Tools used in Six Sigma

Contents

- SIPOC diagram,
- Root Cause Analysis,
- Frequency distribution and Histogram,
- Run charts,
- Stem-and-leaf plots,
- Pareto diagrams,
- Cause and Effect Diagrams,
- Box Plots,
- Normal probability plots.

SIPOC diagram

- A **SIPOC analysis** is a simple tool for identifying the **S**uppliers and their **I**nputs into a process, the high-level steps of a **P**rocess, the **O**utputs of the process, and the **C**ustomer (market) segments interested in the outputs.
- Team members identify relevant suppliers by asking the following questions:

  Where does information and material come from?

  Who are the suppliers?
- Team members identify relevant inputs by asking the following questions:

  What do your suppliers provide?

  What effect do the inputs or supplies (*X*s) have on the process?

  What effect do the inputs or supplies (*X*s) have on the CTQs?
- Team members identify relevant outputs by asking the following questions:

  What products or services does this process make?

  What are the CTQs that are critical to the customer's perception of quality?
- Team members identify the customer (market) segments for the outputs by asking the following questions:

  Who are the customers or market segments of these outputs?

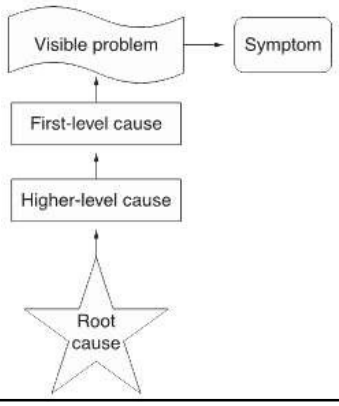
  Have you identified the CTQs for each market segment?

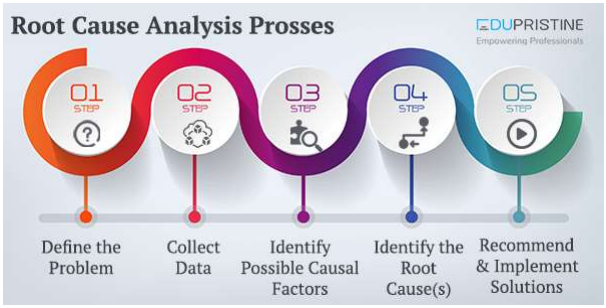
SIPOC Analysis for the Dormitory Project

Suppliers	Inputs (*X*s)	Process (*X*s)	Outputs (CTQs)	Customers (Market Segments)
Architects	Drawing and blueprints	Flowchart of the processes for building new on-campus housing (not shown here)	Dormitory building	Executives in residence
Coral Gables	Permits		Dormitory rooms	M.B.A. students
Contractors	Construction		Public areas	Undergrad business students
Sub-Contractors	Construction		Entertainment areas	Dean of the School of Business
Vendors	Materials and supplies			Campus police for security and safety
				Facilities administration for maintenance, power, water, gas, etc.
				Facilities administration for grounds

Root Cause Analysis (RCA)

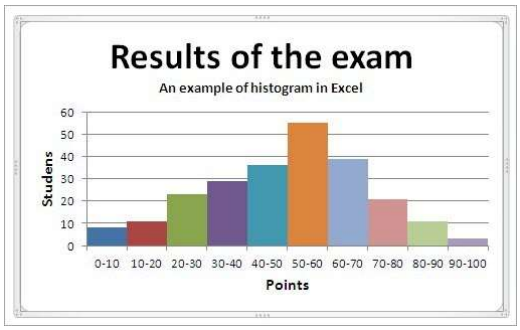
- A root cause is defined as a factor that caused a nonconformance and should be permanently eliminated through process improvement.
- RCA is defined as a collective term that describes a wide range of approaches, tools, and techniques used to uncover causes of problems.





