CHAPTER 7

QUALITY TOOLS

Expected Outcomes

Able to get understanding of 7 QC Tools
Able to apply 7 QC Tools in solving quality problems

Chapter Outline

Basic 7 QC Tools:

- Pareto Diagram

- Cause-and-Effect Diagram

- Check Sheets

- Histogram

- Control Charts For
  - Variables
  - Attributes

- Scatter Diagrams

- Stratification (Flow Chart or Run Chart)

Pareto Diagram

- Identified by Vilfredo Pareto (1848 to 1923), conducted studies of the distribution of wealth

- Dr. Juran recognized the concept as a universal - he coined the phrases vital few and useful many

- Examples of the vital few are:
  - A few problems account for the bulk of the process downtime
  - A few items account for the bulk of the inventory cost
  - A few suppliers account for the majority of rejected parts

- A Pareto diagram is a graph that ranks data classifications in descending order from left to right

Pareto Diagram

Pareto chart is constructed using the   :

1. Determine the method of classifying the data: by problem, cause, nonconformity and so forth

2. Determine what data to be gathered

3. Collect data for an appropriate time interval or use historical data

4. Determine the total number of nonconformities, calculate the percentage in each category and rank order categories from largest to smallest

5. Construct the diagram and find the vital few

It is applicable to problem identification and the measurement of progress

Pareto Diagram

Example: **Pareto Chart of Paint defects in a car painting shop**
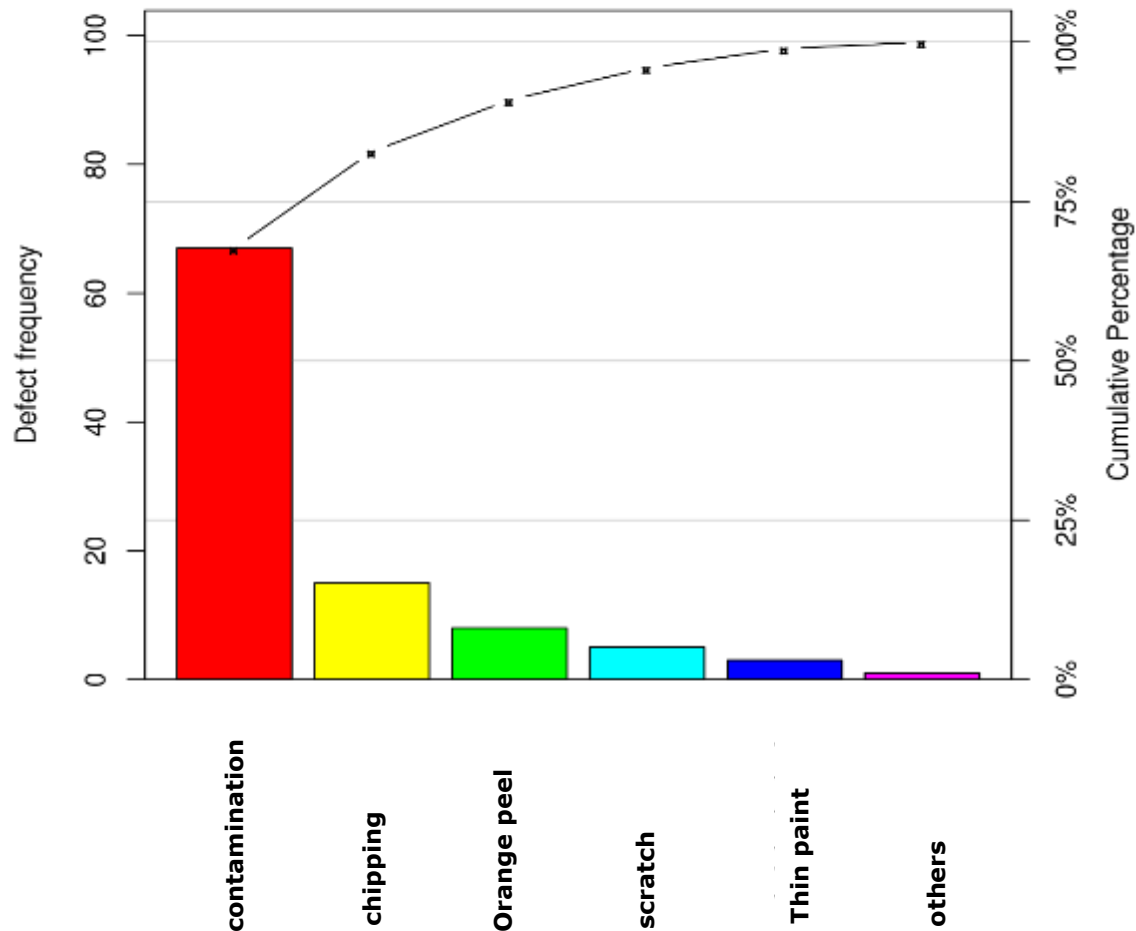
Cause and Effect Diagram

