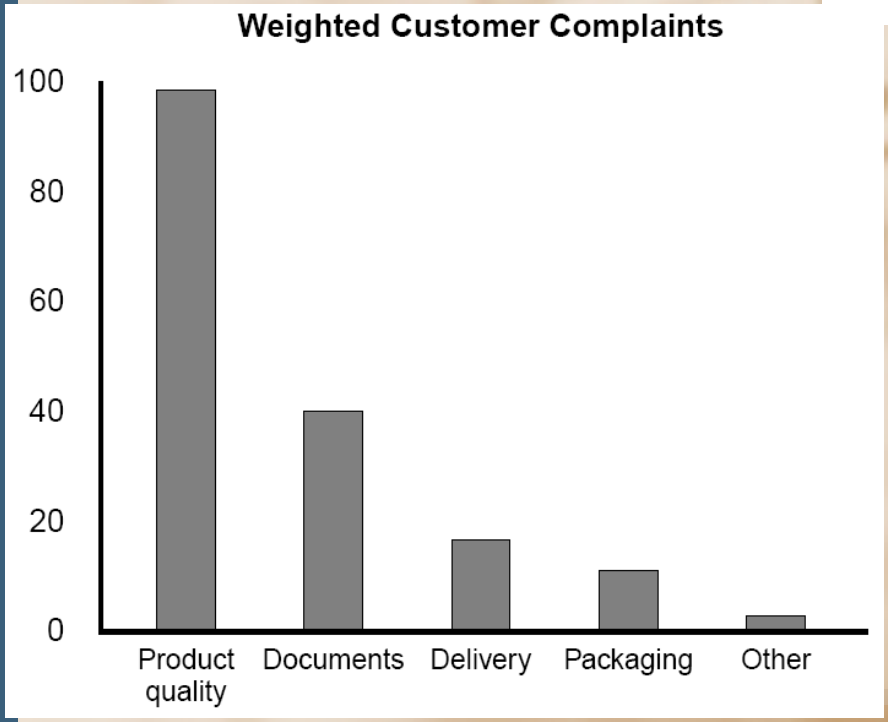
weighted ***Pareto chart***

In a weighted Pareto chart, each category is assigned a weight, which lengthens or shortens the bars. This reflects the relative importance or cost of each category.

When to Use:

- When a Pareto analysis is appropriate, and . . .
- When the categories do not result in equal cost or pain to the organization, or . . .
- When there are more opportunities for one category to occur than another





Documents	1
Product quality	3
Packaging	1
Delivery	2
Other	0.5

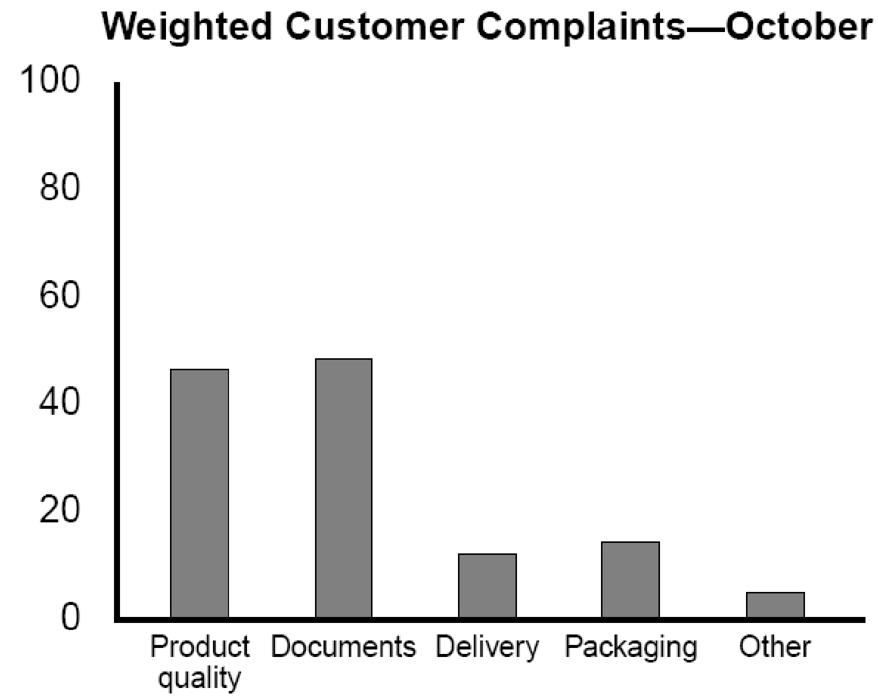
comparative *Pareto charts*

Comparative Pareto charts place two or more Pareto charts side by side to compare two or more sets of data. The data differ in some fundamental way but can be analyzed using the same categories.

When to Use

- When a Pareto or weighted Pareto chart is appropriate, and . . .
- When you wish to compare two or more sets of data, and . . .
- When all sets of data will be analyzed using the same categories, and . . .
- When each set of data differs from the others on a significant variable.

  - *Comparing data from different processes*
  - *Comparing data from different times*
  - *Comparing data before and after process changes, to assess improvement*



The best Pareto chart uses a measurement that reflects cost to the organization.

If every category identified has equal cost or pain to the organization, then frequency is a good measurement.

If not, it is more useful to measure dollars, time, or some other indicator of cost. If it is possible to measure cost or time directly, do so.

