



The Tool Guide

(Manual de Herramientas)

CONTENIDO

1. PROJECT PLANNING TOOLS	5
1.1. Gantt Chart	5
1.1.1. Description	5
1.1.2. When to Use Gantt Charts	5
1.1.3. Gantt Chart Basic Procedure	5
1.1.4. Gantt Chart Example.....	6
1.1.5. Gantt Chart Considerations.....	7
1.2. Plan–Do–Check–Act Cycle.....	7
1.2.1. Description	7
1.2.2. When to Use Plan-Do-Check-Act.....	7
1.2.3. Plan-Do-Check-Act Procedure.....	7
1.2.4. Plan-Do-Check-Act Example	8
2. DATA COLLECTION & ANALISYS TOOLS	10
2.1. Box and Whisker Plot.....	10
2.1.1. Description	10
2.1.2. Why Use a Box and Whisker Plot?	10
2.1.3. When to Use a Box and Whisker Plot	10
2.1.4. Box and Whisker Plot Procedure	11
2.1.5. Box and Whisker Plot Example	12
2.2. Check Sheet	13
2.2.1. Description	13
2.2.2. When to Use a Check Sheet.....	13
2.2.3. Check Sheet Procedure	13
2.2.4. Check Sheet Example.....	13
2.3. Control Chart.....	13
2.3.1. Description	14
2.3.2. When to Use a Control Chart	14
2.3.3. Control Chart Basic Procedure.....	14
2.4. Design of Experiments.....	15
2.5. Histogram.....	16
2.5.1. Description	16
2.5.2. When to Use a Histogram	16
2.5.3. Histogram Construction.....	16
2.5.4. Histogram Analysis	16
2.6. Scatter Diagram	16
2.6.1. Description	17
2.6.2. When to Use a Scatter Diagram.....	17

2.6.3.	Scatter Diagram Procedure.....	17
2.6.4.	Scatter Diagram Example	18
2.6.5.	Scatter Diagram Considerations	19
2.7.	Stratification	19
2.7.1.	Description	19
2.7.2.	When to Use Stratification.....	20
2.7.3.	Stratification Procedure	20
2.7.4.	Stratification Example.....	20
2.7.5.	Stratification Considerations.....	21
2.8.	Survey	21
2.8.1.	Description	21
2.8.2.	When to Use a Survey	21
2.8.3.	Survey Basic Procedure.....	21
2.8.4.	Survey Considerations	22
3.	PROCESS ANALISYS TOOLS	23
3.1.	Flowchart	23
3.1.1.	Description	23
3.1.2.	When to Use a Flowchart.....	23
3.1.3.	Flowchart Basic Procedure	23
3.1.4.	Flowchart Considerations.....	24
3.1.5.	Flowchart Examples.....	25
3.1.6.	Commonly Used Symbols in Detailed Flowcharts.....	26
3.2.	Failure Modes and Effects Analysis (FMEA)	26
3.2.1.	Description	26
3.2.2.	When to Use FMEA	27
3.2.3.	FMEA Procedure	27
3.2.4.	FMEA Example	28
3.3.	Mistake Proofing	29
3.3.1.	Description	29
3.3.2.	When to Use Mistake Proofing.....	29
3.3.3.	Mistake-Proofing Procedure.....	29
3.3.4.	Mistake-Proofing Example	30
4.	CAUSE ANALISYS TOOLS	33
4.1.	Fishbone Diagram.....	33
4.1.1.	Description	33
4.1.2.	When to Use a Fishbone Diagram	33
4.1.3.	Fishbone Diagram Procedure	33
4.1.4.	Fishbone Diagram Example.....	34
4.2.	Pareto Chart.....	34
4.2.1.	Description	34
4.2.2.	When to Use a Pareto Chart	34

4.2.3.	Pareto Chart Procedure	34
4.2.4.	Pareto Chart Examples	35
4.3.	Scatter Diagram	36
4.3.1.	Description	36
4.3.2.	When to Use a Scatter Diagram.....	36
4.3.3.	Scatter Diagram Procedure.....	36
4.3.4.	Scatter Diagram Example	37
4.3.5.	Scatter Diagram Considerations	38
5.	IDEA CREATION TOOLS	39
5.1.	Affinity Diagram.....	39
5.1.1.	Description	39
5.1.2.	When to Use an Affinity Diagram	39
5.1.3.	Affinity Diagram Procedure	39
5.1.4.	Affinity Diagram Example	40
5.1.5.	Affinity Diagram Considerations	41
5.2.	Benchmarking	41
5.3.	Brainstorming	43
5.3.1.	Description	43
5.3.2.	When to Use Brainstorming	44
5.3.3.	Brainstorming Procedure	44
5.3.4.	Brainstorming Considerations	44
5.4.	Nominal Group Technique (NGT).....	44
5.4.1.	Description	44
5.4.2.	When to Use Nominal Group Technique.....	45
5.4.3.	Nominal Group Technique Procedure.....	45
5.4.4.	Nominal Group Technique Considerations	45
6.	EVALUATION & DECISION – MAKING TOOLS	46
6.1.	Decision Matrix	46
6.1.1.	Description	46
6.1.2.	When to Use a Decision Matrix	46
6.1.3.	Decision Matrix Procedure	46
6.1.4.	Decision Matrix Example.....	47
6.1.5.	Decision Matrix Considerations	48
6.2.	Multivoting.....	49
6.2.1.	Description	49
6.2.2.	When to Use Multivoting	49
6.2.3.	Multivoting Procedure	49
6.2.4.	Multivoting Example	50

1. PROJECT PLANNING TOOLS

These tools can help you manage an improvement project:

Gantt chart: a bar chart that shows the tasks of a project, when each must take place, how long each will take and completion status.

PDCA Cycle (plan-do-check-act) or PDSA (plan-do-study-act): a four-step model for carrying out change that can be repeated again and again for continuous improvement.

1.1. Gantt Chart

Also Called: milestones chart, project bar chart, activity chart.

1.1.1. *Description*

A Gantt chart is a bar chart that shows the tasks of a project, when each must take place and how long each will take. As the project progresses, bars are shaded to show which tasks have been completed. People assigned to each task also can be represented.