- A chart of this type will help identify causes for nonconforming or defective products or services

- Causes are usually broken down into the major causes of work methods, materials, machine, man / people and the environment - each major cause is further subdivided into numerous minor causes

- Diagram are useful in:
  - Analyzing actual conditions for improvement, more efficient use of resources and reduced costs
  - Elimination conditions causing nonconformities and customer complaint
  - Educate and train personnel in decision making and corrective action activities
  - Standardization of existing and proposed operations

Cause and Effect Diagram

To construct a cause-and-effect diagram:

1. Clearly identify the effect or the problem. Problem statement is placed in a box at the end of a line

2. Identify the causes. Brainstorming is the usual method for identifying these causes.

3. Build the diagram. Organize the causes and sub-causes in diagram format.

4. Draw the effect box and the center line. Connect the potential causes boxes to the center line.

5. Analyze the diagram and take corrective action
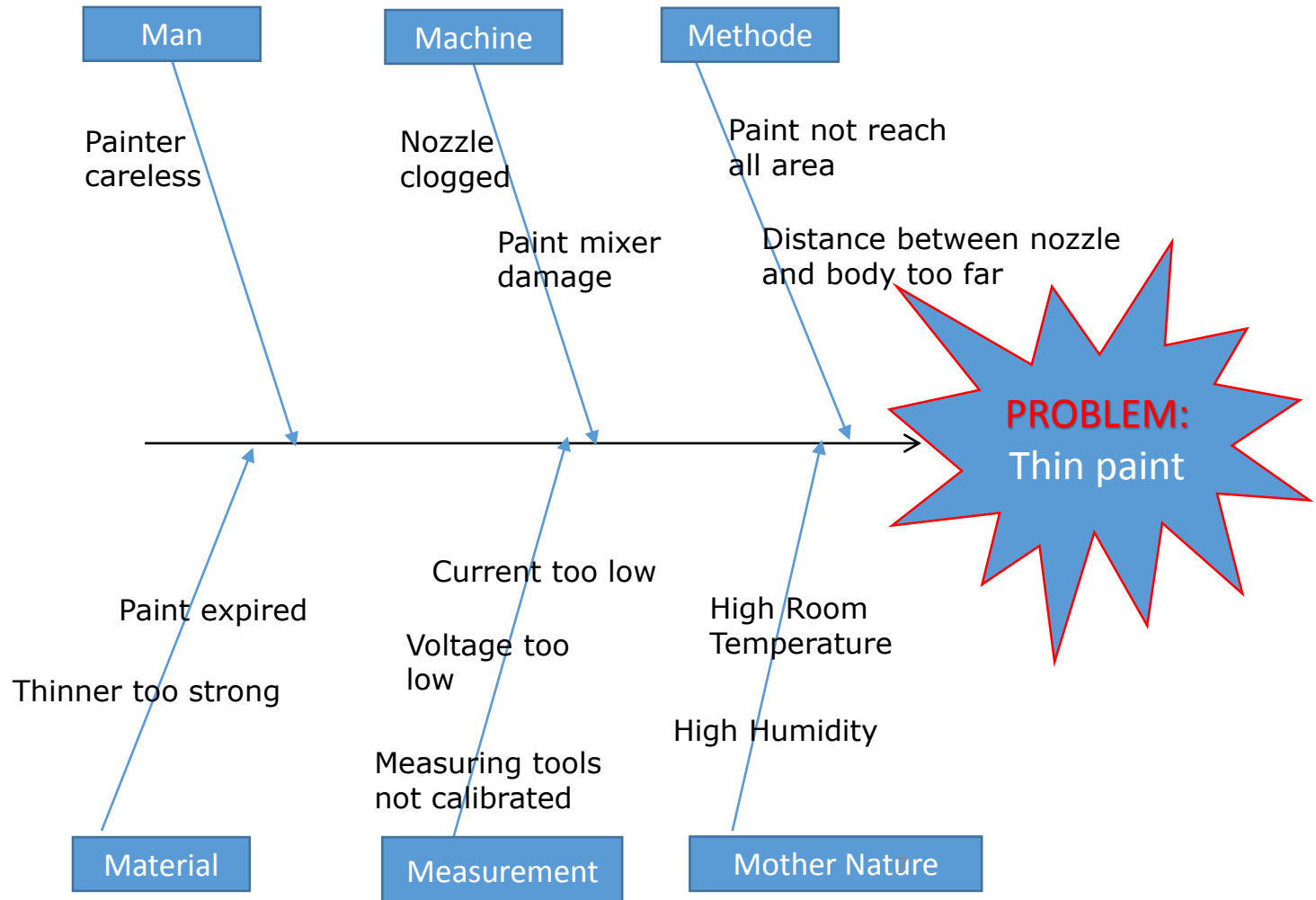
Check Sheets

- A check sheet is a data recording device

- As events occur in categories, a check or mark is placed on the check sheet in the appropriate category

