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# Quality Tools, The Basic Seven

This topic actually contains an assortment of tools, some developed by quality engineers, and some adapted from other applications. They provide the means for making quality management decisions based on facts. No particular tool is mandatory, any one may be helpful, depending on circumstances. A number of software programs are available as aids to the application of some of these tools.

Total Quality Management (TQM) and Total Quality Control (TQC) literature make frequent mention of seven basic tools. Kaoru Ishikawa contends that 95% of a company's problems can be solved using these seven tools. The tools are designed for simplicity. Only one, control charts require any significant training. The tools are:

- Flow Charts
- Ishikawa Diagrams
- Checklists
- Pareto Charts
- Histograms
- Scattergrams
- Control Charts

**Flow Charts**

A flow chart shows the steps in a process i.e., actions which transform an input to an output for the next step. This is a significant help in analyzing a process but it must reflect the actual process used rather than what the process owner thinks it is or wants it to be. The differences between the actual and the intended process are often surprising and provide many ideas for improvements. Figure 1 shows the flow chart for a hypothetical technical report review process. Measurements could be taken at each step to find the most significant causes of delays, these may then be flagged for improvement.

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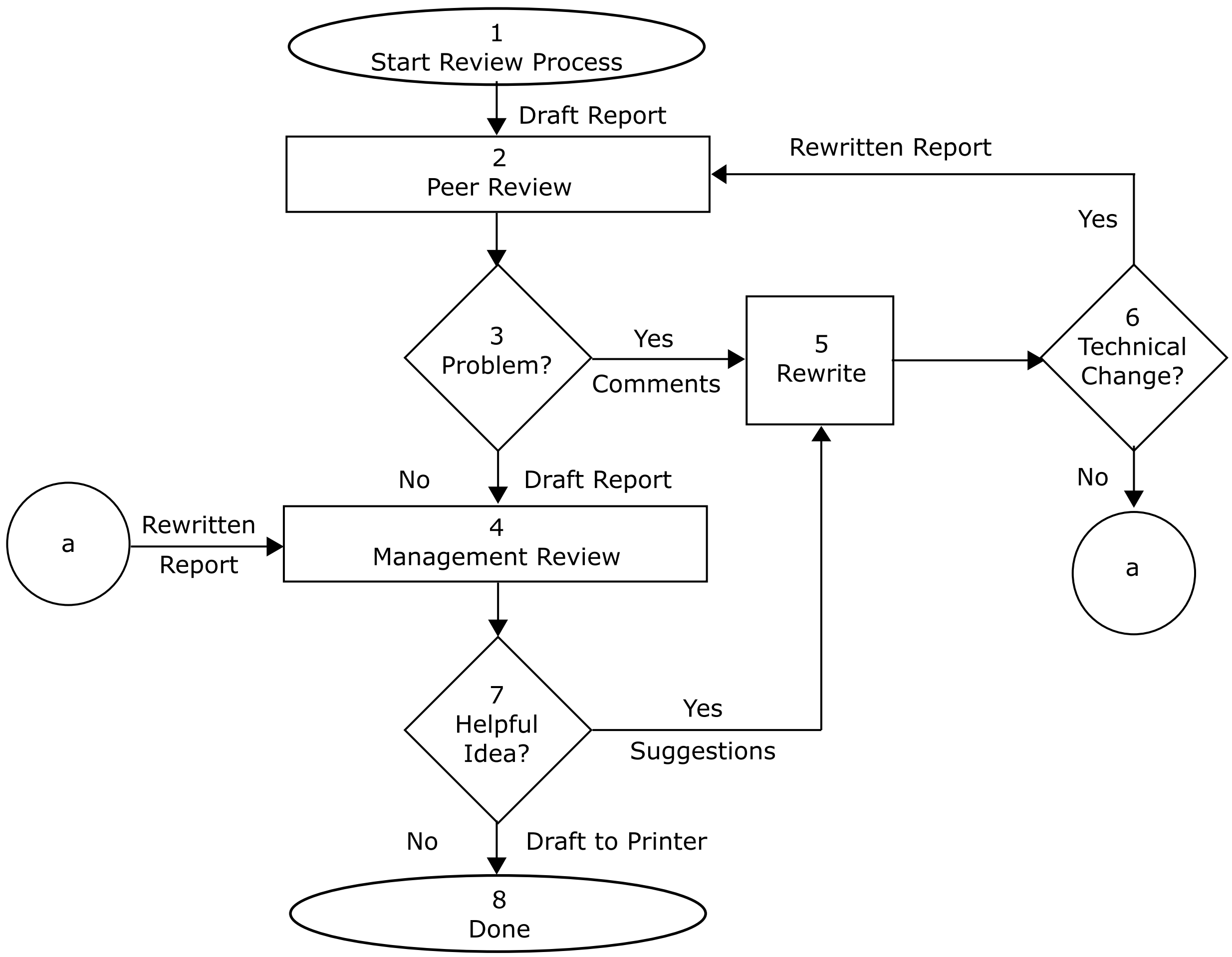


