QUALITY CONTROL TOOLS

Scatter Diagrams

Scatter diagrams are used to study possible relationships between two variables. Although these diagrams cannot prove that one variable causes the other, they do indicate the existence of a relationship, as well as the strength of that relationship.

A scatter diagram is composed of a horizontal axis containing the measured values of one variable and a vertical axis representing the measurements of the other variable.

The purpose of the scatter diagram is to display what happens to one variables when another variable is changed. The diagram is used to test a theory that the two variables are related. The type of relationship that exits is indicated by the slope of the diagram.

Key Terms

- **Variable** - a quality characteristic that can be measured and expressed as a number on some continuous scale of measurement.
- **Relationship** - Relationships between variables exist when one variable depends on the other and changing one variable will affect the other.
- **Data Sheet** - contains the measurements that were collected for plotting the diagram.
- **Correlation** - an analysis method used to decide whether there is a statistically significant relationship between two variables.
- **Regression** - an analysis method used to identify the exact nature of the relationship between two variables.

History

The Guide to Quality Control and The Statistical Quality Control Handbook, written by a Japanese quality consultant named Kaoru Ishikawa are useful in providing an understanding on how to use and interpret a scatter diagram. Ishikawa believed that there was no end to quality improvement and in 1985 suggested that seven base tools be used for collection and analysis of quality data. Among the tools was the scatter diagram.

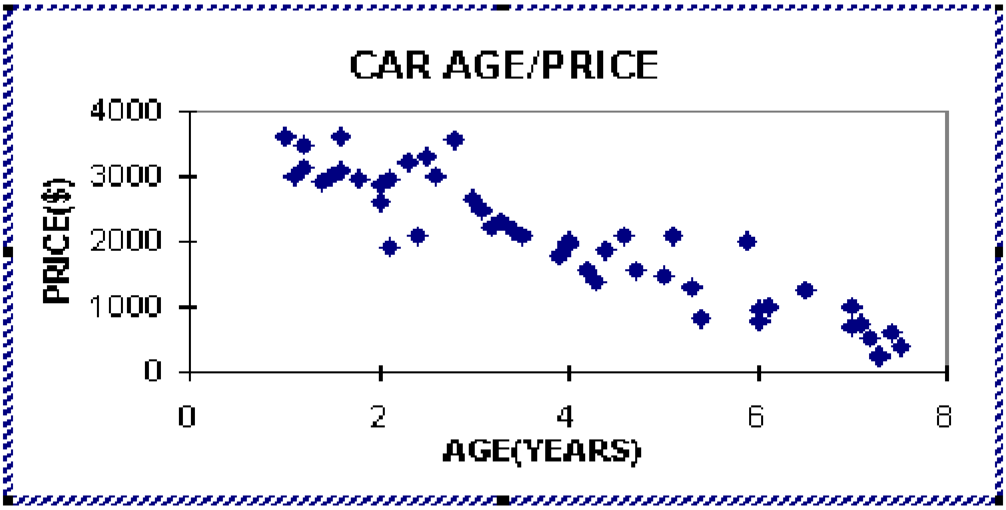
Construction of Scatter Diagrams

- Collect and construct a data sheet of 50 to 100 paired samples of data, which you suspect to be related. Construct your data sheet as follows:

Car	Age(In Years)	Price(In Dollars)
1	2	4000
2	4	2500
3	1	5000
4	5	1250
:	:	:
:	:	:
:	:	:
:	:	:
100	7	1000

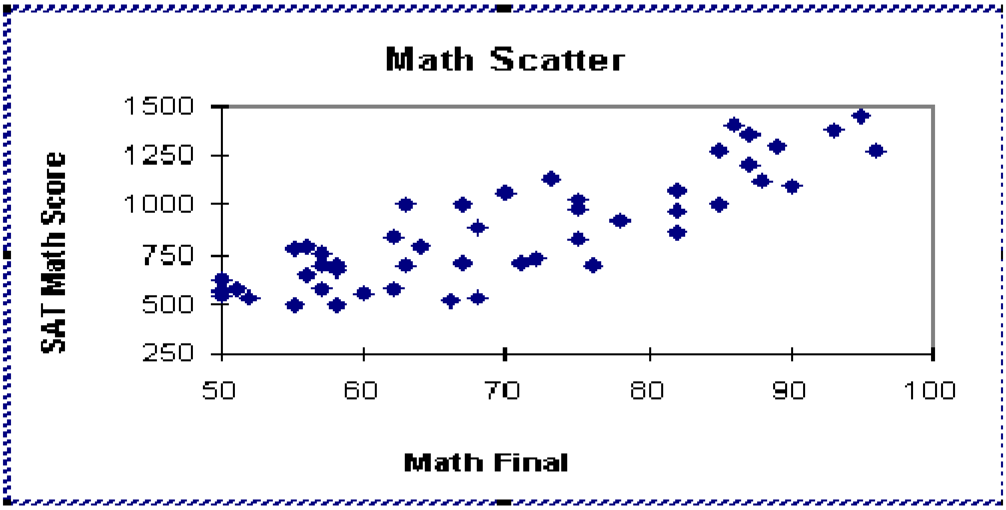
- Draw the axes of the diagram. The first variable (the independent variable) is usually located on the horizontal axis and its values should increase as you move to the right. The vertical axis usually contains the second variable (the dependent variable) and its values should increase as you move up the axis.

- Plot the data on the diagram. The resulting scatter diagram may look as follows:

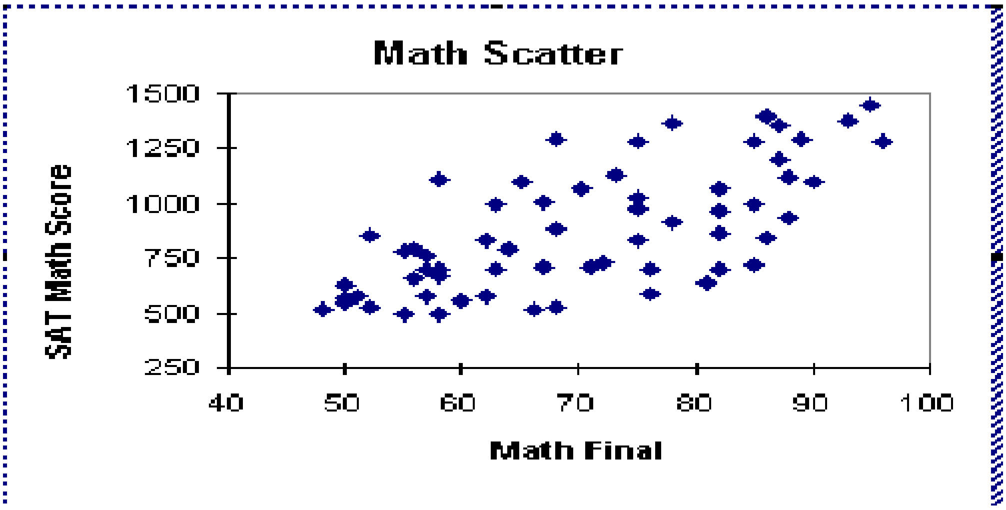


Interpretations

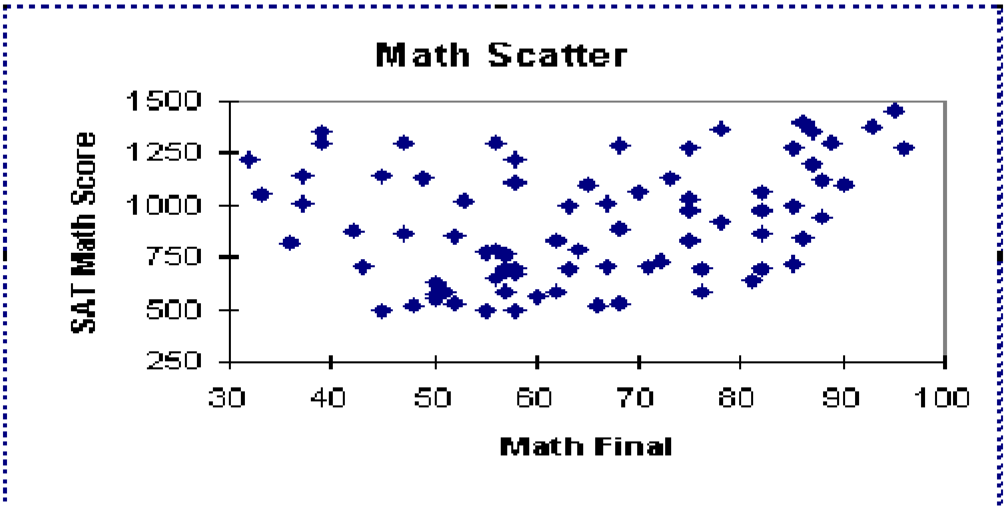
The scatter diagram is a useful tool for identifying a potential relationship between two variables. The shape of the scatter diagram presents valuable information about the graph. It shows the type of relationship which may be occurring between the two variables. There are several different patterns (meanings) that scatter diagrams can have. The following describe five of the most common scenarios:



