THE 7 QC TOOLS

1   **Introduction**

The 7 QC Tools are simple statistical tools used for problem solving. These tools were either developed in Japan or introduced to Japan by the Quality Gurus such as Deming and Juran. In terms of importance, these are the most useful. Kaoru Ishikawa has stated that these 7 tools can be used to solve 95 percent of all problems. These tools have been the foundation of Japan's astomishing industrial resurgence after the second world war.

The following are the 7 QC Tools :

1. Pareto Diagram
2. Cause & Effect Diagram
3. Histogram
4. Control Charts
5. Scatter Diagrams
6. Graphs
7. Check Sheets

2   **Pareto Diagram**

Pareto Diagram is a tool that arranges items in the order of the magnitude of their contribution, thereby identifying a few items exerting maximum influence. This tool is used in SPC and quality improvement for prioritising projects for improvement, prioritising setting up of corrective action teams to solve problems, identifying products on which most complaints are received, identifying the nature of complaints occurring most often, identifying most frequent causes for rejections or for other similar purposes.

The origin of the tool lies in the observation by an Italian economist Vilfredo Pareto that a large portion of wealth was in the hands of a few people. He observed that such distribution pattern was common in most fields. Pareto principle also known as the 80/20 rule is used in the field of materials management for ABC analysis. 20% of the items purchased by a company account for 80% of the value. These constitute the A items on which maximum attention is paid.

Dr.Juran suggested the use of this principle to quality control for separating the "vital few" problems from the "trivial many" now called the "useful many".

Procedure :

The steps in the preparation of a Pareto Diagram are :

1. From the available data calculate the contribution of each individual item.

2. Arrange the items in descending order of their individual contributions. If there are too many items contributing a small percentage of the contribution, group them together as "others". It is obvious that "others" will contribute more than a few single individual items. Still it is kept last in the new order of items.

3. Tabulate the items, their contributions in absolute number as well as in percent of total and cumulative contribution of the items.

4. Draw X and Y axes. Various items are represented on the X-axis. Unlike other graphs Pareto Diagrams have two Y-axes - one on the left representing numbers and the one on right representing the percent contributions. The scale for X-axis is selected in such a manner that all the items including others are accommodated between the two Y-axes. The scales for the   Y-axes are so selected that the total number of items on the left side and 100% on the right side occupy the same height.

5. Draw bars representing the contributions of each item.

6. Plot points for cumulative contributions at the end of each item. A simple way to do this is to draw the bars for the second and each subsequent item at their normal place on the X-axis as well as at a level where the previous bar ends. This bar at the higher level is drawn in dotted lines. Drawing the second bar is not normally recommended in the texts.

7. Connect the points. If additional bars as suggested in step 6 are drawn this becomes simple. All one needs to do is - connect the diagonals of the bars to the origin.

8. The chart is now ready for interpretation. The slope of the chart suddenly changes at some point. This point separates the 'vital few' from the 'useful many' like the A,B and C class items in materials management.

An example of a Pareto Chart is given in Annexure - 1

3   **Cause & Effect Diagram**

A Cause-and Effect Diagram is a tool that shows systematic relationship between a result or a symptom or an effect and its possible causes. It is an effective tool to systematically generate ideas about causes for

problems and to present these in a structured form. This tool was devised by Dr. Kouro Ishikawa and as mentioned earlier is also known as Ishikawa Diagram.

Structure

Another name for the tool, as we have seen earlier, is Fish-Bone Diagram due to the shape of the completed structure. If we continue the analogy, we can term various parts of the diagram as spine or the backbone, large bones, middle bones and small bones as seen in the structure of cause-and-effect diagram.

The symptom or result or effect for which one wants to find causes is put in the dark box on the right. The lighter boxes at the end of the large bones are main groups in which the ideas are classified. Usually four to six such groups are identified. In a typical manufacturing problem, the groups may consist of five Ms - Men, Machines, Materials, Method and Measurement. The six M Money may be added if it is relevant. In some cases Environment is one of the main groups. Important subgroups in each of these main groups are represented on the middle bones and these branch off further into subsidiary causes represented as small bones. The arrows indicate the direction of the path from the cause to the effect.