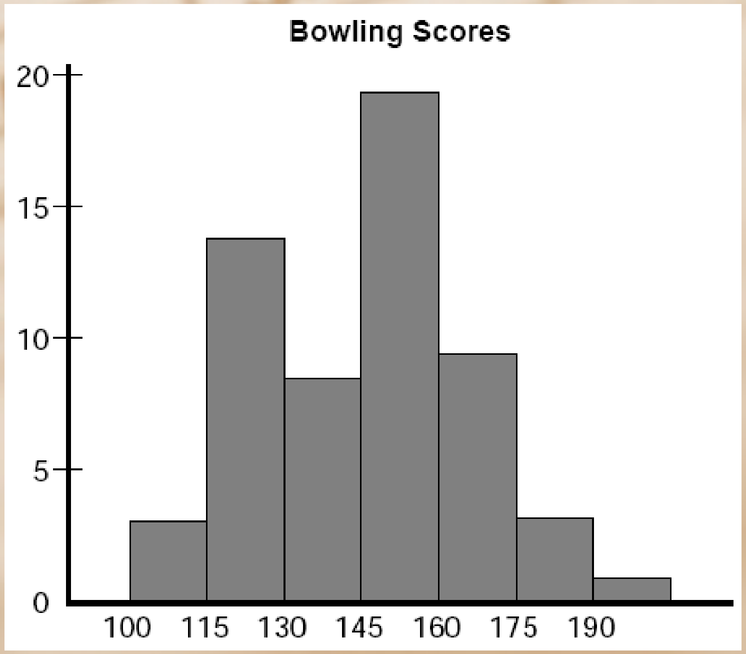
If not, use a weighted Pareto chart and estimate weights for each category to translate frequency into cost.

Histogram

A **frequency distribution** shows *how often each different value* in a set of data occurs. A histogram is the most commonly used graph to show frequency distributions. It looks very much like a bar chart, but there are important differences between them.

A *histogram* is the appropriate graph to use when the data are *numerical*. The bars in a histogram *touch to* indicate that the numerical scale is continuous.

If the data are *categorical* (nominal or ordinal) use a bar chart. The bars in a bar chart have *spaces* between them.



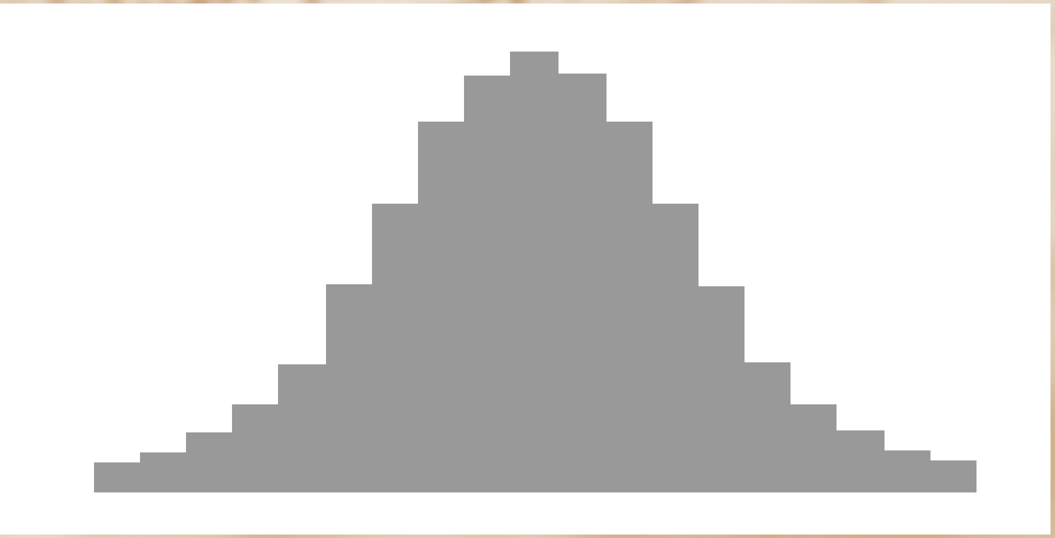
When to Use:

- When the data are numerical, and . . .
- When you want to see the shape of the data's distribution, especially:
  - When determining whether the output of a process is distributed approximately normally, or . . .
  - When analyzing whether a process can meet the customer's requirements, or . . .
  - When analyzing what the output from a supplier's process looks like, or
  - When seeing whether a process change has occurred from one time period to another, or . . .
  - When determining whether the outputs of two or more processes are different, or . . .
  - When you wish to communicate the distribution of data quickly and easily to others

The histogram shapes

Normal distribution

A common pattern is the bell-shaped curve known as the *normal distribution*. In a normal distribution, points are as likely to occur on one side of the average as on the other. Statistical calculations such as the normal probability plot or goodness-of-fit tests must be used to prove a normal distribution. However, if the histogram has a different shape, it proves that the distribution is not normal.



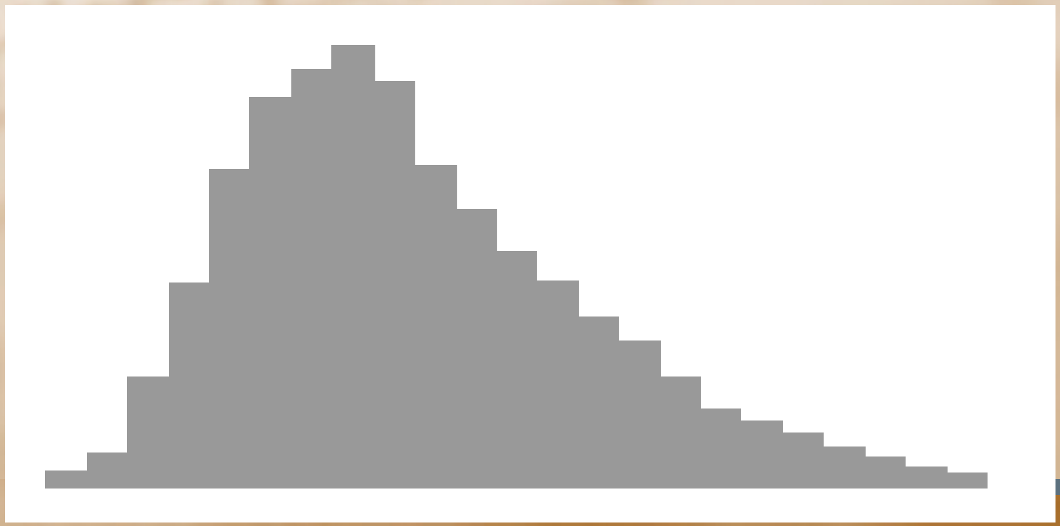
Skewed distribution

The skewed distribution is unsymmetrical because a natural limit prevents outcomes on one side. The distribution's peak is off center toward the limit and a tail stretches away from it.