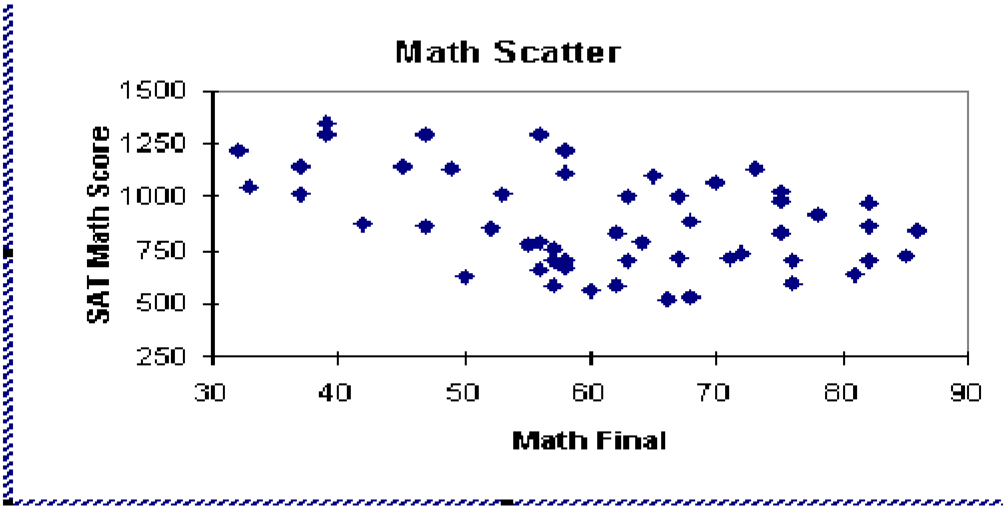
1. The first pattern is positive correlation, that is, as the amount of variable x increases, the variable y also increases. It is tempting to think this is a cause/effect relationship. This is an incorrect thinking pattern, because correlation does not necessarily mean causality. This simple relationship could be caused by something totally different. For instance, the two variables could be related to a third, such as curing time or stamping temperature. Theoretically, if x is controlled, we have a chance of controlling y.



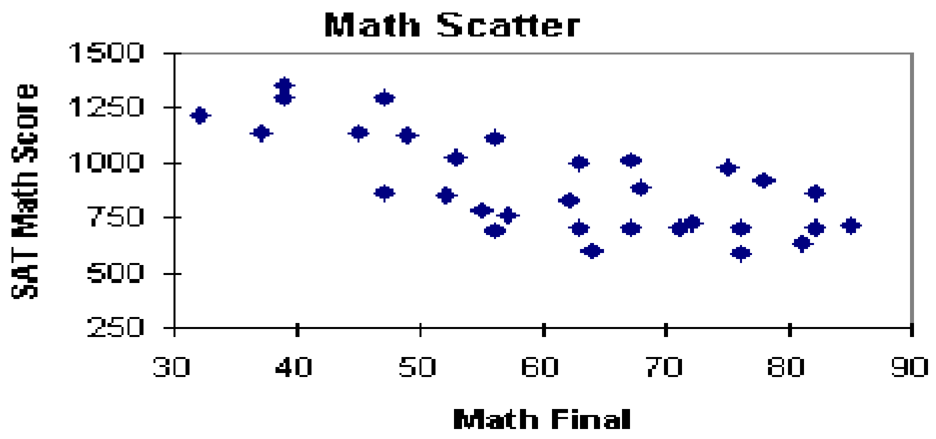
2. Secondly, we have possible positive correlation, that is, if x increases, y will increase somewhat, but y seems to be caused by something other than x. Designed experiments must be utilized to verify causality.



3. We also have the no correlation category. The diagram is so random that there is no apparent correlation between the two variables.



4. There is also possible negative correlation, that is, an increase in x will cause a tendency for a decrease in y, but y seems to have causes other than x.

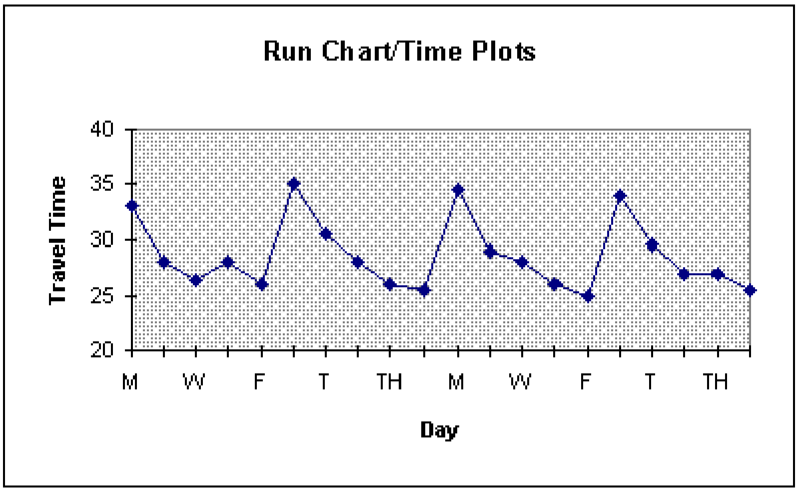


5. Finally, we have the negative correlation category. An increase in x will cause a decrease in y. Therefore, if y is controlled, we have a good chance of controlling x.

Key Observations

- ✓ A strong relationship between the two variables is observed when most of the points fall along an imaginary straight line with either a positive or negative slope.
- ✓ No relationship between the two variables is observed when the points are randomly scattered about the graph.

RUN CHARTS/TIME PLOT/TREND CHART



To access the information that you are interested in, select the topic from the Tutorial outline. At the end of each section is hypertext to enable a user to jump to any section of the tutorial, or if they wish, they can continue on to the next section by scrolling down.

PURPOSE

In-depth view into Run Charts--a quality improvement technique; how Run charts are used to monitor processes; how using Run charts can lead to improved process quality

USAGE

Run charts are used to analyze processes according to time or order. Run charts are useful in discovering patterns that occur over time.

KEY TERMS

Trends: Trends are patterns or shifts according to time. An upward trend, for instance, would contain a section of data points that increased as time passed.

Population: A population is the entire data set of the process. If a process produces one thousand parts a day, the population would be the one thousand items.

Sample: A sample is a subgroup or small portion of the population that is examined when the entire population cannot be evaluated. For instance, if the process does produce one thousand items a day, the sample size could be perhaps three hundred.

HISTORY

Run charts originated from control charts, which were initially designed by Walter Shewhart. Walter Shewhart was a statistician at Bell Telephone Laboratories in New York. Shewhart developed a system for bringing processes into statistical control by developing ideas which would allow for a system to be controlled using control charts. Run charts evolved from the development of these control charts, but run charts focus more on time patterns while a control chart focuses more on acceptable limits of the process. Shewhart's discoveries are the basis of what as known as SQC or Statistical Quality Control.

INSTRUCTIONS FOR CREATING A CHART

Step 1 : Gathering Data

To begin any run chart, some type of process or operation must be available to take measurements for analysis. Measurements must be taken over a period of time. The data must be collected in a chronological or sequential form. You may start at any point and end at any point. For best results, at least 25 or more samples must be taken in order to get an accurate run chart.