**Figure 1. Flow Chart of Review Process**

In making a flow chart, the process owner often finds the actual process to be quite different than it was thought to be. Often, non-value-added steps become obvious and eliminating these provides an easy way to improve the process. When the process flow is satisfactory, each step becomes a potential target for improvement. Priorities are set by measurements. In Figure 1, the average time to complete peer review (get from Step 2 to Step 4) and to complete management review (get from Step 4 to Step 8) may be used to decide if further analysis to formulate corrective action is warranted. It may be necessary to expand some steps into their own flow charts to better understand them. For example, if we have an unsatisfactory amount of time spent in management review we might expand Step 4 as shown in Figure 2.

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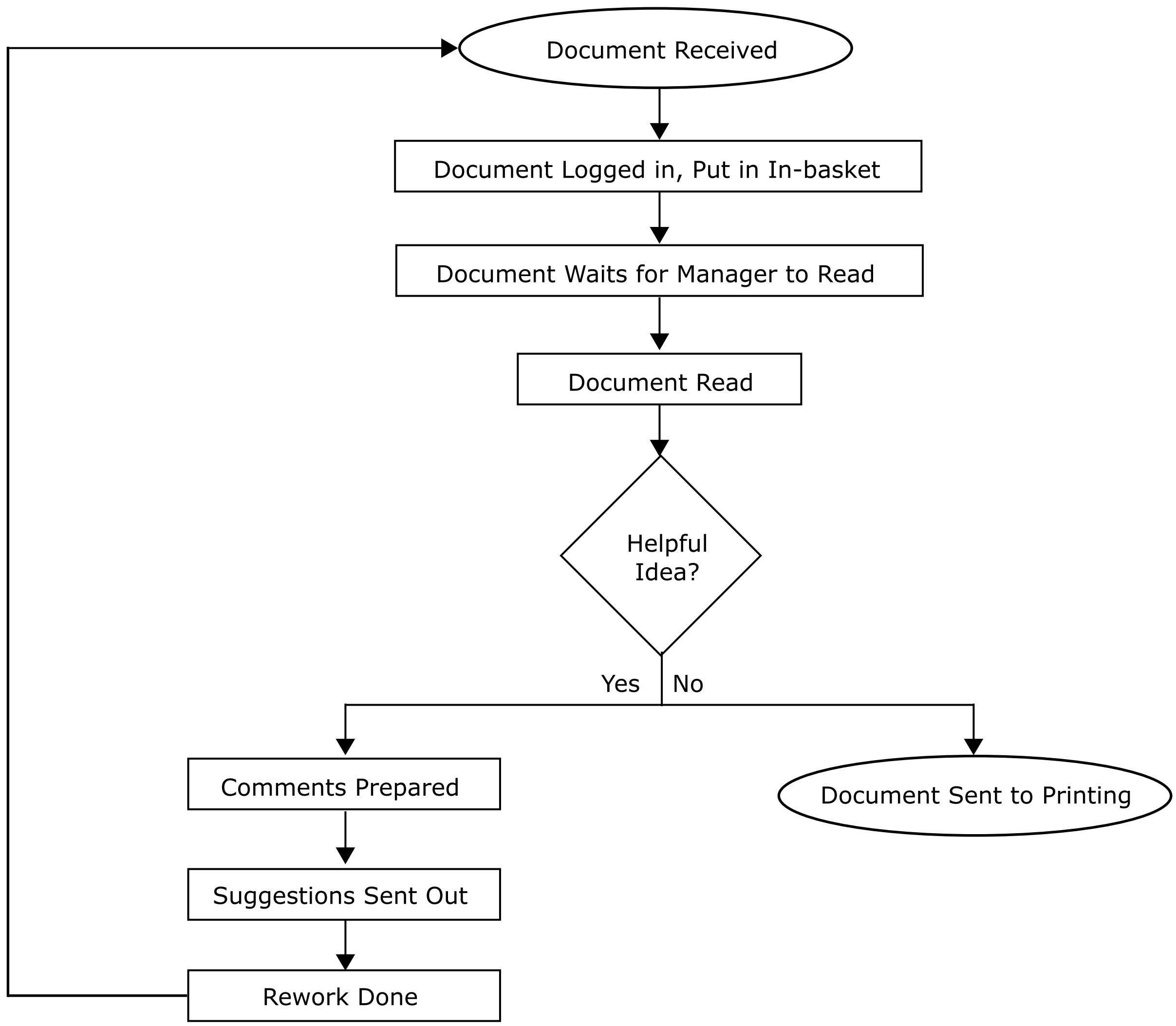