For example, a distribution of analyses of a very pure product would be skewed, because the product cannot be more than 100 percent pure.

Other examples of natural limits are holes that cannot be smaller than the diameter of the drill bit or call-handling times that cannot be less than zero.

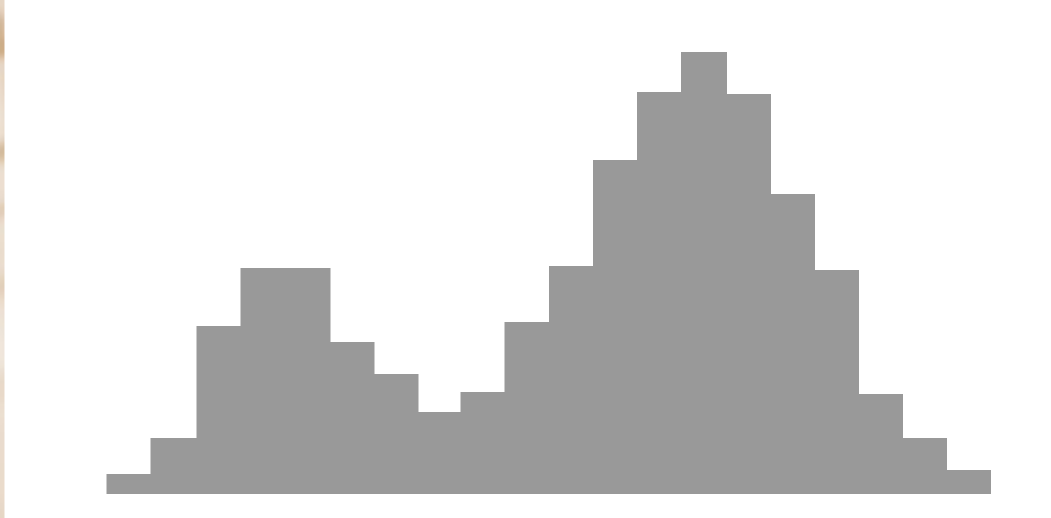
These distributions are called right- or left-skewed according to the direction of the tail.



Double-peaked or bimodal distirution

The outcomes of two processes with different distributions are combined in one set of data.

For example, a distribution of production data from a two-shift operation might be bimodal, if each shift produces a different distribution of results. Stratification often reveals this problem.



Plateau

The plateau might be called a *multimodal* distribution. Several processes with normal distributions are combined. Because there are many peaks close together, the top of the distribution resembles a plateau.

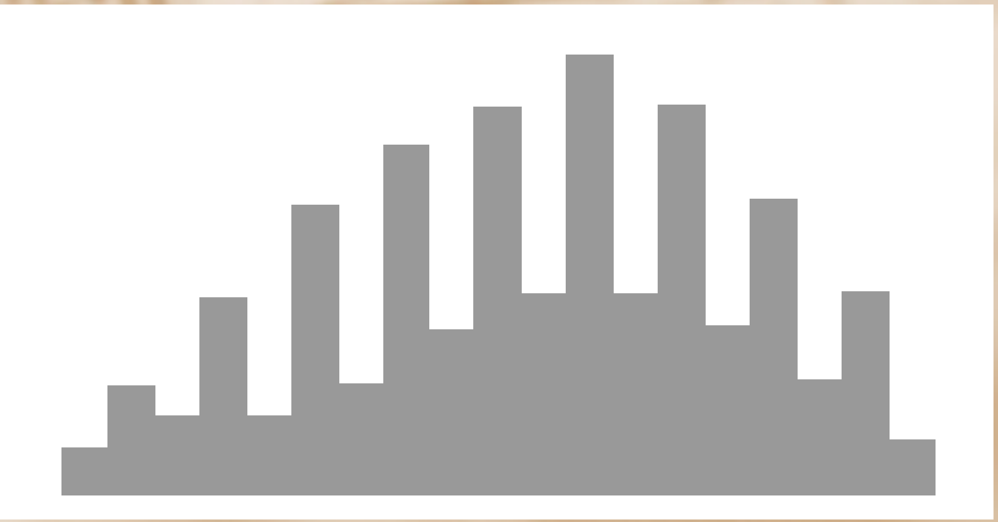
Edge peak

The edge peak distribution looks like the normal distribution except that it has a large peak at one tail. Usually this is caused by faulty construction of the histogram, with data lumped together into a group labeled “greater than. . . .”