Step 2 : Organizing Data

Once the data has been placed in chronological or sequential form, it must be divided into two sets of values x and y. The values for x represent time and the values for y represent the measurements taken from the manufacturing process or operation.

Step 3 : Charting Data

Plot the y values versus the x values by hand or by computer, using an appropriate scale that will make the points on the graph visible. Next, draw vertical lines for the x values to separate time intervals such as weeks. Draw horizontal lines to show where trends in the process or operation occur or will occur.

Step 4 : Interpreting Data

After drawing the horizontal and vertical lines to segment data, interpret the data and draw any conclusions that will be beneficial to the process or operation. Some possible outcomes are:

- Trends in the chart
- Cyclical patterns in the data
- Observations from each time interval are consistent

RUN CHART EXAMPLE

Problem Scenario

You have just moved into a new area that you are not familiar with. Your desire is to arrive at work on time, but you have noticed over your first couple of weeks on the job that it doesn't take the same amount of time each day of the week. You decide to monitor the amount of time it takes to get to work over the next four weeks and construct a run chart.

Step 1: Gathering Data

Collect measurements each day over the next four weeks. Organize and record the data in chronological or sequential form.

	M	T	W	TH	F
WEEK 1	33	28	26.5	28	26
WEEK 2	35	30.5	28	26	25.5
WEEK 3	34.5	29	28	26	25
WEEK 4	34	29.5	27	27	25.5

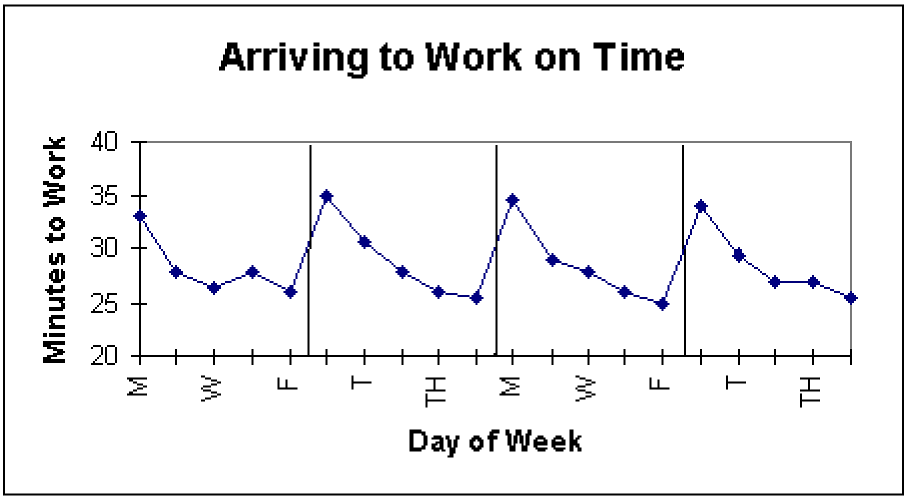
Step 2: Organizing Data

Determine what the values for the x (time, day of week) and day (data, minutes to work) axis will be.

	Day	Travel Time
WEEK 1	M	33
	T	28
	W	26.5
	TH	28
	F	26
WEEK 2	M	35
	T	30.5
	W	28
	TH	26
	F	25.5
WEEK 3	M	34.5
	T	29
	W	28
	TH	26
	F	25
WEEK 4	M	34
	T	29.5
	W	27
	TH	27
	F	25.5

Step 3: Charting Data

Plot the y values versus the x values by hand or by computer using the appropriate scale. Draw horizontal or vertical lines on the graph where trends or inconsistencies occur.

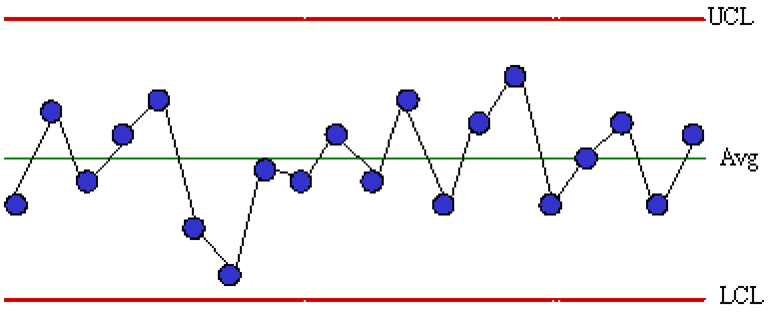


Step 4: Interpreting Data

Interpret results and draw any conclusions that are important. An overall decreasing trend occurs each week with Mondays taking the most amount of time and Fridays generally taking the least amount of time. Therefore you accordingly allow yourself more time on Mondays to arrive to work on time.

Control Chart

A control chart represents a picture of a process over time. To effectively use control charts, one must be able to interpret the picture. What is this control chart telling me about my process? Is this picture telling me that everything is all right and I can relax? Is this picture telling me that something is wrong and I should get up and find out what has happened? A control chart tells you if your process is in statistical control. The chart above is an example of a stable (in statistical control) process.



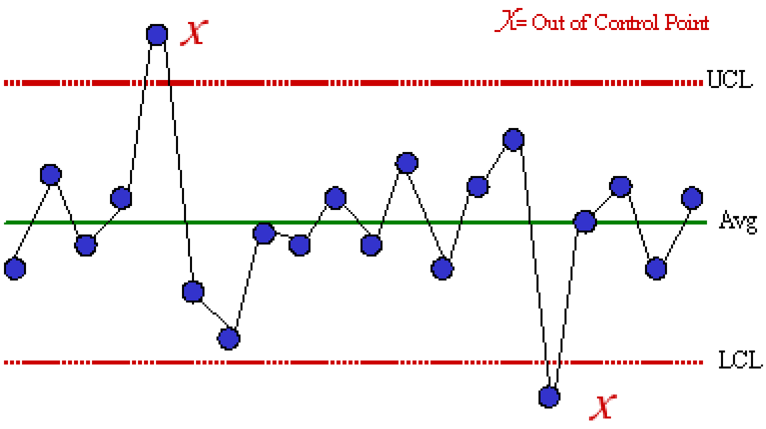
This pattern is typical of processes that are stable. Three characteristics of a process that is in control are:

- Most points are near the average
- A few points are near the control limits
- No points are beyond the control limits

If a control chart does not look similar to the one above, there is probably a special cause present. Various tests for determining if a special cause is present are given below.

Points Beyond the Control Limits

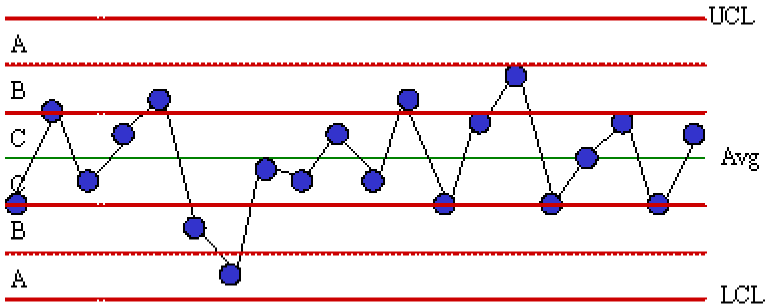
A special cause is present in the process if any points fall above the upper control limit or below the lower control limit. Action should be taken to find the special cause and permanently remove it from the process. If there is a point beyond the control



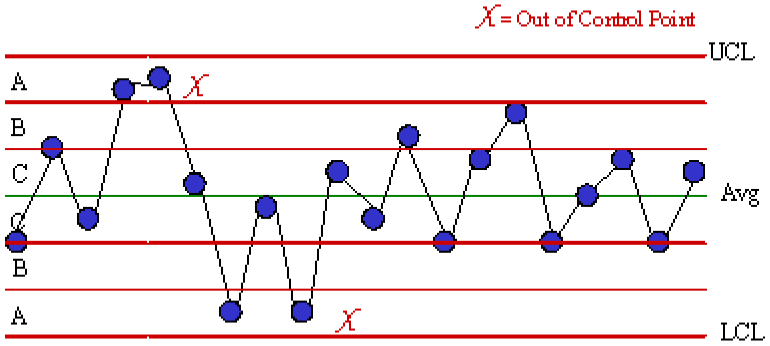
limits, there is no need to apply the other tests for out of control situations. Points on the control limits are not considered to be out of statistical control.