- Given a list of items or events, the user of a check sheet marks down the number of times a particular event or item occurs – the user checks off occurrences

- Checklist is differ where it lists all of the important steps or actions that need to take place or things that need to be remembered

Check Sheets

STATION	NO.	DEFECT	PICTURE	CHECKED BY
Station 3	1	Contamination interior of vehicle		
	2	Exterior of vehicle Contamination		
	3	Scratches on Bonet		

Histogram

Construction of a histogram for grouped data:
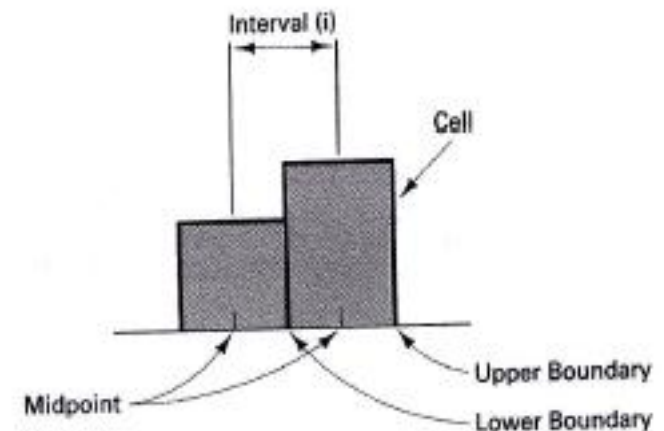
1. Collect data and construct a tally sheet

2. Calculate the range

   Range = R = $X_{high} - X_{low}$

3. Create the cells

   Determine cell interval, cell midpoints and cell boundary

4. Label the axes

5. Post the values

6. Interpret the histogram

Histogram

Determine the cell boundaries

- Cell boundary are the extreme or limit values of a cell, refer to as the upper boundary and the lower boundary

- Boundaries are established so there is no question as to the location of an observation

- Determine the lower cell boundary :

    Divide the cell interval by 2 and subtract that value from the cell midpoint

- Determine the upper cell boundary :

    Add the cell interval to the lower cell boundary

Histogram

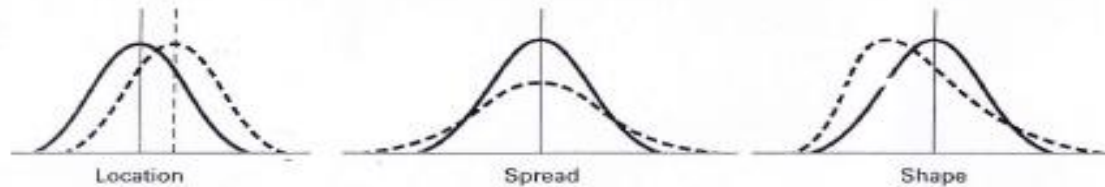The histogram describes the variation in the process. It is used to :