Frequency distribution and Histogram

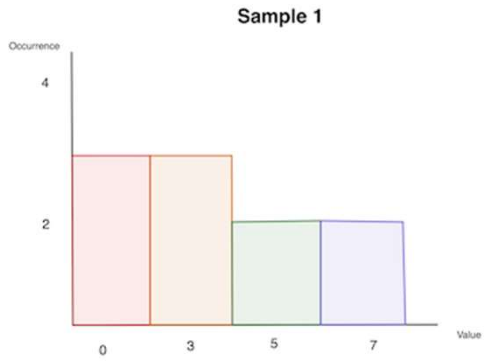
- A histogram is a graphical representation in a bar chart that shows pattern falls within different conditions. It is a distribution of numerical data and it provides necessary information about shape and dispersion or spread of a set of sample data.
- In order to construct Histogram, it is necessary to divide the range of values into specific intervals such as an interval of 5, 10, 15 etc.
- The size of each interval is equal and these intervals are not overlapping with each other.
- Horizontal X-axis represents “points” obtained by the students in a class and Y-axis represents the “number of students”. The points or marks received by the students are divided into an equal interval of 10 points and are obtained at a total of 10 intervals on the graph.
- The histogram is created based on the marks of each student that fall within different intervals as shown in the graph.



Frequency distribution and Histogram

- Sample 1 = [0,3,0,5,7,3,0,7,3,5]

Value	Frequency
0	3
3	3
5	2
7	2

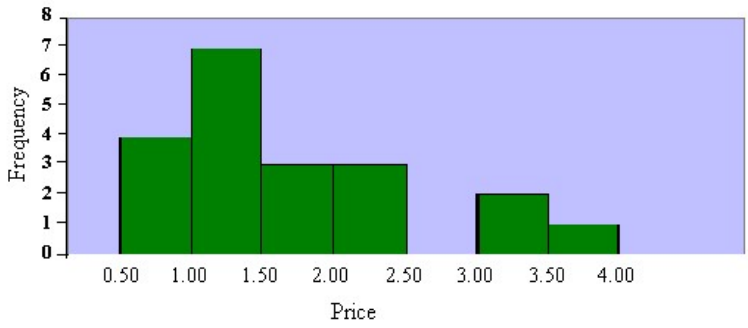


Frequency distribution and Histogram

- Sample 2 =

1.45	2.20	0.75	1.23	1.25
1.25	3.09	1.99	2.00	0.78
1.32	2.25	3.15	3.85	0.52
0.99	1.38	1.75	1.22	1.75

0.50 - 0.99	4
1.00 - 1.49	7
1.50 - 1.99	3
2.00 - 2.49	3
2.50 - 2.99	
3.00 - 3.49	2
3.50 - 3.99	1
Total	20

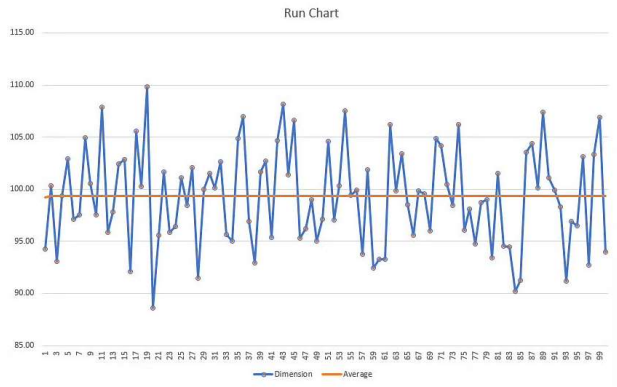


Run charts

A run chart is a type of chart that displays the measurement of a series over time. Run charts are often used to monitor the performance of a process, with the focus on process improvement.