Zone Tests: Setting the Zones and Zone A

The zone tests are valuable tests for enhancing the ability of control charts to detect small shifts quickly. The first step in using these tests is to divide the control chart into zones. This is done by dividing the area between the average and the upper control limit into three equally spaced areas. This is then repeated for the area between the average and the lower control limit.



The zones are called zones A, B, and C. There is a zone A for the top half of the chart and a zone A for the bottom half of the chart. The same is true for zones B and C. Control charts are based on 3 sigma limits of the variable being plotted. Thus, each zone is one standard deviation in width. For example, considering the top half of the chart, zone C is the region from the average to the average plus one standard deviation. Zone B is the region between the average plus one standard deviation and the average plus two standard deviations. Zone A is the region between the average plus two standard deviations and the average plus three standard deviations

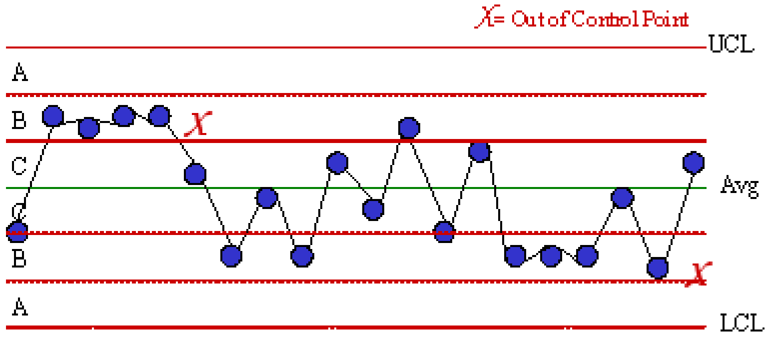


A special cause exists if two out of three consecutive points fall in zone A or beyond. The figure below shows an example of this test. The test is applied for the zone A above the average and then for the zone A below the average.

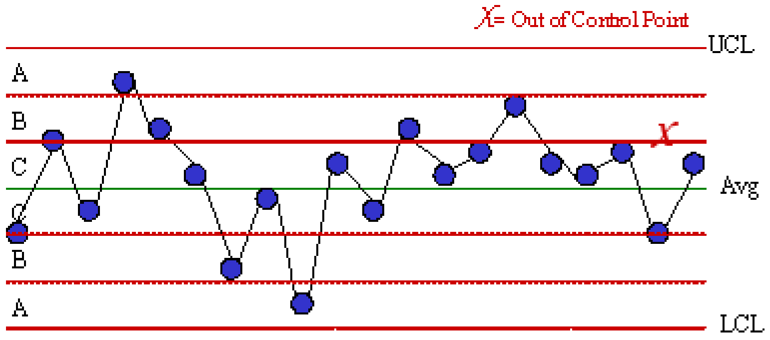
This test, like those below, is applied to both halves of the chart. However, only one half is considered at a time. For example, if one point falls in the zone A above the average and the next point falls in zone A below the average, this is not two out of three consecutive points in zone A or beyond. The two points in zone A must be on the same side of the average.

Zone Tests: Zones B and C

A special cause exists if four out five consecutive points fall in zone B or beyond. The figure to the left shows an example of this test. This test is applied for zone B above the average and then for zone B below the average.

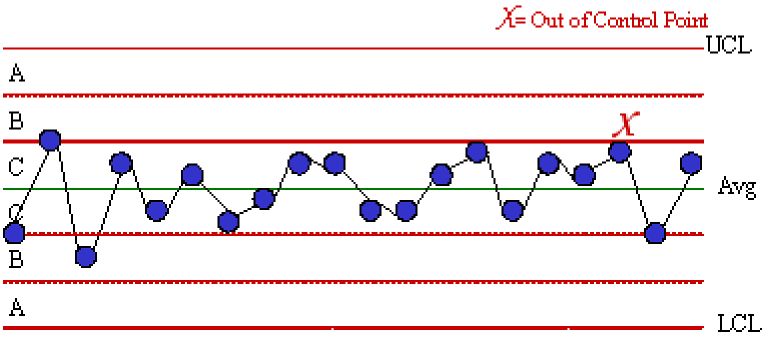


A special cause exists if seven consecutive points fall in zone C or beyond. An example of this test is shown below. The test should be applied for the zone C above the average and then for the zone C below the average.



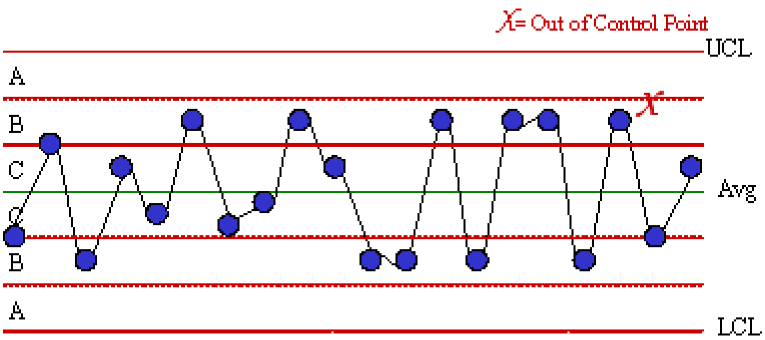
Test for Stratification

Stratification occurs if two or more processes (distributions) are being sampled systematically. For example, stratification can occur if samples are taken once a shift and a subgroup size of 3 is formed based on the results from three shifts. It is possible that the shifts are operating at a different average or variability. Stratification (a special cause) exists if fifteen or more consecutive points fall in zone C either above or below the average. Note that the points tend to hug the centerline. This test involves the use of the zones but is applied to the entire chart and not one-half of the chart at a time.



Test for Mixtures

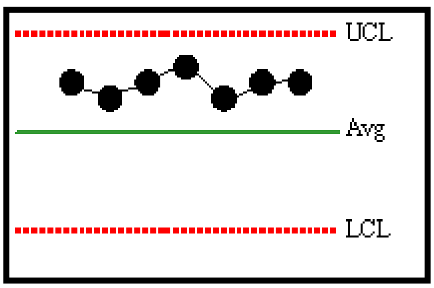
A mixture exists when there is more than one process present but sampling is done for each process separately. For example, suppose you take three samples per shift and form a subgroup based on these three samples. If different shifts are operating at different averages, a mixture can occur. A mixture (a special cause) is present if eight or more consecutive points lie on both sides of the average with none of the points in zone C. The figure shows an example of this test. Note the absence of points in zone C. This test is applied to the entire chart.



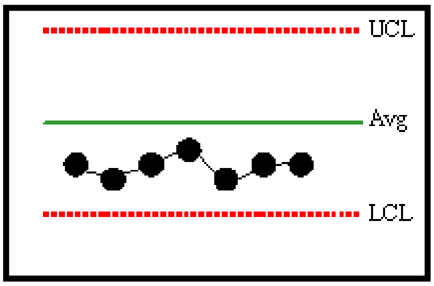
Rule of Seven Tests

These tests are often taught initially to employees as the method for interpreting control charts (along with points beyond the limits). The tests state that an out of control situation is present if one of the following conditions is true:

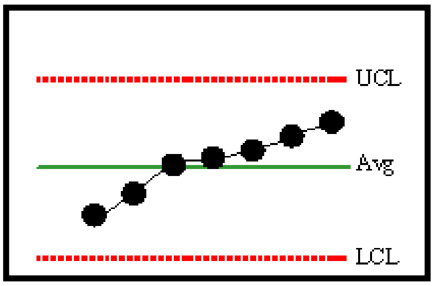
1) Seven points in a row above the average,



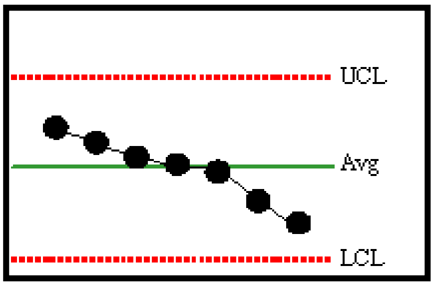
2) Seven points in a row below the average,



3) Seven points in a row trending up, or



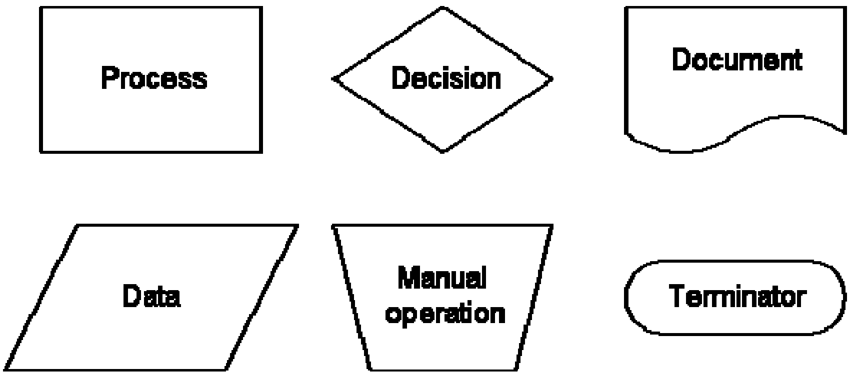
4) Seven points in a row trending down. These four conditions are shown in the figure above.