Cause-and Effect diagram is a tool that provides best results if used by a group or team. Each individual may have a few ideas for the causes and his thinking is restricted to those theories. More heads are needed to make a comprehensive list of the causes. Brainstorming technique is therefore very useful in identifying maximum number of causes.

Procedure

The steps in the procedure to prepare a cause-and-effect diagram are :

1. Agree on the definition of the 'Effect' for which causes are to be found. Place the effect in the dark box at the right. Draw the spine or the backbone as a dark line leading to the box for the effect.

2. Determine the main groups or categories of causes. Place them in boxes and connect them through large bones to the backbone.

3. Brainstorm to find possible causes and subsidiary causes under each of the main groups. Make sure that the route from the cause to the effect is correctly depicted. The path must start from a root cause and end in the effect.

4. After completing all the main groups, brainstorm for more causes that may have escaped earlier.

5. Once the diagram is complete, discuss relative importance of the causes. Short list the important root causes.

An example of a cause and effect diagram is given in Annexure - 2

4   Histogram

Histograms or Frequency Distribution Diagrams are bar charts showing the distribution pattern of observations grouped in convenient class intervals and arranged in order of magnitude. Histograms are useful in studying patterns of distribution and in drawing conclusions about the process based on the pattern.

The Procedure to prepare a Histogram consists of the following steps :

1. Collect data (preferably 50 or more observations of an item).

2. Arrange all values in an ascending order.

3. Divide the entire range of values into a convenient number of groups each representing an equal class interval. It is customary to have number of groups equal to or less than the square root of the number of observations. However one should not be too rigid about this. The reason for this cautionary note will be obvious when we see some examples.

4. Note the number of observations or frequency in each group.

5. Draw X-axis and Y-axis and decide appropriate scales for the groups on X-axis and the number of observations or the frequency on Y-axis.

6. Draw bars representing the frequency for each of the groups.

7. Provide a suitable title to the Histogram.

8. Study the pattern of distribution and draw conclusion.
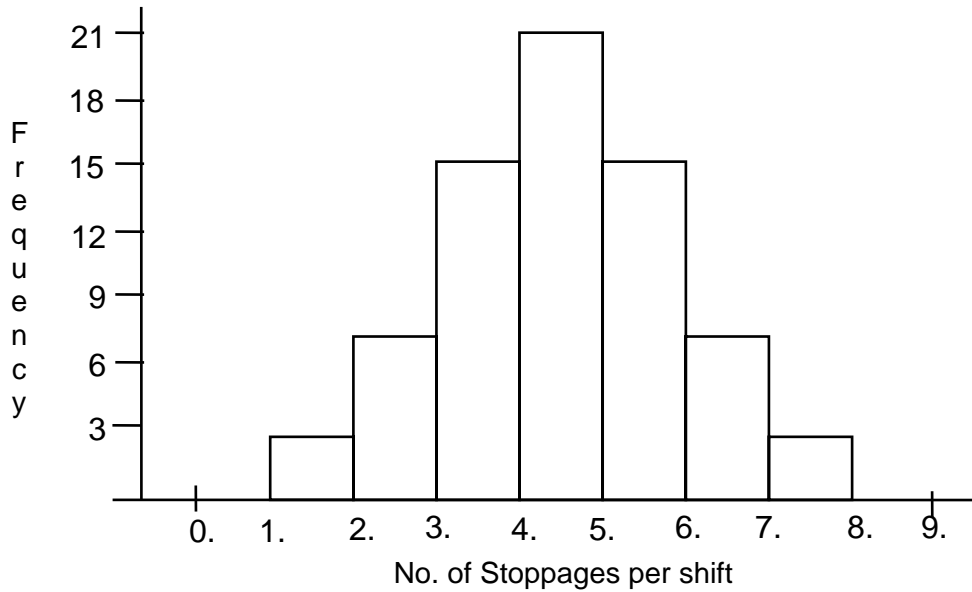
Stoppages due to Machines Problem

Diagram - 1

The Histogram is normal if the highest frequency is in the central group and there is symmetrical tapering on either side of the central group as in diagram 1. The natural or normal distribution would indicate that the process being studied is under control. Let us see a few instances of Histograms that are not normal and what conclusions one can drawn from them.