• Solve problems

• Determine the process capability

• Compare with specifications

• Suggest the shape of the population

• Indicate discrepancies in data such as gaps

Frequency Histogram
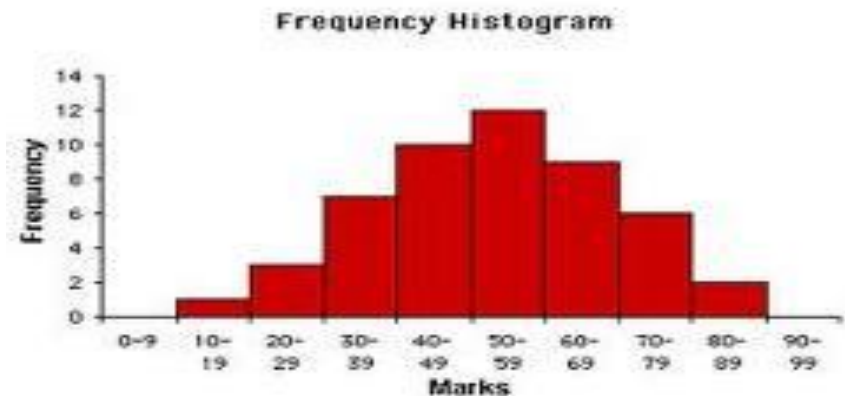
Histogram

Analysis of Histograms :

1. Shape – Symmetry / Skewness
2. Location and Spread

Location   Spread   Shape

3. Kurtosis – Peakedness of the distribution
    - Leptokurtic – distribution with a high peak
    - Platykurtic – flatter curve
    - Bimodal – distribution with 2 distinct peaks

Bimodal   Leptokurtic   Platykurtic
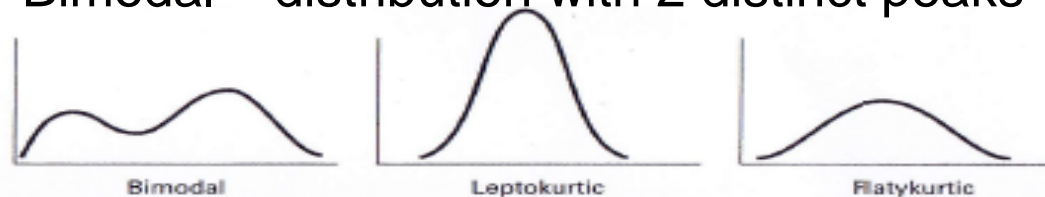
Control Chart

- The control chart is a graph used to study how a process changes over time.

- Data are plotted in time order.

- A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit.

- These lines are determined from historical data.