Comb

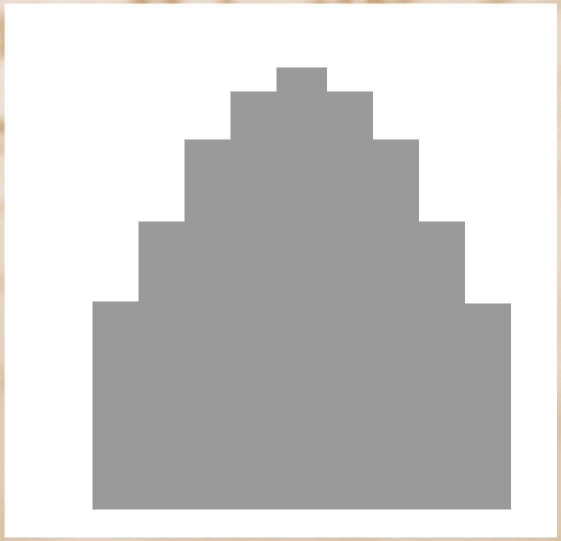
In a comb distribution, the bars are alternately tall and short. This distribution often results from rounded-off data and/or an incorrectly constructed histogram.

For example, temperature data rounded off to the nearest 0.2 degree would show a comb shape if the bar width for the histogram were 0.1 degree.



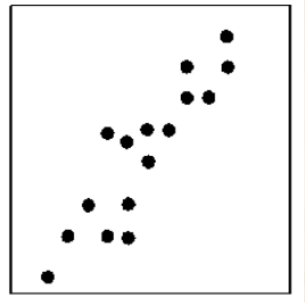
Truncated or heart-cut

The truncated distribution looks like a normal distribution with the tails cut off. The supplier might be producing a normal distribution of material and then relying on inspection to separate what is within specification limits from what is out of spec. The resulting shipments to the customer from inside the specifications are the heart cut.



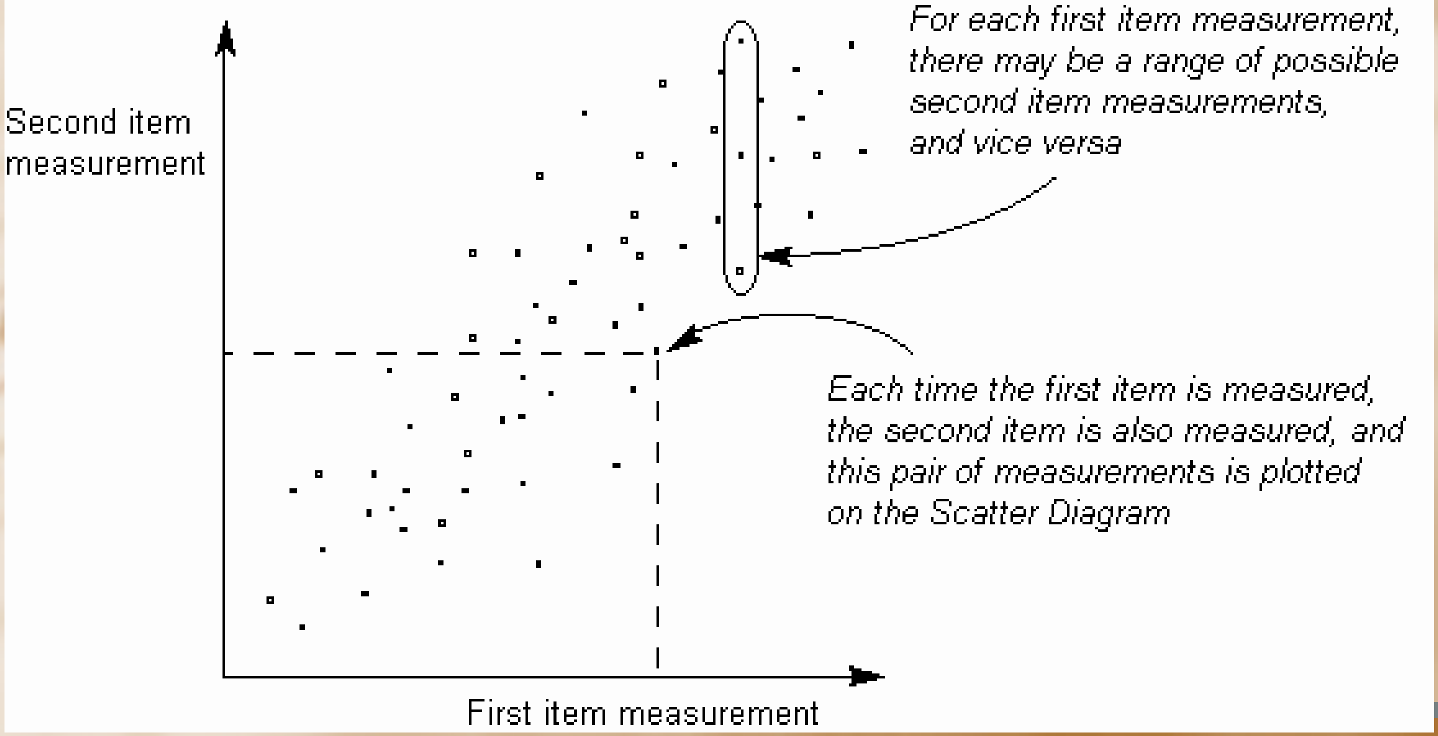
- If there are few data points, interpret the histogram cautiously. *Any conclusions drawn from a histogram with less than 50 observations should be seriously questioned.*
- Any interpretation of a histogram shape is only a theory that must be verified by direct observation of the process.
- A histogram cannot be used to definitely conclude that a distribution is normal.
- There are other distributions that are similar in appearance.
- If a process is stable, the histogram can predict future performance. If a process is not stable, the histogram merely summarizes past performance. If you discover that an unusual event occurred during the time period of your histogram, then any analysis of the histogram may apply only to that time period.

Scatter diagram



Scatter diagrams are used *to evaluate the correlation* of one variable with the other:

- the ***independent*** variable is shown on the horizontal (bottom) axis;
- the ***dependent*** variable is shown on the vertical (side) axis.