Useful for

- finding the trend in the data
- identifying seasonal variations
- monitoring changes in behaviour over time
- detecting outliers



Stem-and-leaf plots

- A **stem-and-leaf diagram** is a good way to obtain an informative visual display of a data

4.6	4.0	3.7	4.1	4.1	5.6	4.5	6.0	6.0	3.4
3.4	4.6	3.7	4.2	4.6	4.7	4.1	3.7	3.4	3.3
3.7	4.1	4.5	4.6	4.4	4.8	4.3	4.4	5.1	3.9

3	7 4 4 7 7 4 3 7 9
4	6 0 1 5 6 2 6 7 1 1 5 6 4 8 3 4
5	6 1
6	0 0

Example

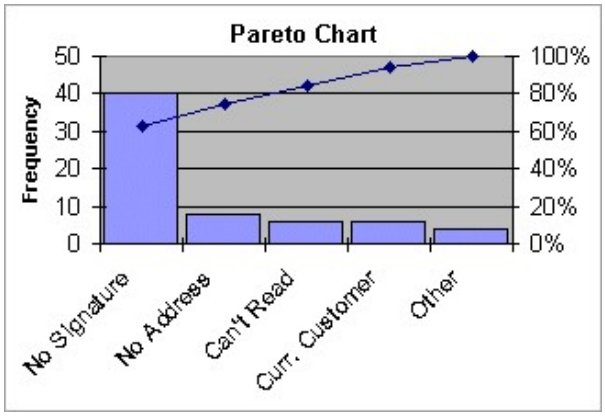
Data
17
24
32
38
41
44
48
51
52
54
57
59
63
67
69
74
78
88
92

Stem	Leaf
1	7
2	4
3	2, 8
4	1, 4, 8
5	1, 2, 4, 7, 9
6	3, 7, 9
7	4, 8
8	8
9	2

Pareto diagram

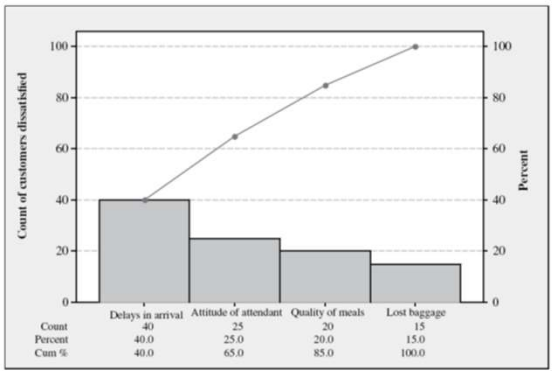
- A Pareto Chart is a Bar graph as well as a Line graph that graphically summarizes the group of data. The data may be related to cost, time, defects etc. Here, bars in a graph represent the values in descending order i.e. the longest bar at the left side and the shortest bar is on the right side and the cumulative total is represented by Lines.
- Vilfredo Pareto (1848-1923) Italian economist
  - 20% of the population has 80% of the wealth
- Juran used the term "vital few, trivial many". He noted that 20% of the quality problems caused 80% of the dollar loss
- The left vertical line or axis represents the frequency of occurrences; this occurrence may be related to cost, defects or any other unit of measure. The right vertical axis represents the cumulative percentage of the total number of occurrences.
- To construct a Pareto Chart, a different range of data is divided into groups and called a segment or categories. Consider the below sample Pareto Chart that is drawn for credit card application.

- Assume that the credit card application has been delayed and you want to investigate the process associated with it and identify the root cause of the delay.
- To draw the Pareto Chart, you need to categorize a group of data as shown below:
  - No signature
  - Address not updated.
  - Non-legible handwriting.
  - Already a registered customer.
  - Any other reason



- Pareto diagram of reasons for airline customer dissatisfaction.

Reasons	Count
Lost baggage	15
Delay in arrival	40
Quality of meals	20
Attitude of attendant	25



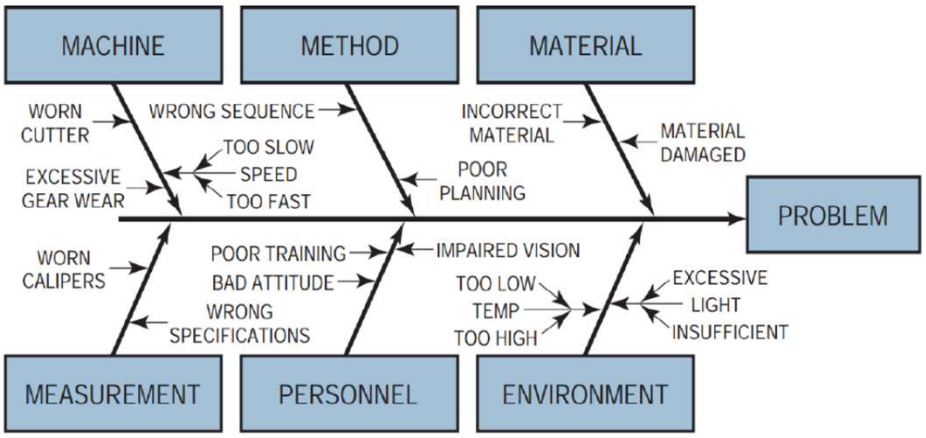
Cause and Effect Diagrams (Ishikawa Diagram)(Fish Bone Diagram)