- By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Source: ASQ

Control Chart

Example:
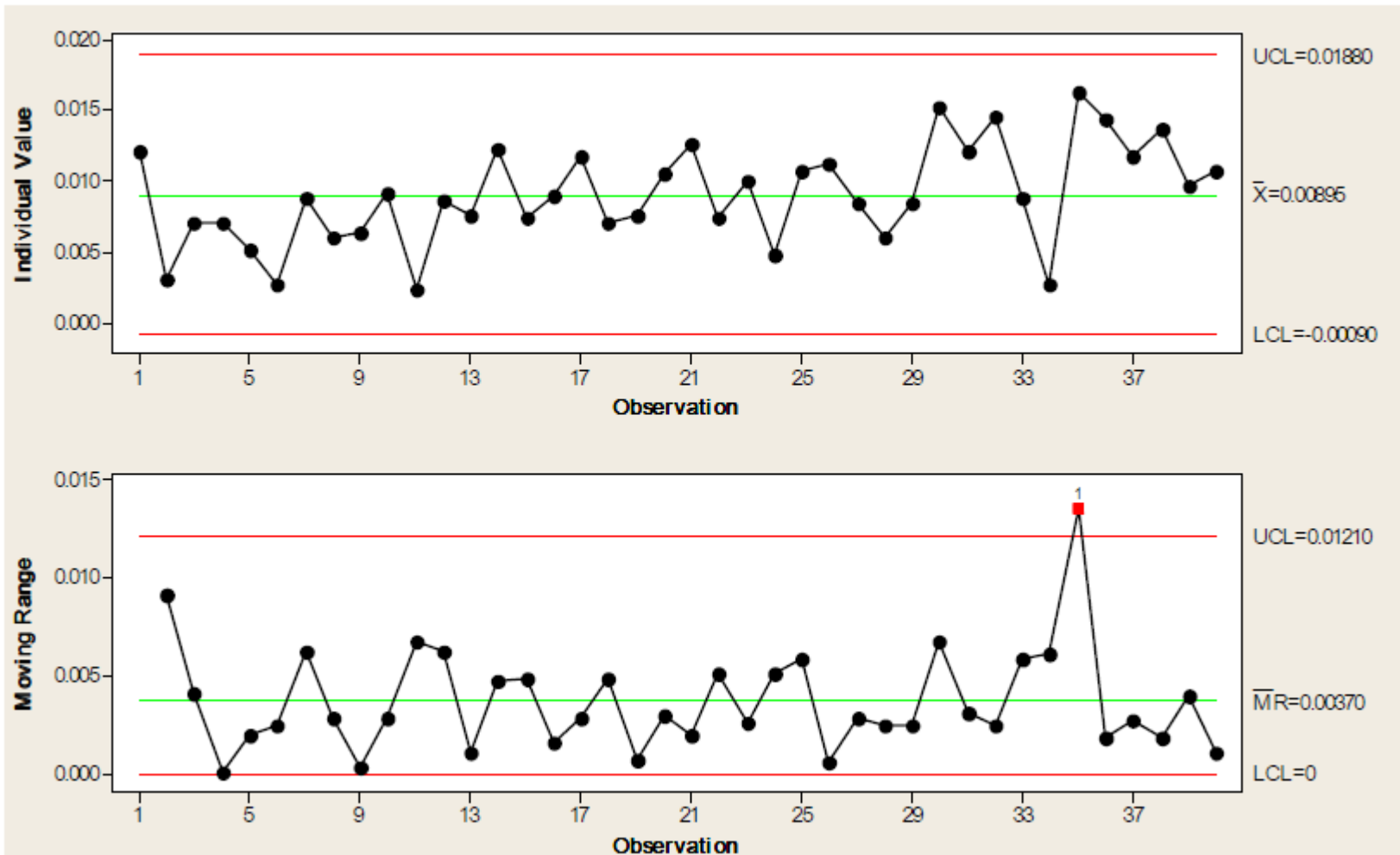
Control Chart

There are three main elements of a control chart as shown:

- A control chart begins with a time series graph.

- A central line (X) is added as a visual reference for detecting shifts or trends – this is also referred to as the process location.

- Upper and lower control limits (UCL and LCL) are computed from available data and placed equidistant from the central line. This is also referred to as process dispersion.

Source: ASQ

Control Chart

Control limits (CLs) ensure time is not wasted looking for unnecessary trouble – the goal of any process improvement practitioner should be to only take action when warranted. Control limits are calculated by:

- Estimating the <u>standard deviation</u>, σ, of the sample data

- Multiplying that number by three

- Adding (3 x σ to the average) for the UCL and subtracting (3 x σ from the average) for the LCL

Mathematically, the calculation of control limits looks like:

$$CL = average \pm 3 * \hat{\sigma}$$

Because control limits are calculated from process data, they are independent of customer expectations or specification limits.

Scatter Diagram

- Also called: scatter plot, X–Y graph

- 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 tighter the points will hug the line.

*Source: ASQ

Scatter Diagram

When to Use a Scatter Diagram

- When you have paired numerical data.

- When your dependent variable may have multiple values for each value of your independent variable.

- When trying to determine whether the two variables are related, such as…
    - When trying to identify potential root causes of problems.
    - After brainstorming causes and effects using a fishbone diagram, to determine objectively whether a particular cause and effect are related.
    - When determining whether two effects that appear to be related both occur with the same cause.
   - When testing for autocorrelation before constructing a control chart.

Scatter Diagram

**Scatter Diagram Procedure**

- Collect pairs of data where a relationship is suspected.

- Draw a graph with the independent variable on the horizontal axis and the dependent variable on the vertical axis. For each pair of data, put a dot or a symbol where the x-axis value intersects the y-axis value. (If two dots fall together, put them side by side, touching, so that you can see both.)