1.1.2. *When to Use Gantt Charts*

- When scheduling and monitoring tasks within a project.
- When communicating plans or status of a project.
- When the steps of the project or process, their sequence and their duration are known.
- When it's not necessary to show which tasks depend on completion of previous tasks.

1.1.3. *Gantt Chart Basic Procedure*

1.1.3.1. *Construction*

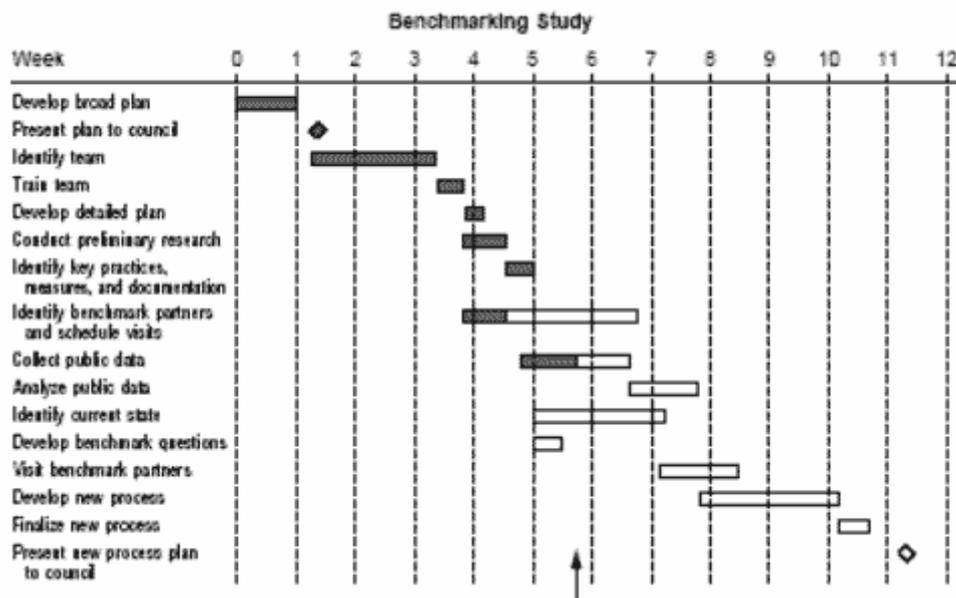
1. Identify tasks:
 - Identify the tasks needed to complete the project.
 - Identify key milestones in the project by brainstorming a list, or by drawing a flowchart, storyboard or arrow diagram for the project.
 - Identify the time required for each task.
 - Identify the sequence: Which tasks must be finished before a following task can begin, and which can happen simultaneously? Which tasks must be completed before each milestone?
2. Draw a horizontal time axis along the top or bottom of a page. Mark it off in an appropriate scale for the length of the tasks (days or weeks).
3. Down the left side of the page, write each task and milestone of the project in order. For events that happen at a point in time (such as a presentation), draw a diamond under the time the event must happen. For activities that occur over a period of time (such as developing a plan or holding a series of interviews), draw a bar that spans the appropriate times on the timeline: Align the left end of the bar with the time the activity begins, and align the right end with the time the activity concludes. Draw just the outlines of the bars and diamonds; don't fill them in.
4. Check that every task of the project is on the chart.

1.1.3.2. Using the Chart

5. As events and activities take place, fill in the diamonds and bars to show completion. For tasks in progress, estimate how far along you are and fill in that much of the bar.
6. Place a vertical marker to show where you are on the timeline. If the chart is posted on the wall, for example, an easy way to show the current time is with a heavy dark string hung vertically across the chart with two thumbtacks.

1.1.4. Gantt Chart Example

The figure below shows a Gantt chart used to plan a benchmarking study. Twelve weeks are indicated on the timeline. There are two milestone events, presentations of plans for the project and for the new process developed in the study. The rest of the tasks are activities that stretch over periods of time.



Gantt Chart Example

The chart shows the status at Thursday of the sixth week. The team has finished seven tasks through identifying key practices, measures and documentation.

This is a hectic time on the project, with three time-consuming activities that must happen simultaneously:

- The team estimates it is one-fourth finished with identifying benchmark partners and scheduling visits; one-fourth of that bar is filled.
- Team members have not yet begun to identify the current state.
- They are halfway through collecting public data, which puts them slightly ahead of schedule for that task.

They are behind schedule for the first two of these tasks and ahead of schedule for the third. Perhaps they need to reallocate their workforce to be able to cover the three activities simultaneously.

There is a fourth activity that could be happening now (develop benchmark questions), but it is not urgent yet. Eventually the team will have to allocate resources to cover it too, before visits can begin.

1.1.5. *Gantt Chart Considerations*

- Sometimes Gantt charts are drawn with additional columns showing details such as the amount of time the task is expected to take, resources or skill level needed or person responsible.
- Beware of identifying reviews or approvals as events unless they really will take place at a specific time, such as a meeting. Reviews and approvals often can take days or weeks.
- The process of constructing the Gantt chart forces group members to think clearly about what must be done to accomplish their goal. Keeping the chart updated as the project proceeds helps manage the project and head off schedule problems.
- It can be useful to indicate the critical points on the chart with bold or colored outlines of the bars.
- Computer software can simplify constructing and updating a Gantt chart.

1.2. Plan-Do-Check-Act Cycle

Also called: PDCA, plan-do-study-act (PDSA) cycle, Deming cycle, Shewhart cycle

1.2.1. *Description*

The plan-do-check-act cycle is a four-step model for carrying out change. Just as a circle has no end, the PDCA cycle should be repeated again and again for continuous improvement.



Plan-do-check-act cycle

1.2.2. *When to Use Plan-Do-Check-Act*

- As a model for continuous improvement.
- When starting a new improvement project.
- When developing a new or improved design of a process, product or service.
- When defining a repetitive work process.
- When planning data collection and analysis in order to verify and prioritize problems or root causes.
- When implementing any change.