Diagram 2 shows two peaks with a little valley between them. Such a distribution is known as Bimodal Distribution. It indicates that the lot being examined is mixed. It may be due to pooling of production from two machines or two shifts, each having a different central value. When one encounters such a distribution, one should study the two lots separately if the identity of the two lots can be ascertained. For instance if one is examining the dimensions of containers and encounters bimodal distribution, the containers from the two moulds can be separated by the mould mark on them. Segregating the data from
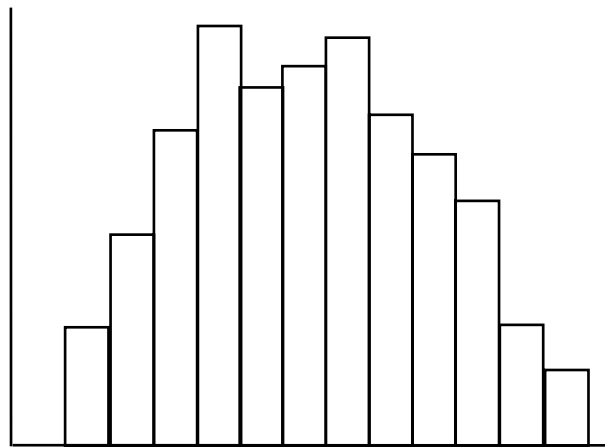
Bimodal Distribution
Diagram - 2
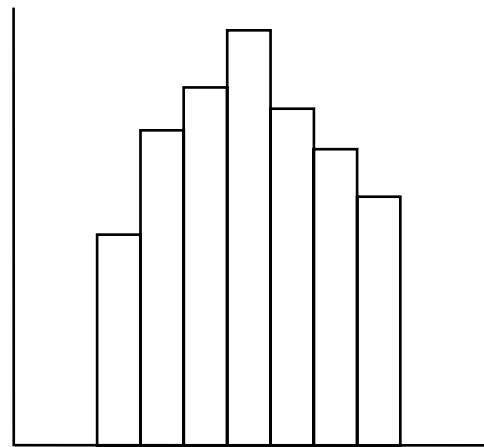
High Plateau
Diagram - 3

different lots is known as Stratification of data. We will see more about this soon. Each lot may then exhibit a normal distribution. In that case one only needs to find why the two lots are different and eliminate the cause. Diagram 3 shows a High Plateau that reminds one of Empire State building. One often encounters this type of distribution in incoming materials if the supplier has sorted out and removed items showing wide variation. It can also occur in finished products if there is inspection and sorting at the end of the production line. Such a distribution indicates that the actual variation in the process is more than what is seen in the Histogram. The items with wider variation have been removed before sampling. Such a process generates waste, is uneconomical and needs to be improved to reduce the variation.

Cliff pattern seen in Diagram 5 may arise due to inspection and sorting out the items only at one end - those below a specific value, but not at the other end. It can also occur when the lower end is zero, and the variation on the higher end goes well beyond twice the value at the peak. Alternate peaks and vales as shown in Diagram 4 is an unnatural pattern that may arise even if the process is under control if the figures have been rounded off incorrectly or class intervals have been selected wrongly. Examine the process of rounding of figures in the data and regroup the data in correct classes and you may get a normal pattern.