- Look at the pattern of points to see if a relationship is obvious. If the data clearly form a line or a curve, you may stop. The variables are correlated.
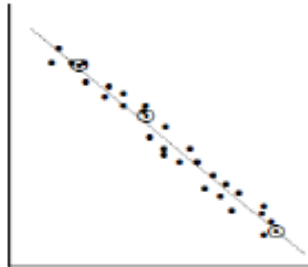
Scatter Diagram

- Pattern in scatter diagram
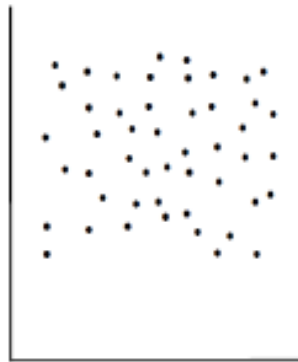
- no correlation
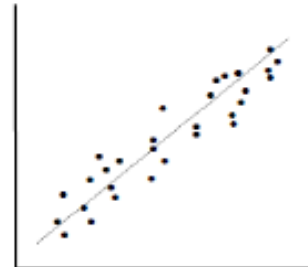- lack of relationship between the two variables
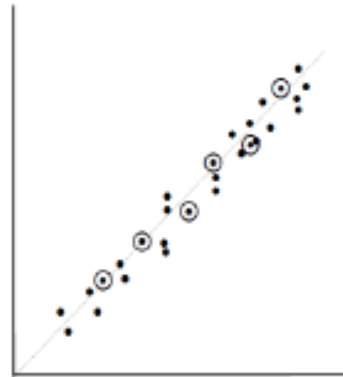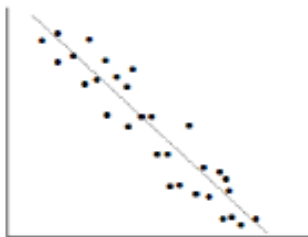
- strong positive correlation

Scatter Diagram

- strong negative correlation
- weak positive correlation
- weak negative correlation
- complex correlation

Scatter Diagram

- **Correlation coefficients** measure the strength of association between two variables. The most common correlation coefficient, called the **Pearson product-moment correlation coefficient**, measures the strength of the *linear association* between variables.

$$r = \cfrac{\sum XY - \cfrac{\sum X \sum Y}{N}}{\sqrt{\left(\sum X^2 - \cfrac{(\sum X)^2}{N}\right)\left(\sum Y^2 - \cfrac{(\sum Y)^2}{N}\right)}}$$

Source: Stattrek

Scatter Diagram

How to Interpret a Correlation Coefficient

- The sign and the <u>absolute value</u> of a correlation coefficient describe the direction and the magnitude of the relationship between two variables.

- The value of a correlation coefficient ranges between -1 and 1.

- The greater the absolute value of a correlation coefficient, the stronger the *linear* relationship.

- The strongest linear relationship is indicated by a correlation coefficient of -1 or 1.

- The weakest linear relationship is indicated by a correlation coefficient equal to 0.

- A positive correlation means that if one variable gets bigger, the other variable tends to get bigger.

- A negative correlation means that if one variable gets bigger, the other variable tends to get smaller.
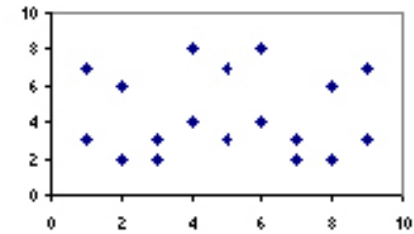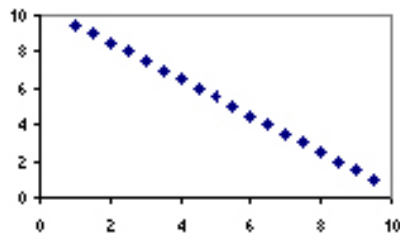
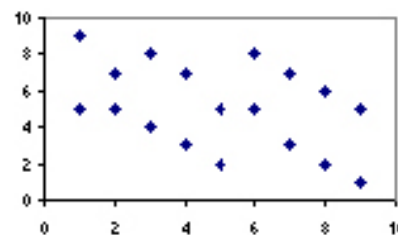# Scatter Diagram
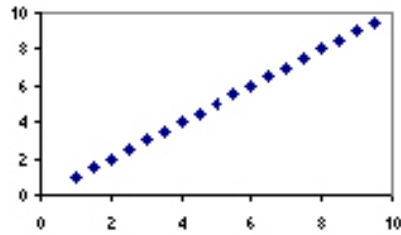
Maximum positive correlation
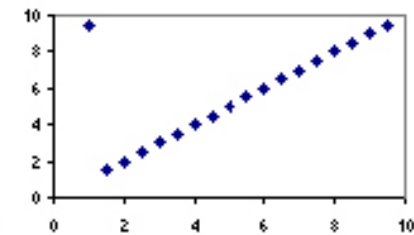(r = 1.0)
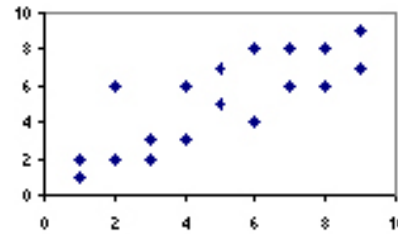
Strong positive correlation
(r = 0.80)

