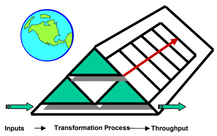


Managing Operations: A Focus on Excellence

Cox, Blackstone, and Schleier, 2003

Chapter 14

The Tools of Quality:

Exceeding Customer's Expectations

The Seven Tools of Quality

1. Control chart
2. Run chart
3. Pareto chart
4. Flow chart
5. Cause and effect diagram
6. Histogram
7. Scatter diagram

Statistical Process Control

- A method of inspection by which it can be determined whether a process is in control
- Differs from Acceptance Sampling in that SPC does not make judgements about the quality of the item processed.
- Key tool is the Control Chart of which several types exist.

SPC Defined

- All processes are affected by multiple factors and, therefore, SPC can be applied to any process.
- There is inherent variation in any process which can be measured and "controlled."
- SPC does not eliminate variation, but it does allow the user to track special cause variation.
- "SPC is a statistical method of separating variation resulting from special causes from natural variation and to establish and maintain consistency in the process, enabling process improvement." (Goetsch & Davis, 2003. p. 631)

Variation in Processes

- Common Cause variation - the variation which in inherent in the process itself; when sampled, a normal distribution is found; a process is said to be in statistical control when *only* common cause variation exists.
- Special (or Assignable) Cause variation - the variation in process output that might be traced to a specific cause; the process is said to be out of control when a special cause variation exists.

Rationale for SPC

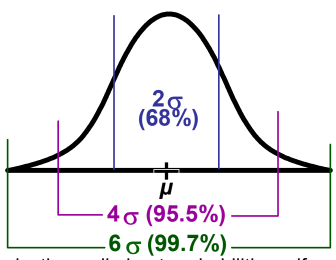
Control of Variation
Continuous Improvement
Predictability of Processes
Elimination of Waste
Product Inspection

Creating Control Charts

- All control charts rely on the periodic sampling and measurement of items.
- The data collected will allow the calculation of a centerline, and upper and lower control limits.
- The centerline is the mean of all samples, whereas the control limits are, conceptually, the mean +/- three standard deviations.

Interpreting Control Charts

SPC is based upon the Central Limit Theorem which tells us, in effect, that the samples will follow a normal distribution regardless of the shape of the parent distribution.

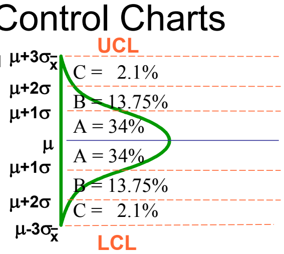


Interpreting control charts is, then, all about probabilities – if the observations aren't probable, then there must be a special cause variation.

Interpreting Control Charts

Special Cause Variation is assumed to exist if:

1. Any point falls outside the control limits.
2. Nine consecutive observations fall on one side of the mean.
3. Six consecutive observations are increasing (or decreasing.)
4. 14 observations alternate above and below the mean.
5. Two of three consecutive points fall in zone C in one-half of the chart.
6. Four of five consecutive points fall in zone B in one-half of the chart.



7. 15 consecutive observations in the A zones.
8. Eight consecutive points outside of the A zones.

Risks of SPC

- SPC has the same Type I and Type II risks as acceptance sampling
- If the process if in fact in control but we conclude that it is out of control, we have committed a Type I error.
- If the process if in fact out of control but we conclude that it is in control, we have committed a Type II error.

Common control charts for variables & attributes

Data Category	Chart Type	Statistical Qty
Variables data	X-bar & R	Mean & Range
	X-tilde & R	Median & Range
	X-Rs	Individual values
Attributes data	P-chart	Percent defective
	Np-chart	Number of defectives
	C-chart	Number of defects
	U-chart	Number of defects per unit (area, time, length, etc.)

What SPC does not do

- SPC only determines whether a process is in statistical control **NOT** whether the process is producing within specifications nor whether the process is even capable of producing within specifications.
- We must rely on another measure AFTER we have assured that the process is in control using SPC.