1.2.3. *Plan-Do-Check-Act Procedure*

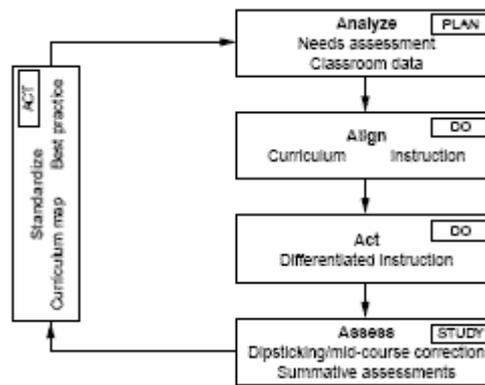
1. Plan. Recognize an opportunity and plan a change.
2. Do. Test the change. Carry out a small-scale study.
3. Study. Review the test, analyze the results and identify what you've learned.
4. Act. Take action based on what you learned in the study step: If the change did not work, go through the cycle again with a different plan. If you were successful, incorporate what you learned from the test into wider changes. Use what you learned to plan new improvements, beginning the cycle again.

1.2.4. Plan-Do-Check-Act Example

The Pearl River, NY School District, a 2001 recipient of the Malcolm Baldrige National Quality Award, uses the PDCA cycle as a model for defining most of their work processes, from the boardroom to the classroom.

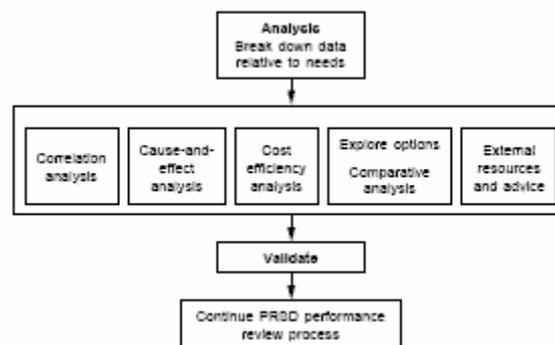
PDCA is the basic structure for the district’s overall strategic planning, needs-analysis, curriculum design and delivery, staff goal-setting and evaluation, provision of student services and support services, and classroom instruction.

The figure below shows their “A+ Approach to Classroom Success.” This is a continuous cycle of designing curriculum and delivering classroom instruction. Improvement is not a separate activity: It is built into the work process.



Plan-do-check-act example

Plan. The A+ Approach begins with a “plan” step called “analyze.” In this step, students’ needs are analyzed by examining a range of data available in Pearl River’s electronic data “warehouse,” from grades to performance on standardized tests. Data can be analyzed for individual students or stratified by grade, gender or any other subgroup. Because PDCA does not specify how to analyze data, a separate data analysis process is used here as well as in other processes throughout the organization.



Pearl River: analysis process

Do. The A+ Approach continues with two “do” steps:

1. “Align” asks what national and state standards require and how they will be assessed. Teaching staff also plans curriculum by looking at what is taught at earlier and later grade

levels and in other disciplines to assure a clear continuity of instruction throughout the student's schooling.

Teachers develop individual goals to improve their instruction where the "analyze" step showed any gaps.

2. The second "do" step is, in this example, called "act." This is where instruction is actually provided, following the curriculum and teaching goals. Within set parameters, teachers vary the delivery of instruction based on each student's learning rates and styles and varying teaching methods.

Check. The "check" step is called "assess" in this example. Formal and informal assessments take place continually, from daily teacher "dipstick" assessments to every-six-weeks progress reports to annual standardized tests. Teachers also can access comparative data on the electronic database to identify trends. High-need students are monitored by a special child study team.

Throughout the school year, if assessments show students are not learning as expected, mid-course corrections are made such as re-instruction, changing teaching methods and more direct teacher mentoring. Assessment data become input for the next step in the cycle.

Act. In this example the "act" step is called "standardize." When goals are met, the curriculum design and teaching methods are considered standardized. Teachers share best practices in formal and informal settings. Results from this cycle become input for the "analyze" phase of the next A+ cycle.

2. DATA COLLECTION & ANALISYS TOOLS

Use the following tools to collect or analyze data:

Box and Whisker Plot: A tool used to display and analyze multiple sets of variation data on a single graph.

Check sheet: A generic tool that can be adapted for a wide variety of purposes, the check sheet is a structured, prepared form for collecting and analyzing data.

Control chart: A graph used to study how a process changes over time. Comparing current data to historical control limits leads to conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Design of experiments: A method for carrying out carefully planned experiments on a process. Usually, design of experiments involves a series of experiments that start by looking broadly at a great many variables and then focus on the few critical ones.

Histogram: The most commonly used graph for showing frequency distributions, or how often each different value in a set of data occurs.

Scatter diagram: A diagram that graphs pairs of numerical data, one variable on each axis, to look for a relationship.

Stratification: A technique that separates data gathered from a variety of sources so that patterns can be seen.

Survey: Data collected from targeted groups of people about their opinions, behavior or knowledge.

2.1. Box and Whisker Plot

2.1.1. *Description*

A box and whisker plot is a graphical method of displaying variation in a set of data. In most cases a histogram provides a sufficient display; however, a box and whisker plot can provide additional detail while allowing multiple sets of data to be displayed in the same graph. Some types are called box and whisker plots with outliers.

2.1.2. *Why Use a Box and Whisker Plot?*

Box and whisker plots are very effective and easy to read. They summarize data from multiple sources and display the results in a single graph. Box and whisker plots allow for comparison of data from different categories for easier, more effective decision-making.

2.1.3. *When to Use a Box and Whisker Plot*

Use box and whisker plots when you have multiple data sets from independent sources that are related to each other in some way. Examples include test scores between schools or classrooms, data from before and after a process change, similar features on one part such as cam shaft lobes, or data from duplicate machines manufacturing the same products.

2.1.4. *Box and Whisker Plot Procedure*

A box and whisker plot is developed from five statistics.