Zero correlation
(r = 0)

Maximum negative correlation
(r = -1.0)

Moderate negative correlation
(r = -0.43)

Strong correlation & outlier
(r = 0.71)

Stratification – Flow Chart

- A flowchart is a picture of the separate steps of a process in sequential order.

- Elements that may be included are: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

- The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes.

Source: ASQ

Stratification – Flow Chart

When to Use a Flowchart

- To develop understanding of how a process is done.

- To study a process for improvement.

- To communicate to others how a process is done.

- When better communication is needed between people involved with the same process.

- To document a process.

- When planning a project.
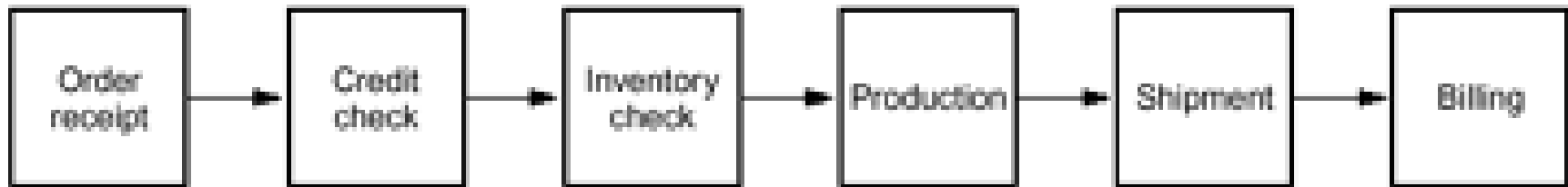
Stratification – Flow Chart

Flowchart Basic Procedure

- Define the process to be diagrammed. Write its title at the top of the work surface.

- Discuss and decide on the boundaries of your process: Where or when does the process start? Where or when does it end?

- Brainstorm the activities that take place. Write each on a card or sticky note.

- Arrange the activities in proper sequence.

- When all activities are included and everyone agrees that the sequence is correct, draw arrows to show the flow of the process.

- Review the flowchart with others involved in the process (workers, supervisors, suppliers, customers) to see if they agree that the process is drawn accurately.

Stratification – Flow Chart

Flowchart example

High–Level Flowchart for an Order-Filling Process

Stratification – Flow Chart

Detailed Flowchart for an Order-Filling Process

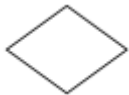*Source: ASQ

Stratification – Flow Chart
Commonly Used Symbols in Detailed Flowcharts

- One step in the process

- 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.")

- Delay or wait

- Link to another page or another flowchart. The same symbol on the other page indicates that the flow continues there

- Input or output

- Document

- Alternate symbols for start and end points

Source: ASQ

Stratification – Run Chart

- A run chart is used to monitor the behavior of a variable over time for a process or system.

- Run charts graphically display cycles, trends, shifts, or non-random patterns in behavior over time.

- Run charts can help identify problems and the time when a problem occurred, or monitor progress when solutions are implemented.