A Histogram with an unnatural pattern may indicate that there is possibly something unusual with the process, but is not an evidence of a process being out of control. For instance a Histogram depicting the distribution of age of all citizens will not peak at the centre. It will start with a cliff tapering gradually till around the life expectancy then dropping a little faster and once again tapering into along tail. The distribution of ages of students in a school shows a high

plateau as there is a specific age at which children are admitted into a school and they would pass out of the school by a specific age. Still one needs to consider the reasons for every unnatural pattern and draw conclusions based on the pattern, one's knowledge about the process being studied and judgment based on common sense.
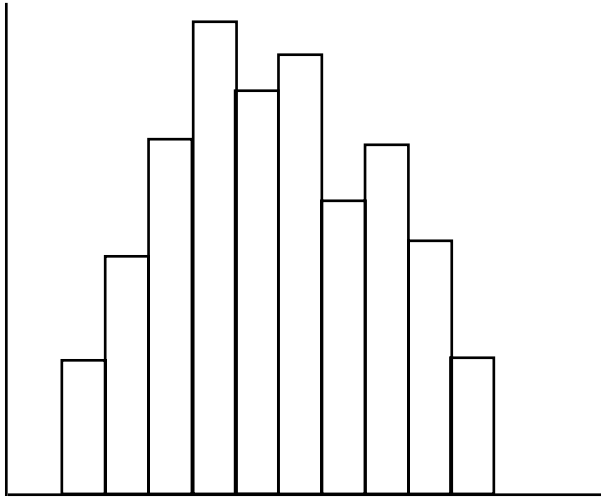
Alternate Peaks and Vales

Diagram - 4
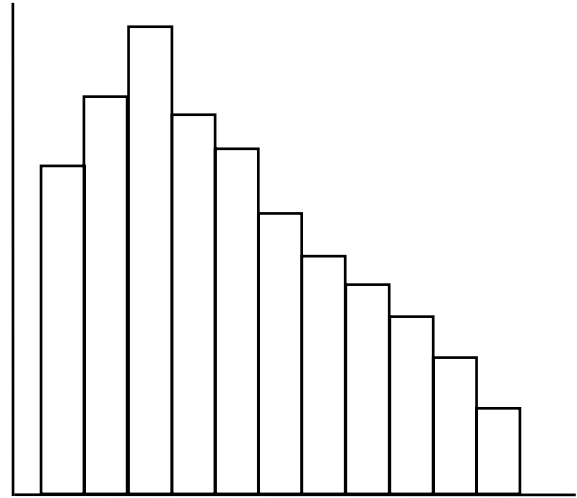
Cliff Pattern

Diagram - 5

5   Control Charts

Variability is inherent in all manufacturing processes. These variations may be due to two causes ;

i.   Random / Chance causes (un-preventable).

ii. Assignable causes (preventable).

Control charts was developed by Dr. Walter A. Shewhart during 1920's while he was with Bell Telephone Laboratories.

These charts separate out assignable causes.

Control chart makes possible the diagnosis and correction of many production troubles and brings substantial improvements in the quality of the products and reduction of spoilage and rework.

It tells us when to leave a process alone as well as when to take action to correct trouble.

BASIC CONCEPTS :

a. *Data is of two types :*

Variable - measured and expressed quantitatively
Attribute - quanlitative

b. Mean and Range :

$\overline{X}$ - Mean is the average of a sub-group
R - Range is the difference between the minimum and maximum in a sub-group

c. Control Charts for Variables

Charts depleting the variations in $\overline{X}$ and R with time are known as $\overline{X}$ and R charts. $\overline{X}$ and R charts are used for variable data when the sample size of the subgroup is 2-5. When the subgroup size is larger, s Charts are used instead of R charts where s is the standard deviation of the subgroup.

d. Control Charts for Attributes

The control charts for attributes are p-chart, np-chart, c-chart and u-chart. Control charts for defectives are p and np charts. P charts are used when the sample size is constant and np charts are used when the sample size is variable. In the case where the number of defects is the data available for plotting, c and u charts are used. If the sample size is constant, c charts are used and u charts are used for variable sample sizes.