**Figure 2. Flow Chart of Management Review**

Figure 2 shows many possibilities for delay in management review. It may be that it takes too long for the manager to get around to reading the document. Or, too much time may be consumed in rework to address the comments of the manager. Only some more measurements will tell. Corrective actions to the former may include the delegation of review authority. Training the technical writers to avoid the most frequent complaints of the managers could possibly cure the latter. It may also be found that the manager feels obligated to make some comment on each report he reviews, and changing this perception may be helpful. Whatever the solution, information provided by the flow chart would point the way.

A danger in flow charting is the use of assumed or desired steps rather than actual process steps in making the chart. The utility of the chart will correlate directly to its accuracy. Another danger is that the steps plotted may not be under the control of the user. If the analyst does not "own the process" the chart may not be too helpful. It may, however, be quite useful to a process improvement team including all the functions involved.

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## Ishikawa Diagrams

Ishikawa diagrams are named after their inventor, Kaoru Ishikawa. They are also called fishbone charts, after their appearance, or cause and effect diagrams after their function. Their function is to identify the factors that are causing an undesired effect (e.g., defects) for improvement action, or to identify the factors needed to bring about a desired result (e.g., a winning proposal). The factors are identified by people familiar with the process involved. As a starting point, major factors could be designated using the "four M's": Method, Manpower, Material, and Machinery; or the "four P's": Policies, Procedures, People, and Plant. Factors can be subdivided, if useful, and the identification of significant factors is often a prelude to the statistical design of experiments. Figure 3 is a partially completed Ishikawa diagram attempting to identify potential causes of defects in a wave solder process.

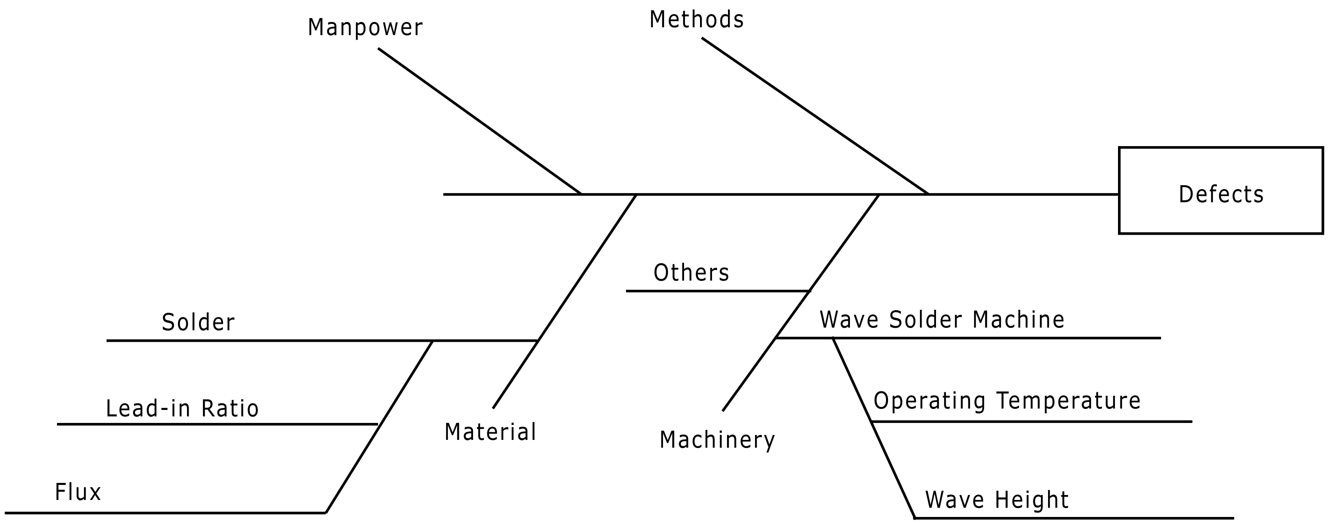


**Figure 3. Partially Completed Ishikawa Diagram**

## Checklists

Checklists are a simple way of gathering data so that decisions can be based on facts, rather than anecdotal evidence. Figure 4 shows a checklist used to determine the causes of defects in a hypothetical assembly process. It indicates that "not-to-print" is the biggest cause of defects, and hence, a good subject for improvement. Checklist items should be selected to be mutually exclusive and to cover all reasonable categories. If too many checks are made in the "other" category, a new set of categories is needed.