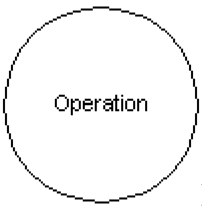
FLOW CHARTS

OVERVIEW

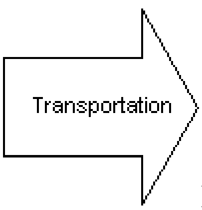
- Quality Improvement Tool: Flow charts used specifically for a process.
- A flow chart is defined as a pictorial representation describing a process being studied or even used to plan stages of a project. Flow charts tend to provide people with a common language or reference point when dealing with a project or process.
- Four particular types of flow charts have proven useful when dealing with a process analysis: top-down flow chart, detailed flow chart, work flow diagrams, and a deployment chart. Each of the different types of flow charts tend to provide a different aspect to a process or a task. Flow charts provide an excellent form of documentation for a process, and quite often are useful when examining how various steps in a process work together.
- When dealing with a process flow chart, two separate stages of the process should be considered: the finished product and the making of the product. In order to analyze the finished product or how to operate the process, flow charts tend to use simple and easily recognizable symbols. The basic flow chart symbols below are used when analyzing how to operate a process.



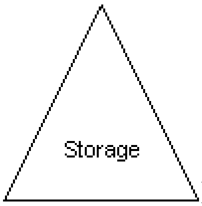
In order to analyze the second condition for a flow process chart, one should use the ANSI standard symbols. The ANSI standard symbols used most often include the following:



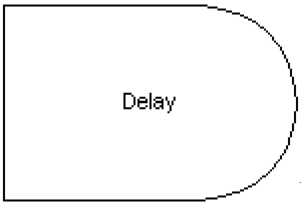
Drive Nail, Cement, Type Letter.



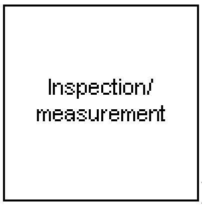
Move Material by truck, conveyor, or hand.



Raw Material in bins, finished product on pallets, or filed documents.



Wait for elevator, papers waiting, material waiting



Read gages, read papers for information, or check quality of goods.

Any combination of two or more of these symbols show an understanding for a joint process.

INSTRUCTIONS

Step-by-Step process of how to develop a flow chart.

- Gather information of how the process flows: use a)conservation, b)experience, or c)product development codes.
- Trial process flow.
- Allow other more familiar personnel to check for accuracy.
- Make changes if necessary.
- Compare final actual flow with best possible flow.

Note: Process should follow the flow of Step1, Step 2, ... , Step N.

Step N= End of Process

CONSTRUCTION/INTERPRETATION tip for a flow chart.

- Define the boundaries of the process clearly.
- Use the simplest symbols possible.
- Make sure every feedback loop has an escape.

- There is usually only one output arrow out of a process box. Otherwise, it may require a decision diamond.

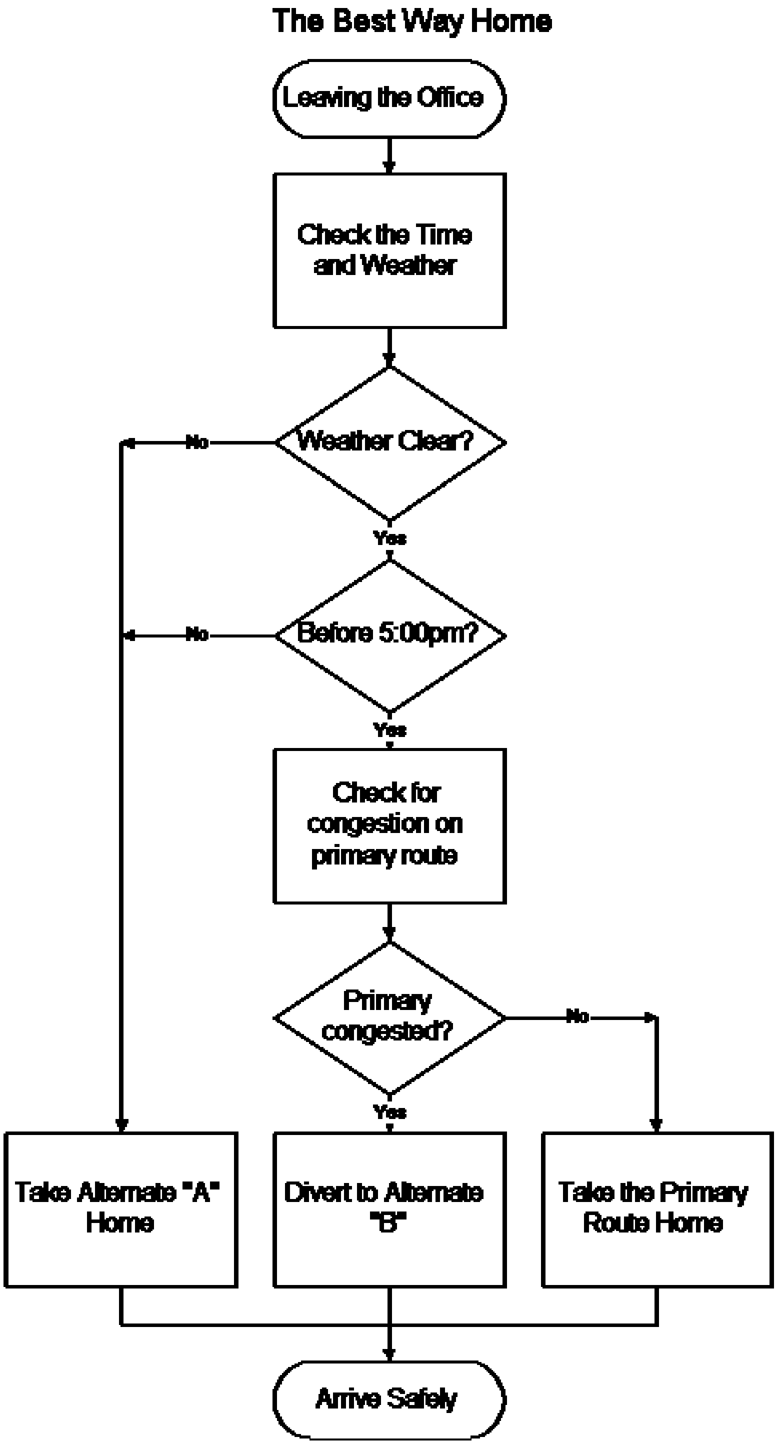
INTERPRETATION

- Analyze flow chart of actual process.
- Analyze flow chart of best process.
- Compare both charts, looking for areas where they are different. Most of the time, the stages where differences occur is considered to be the problem area or process.
- Take appropriate in-house steps to correct the differences between the two seperate flows.