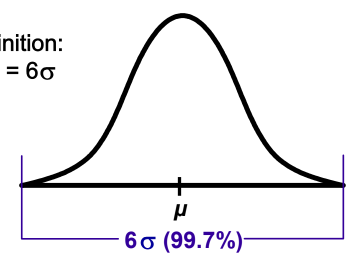
Process Capability

- Process capability is the ability of the process, as it currently exists, to product within specifications.
- One measure known as C_p compares the natural variation of the process to the specification width.
- Another, more precise, measure known as C_{pk} compares the natural variation of the process to the specification width and target.

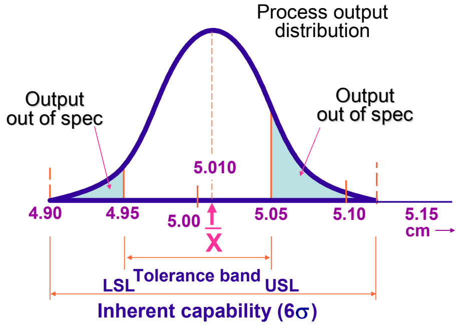
Process Capability

Process Capability (PC) is the range in which "all" output can be produced – the inherent capability of the process.

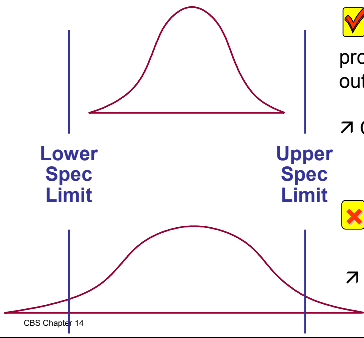
Definition:
PC = 6σ



Process Capability and Process Specifications



Process Capability and Process Specifications



This process is CAPABLE of producing all good output.

↗ Control the process.

This process is NOT CAPABLE.

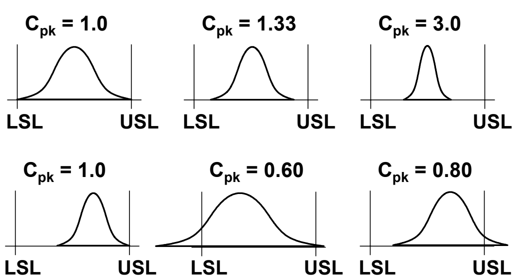
↗ INSPECT - Sort out the defectives

Process Capability Index

Index C_{pk} compares the spread and location of the process, relative to the specifications.

$$C_{pk} = \text{the smaller of: } \begin{cases} \dfrac{\text{Upper Spec Limit} - \bar{\bar{X}}}{3\sigma} \\ \text{OR} \\ \dfrac{\bar{\bar{X}} - \text{Lower Spec Limit}}{3\sigma} \end{cases}$$

C_{pk} Values



Run Charts

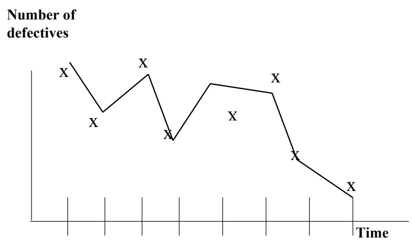


Figure 14.13. Run chart

Pareto Chart

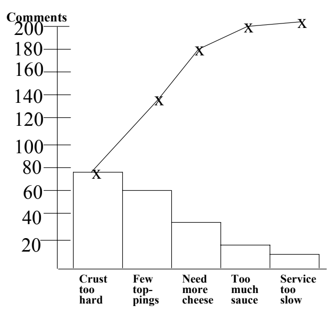


Figure 14.14. Pareto Analysis of problems at a pizza parlor

Flow Chart

Element	Time (distance)	Brief Description
O	5 min.	Sale is made. Items sold are entered into POS terminal.
D	4 hours	Average delay until the end of the day.
O	1 min.	Inventory records are updated for sales and receipts by computer.
D	14 hours	Delay until order review.
O	20 min.	Manager builds an order to maximize discount/minimize freight costs by ordering reorder items and other items required to reach discount.
→	3 days	Mail order to vendor.
O	3 days	Vendor processes order.
→	3 days	Vendor ships order.
□	5 min.	Inspect shipment for damage.
→	5 min.	Move shipment to stock room.
D	2 days	Temporarily placed in stock room until time is available to stock shelf.
→	2 min.	Move coffees to proper shelves.
O	30 minutes	Coffees/teas placed in correct display containers.
Δ	15 days	Wait until time to pay invoice.
	5 min.	Pay invoice.