Scatter diagram

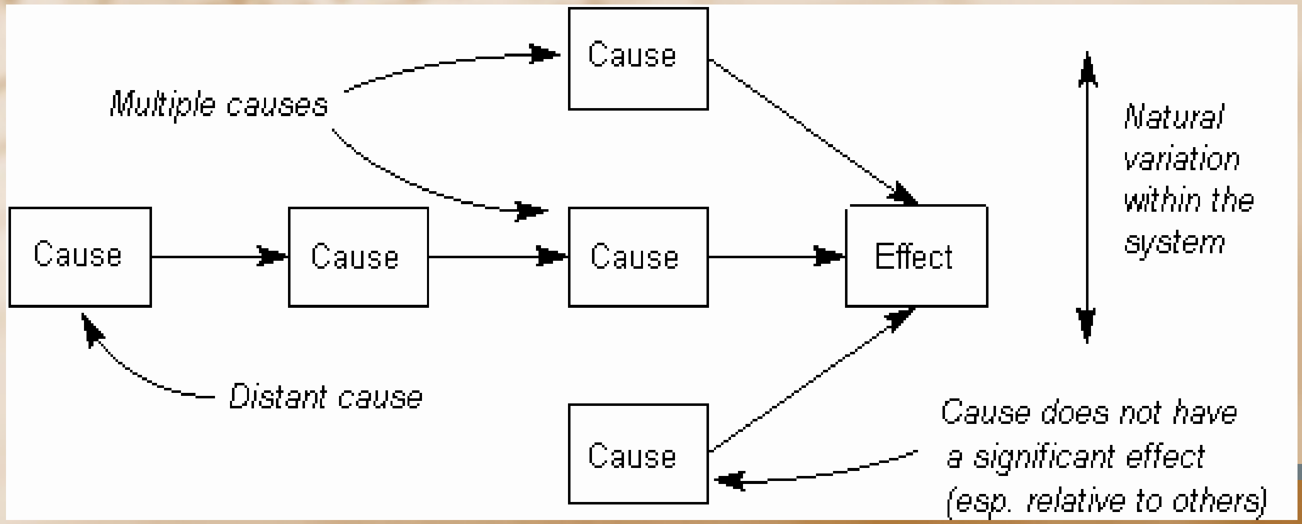
Scatter Diagram shows correlation between two items for three reasons:

1. There is a ***cause and effect relationship*** between the two measured items, where one is causing the other (at least in part).

2. The two measured items are both caused by a third item.

For example, a correlation between cracks and transparency of glass utensils because changes in both are caused by changes in furnace temperature.

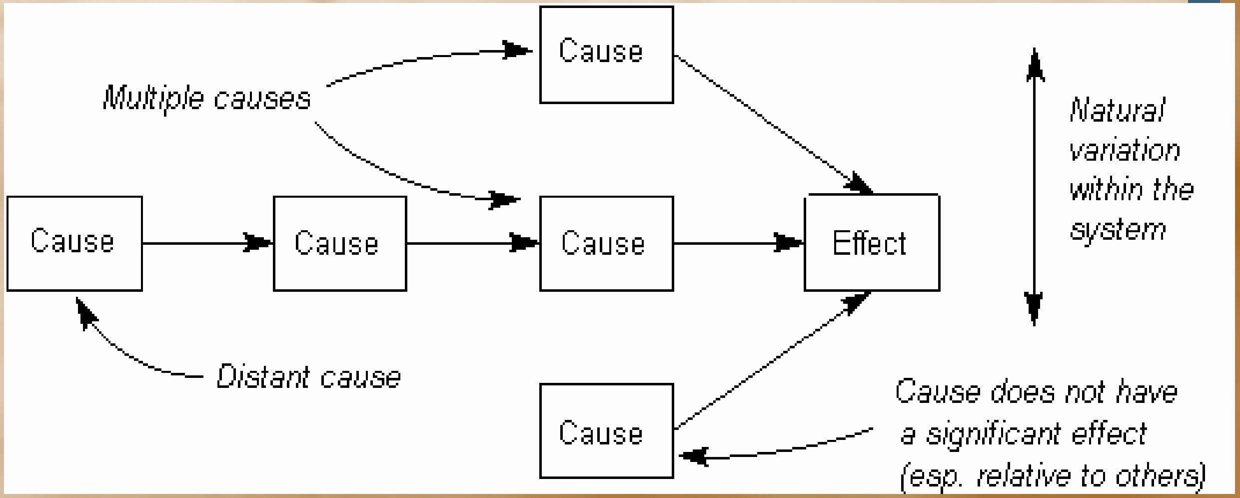
3. Complete coincidence. It is possible to find high correlation of unrelated items, such as the number of ants crossing a path and newspaper sales.