6   Scatter Diagram

When solving a problem or analysing a situation one needs to know the relationship between two variables. A relationship may or may not exist between two variables. If a relationship exists, it may be positive or negative, it may be strong or weak and may be simple or complex. A tool to study the relationship between two variables is known as Scatter Diagram. It consists of plotting a series of points representing several observations on a graph in which one variable is on X-axis and the other variable in on Y-axis. If more than one set of values are identical, requiring more points at the same spot, a small circle is drawn around the original dot to indicate second point with the same values. The way the points lie scattered in the quadrant gives a good indication of the relationship between the two variables. Let us see some common patterns seen in Scatter Diagrams and the conclusions one can draw based on these patterns. Diagrams 6 to 11 show some of the more common patterns.
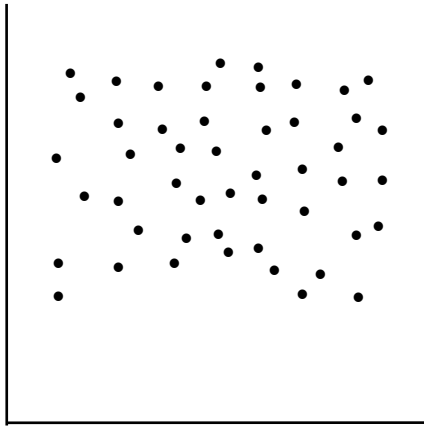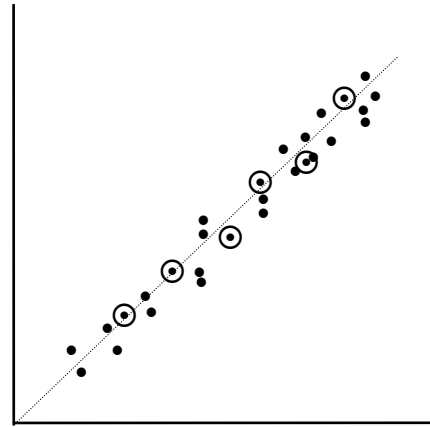
Diagram - 6

Diagram - 7

Diagram 6 shows a random distribution of points all over the quadrant. Such a distribution or scatter indicates a lack of relationship between the two variables being studied. In Diagram 7, the points appear scattered closely along a line (shown as a dotted line in the diagram) travelling from the Southwest to the Northeast direction indicating that if the variable on X-axis increases, the