EXAMPLE

Process Flow Chart- Finding the best way home

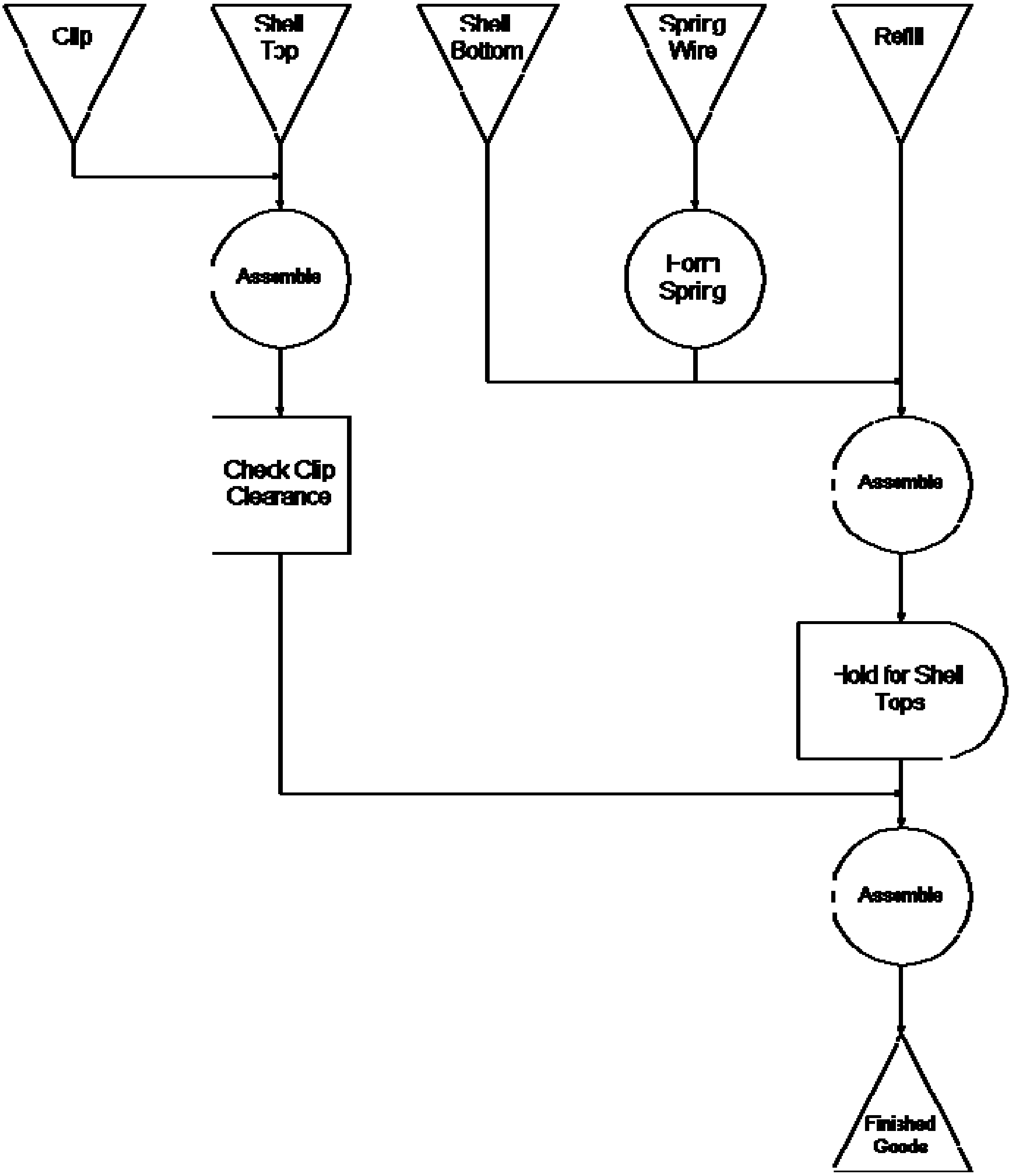
This is a simple case of processes and decisions in finding the best route home at the end of the working day.



Process Flow Chart- How a process works

(Assembling a ballpoint pen)

Ball-Point Pen Assembly



Cause and Effect Diagram

PURPOSE and USAGE

To provide a pictorial display of a list in which you identify and organize possible causes of problems, or factors needed to ensure success of some effort.

It is an effective tool that allows people to easily see the relationship between factors to study processes, situations, and for planning.

HISTORICAL BACKGROUND

The cause-and-effect diagram is also called the Ishikawa diagram (after its creator, Kaoru Ishikawa of Japan), or the fishbone diagram (due to its shape).

This diagram was adopted by Dr. W. Edwards Deming as a helpful tool in improving quality. Dr. Deming has taught Total Quality Management in Japan since World War II. He has also helped develop statistical tools to be used for the census and taught the military his methods of quality management. Both Ishikawa and Deming use this diagram as one the first tools in the quality management process.

Fishbone Diagram Example

This fishbone diagram was drawn by a manufacturing team to try to understand the source of periodic iron contamination. The team used the six generic headings to prompt ideas. Layers of branches show thorough thinking about the causes of the problem.

For example, under the heading “Machines,” the idea “materials of construction” shows four kinds of equipment and then several specific machine numbers.

Note that some ideas appear in two different places. “Calibration” shows up under “Methods” as a factor in the analytical procedure, and also under “Measurement” as a cause of lab error. “Iron tools” can be considered a “Methods” problem when taking samples or a “Manpower” problem with maintenance personnel.

Example: Copier Problem

I. PEOPLE
- A. Employees
  - 1. Full time
  - 2. Part-time
- B. Training
  - 1. Formal
    - a. Recent
    - b. Adequate
    - c. Consistent
  - 2. On-the-Job
    - a. Recent
    - b. Frequent