- Cause-Effect is also known as Fish-bone diagram as the shape is somewhat similar to the side view of a fish skeleton. During problem-solving, everyone in the team has a different opinion about the root cause of the issue or problem.
- Fish-bone diagram captures all causes, ideas and uses brainstorming method to identify the strongest root cause. Cause-Effect diagram records causes of specific problems or issues related to the processor system. You will get many different causes for a specific problem.
- To start with the fishbone, you need to state your problem as a question, that too in terms of "why". This will help in brainstorming as each question should have an answer. In the end, the entire team should agree on the problem statement and then place this question at the "head" of the fish-bone.

- Construct a Cause-and-Effect Diagram for

(1) Low performance of students in exam

(2) Low attendance in class



Cause and Effect Diagrams (Ishikawa Diagram)(Fish Bone Diagram)

- Cause-Effect is also known as Fish-bone diagram as the shape is somewhat similar to the side view of a fish skeleton. During problem-solving, everyone in the team has a different opinion about the root cause of the issue or problem.
- Fish-bone diagram captures all causes, ideas and uses brainstorming method to identify the strongest root cause. Cause-Effect diagram records causes of specific problems or issues related to the processor system. You will get many different causes for a specific problem.
- To start with the fishbone, you need to state your problem as a question, that too in terms of “why”. This will help in brainstorming as each question should have an answer. In the end, the entire team should agree on the problem statement and then place this question at the “head” of the fish-bone.

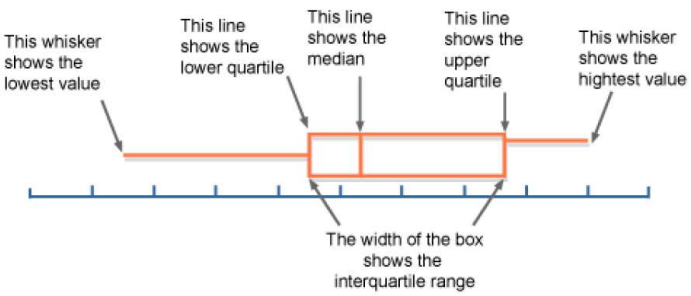
- Construct a Cause-and-Effect Diagram for

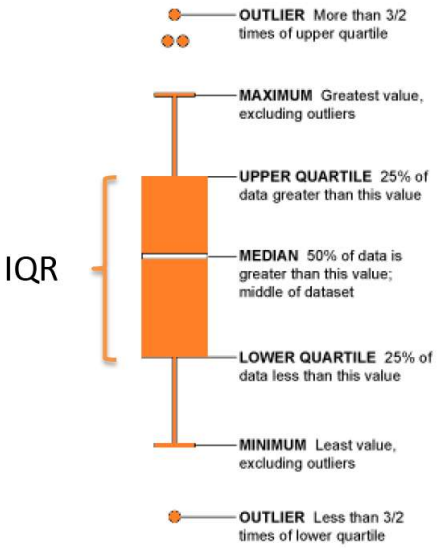
(1) Low performance of students in exam

(2) Low attendance in class

Box Plots

- A box and whisker plot is defined as a graphical method of displaying variation in a set of data.