| Defect | Monday | Tuesday | Wednesday | Thursday | Friday | Total |
|---|---|---|---|---|---|---|
| Solder | I | II | | I | | 4 |
| Part | II | | I | II | I | 6 |
| Not-to-Print | III | II | I | III | II | 11 |
| Timing | | I | I | | I | 3 |
| Other | | I | | | | 1 |

**Figure 4. Checklist for Detects Found**

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Figure 4 could also be used to relate the number of defects to the day of the week to see if there is any significant difference in the number of defects between workdays. Other possible column or row entries could be production line, shift, product type, machine used, operator, etc., depending on what factors are considered useful to examine. So long as each factor can be considered mutually exclusive, the chart can provide useful data. An Ishikwa Diagram may be helpful in selecting factors to consider. The data gathered in a checklist can be used as input to a Pareto chart for ease of analysis. Note that the data does not directly provide solutions. Knowing that "not-to-print" is the biggest cause of defects only starts the search for the root cause of "not-to-print" situations. (This is in contrast to the design of experiments which could yield the optimal settings for controllable process settings such as temperature and wave height.)

## Pareto Charts

Alfredo Pareto was an economist who noted that a few people controlled most of a nation's wealth. "Pareto's Law" has also been applied to many other areas, including defects, where a few causes are responsible for most of the problems. Separating the "vital few" from the "trivial many" can be done using a diagram known as a Pareto chart. Figure 5 shows the data from the checklist shown in Figure 4 organized into a Pareto chart.