II. METHODS
- A. Manufacturer’s recommended procedures
- B. Manufacturer’s recommended materials
- C. Consistent

III. MATERIALS
- A. Paper

1. Size
2. Thickness
    a. Too thick
    b. Too thin
3. Condition of originals
    a. Creased
    b. Poor quality

B. Toner
1. Too little
2. Too much
3. Lumpy
4. Too thin

IV. ENVIRONMENT

A. Temperature
1. Too hot
2. Too cold

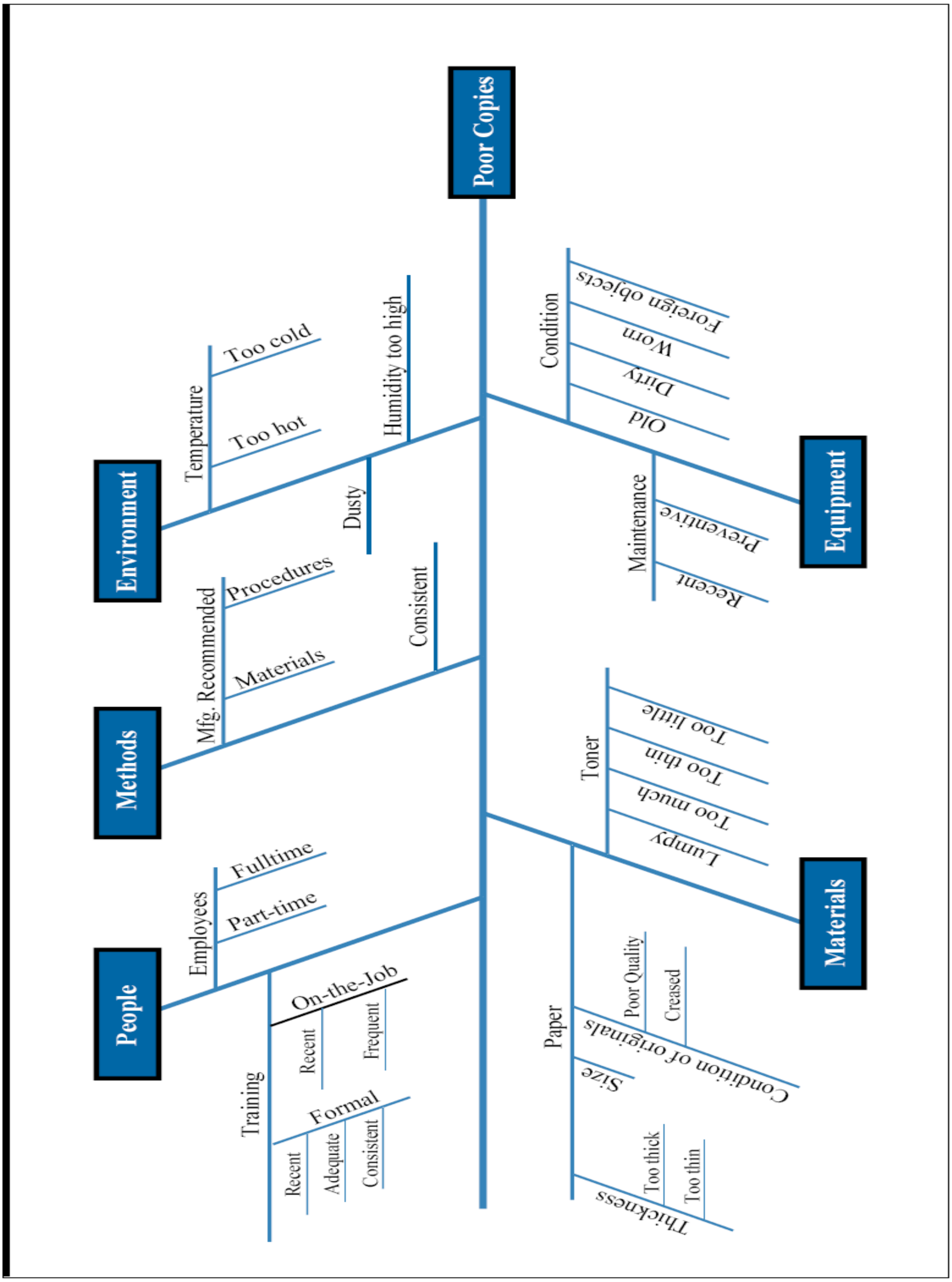
B. Humidity too high

C. Dusty

V. EQUIPMENT

A. Condition
1. Dirty
2. Foreign objects
3. Old
4. Worn

B. Maintenance agreement
1. Recent maintenance
2. Preventive maintenance



Poor Copies
Environment
Temperature
Too cold
Too hot
Humidity too high
Dusty
Methods
Mfg. Recommended
Procedures
Materials
Consistent
People
Employees
Fulltime
Part-time
Training
On-the-Job
Recent
Frequent
Formal
Recent
Adequate
Consistent
Equipment
Condition
Foreign objects
Worn
Dirty
Old
Maintenance
Preventive
Recent
Materials
Toner
Too little
Too thin
Too much
Lumpy
Paper
Poor Quality
Creased
Condition of originals
Size
Thickness
Too thick
Too thin

Histograms

Overview

Overview: This histogram tutorial will provide information on how to construct and interpret histograms for use in quality process control (Q.C.). The main areas that will be covered in this tutorial are the following:

- Tutorial Instructions
- Histogram Background
- Creating a Histogram (interactively by example)
- Interpreting Histograms
- Recommended Additional Q.C. Topics and Software

Purpose: The purpose of this tutorial is to let you become familiar with graphical histograms which are used widely in quality control (Q.C.). Histograms are effective Q.C. tools which are used in the analysis of data. They are used as a check on specific process parameters to determine where the greatest amount of variation occurs in the process, or to determine if process specifications are exceeded. This statistical method does not prove that a process is in a state of control. Nonetheless, histograms alone have been used to solve many problems in quality control.

Key Terms:

Histogram - a vertical bar chart of a frequency distribution of data

Q.C. Methodology - a statistical tool used in the analysis and determination of possible solutions to quality control problems in industry

Frequency Distribution - a variation in a numeric sample of data

Creating a Histogram

1. Determine the range of the data by subtracting the smallest observed measurement from the largest and designate it as R.

   Example:

   Largest observed measurement = 1.1185 inches

   Smallest observed measurement = 1.1030 inches

   R = 1.1185 inches - 1.1030 inches =.0155 inch

2. Record the measurement unit (MU) used. This is usually controlled by the measuring instrument least count.

   Example: MU = .0001 inch

3. Determine the number of classes and the class width. The number of classes, k, should be no lower than six and no higher than fifteen for practical purposes. Trial and error may be done to achieve the best distribution for analysis.

   Example: k=8

4. Determine the class width (H) by dividing the range, R, by the preferred number of classes, k.

   Example: R/k = .0155/8 = .0019375 inch

   The class width selected should be an odd-numbered multiple of the

   measurement unit, MU. This value should be close to the H value:

   MU = .0001 inch

   Class width = .0019 inch or .0021 inch

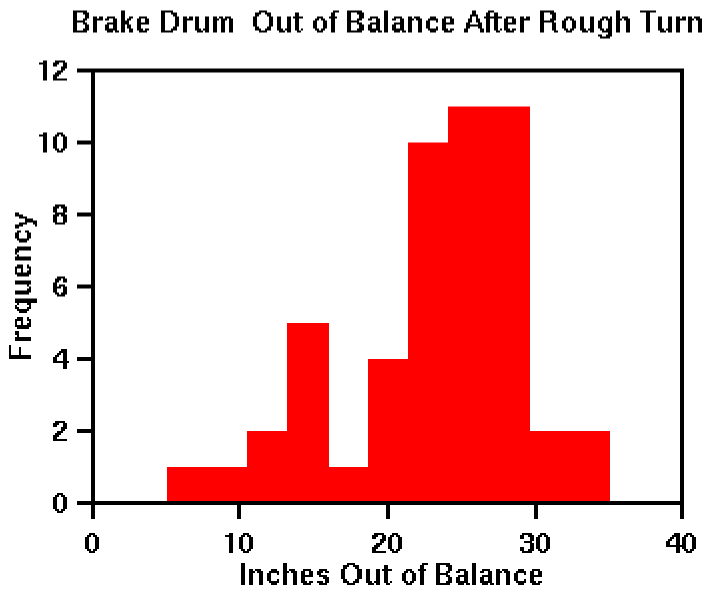
5. Establish the class midpoints and class limits. The first class midpoint should be located near the largest observed measurement. If possible, it should also be a convenient increment. Always make the class widths equal in size, and express the class limits in terms which are one-half unit beyond the accuracy of the original measurement unit. This avoids plotting an observed measurement on a class limit.

   Example: First class midpoint = 1.1185 inches, and the

   class width is .0019 inch. Therefore, limits would be

   1.1185 + or - .0019/2.

6. Determine the axes for the graph. The frequency scale on the vertical axis should slightly exceed the largest class frequency, and the measurement scale along the horizontal axis should be at regular intervals which are independent of the class width. (See example below steps.)



7. Draw the graph. Mark off the classes, and draw rectangles with heights corresponding to the measurement frequencies in that class.

8. Title the histogram. Give an overall title and identify each axis.

Now you have a histogram!!

Interpretations

When combined with the concept of the normal curve and the knowledge of a particular process, the histogram becomes an effective, practical working tool in the early stages of data analysis. A histogram may be interpreted by asking three questions:

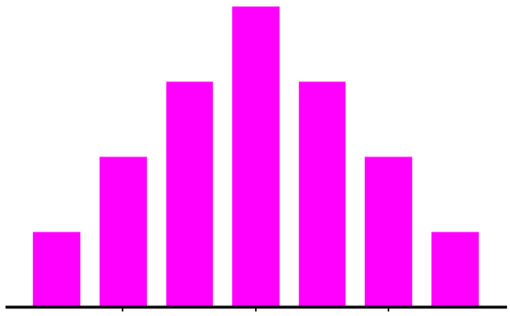
1. Is the process performing within specification limits?
2. Does the process seem to exhibit wide variation?
3. If action needs to be taken on the process, what action is appropriate?

The answer to these three questions lies in analyzing three characteristics of the histogram.

1. How well is the histogram centered? The centering of the data provides information on the process aim about some mean or nominal value.
2. How wide is the histogram? Looking at histogram width defines the variability of the process about the aim.
3. What is the shape of the histogram? Remember that the data is expected to form a normal or bell-shaped curve. Any significant change or anomaly usually indicates that there is something going on in the process which is causing the quality problem.