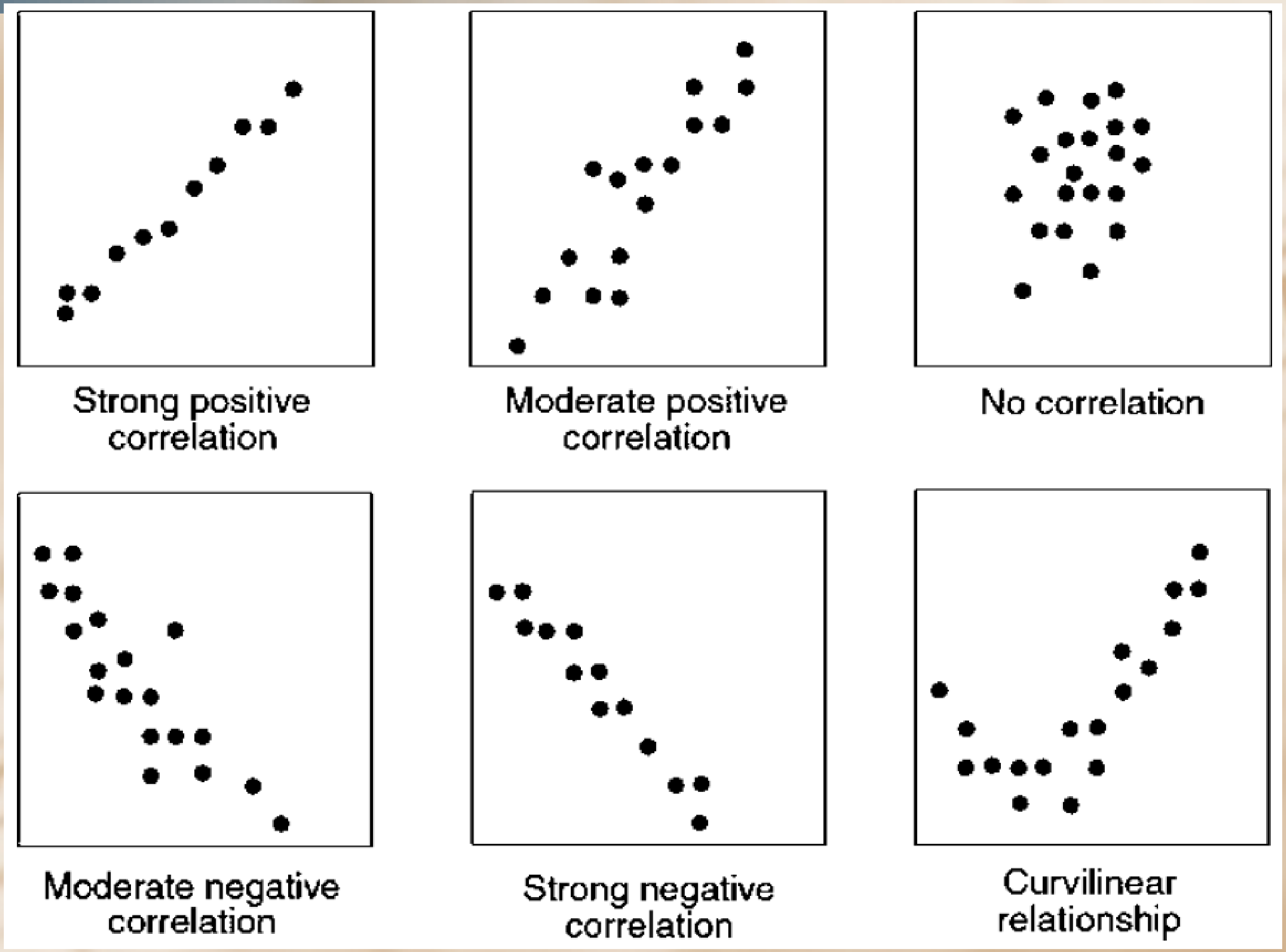


Scatter diagram

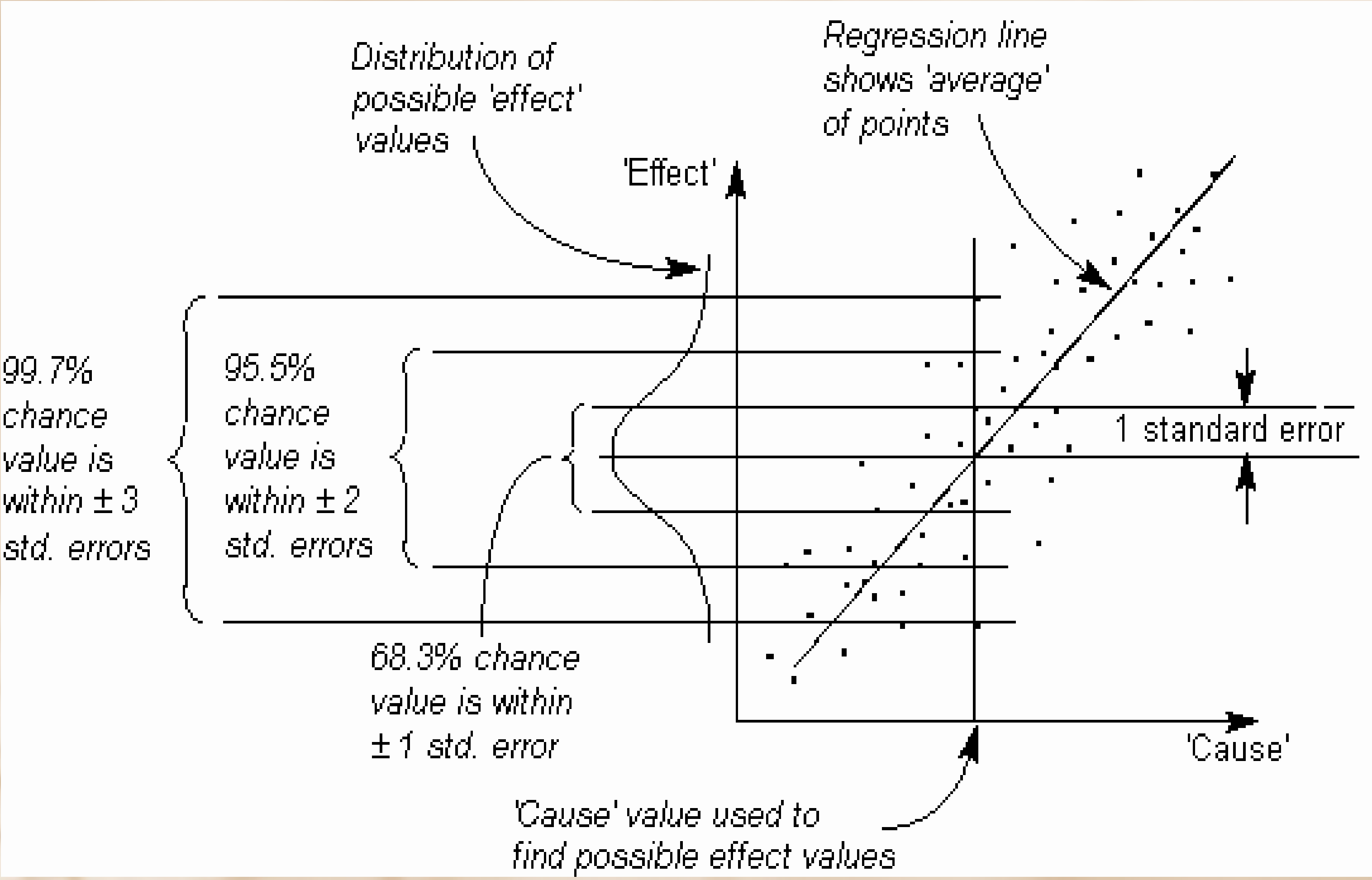
Where there is a cause-effect relationship, the degree of scatter in the diagram may be affected by several factors:

- The *proximity* of the cause and effect - a high correlation if the cause is directly connected to the effect than if it is at the end of a chain of causes. Thus a root cause may not have a clear relationship with the end effect.
- *Multiple causes* of the effect. When measuring one cause, other causes are making the effect vary in an unrelated way. Other causes may also be having a greater effect, swamping the actual effect of the cause.
- Natural *variation* in the system. The effect may not react in the same way each time, even to a close major cause.





Points which appear well outside a visible trend region may be due to special causes of variation, and ***should be investigated as such***.



The *correlation coefficient* gives a numerical value to the degree of correlation. This will vary ***from -1*** (perfect negative correlation), ***through 0*** (no correlation at all), ***to +1*** (perfect positive correlation). The closer the value is to plus or minus 1, the better the correlation. In a perfect correlation, all points lie on a straight line.

Scatter diagram - example

A town planning team, during an investigation of road accidents, identified a number of possible causes.

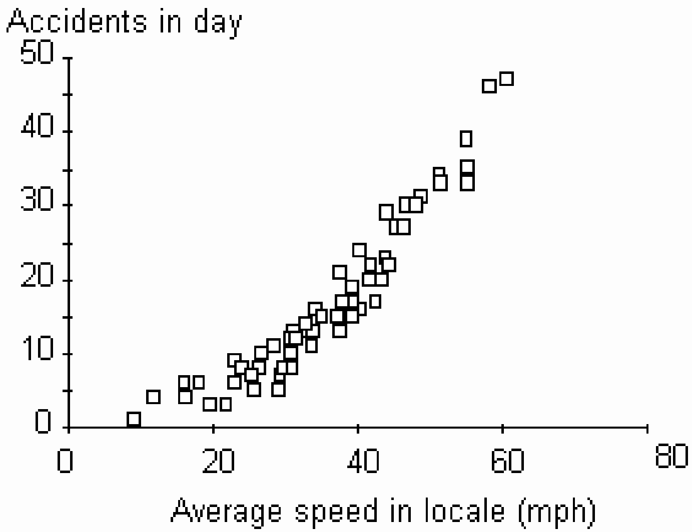
Three main causes were suspected:

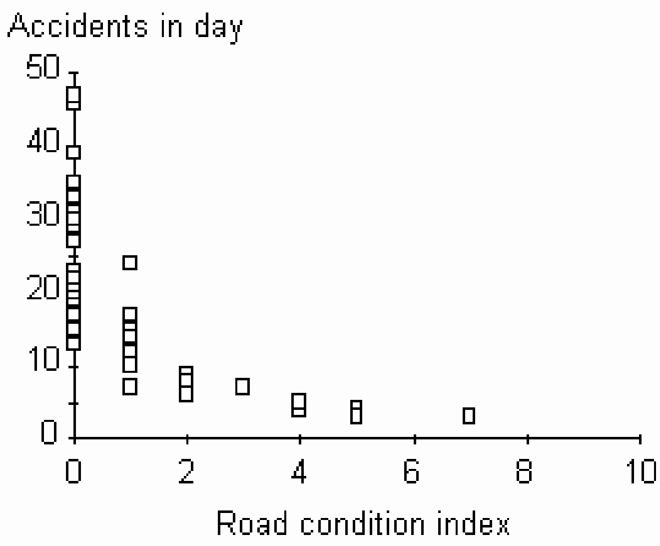
1. the speed of the vehicles,
2. the traffic density,
3. the local weather conditions.

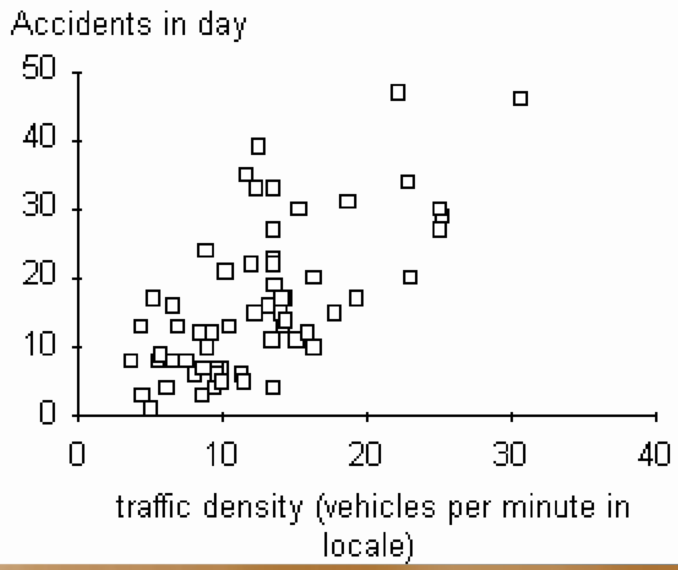
As there was no clear evidence available to support any of these hypotheses, they decided to measure them, and used Scatter Diagrams to check whether the link between any of the causes was strong enough to take further action.