Summary of Work Elements

Element		Number	Time/distance		Percentage
O	6	3 days		61 min.	11
D	3	2 days	18 hrs.		11
→	4	6 days		7 min.	22
Δ	1	15 days			56
□	1			5 min.	0

Figure 11.7. Process flow chart—current method of inventory replenishment

Cause and Effect Diagram

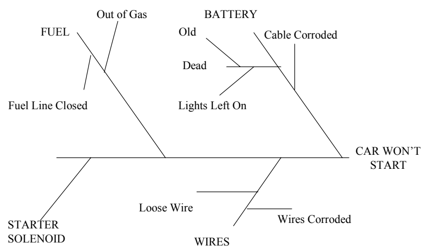


Figure 14.15. Ishikawa (cause and effect) diagram for "car won't start"

Histogram

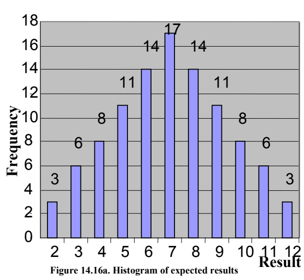


Figure 14.16a. Histogram of expected results

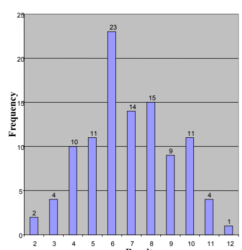


Figure 14.16b. Histogram of actual results

Possible Histogram Shapes

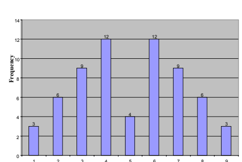


Figure 14.18. Bimodal histogram

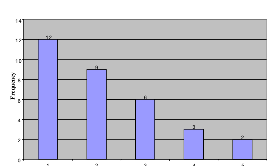


Figure 14.19. Cliff-like histogram

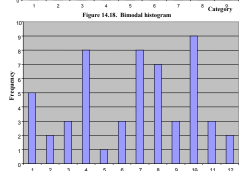


Figure 14.20. Saw-toothed histogram

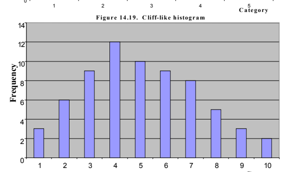


Figure 14.21. Skewed histogram

Scatter Diagram

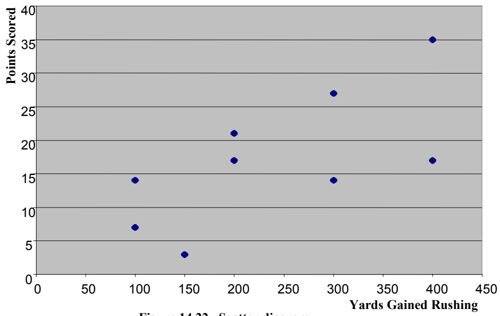


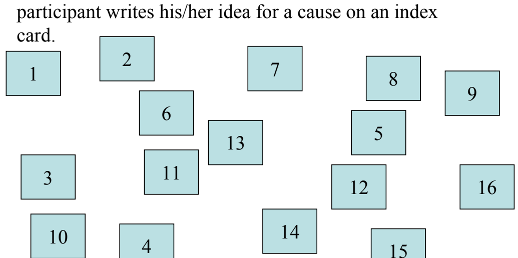
Figure 14.22. Scatter diagram

The Seven "New" Tools

1. Affinity diagram
2. Relational diagram
3. Tree diagram
4. Matrix diagram
5. Program decision process chart
6. Arrow diagram
7. Matrix data analysis

Affinity Diagram

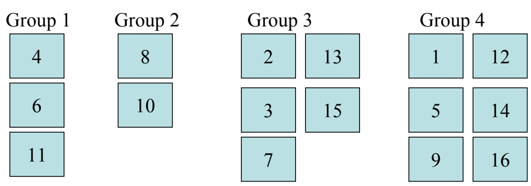
A method to "get your arms around" a complex problem. Similar to a brainstorming session wherein each participant writes his/her idea for a cause on an index card.