Examples of Typical Distributions

NORMAL



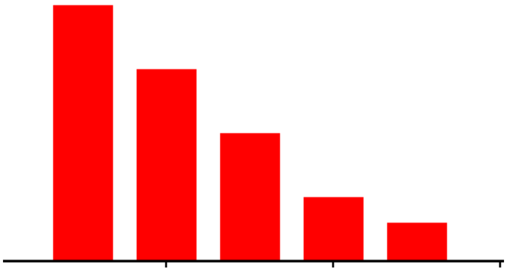
- Depicted by a bell-shaped curve
  - most frequent measurement appears as center of distribution
  - less frequent measurements taper gradually at both ends of distribution
- Indicates that a process is running normally (only common causes are present).

BI-MODAL

- Distribution appears to have two peaks
- May indicate that data from more than process are mixed together

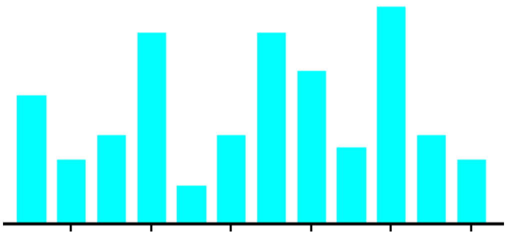
- materials may come from two separate vendors
- samples may have come from two separate machines.

CLIFF-LIKE



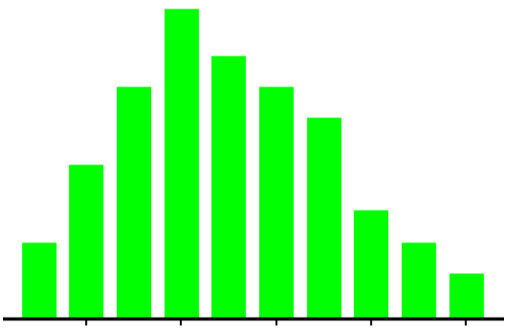
- Appears to end sharply or abruptly at one end
- Indicates possible sorting or inspection of non-conforming parts.

SAW-TOOTHED



- Also commonly referred to as a comb distribution, appears as an alternating jagged pattern
- Often indicates a measuring problem
  - improper gage readings
  - gage not sensitive enough for readings.

SKEWED



- Appears as an uneven curve; values seem to taper to one side.

It is worth mentioning again that this or any other phase of histogram analysis must be married to knowledge of the process being studied to have any real value. Knowledge of the data analysis itself does not provide sufficient insight into the quality problem.

OTHER CONSIDERATIONS

Number of samples.

For the histogram to be representative of the true process behavior, as a general rule, at least fifty (50) samples should be measured.

Limitations of technique.

Histograms are limited in their use due to the random order in which samples are taken and lack of information about the state of control of the process. Because samples are gathered without regard to order, the time-dependent or time-related trends in the process are not captured. So, what may appear to be the central tendency of the data may be deceiving. With respect to process statistical control, the histogram gives no indication whether the process was operating at its best when the data was collected. This lack of information on process control may lead to incorrect conclusions being drawn and, hence, inappropriate decisions being made. Still, with these considerations in mind, the histogram's simplicity of construction and ease of use make it an invaluable tool in the elementary stages of data analysis.

Pareto Analysis

Vilfredo Pareto was an Italian economist who noted that approximately 80% of wealth was owned by only 20% of the population. This was true in almost all the societies he studied. This is only one application of this important 80/20 principle. It shows the lack of symmetry that almost always appears between work put in and results achieved. This can be seen in area after area of competitive activity. The figures 80 and 20 are illustrative – for example, 13% of work could generate 92% of returns.

Pareto analysis is a very simple technique that helps you to choose the most effective changes to make. It uses the Pareto principle – the idea that by doing 20% of work you can generate 80% of the advantage of doing the entire job. Pareto analysis is a formal technique for finding the changes that will give the biggest benefits. It is useful where many possible courses of action are competing for your attention.

How to Use the Tool:

To start using the tool, write out a list of the changes you could make. If you have a long list, group it into related changes.

Then score the items or groups. The scoring method you use depends on the sort of problem you are trying to solve. For example, if you are trying to improve profitability, you would score options on the basis of the profit each group might generate. If you are trying to improve customer satisfaction, you might score on the basis of the number of complaints eliminated by each change.

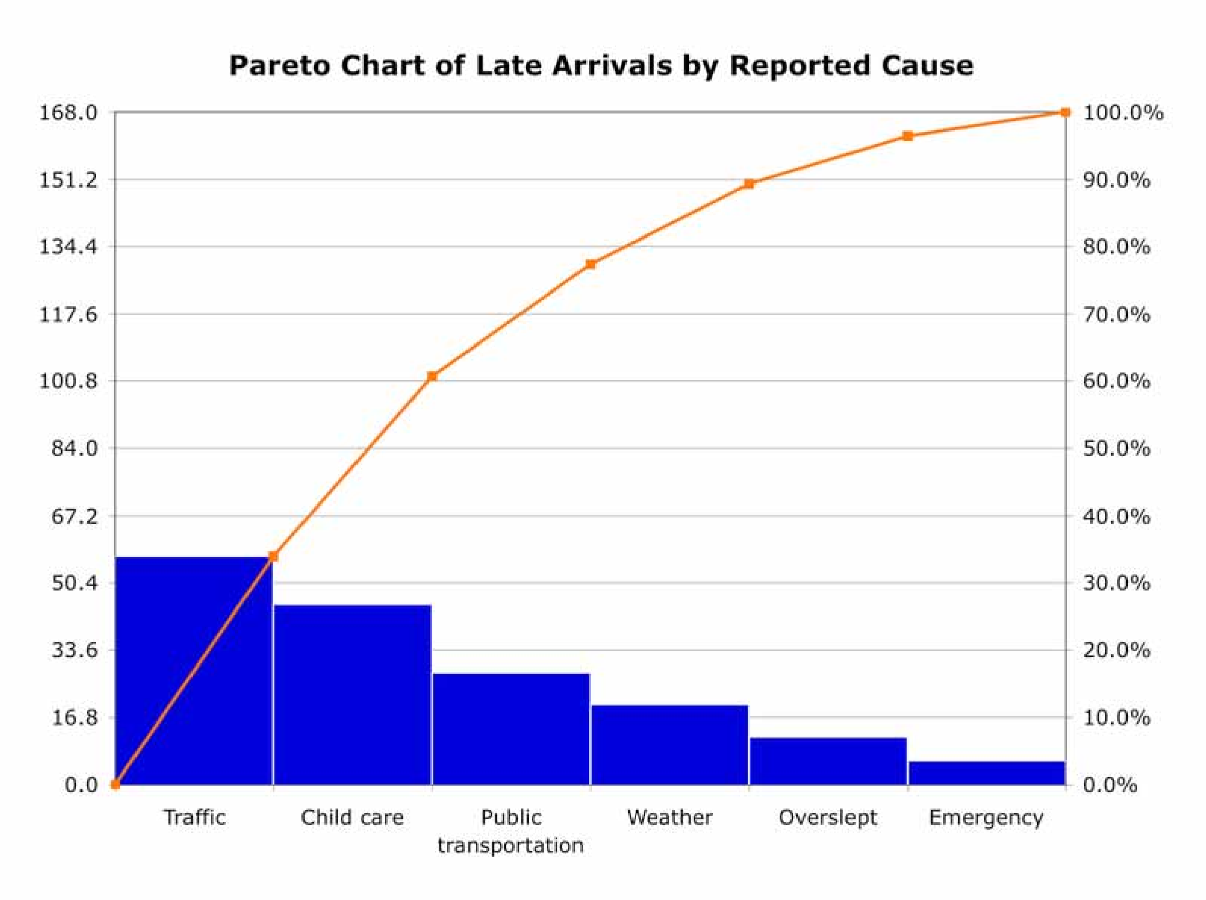
The first change to tackle is the one that has the highest score. This one will give you the biggest benefit if you solve it.

The options with the lowest scores will probably not even be worth bothering with – solving these problems may cost you more than the solutions are worth.

Key points:

To use it:

- ✓ List the problems you face, or the options you have available
- ✓ Group options where they are facets of the same larger problem
- ✓ Apply an appropriate score to each group
- ✓ Work on the group with the highest score


Pareto Chart of Late Arrivals by Reported Cause
168.0
151.2
134.4
117.6
100.8
84.0
67.2
50.4
33.6
16.8
0.0
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Traffic
Child care
Public transportation
Weather
Overslept
Emergency