Scatter diagram

Road condition index	Average speed (mph)	Traffic density (veh/min)	Accidents in day
1	28.4	13.4	11
1	37.6	4.3	13
0	39.4	14.3	17
7	19.6	4.4	3
1	31.0	6.8	13
5	16.2	6.1	4

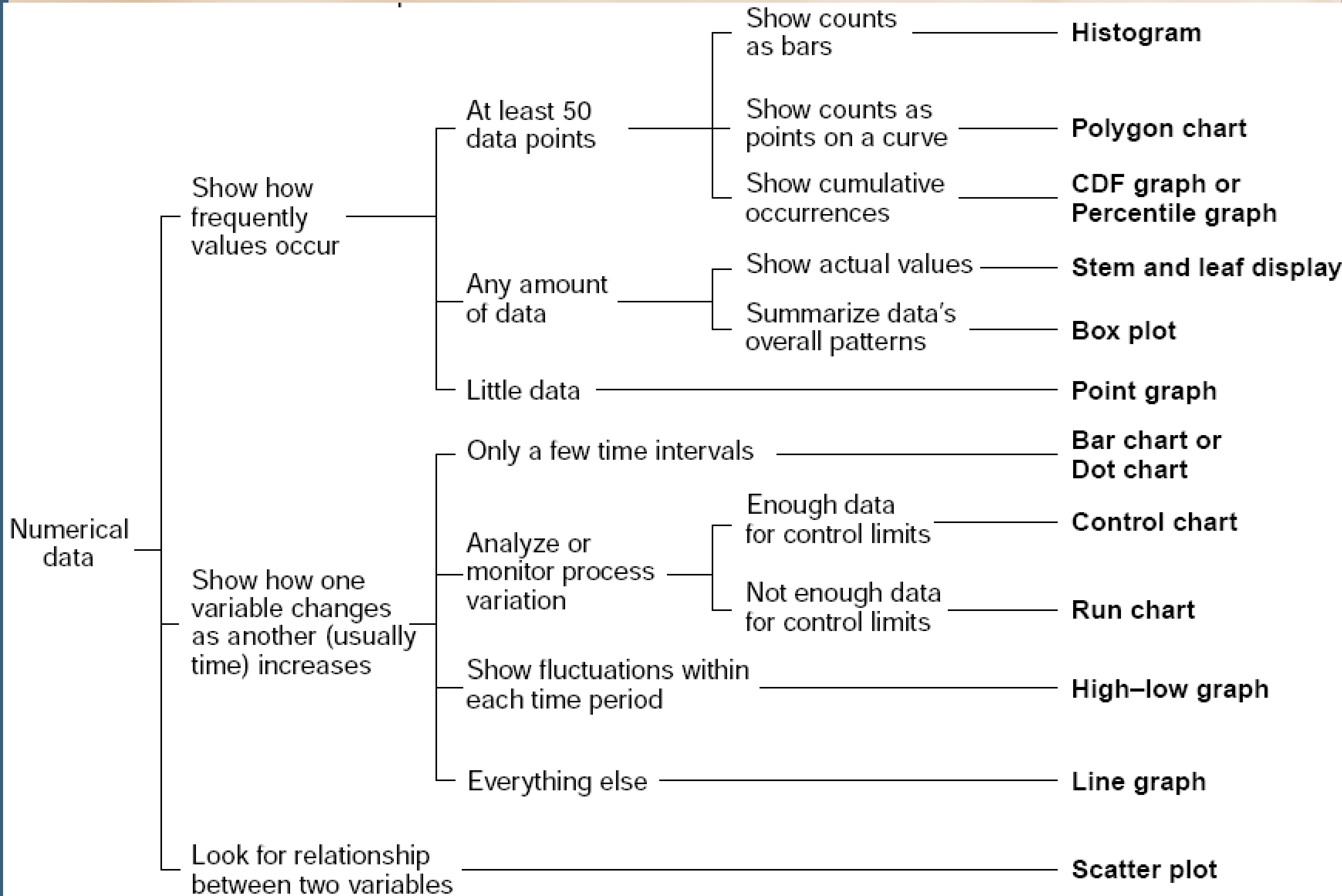






To take a decision based on the statistical methods, data classification is necessary:

- *Understanding of the issue of fact* – checking the dispersion in the process samples, variability of failures/discrepancies in production/deliveres;
- *Analysis of number of discrepancies*, failures, and cause of their occurence;
- *Process control* – study of process development, comparison of the real and required values, a width of intervals of fluctuation of values;
- *Calibration, adjustment*, setting of parameters of equipment and process;
- *Approval / refusal* of supplies / materials / sevices after their inspection.


Numerical data
Show how frequently values occur
At least 50 data points
Show counts as bars
Histogram
Show counts as points on a curve
Polygon chart
Show cumulative occurrences
CDF graph or Percentile graph
Any amount of data
Show actual values
Stem and leaf display
Summarize data's overall patterns
Box plot
Little data
Point graph
Show how one variable changes as another (usually time) increases
Only a few time intervals
Bar chart or Dot chart
Analyze or monitor process variation
Enough data for control limits
Control chart
Not enough data for control limits
Run chart
Show fluctuations within each time period
High–low graph
Everything else
Line graph
Look for relationship between two variables
Scatter plot