1. Minimum value – the smallest value in the data set
2. Second quartile – the value below which the lower 25% of the data are contained
3. Median value – the middle number in a range of numbers
4. Third quartile – the value above which the upper 25% of the data are contained
5. Maximum value – the largest value in the data set

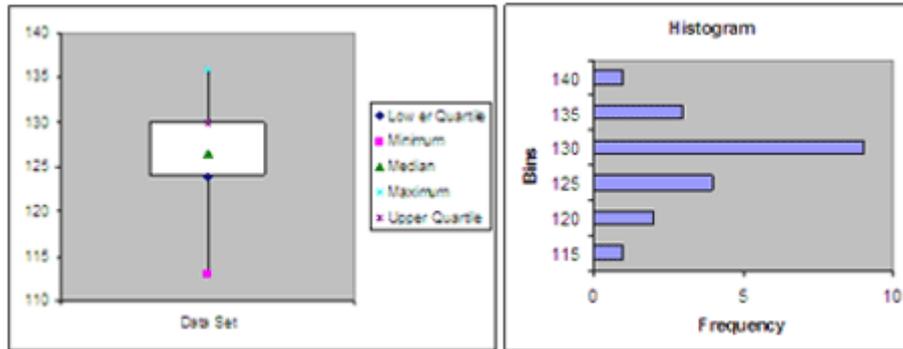
For example, given the following 20 data points, the five required statistics are displayed.

Number	Data	
1	113	Minimum: 113
2	116	
3	119	
4	121	
5	124	
	_____	2nd Quartile: 124
6	124	
7	125	
8	126	
9	126	
10	126	
	_____	Median: 126.5
11	127	
12	127	
13	128	
14	129	
15	130	
	_____	3rd Quartile: 130
16	130	
17	131	
18	132	
19	133	

20	136	Maximum: 136
-----------	-----	--------------

Note that for a data set with an even number of values, the median is calculated as the average of the two middle values.

Here are the data represented in box and whisker plot format.



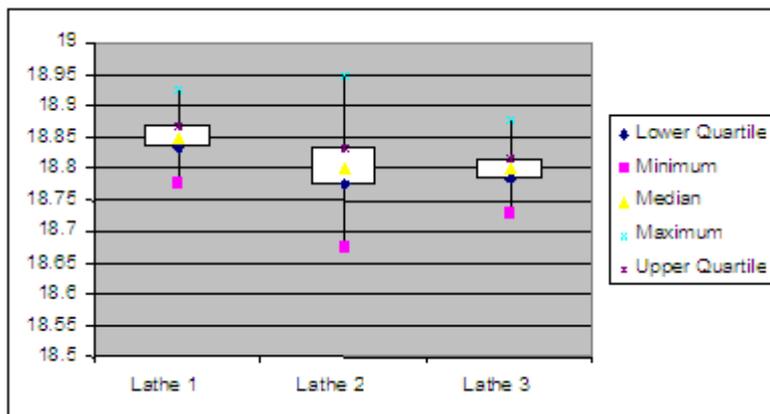
Left: The center represents the middle 50%, or 50th percentile of the data set and is derived using the lower and upper quartile values. The median value is displayed inside the "box." The maximum and minimum values are displayed with vertical lines ("whiskers") connecting the points to the center box.

Right: For comparison, a histogram of the data is also shown, showing the frequency of each value in the data set.

2.1.5. Box and Whisker Plot Example

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 +/- 1.0 mm.

Diameter measurements from a sample of shafts taken from each roughing lathe are displayed in a box and whisker plot.



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 appears to be performing comparably to Lathe 1. However, it is targeted low in the tolerance, and is making shafts below specification.

2.2. Check Sheet

Also called: defect concentration diagram

2.2.1. *Description*

A check sheet is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

2.2.2. *When to Use a Check Sheet*

- When data can be observed and collected repeatedly by the same person or at the same location.
- When collecting data on the frequency or patterns of events, problems, defects, defect location, defect causes, etc.
- When collecting data from a production process.

2.2.3. *Check Sheet Procedure*

1. Decide what event or problem will be observed. Develop operational definitions.
2. Decide when data will be collected and for how long.
3. Design the form. Set it up so that data can be recorded simply by making check marks or Xs or similar symbols and so that data do not have to be recopied for analysis.
4. Label all spaces on the form.
5. Test the check sheet for a short trial period to be sure it collects the appropriate data and is easy to use.
6. Each time the targeted event or problem occurs, record data on the check sheet.

2.2.4. *Check Sheet Example*

The figure below shows a check sheet used to collect data on telephone interruptions. The tick marks were added as data was collected over several weeks.

Reason	Day					Total
	Mon	Tues	Wed	Thurs	Fri	
Wrong number	+++			+++	+++	20
Info request						10
Boss	+++		+++			19
Total	12	6	10	8	13	49

Check Sheet Example

2.3. Control Chart

Also called: statistical process control

2.3.1. Description

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

2.3.2. When to Use a Control Chart

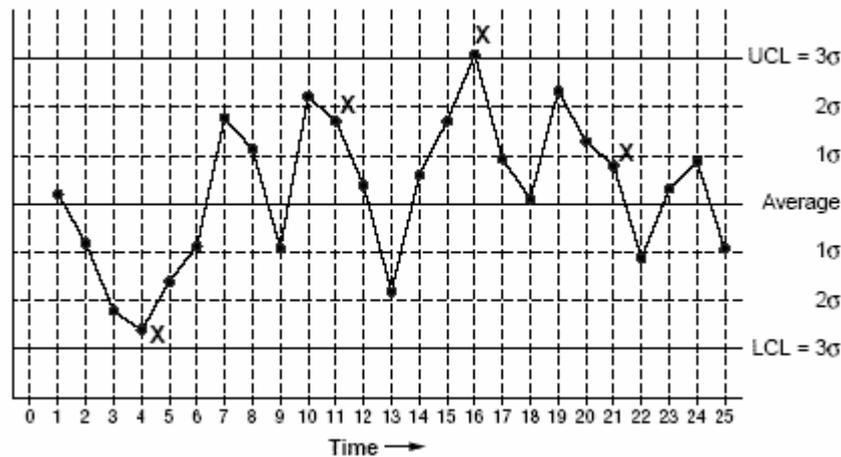
- When controlling ongoing processes by finding and correcting problems as they occur.
- When predicting the expected range of outcomes from a process.
- When determining whether a process is stable (in statistical control).
- When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process).
- When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process.