variable on Y-axis also increases. This is a positive relationship. As the points are very closely scattered around the straight line, the relationship is said to be strong. Diagram 8, in which the points are scattered closely around a line sloping in Northwest to Southeast direction, indicates a strong negative relationship. A negative relationship means that the variable on Y-axis goes down as the variable on X-axis goes up. Diagrams 9 and 10 shows a scatter of points loosely spread around lines in directions similar to Diagrams 10 and 8 respectively. Hence scatter in Diagram 9 indicates a weak positive relationship and that in Diagram 10 indicates a weak negative relationship. Weak relationship means that the variables are related but there are possibly other factors besides the variable on X-axis also affecting the variable on Y-axis. If other factors are kept constant in a controlled experiment and the data is again plotted, it would result in a scatter showing a strong relationship. Diagrams 7 to 10 showed a simple linear relationship between the two variables over the entire range. Very often the relationship is not that simple. The variable on Y-axis may increase up to a point as the variable on X-axis is increased but after that it may stay the same or even decrease. Diagram 11 shows one such complex scatter.
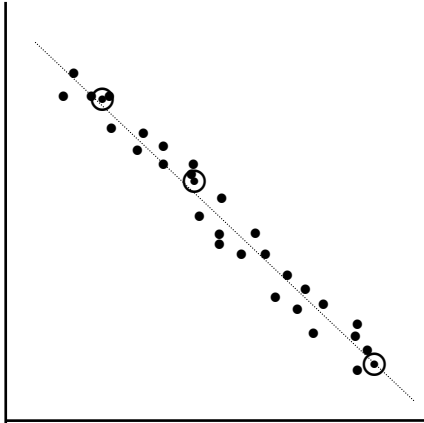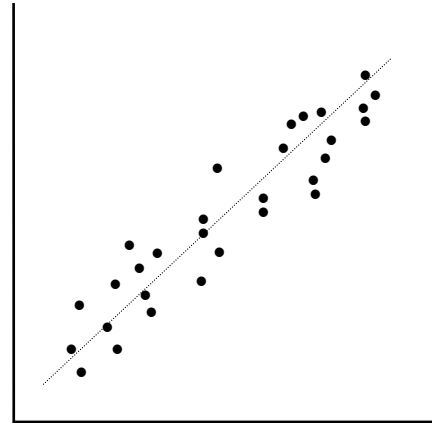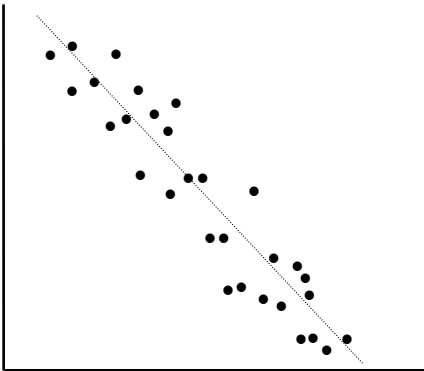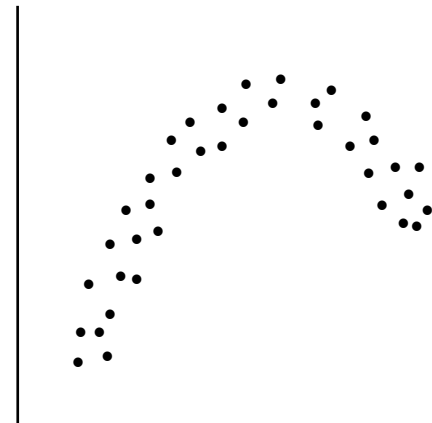
Diagram - 8