- For the following ordered data construct a box plot. 3, 5, 5, 6, 6, 7, 8, 10, 11, 12, 12

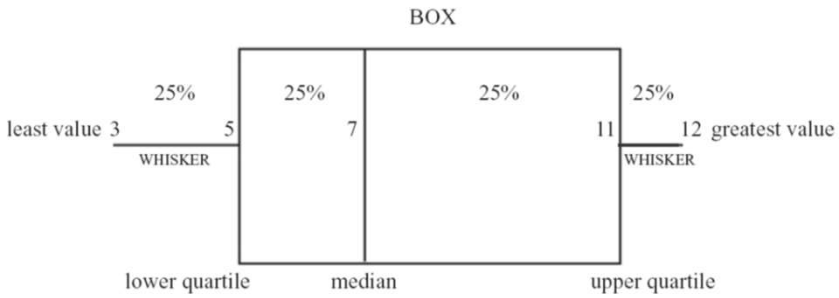
Solution

Q1 = 5

Q2 = 7

Q3 = 11

IQR = 6



- The "Whiskers" extend to the smallest and largest data point ≤ 1.5 (IQR) from Q1, Q3. Outliers are points lying between 1.5 × IQR and 3 × IQR from Q1, Q3. Extreme Outliers are points lying beyond 3 × IQR from Q1, Q3.

Exercise

For the following:

a) Find the median, lower quartile, upper quartile and the interquartile range.

b) Draw a box and whisker plot, identifying any outliers.

- Remember to order the data before you begin.

1) 32 30 36 27 24 33 34

2) 998 92 432 223 785 335 367 444 457 458 488

Answer

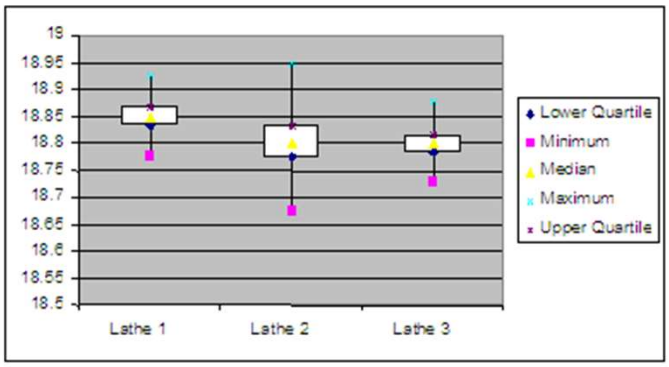
1) Q1 = 27, Q2 = 32, Q3 = 34 IQR = 7 No outliers.

2) Q1 = 335, Q2 = 444, Q3 = 488 IQR = 153 Outliers=785, 92, extreme outliers = 998

Box Plots

- Suppose you wanted to compare the performance of three lathes responsible for the rough turning of a motor shaft. The design specification is 18.85 +/- 0.1 mm.
- Diameter measurements from a sample of shafts taken from each roughing lathe are displayed in a box and whisker plot in Figure

1. Lathe 1 appears to be making good parts, and is centered in the tolerance.
2. Lathe 2 appears to have excess variation, and is making shafts below the minimum diameter.
3. Lathe 3 is performing with relatively less variation than Lathe 2; however, it is centered on the lower side of the specification and is making shafts below specification



Normal probability plots

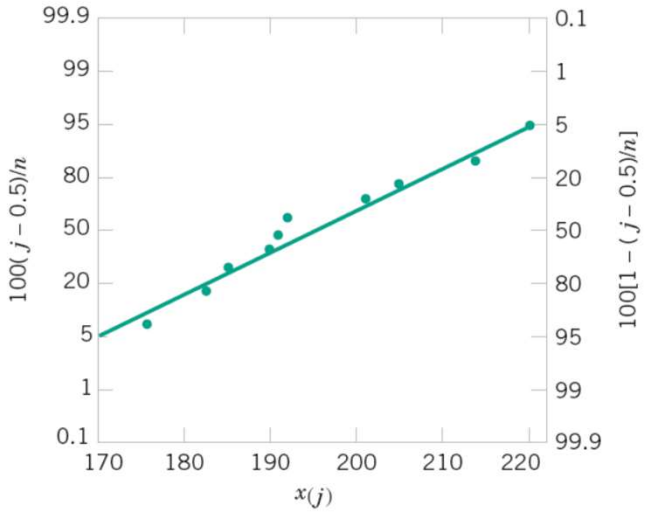
- How do we know whether a normal distribution is a reasonable model for data? **Probability plotting** is a graphical method for determining whether sample data conform to a hypothesized distribution based on a subjective visual examination of the data.
- Probability plotting typically uses special graph paper, known as **probability paper,** that has been designed for the hypothesized distribution.