2.3.3. Control Chart Basic Procedure

1. Choose the appropriate control chart for your data.
2. Determine the appropriate time period for collecting and plotting data.
3. Collect data, construct your chart and analyze the data.
4. Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

Out – Of – Control Signals:

- A single point outside the control limits. In Figure 1, point sixteen is above the UCL (upper control limit).
- Two out of three successive points are on the same side of the centerline and farther than 2σ from it. In Figure 1, point 4 sends that signal.
- Four out of five successive points are on the same side of the centerline and farther than 1σ from it. In Figure 1, point 11 sends that signal.
- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure 1, point 21 is eighth in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.



Control Chart: Out-of-Control Signals

5. Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.
6. When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

2.4. Design of Experiments

This branch of applied statistics deals with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters.

A strategically planned and executed experiment may provide a great deal of information about the effect on a response variable due to one or more factors. Many experiments involve holding certain factors constant and altering the levels of another variable. This One-Factor-at-a-Time (or OFAT) approach to process knowledge is, however, inefficient when compared with changing factor levels simultaneously.

Many of the current statistical approaches to designed experiments originate from the work of R. A. Fisher in the early part of the 20th century. Fisher demonstrated how taking the time to seriously consider the design and execution of an experiment before trying it helped avoid frequently encountered problems in analysis. Key concepts in creating a designed experiment include blocking, randomization and replication.

A well-performed experiment may provide answers to questions such as:

- What are the key factors in a process?
- At what settings would the process deliver acceptable performance?
- What are the key, main and interaction effects in the process?
- What settings would bring about less variation in the output?

A repetitive approach to gaining knowledge is encouraged, typically involving these consecutive steps:

1. A screening design which narrows the field of variables under assessment.
2. A "full factorial" design which studies the response of every combination of factors and factor levels, and an attempt to zone in on a region of values where the process is close to optimization.
3. A response surface design to model the response.

Blocking: When randomizing a factor is impossible or too costly, blocking lets you restrict randomization by carrying out all of the trials with one setting of the factor and then all the trials with the other setting.

Randomization: Refers to the order in which the trials of an experiment are performed. A randomized sequence helps eliminate effects of unknown or uncontrolled variables.

Replication: Repetition of a complete experimental treatment, including the setup.

2.5. Histogram

2.5.1. *Description*

A frequency distribution shows how often each different value in a set of data occurs. A histogram is the most commonly used graph to show frequency distributions. It looks very much like a bar chart, but there are important differences between them.

2.5.2. *When to Use a Histogram*

- When the data are numerical.
- When you want to see the shape of the data's distribution, especially when determining whether the output of a process is distributed approximately normally.
- When analyzing whether a process can meet the customer's requirements.
- When analyzing what the output from a supplier's process looks like.
- When seeing whether a process change has occurred from one time period to another.
- When determining whether the outputs of two or more processes are different.
- When you wish to communicate the distribution of data quickly and easily to others.

2.5.3. *Histogram Construction*

- Collect at least 50 consecutive data points from a process.
- Use the [histogram worksheet](#) to set up the histogram. It will help you determine the number of bars, the range of numbers that go into each bar and the labels for the bar edges. After calculating W in step 2 of the worksheet, use your judgment to adjust it to a convenient number. For example, you might decide to round 0.9 to an even 1.0. The value for W must not have more decimal places than the numbers you will be graphing.
- Draw x- and y-axes on graph paper. Mark and label the y-axis for counting data values. Mark and label the x-axis with the L values from the worksheet. The spaces between these numbers will be the bars of the histogram. Do not allow for spaces between bars.
- For each data point, mark off one count above the appropriate bar with an X or by shading that portion of the bar.

2.5.4. *Histogram Analysis*

- Before drawing any conclusions from your histogram, satisfy yourself that the process was operating normally during the time period being studied. If any unusual events affected the process during the time period of the histogram, your analysis of the histogram shape probably cannot be generalized to all time periods.
- Analyze the meaning of your histogram's shape.

2.6. Scatter Diagram

Also called: scatter plot, X-Y graph

2.6.1. Description

The scatter diagram graphs pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line.

2.6.2. When to Use a Scatter Diagram

- When you have paired numerical data.
- When your dependent variable may have multiple values for each value of your independent variable.
- When trying to determine whether the two variables are related, such as...
 - When trying to identify potential root causes of problems.
 - After brainstorming causes and effects using a fishbone diagram, to determine objectively whether a particular cause and effect are related.
 - When determining whether two effects that appear to be related both occur with the same cause.
 - When testing for autocorrelation before constructing a control chart.

2.6.3. Scatter Diagram Procedure

1. Collect pairs of data where a relationship is suspected.
2. Draw a graph with the independent variable on the horizontal axis and the dependent variable on the vertical axis. For each pair of data, put a dot or a symbol where the x-axis value intersects the y-axis value. (If two dots fall together, put them side by side, touching, so that you can see both.)
3. Look at the pattern of points to see if a relationship is obvious. If the data clearly form a line or a curve, you may stop. The variables are correlated. You may wish to use regression or correlation analysis now. Otherwise, complete steps 4 through 7.
4. Divide points on the graph into four quadrants. If there are X points on the graph,
 - Count X/2 points from top to bottom and draw a horizontal line.
 - Count X/2 points from left to right and draw a vertical line.
 - If number of points is odd, draw the line through the middle point.
5. Count the points in each quadrant. Do not count points on a line.
6. Add the diagonally opposite quadrants. Find the smaller sum and the total of points in all quadrants.
A = points in upper left + points in lower right
B = points in upper right + points in lower left
Q = the smaller of A and B
N = A + B
7. Look up the limit for N on the trend test table.
 - If Q is less than the limit, the two variables are related.
 - If Q is greater than or equal to the limit, the pattern could have occurred from random chance.

Table 5.18 Trend test table.

<i>N</i>	Limit	<i>N</i>	Limit
1-8	0	51-53	18
9-11	1	54-55	19
12-14	2	56-57	20
15-16	3	58-60	21
17-19	4	61-62	22
20-22	5	63-64	23
23-24	6	65-66	24
25-27	7	67-69	25
28-29	8	70-71	26
30-32	9	72-73	27
33-34	10	74-76	28
35-36	11	77-78	29
37-39	12	79-80	30
40-41	13	81-82	31
42-43	14	83-85	32
44-46	15	86-87	33
47-48	16	88-89	34
49-50	17	90	35

2.6.4. Scatter Diagram Example

The ZZ-400 manufacturing team suspects a relationship between product purity (percent purity) and the amount of iron (measured in parts per million or ppm). Purity and iron are plotted against each other as a scatter diagram, as shown in the figure below.