Diagram - 9

Diagram - 10

Diagram - 11

2.7 **Graphs**

Graphs of various types are used for pictoral representation of data. Pictoral representation enables the user or viewer to quickly grasp the meaning of the data. Different graphical representation of data are chosen depending on the purpose of the analysis and preference of the audience. The different types of graphs used are as given below :

S.No	Type of Graph	Purpose
1.	Bar Graph	To compare sizes of data
2.	Line Graph	To represent changes of data
3.	Gantt Chart	To plan and schedule
4.	Radar Chart	To represent changes in data (before and after)
5.	Band Graph	Same as above

6.	Pie Chart	Used to indicate comparative weights
7.	ISO Graph	To represent data using symbols

8   Check Sheets

8.1   As measurement and collection of data forms the basis for any analysis, this activity needs to be planned in such a way that the information collected is both relevant and comprehensive.

8.2   Check sheets are tools for collecting data. They are designed specific to the type of data to be collected. Check sheets aid in systematic collection of data. Some examples of check sheets are daily maintenance check sheets, attendance records, production log books, etc.
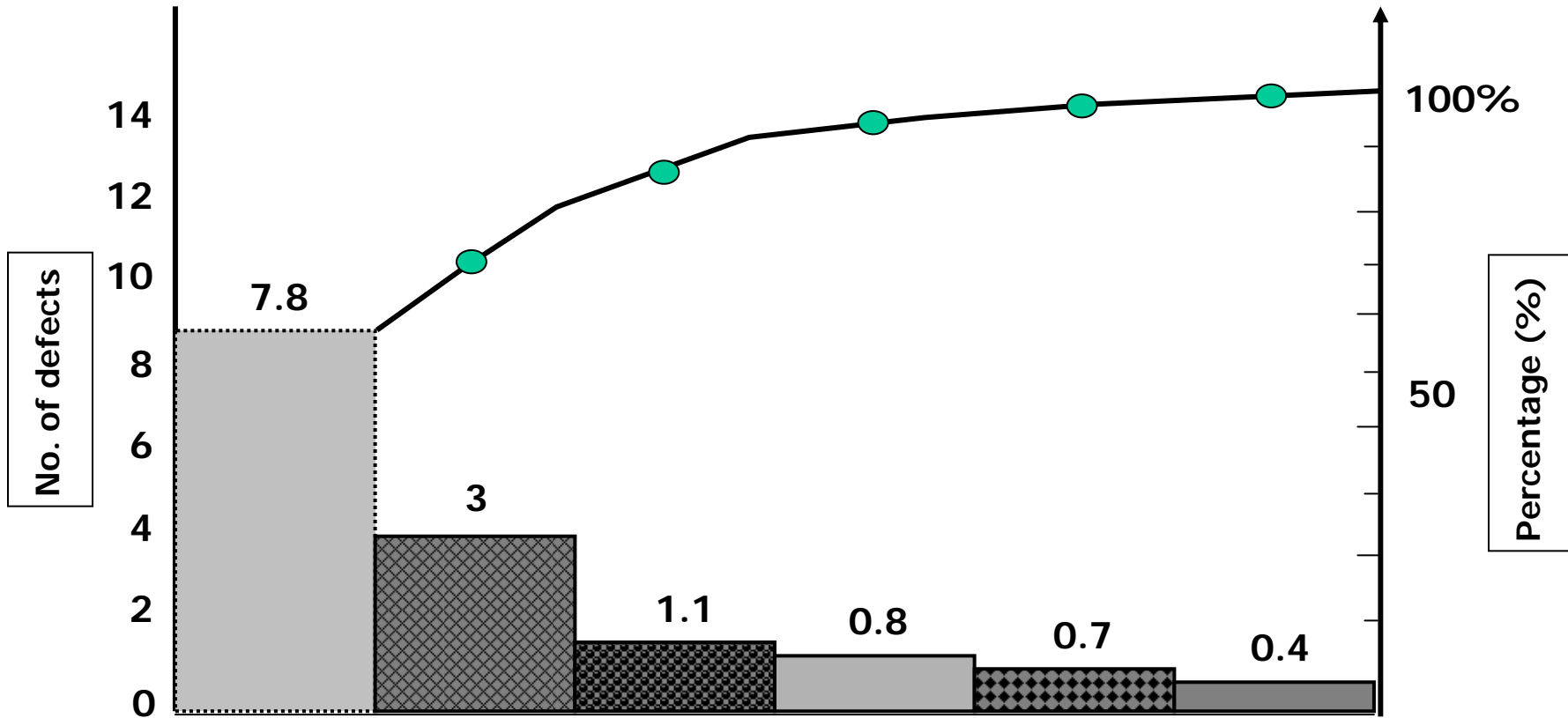
9.   Stratification

Data collected using check sheets needs to be meaningfully classified. Such classification helps gaining a preliminary understanding of relevance and dispersion of the data so that further analysis can be planned to obtain a meaningful output. Meaningful classification of data is called stratification.   Stratification may be by group, location, type, origin, symptom, etc.