- METHODOLOGY
  - To construct a Normal Probability plot, rank order the data from the smallest value to the largest value.
  - Assign probabilities to each value based on rank, the assumed distribution, and the number of samples.
  - Plot the value against its probability on Probability Plot
  - Draw a line of best fit through the center of data.

Normal probability plots (on normal paper)

- You are given 10 observations of a variable: 176, 191, 214, 220, 205, 192, 201, 190, 183, 185.. Construct a normal probability plot for this data.

j	$x_{(j)}$	$(j-0.5)/10$
1	176	0.05
2	183	0.15
3	185	0.25
4	190	0.35
5	191	0.45
6	192	0.55
7	201	0.65
8	205	0.75
9	214	0.85
10	220	0.95



Mean and standard deviation cane be obtained from the line which crosses μ and σ line.

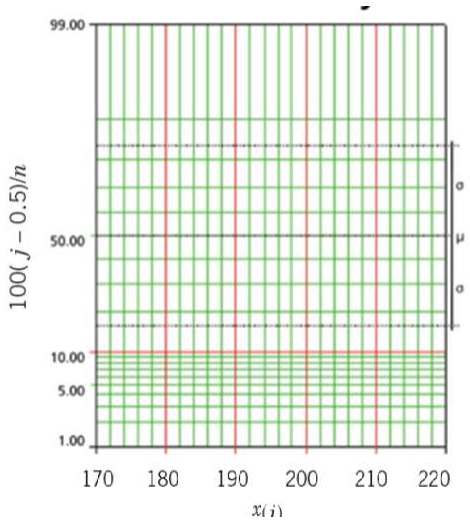
Obtaining Mean, μ and Standard Deviation, σ

- **How to obtain mean, μ?**

Drop a vertical line from the point of intersection of fitted line and the horizontal line at μ.

- **How to obtain standard deviation, σ?**

Drop a vertical line from the point of intersection of fitted line and the horizontal line at σ below the line at μ. Subtract this value from the mean obtained above.

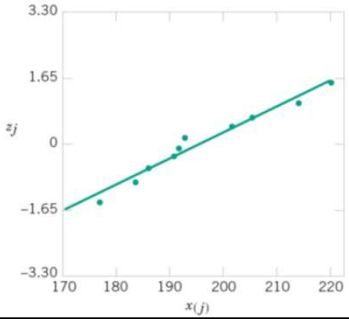


Normal probability plots (on regular graph paper)

- A normal probability plot can also be constructed on ordinary graph paper by plotting the standardized normal scores z_j against $\Phi(j)$, where the standardized normal scores satisfy

$$\frac{j-0.5}{n} = P(Z \le z_j) = \Phi(z_j)$$

- For example, if (j -0.5)/n 0.05, (z) = 0.05 implies that z_j =1.64.



j	$x_{(j)}$	$(j-0.5)/10$	z_j
1	176	0.05	−1.64
2	183	0.15	−1.04
3	185	0.25	−0.67
4	190	0.35	−0.39
5	191	0.45	−0.13
6	192	0.55	0.13
7	201	0.65	0.39
8	205	0.75	0.67
9	214	0.85	1.04
10	220	0.95	1.64

Obtaining Mean, μ and Standard Deviation, σ

- **How to obtain mean, μ?**

Drop a vertical line from the point of intersection of fitted line and the horizontal line at z=0.

- **How to obtain standard deviation, σ?**

Drop a vertical line from the point of intersection of fitted line and the horizontal line at z=1.

Subtract this value from the mean obtained above.