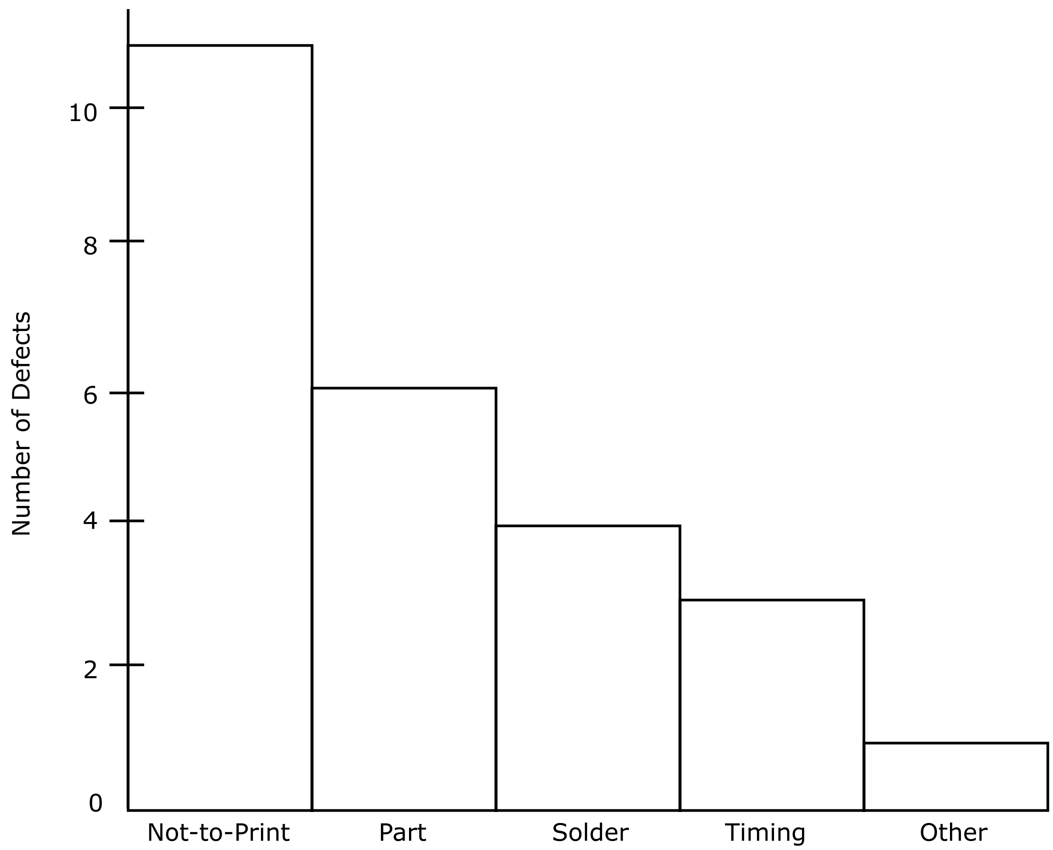


**Figure 5. Pareto Chart**

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Figure 5, like Figure 4, shows the "not-to-print" category as the chief cause of defects. However, suppose the not-to-print problems could be cheaply corrected (e.g., by resoldering a mis-routed wire) while a defect due to "timing" was too expensive to fix and resulted in a scrapped assembly. It may then be useful to analyze the data in terms of the cost incurred rather than the number of instances of each defect category. This might result in the chart shown in Figure 6, which would indicate eliminating the timing problems to be most fruitful.

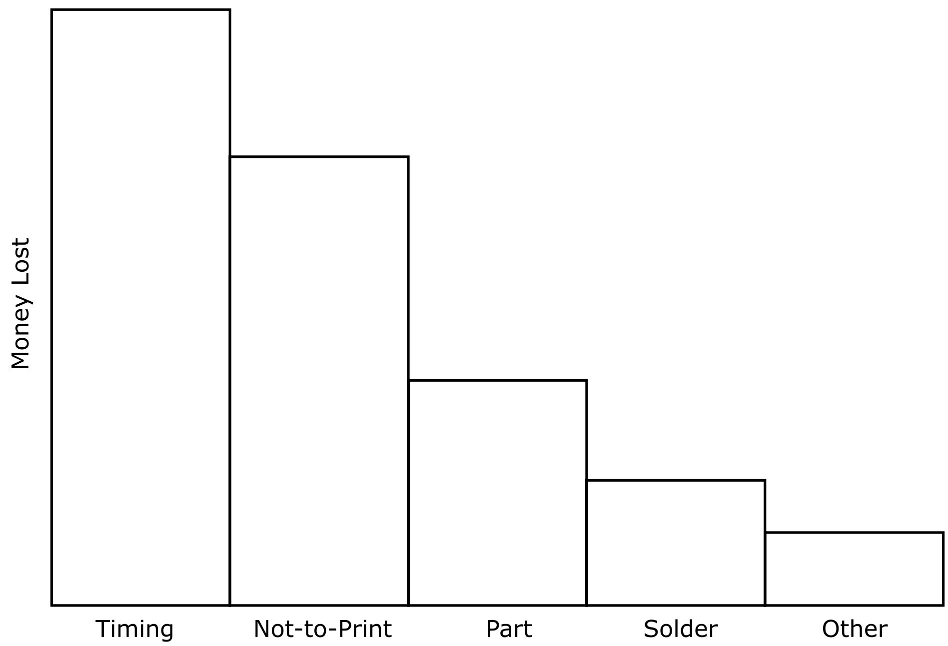


**Figure 6. Pareto Chart of Costs of Defects**

A useful application of Pareto Charts is Stratification, explained in the subtopic Stratification.

Stratification is simply the creation of a set of Pareto charts for the same data, using different possible causative factors. For example, Figure 7 plots defects against three possible sets of potential causes. The figure shows that there is no significant difference in defects between production lines or shifts, but product type three has significantly more defects than do the others. Finding the reason for this difference in number of defects could be worthwhile.

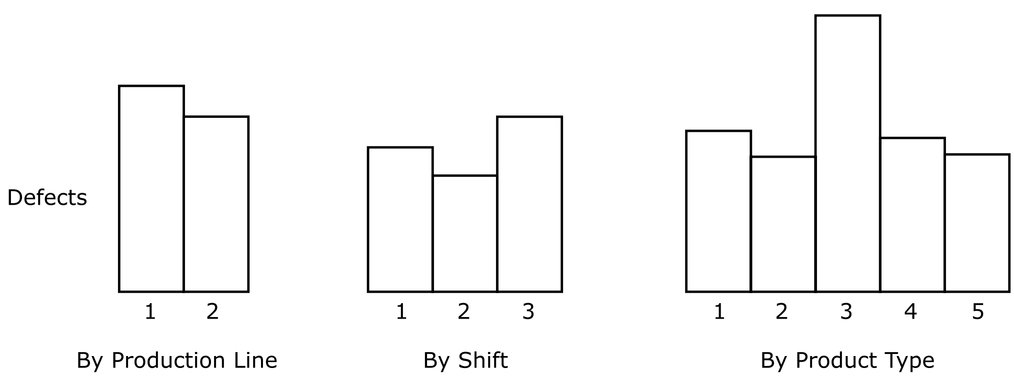


**Figure 7. Stratification**

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## Histograms

Histograms are another form of bar chart in which measurements are grouped into bins; in this case each bin representing a range of values of some parameter. For example, in Figure 8, X could represent the length of a rod in inches. The figure shows that most rods measure between 0.9 and 1.1 inches. If the target value is 1.0 inches, this could be good news. However, the chart also shows a wide variance, with the measured values falling between 0.5 and 1.5 inches. This wide a range is generally a most unsatisfactory situation.