Source: ASQ

Stratification – Run Chart

Benefits

- Simple to create and maintain

- Does not require in-depth statistical training to use

- Displays data in a straightforward, easy to analyze manner
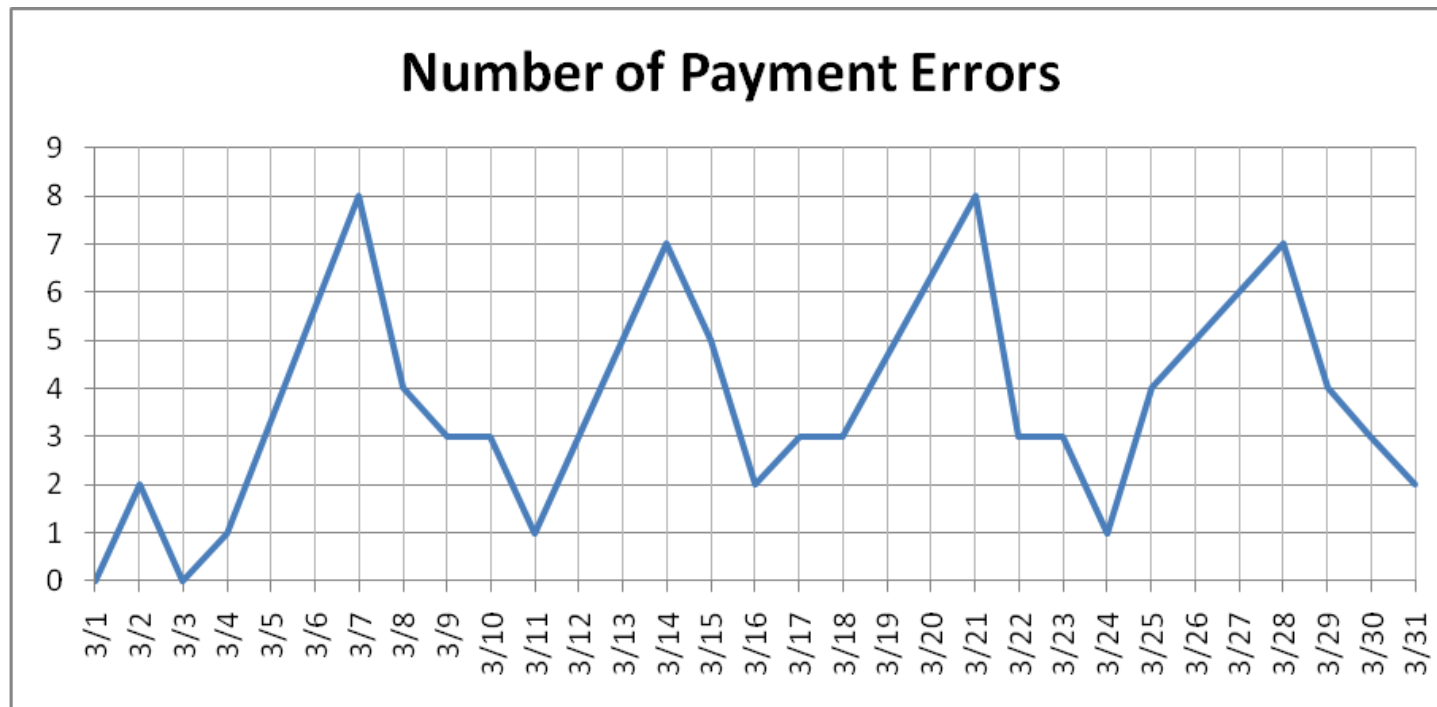
Stratification – Run Chart

How to Use

Step 1. Determine the purpose of the chart and the data to be monitored, collected, and analyzed. Select the time interval (minute, hour, day, month, etc.).

Step 2. Collect the data that will be plotted.

Step 3. Plot time on the horizontal axis (typically located at the bottom).

Step 4. Label the vertical axis and plot the data collected in step 2 on the vertical axis (typically located on the left-hand-side).

Step 5. Title the chart. Indicating which direction is better with an up or down arrow may be helpful.

Stratification – Run Chart

Example

A payment processing manager is checking a recently hired associate's error rate for the month. Below is the number of errors that occurred in March.

Number of Payment Errors

Source: ASQ

References

- http://asq.org/index.aspx#
- http://stattrek.com/statistics/correlation.aspx?Tutorial=AP