There are 24 data points. Median lines are drawn so that 12 points fall on each side for both percent purity and ppm iron.

To test for a relationship, they calculate:

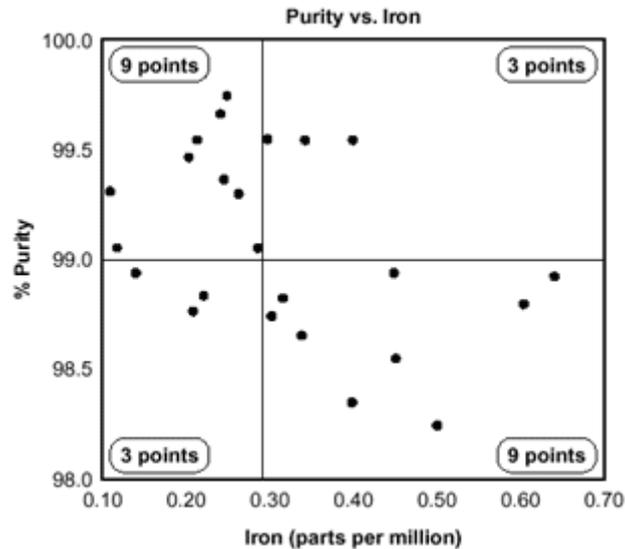
$$A = \text{points in upper left} + \text{points in lower right} = 9 + 9 = 18$$

$$B = \text{points in upper right} + \text{points in lower left} = 3 + 3 = 6$$

$$Q = \text{the smaller of A and B} = \text{the smaller of 18 and 6} = 6$$

$$N = A + B = 18 + 6 = 24$$

Then they look up the limit for *N* on the trend test table. For *N* = 24, the limit is 6. *Q* is equal to the limit. Therefore, the pattern could have occurred from random chance, and no relationship is demonstrated.



Scatter Diagram Example

2.6.5. Scatter Diagram Considerations

- Here are some examples of situations in which might you use a scatter diagram:
 - Variable A is the temperature of a reaction after 15 minutes. Variable B measures the color of the product. You suspect higher temperature makes the product darker. Plot temperature and color on a scatter diagram.
 - Variable A is the number of employees trained on new software, and variable B is the number of calls to the computer help line. You suspect that more training reduces the number of calls. Plot number of people trained versus number of calls.
 - To test for autocorrelation of a measurement being monitored on a control chart, plot this pair of variables: Variable A is the measurement at a given time. Variable B is the same measurement, but at the previous time. If the scatter diagram shows correlation, do another diagram where variable B is the measurement two times previously. Keep increasing the separation between the two times until the scatter diagram shows no correlation.
- Even if the scatter diagram shows a relationship, do not assume that one variable caused the other. Both may be influenced by a third variable.
- When the data are plotted, the more the diagram resembles a straight line, the stronger the relationship.
- If a line is not clear, statistics (N and Q) determine whether there is reasonable certainty that a relationship exists. If the statistics say that no relationship exists, the pattern could have occurred by random chance.
- If the scatter diagram shows no relationship between the variables, consider whether the data might be stratified.
- If the diagram shows no relationship, consider whether the independent (x-axis) variable has been varied widely. Sometimes a relationship is not apparent because the data don't cover a wide enough range.
- Think creatively about how to use scatter diagrams to discover a root cause.
- Drawing a scatter diagram is the first step in looking for a relationship between variables.

2.7. Stratification

2.7.1. Description

Stratification is a technique used in combination with other data analysis tools. When data from a variety of sources or categories have been lumped together, the meaning of the data can be impossible to see. This technique separates the data so that patterns can be seen.

2.7.2. *When to Use Stratification*

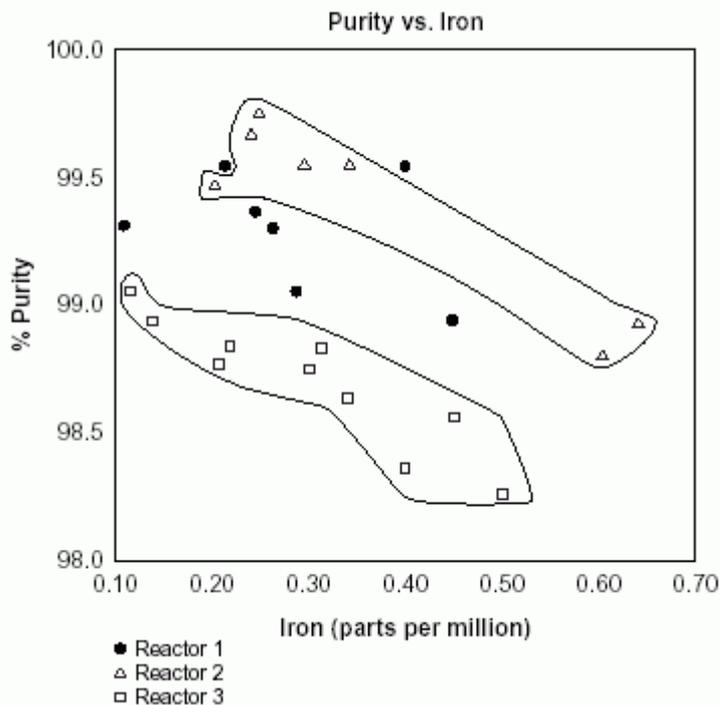
- Before collecting data.
- When data come from several sources or conditions, such as shifts, days of the week, suppliers or population groups.
- When data analysis may require separating different sources or conditions.

2.7.3. *Stratification Procedure*

1. Before collecting data, consider which information about the sources of the data might have an effect on the results. Set up the data collection so that you collect that information as well.
2. When plotting or graphing the collected data on a scatter diagram, control chart, histogram or other analysis tool, use different marks or colors to distinguish data from various sources. Data that are distinguished in this way are said to be "stratified."
3. Analyze the subsets of stratified data separately. For example, on a scatter diagram where data are stratified into data from source 1 and data from source 2, draw quadrants, count points and determine the critical value only for the data from source 1, then only for the data from source 2.