Affinity Diagram

A method to “get your arms around” a complex problem. Similar to a brainstorming session wherein each participant writes his/her idea for a cause on an index card.

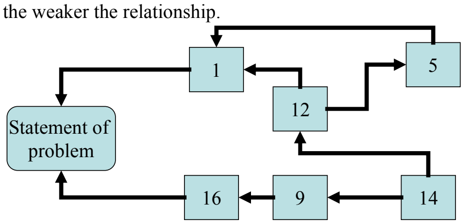
The possible causes are then arranged into groups of similar causes. The groups might be functional areas.



Relational Diagram

Used to logically examine the interrelationships among the causes within a particular grouping.

The problem is written to the left and the causes are placed according to their relationship to the problem -- the further away the weaker the relationship.



Relationship Diagram Example

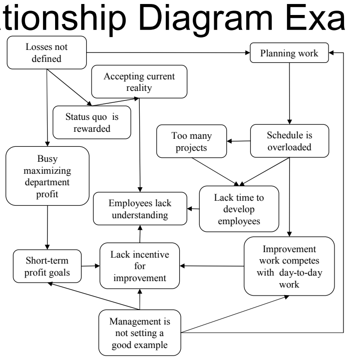
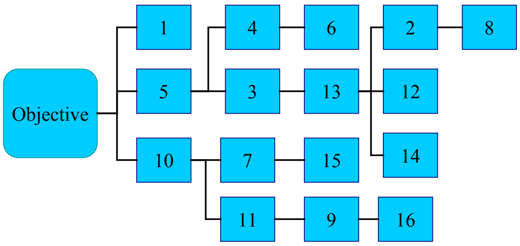


Figure 14.23. Relational diagram

Tree Diagram

Used to identify and sequence the tasks necessary to accomplish an objective (the opposite of the problem) using the affinity diagram and the relationship diagram as a reference.



Tree Diagram Example

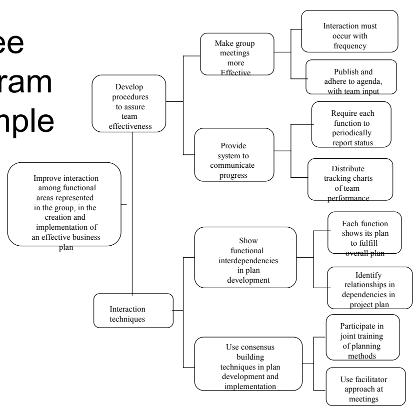


Figure 14.24. Example tree diagram

Matrix Diagram

A\B	B1	B2	B3	B4	B5
A1					
A2					
A3					
A4					
A5					

L-shaped

C5					
C4					
C3					
C2					
C1					
	B1	B2	B3	B4	B5
A1					
A2					
A3					
A4					
A5					

T-shaped

					C5					
					C4					
					C3					
					C2					
					C1					
D5	D4	D3	D2	D1		B1	B2	B3	B4	B5
					A1					
					A2					
					A3					
					A4					
					A5					

X-shaped

Matrix Diagram Example

TASK	Dept 1	Dept 2	Dept 3
1	1	2	
5		1	
10	3	1	2
3	2	3	1
4			1
6		1	2
13	1	3	2
2	2		1
8		2	1
12	1		2
14			1
7	3	2	1
11	3	1	2
9		2	1
16		1	2
15		1	2

The matrix L-diagram is often used to identify and assign responsibility for tasks identified in the tree diagram.