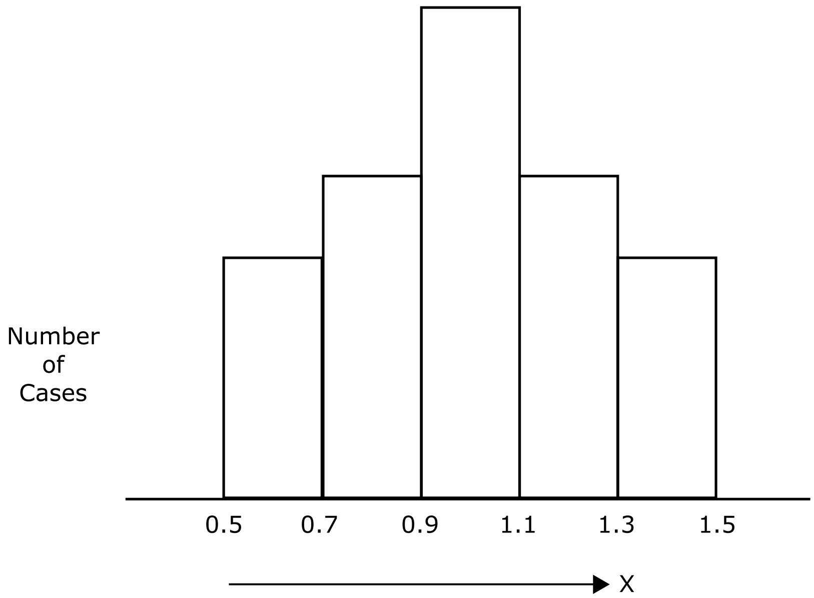


**Figure 8. Histogram**

Besides the central tendency and spread of the data, the shape of the histogram can also be of interest. For example, Figure 9 shows a bi-modal distribution. This indicates that the measurements are not from a homogeneous process, since there are two peaks indicating two central tendencies. There are two (or more) factors that are not in harmony. These could be two machines, two shifts, or the mixed outputs of two suppliers. Since at least one of the peaks must be off target, there is evidence here that improvements can be made.

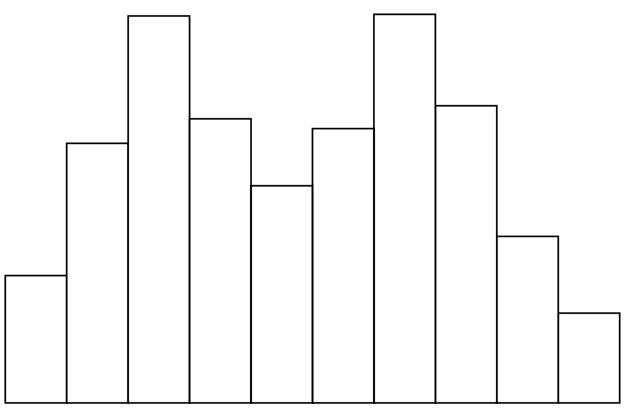

**Figure 9. Bi-modal Histogram**

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In contrast, the histogram of Figure 10 shows a situation in which the spread of measurements is lower on one side of the central tendency than on the other. These could be measurements of miles per gallon attained by an automobile. There are many situations that decrease fuel economy, such as engine settings, tire condition, bad weather, traffic jams, etc., but few situations that can significantly improve it. The wider variance can be attacked by optimizing any of the controllable factors such as tuning the engine, replacing the tires used, etc. Moving the central tendency in the direction of the smaller variance is unlikely unless the process is radically changed (e.g., reducing the weight of the vehicle, installing a new engine, etc.).