Some Examples :
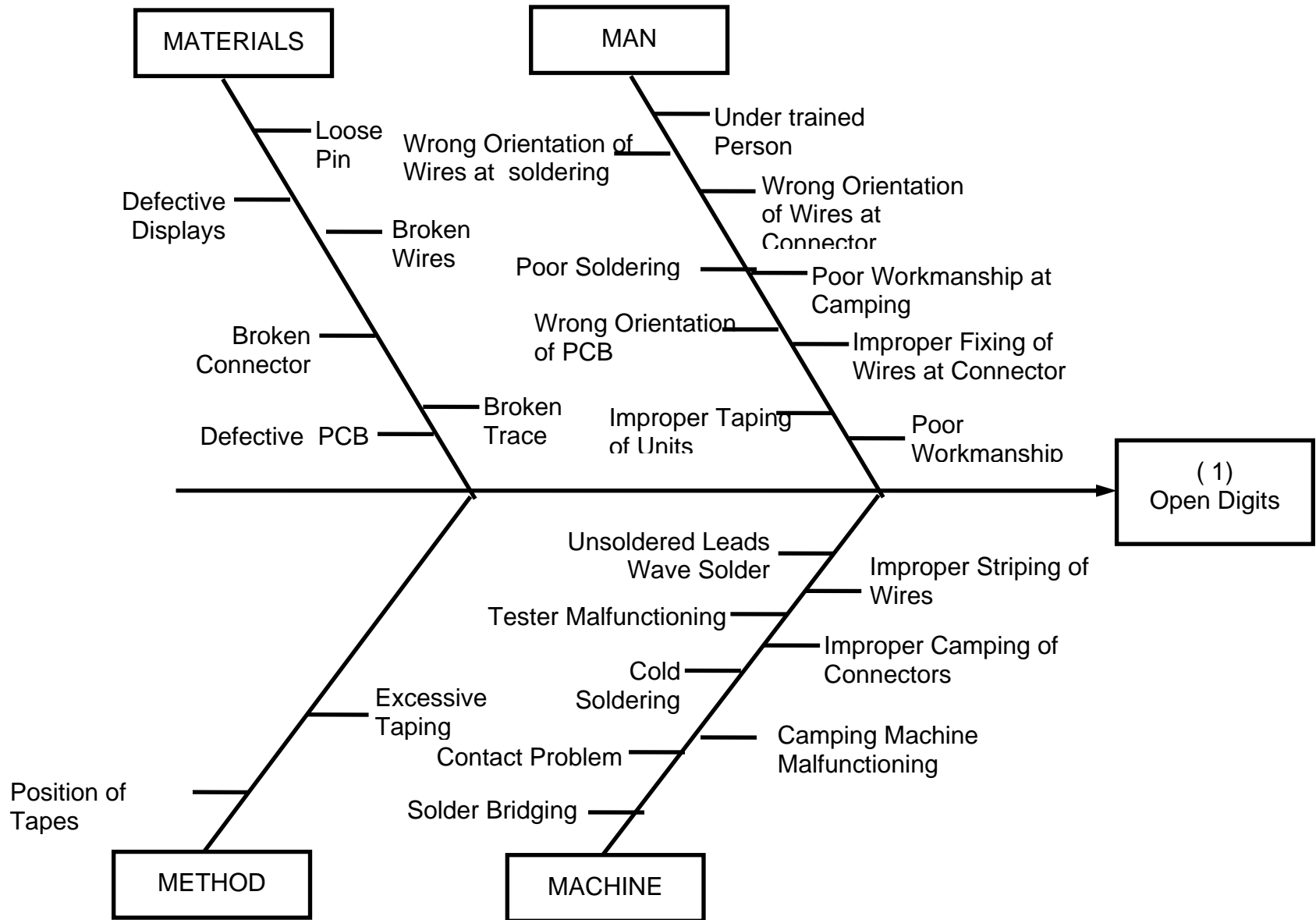
a) Data on rejected product may be classified either machine wise or operator wise or shift wise.

b) Data of production of food grains may be classified nation wise, state wise or district wise, etc.

c) Voting percentages may be classified party wise, state wise, community wise or gender wise, etc.

Pareto Diagram showing the break-down of Defects

Annexure - 1

MATERIALS

- Loose Pin
- Defective Displays
- Broken Wires
- Broken Connector
- Defective PCB
- Broken Trace

MAN

- Under trained Person
- Wrong Orientation of Wires at soldering
- Wrong Orientation of Wires at Connector
- Poor Soldering
- Poor Workmanship at Camping
- Wrong Orientation of PCB
- Improper Fixing of Wires at Connector
- Improper Taping of Units
- Poor Workmanship

(1) Open Digits

METHOD

- Excessive Taping
- Position of Tapes

MACHINE

- Unsoldered Leads Wave Solder
- Improper Striping of Wires
- Tester Malfunctioning
- Improper Camping of Connectors
- Cold Soldering
- Contact Problem
- Camping Machine Malfunctioning
- Solder Bridging

Annexure - 2