1 = primary

2 = secondary

3 = tertiary

Program Decision Process Chart

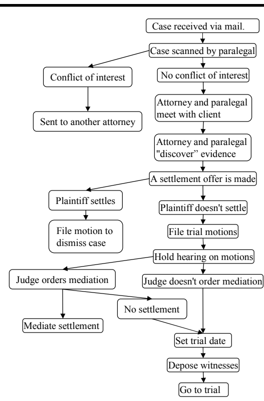


Figure 14.27. Sample program decision process chart

Arrow Diagram

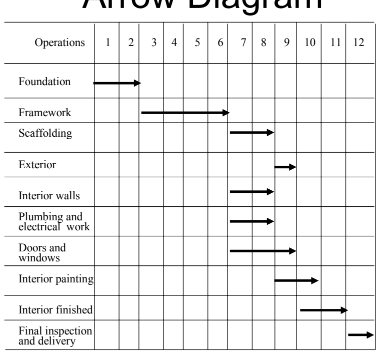


Figure 14.28a. Gantt chart to plan the construction of a house

Arrow Diagram

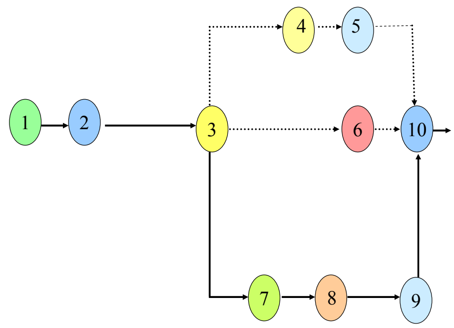


Figure 14.28b. Arrow diagram for construction of a house

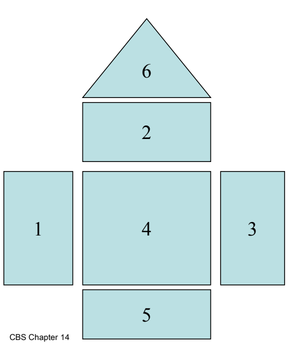
What is QFD?

A specialized method for making customers part of the product development cycle.

It translates customer wants into what the organization produces enabling the organization to:

- Prioritize customer needs;
- Find innovative responses to those needs; and,
- Improve processes to maximize effectiveness.

Structure of QFD



1 Customer Input

2 Manufacturer's Current Requirements/Specifications to Suppliers

3 Planning Matrix
importance rating
competition rating
target values
scale-up needed
sales points

4 Relationships

5 Prioritized list of manufacturer's critical process requirements

6 Process requirement trade-offs

QFD Example

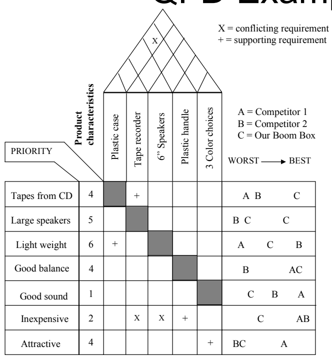
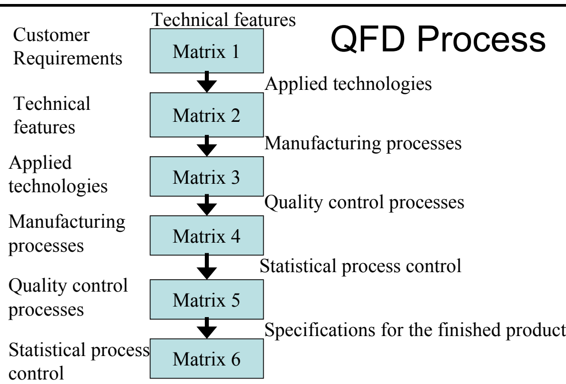
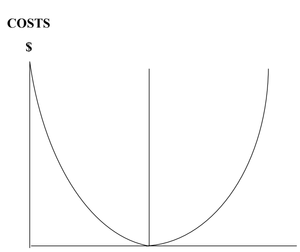


Figure 14.29. House of quality for a boom box

QFD Process



Taguchi Loss Function



$L = k(T-x)^2$ where:

L = loss

k = a constant (typically a measure of intolerance of deviation)

T = target

x = observed value

Figure 14.30. The Taguchi loss function

Business System Model

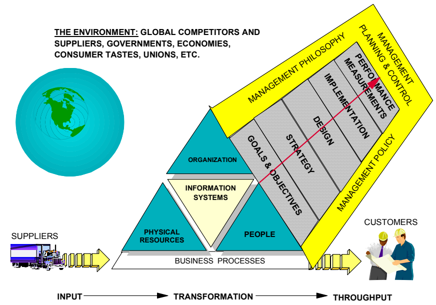


FIGURE 1.6g. BUSINESS SYSTEM MODEL