2.7.4. *Stratification Example*

The ZZ-400 manufacturing team drew a scatter diagram to test whether product purity and iron contamination were related, but the plot did not demonstrate a relationship. Then a team member realized that the data came from three different reactors. The team member redrew the diagram, using a different symbol for each reactor's data:



Now patterns can be seen. The data from reactor 2 and reactor 3 are circled. Even without doing any calculations, it is clear that for those two reactors, purity decreases as iron increases. However, the data from reactor 1, the solid dots that are not circled, do not show that relationship. Something is different about reactor 1.

2.7.5. *Stratification Considerations*

- Here are examples of different sources that might require data to be stratified:
 - Equipment
 - Shifts
 - Departments
 - Materials
 - Suppliers
 - Day of the week
 - Time of day
 - Products

Survey data usually benefit from stratification.

- Always consider before collecting data whether stratification might be needed during analysis. Plan to collect stratification information. After the data are collected it might be too late.
- On your graph or chart, include a legend that identifies the marks or colors used.

2.8. Survey

Variations: questionnaire, e-survey, telephone interview, face-to-face interview, focus group.

2.8.1. *Description*

Surveys collect data from a targeted group of people about their opinions, behavior or knowledge. Common types of surveys are written questionnaires, face-to-face or telephone interviews, focus groups and electronic (e-mail or Web site) surveys.

Surveys are commonly used with key stakeholders, especially customers and employees, to discover needs or assess satisfaction.

2.8.2. *When to Use a Survey*

- When identifying customer requirements or preferences.
- When assessing customer or employee satisfaction, such as identifying or prioritizing problems to address.
- When evaluating proposed changes.
- When assessing whether a change was successful.
- Periodically, to monitor changes in customer or employee satisfaction over time.

2.8.3. *Survey Basic Procedure*

Note: It's often worthwhile to have a survey prepared and administered by a research organization. However, you will still need to work with them on the following steps so that the survey will be most useful.

1. Decide what you want to learn from the survey and how you will use the results.
2. Decide who should be surveyed. Identify population groups; if they are too large to permit surveying everyone, decide how to obtain a sample. Decide what demographic information is needed to analyze and understand the results.
3. Decide on the most appropriate type of survey.
4. Decide whether the survey's answers will be numerical rating, numerical ranking, yes-no, multiple choice or open-ended—or a mixture.
5. Brainstorm questions and, for multiple choice, the list of possible answers. Keep in mind what you want to learn, and how you will use the results. Narrow down the list of questions to the absolute minimum that you must have to learn what you need to learn.

6. Print the questionnaire or interviewers' question list.
7. Test the survey with a small group. Collect feedback.
 - Which questions were confusing?
 - Were any questions redundant?
 - Were answer choices clear? Were they interpreted as you intended?
 - Did respondents want to give feedback about topics that were not included? (Open-ended questions can be an indicator of this.)
 - On the average, how long did it take for a respondent to complete the survey?
 - For a questionnaire, were there any typos or printing errors?

Also test the process of tabulating and analyzing the results. Is it easy? Do you have all the data you need?

- Revise the survey based on test results.
- Administer the survey.
- Tabulate and analyze the data. Decide how you will follow through. Report results and plans to everyone involved. If a sample was involved, also report and explain the margin of error and confidence level.

2.8.4. Survey Considerations

- Conducting a survey creates expectations for change in those asked to answer it. Do not survey if action will not or cannot be taken as a result.
- Satisfaction surveys should be compared to objective indicators of satisfaction, such as buying patterns for customers or attendance for employees, and to objective measures of performance, such as warranty data in manufacturing or re-admission rates in hospitals. If survey results do not correlate with the other measures, work to understand whether the survey is unreliable or whether perceptions are being modified, for better or worse, by the organization's actions.
- Surveys of customer and employee satisfaction should be ongoing processes rather than one-time events.
- Get help from a research organization in preparing, administering and analyzing major surveys, especially large ones or those whose results will determine significant decisions or expenditures.

3. PROCESS ANALYSIS TOOLS

When you want to understand a work process or some part of a process, these tools can help:

Flowchart: A picture of the separate steps of a process in sequential order, including materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

Failure modes and effects analysis (FMEA): A step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service; studying the consequences, or effects, of those failures; and eliminating or reducing failures, starting with the highest-priority ones.

Mistake-proofing: The use of any automatic device or method that either makes it impossible for an error to occur or makes the error immediately obvious once it has occurred.

3.1. Flowchart

Also called: process flowchart, process flow diagram.

Variations: macro flowchart, top-down flowchart, detailed flowchart (also called process map, micro map, service map, or symbolic flowchart), deployment flowchart (also called down-across or cross-functional flowchart), several-leveled flowchart.

3.1.1. Description

A flowchart is a picture of the separate steps of a process in sequential order.

Elements that may be included are: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes.

3.1.2. When to Use a Flowchart

- To develop understanding of how a process is done.
- To study a process for improvement.
- To communicate to others how a process is done.
- When better communication is needed between people involved with the same process.
- To document a process.
- When planning a project.

3.1.3. Flowchart Basic Procedure

Materials needed: sticky notes or cards, a large piece of flipchart paper or newsprint, marking pens.

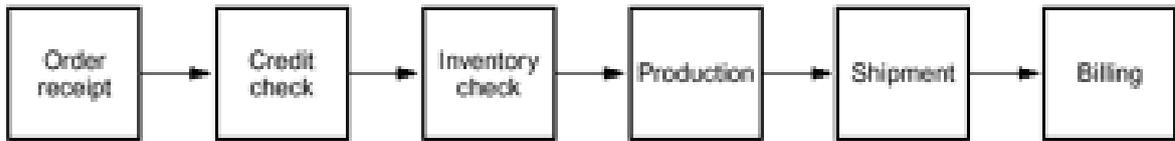
1. Define the process to be diagrammed. Write its title at the top of the work surface.
2. Discuss and decide on the boundaries of your process: Where or when does the process start? Where or when does it end? Discuss and decide on the level of detail to be included in the diagram.