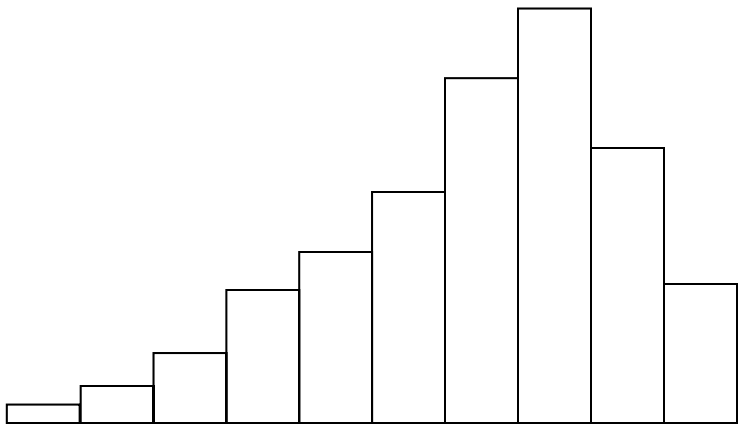

**Figure 10. Skewed Histogram**

### Scattergrams

Scattergrams are a graphical, rather than statistical, means of examining whether or not two parameters are related to each other. It is simply the plotting of each point of data on a chart with one parameter as the x-axis and the other as the y-axis. If the points form a narrow "cloud" the parameters are closely related and one may be used as a predictor of the other. A wide "cloud" indicates poor correlation. Figure 11 shows a plot of defect rate vs. temperature with a strong positive correlation, while Figure 12 shows a weak negative correlation.

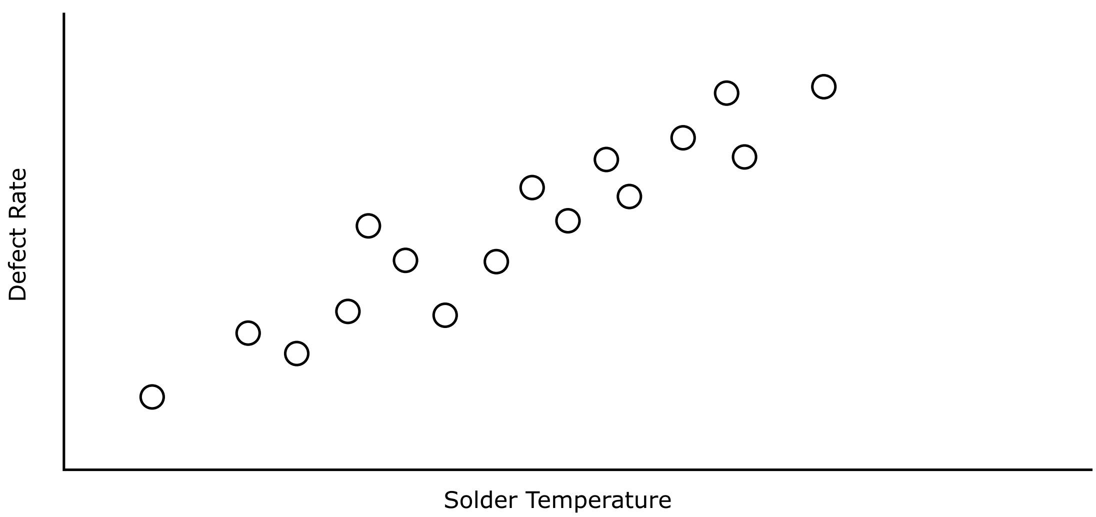


**Figure 11. Scattergram Showing Strong Correlation**

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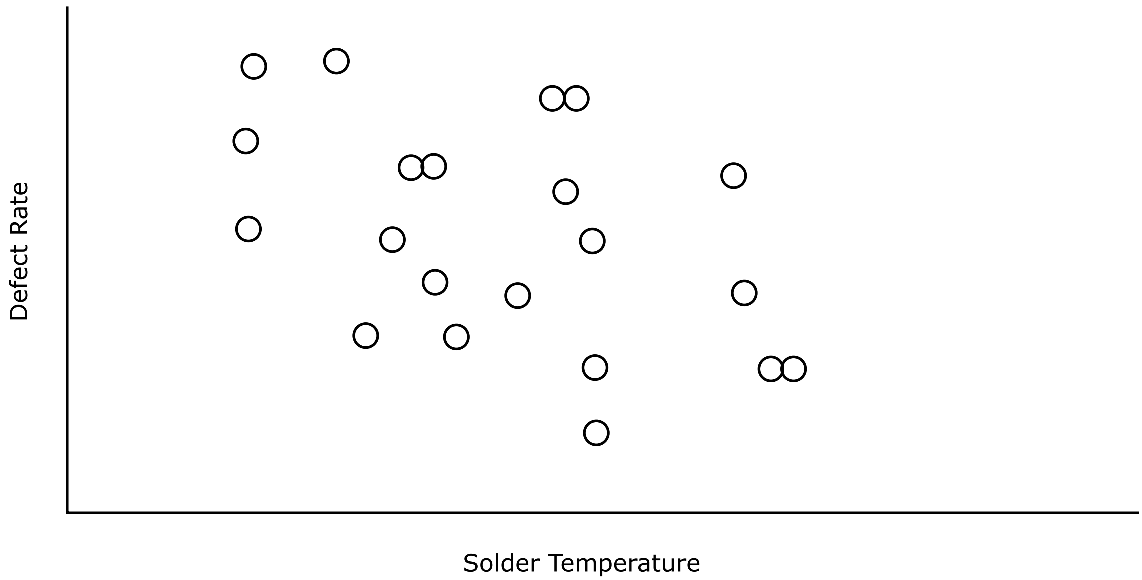


**Figure 12.  Scattergram Showing Weak Correlation**

It should be noted that the slope of a line drawn through the center of the cloud is an artifact of the scales used and hence not a measure of the strength of the correlation.  Unfortunately, the scales used also affect the width of the cloud, which is the indicator of correlation.  When there is a question on the strength of the correlation between the two parameters, a correlation coefficient can be calculated.  This will give a rigorous statistical measure of the correlation ranging from -1.0 (perfect negative correlation), through zero (no correlation) to +1.0 (perfect correlation).

### Control Charts

Control charts are the most complicated of the seven basic tools of TQM, but are based on simple principles.  The charts are made by plotting in sequence the measured values of samples taken from a process.  For example, the mean length of a sample of rods from a production line, the number of defects in a sample of a product, the miles per gallon of automobiles tested sequentially in a model year, etc. These measurements are expected to vary randomly about some mean with a known variance.  From the mean and variance, control limits can be established.  Control limits are values that sample measurements are not expected to exceed unless some special cause changes the process.  A sample measurement outside the control limits therefore indicates that the process is no longer stable, and is usually reason for corrective action.  Other causes for corrective action are non-random behavior of the measurements within the control limits.  Control limits are established by statistical methods depending on whether the measurements are of a parameter, attribute or rate.  A generic control chart is shown as Figure 13.

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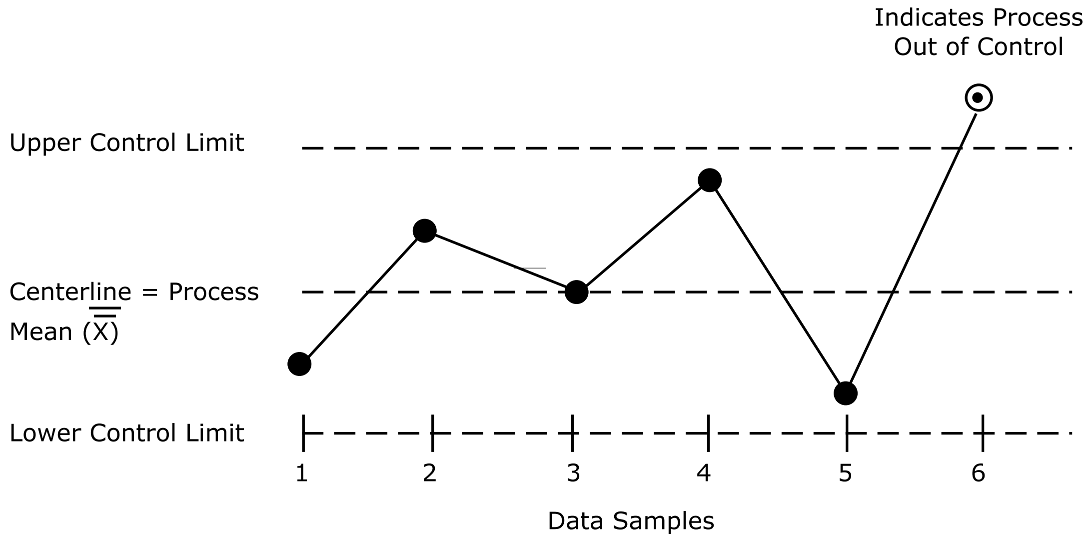


**Figure 13. Control Chart**



**Source:**

- RAC Publication, QKIT, *Quality Toolkit*, 2001.

**For More Information:**

- RAC Publication TQM, *The TQM Toolkit*, 1993.
- Goal/QPC, *The Memory Jogger*, 1988.
- *Handbook of Quality Tools*, By Ozeki, Kazuo & Tetsuichi, Productivity Press, Cambridge, MA, 1990.