3. Brainstorm the activities that take place. Write each on a card or sticky note. Sequence is not important at this point, although thinking in sequence may help people remember all the steps.
4. Arrange the activities in proper sequence.
5. When all activities are included and everyone agrees that the sequence is correct, draw arrows to show the flow of the process.
6. Review the flowchart with others involved in the process (workers, supervisors, suppliers, customers) to see if they agree that the process is drawn accurately.

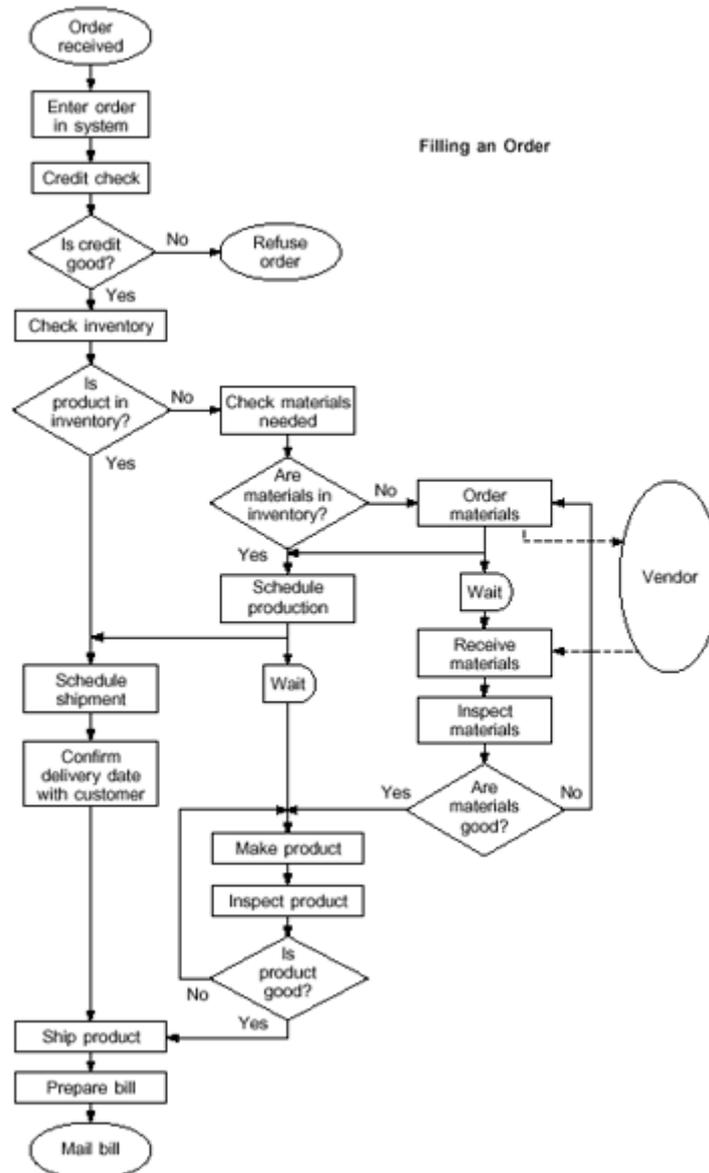
3.1.4. Flowchart Considerations

- Don't worry too much about drawing the flowchart the "right way." The right way is the way that helps those involved understand the process.
- Identify and involve in the flowcharting process all key people involved with the process. This includes those who do the work in the process: suppliers, customers and supervisors. Involve them in the actual flowcharting sessions by interviewing them before the sessions and/or by showing them the developing flowchart between work sessions and obtaining their feedback.
- Do not assign a "technical expert" to draw the flowchart. People who actually perform the process should do it.
- Computer software is available for drawing flowcharts. Software is useful for drawing a neat final diagram, but the method given here works better for the messy initial stages of creating the flowchart.

3.1.5. Flowchart Examples



High-Level Flowchart for an Order-Filling Process



Detailed Flowchart

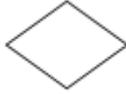
3.1.6. *Commonly Used Symbols in Detailed Flowcharts*



One step in the process; the step is written inside the box. Usually, only one arrow goes out of the box.



Direction of flow from one step or decision to another.



Decision based on a question. The question is written in the diamond. More than one arrow goes out of the diamond, each one showing the direction the process takes for a given answer to the question. (Often the answers are "yes" and "no.")



Delay or wait



Link to another page or another flowchart. The same symbol on the other page indicates that the flow continues there.



Input or output



Document



Alternate symbols for start and end points

3.2. Failure Modes and Effects Analysis (FMEA)

Also called: potential failure modes and effects analysis; failure modes, effects and criticality analysis (FMECA).

3.2.1. *Description*

Failure modes and effects analysis (FMEA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service.

“Failure modes” means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual.

“Effects analysis” refers to studying the consequences of those failures.

Failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones.

Failure modes and effects analysis also documents current knowledge and actions about the risks of failures, for use in continuous improvement. FMEA is used during design to prevent failures. Later it's used for control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service.

Begun in the 1940s by the U.S. military, FMEA was further developed by the aerospace and automotive industries. Several industries maintain formal FMEA standards.

What follows is an overview and reference. Before undertaking an FMEA process, learn more about standards and specific methods in your organization and industry through other references and training.

3.2.2. *When to Use FMEA*

- When a process, product or service is being designed or redesigned, after quality function deployment.
- When an existing process, product or service is being applied in a new way.
- Before developing control plans for a new or modified process.
- When improvement goals are planned for an existing process, product or service.
- When analyzing failures of an existing process, product or service.
- Periodically throughout the life of the process, product or service

3.2.3. *FMEA Procedure*

(Again, this is a general procedure. Specific details may vary with standards of your organization or industry.)

1. Assemble a cross-functional team of people with diverse knowledge about the process, product or service and customer needs. Functions often included are: design, manufacturing, quality, testing, reliability, maintenance, purchasing (and suppliers), sales, marketing (and customers) and customer service.
2. Identify the scope of the FMEA. Is it for concept, system, design, process or service? What are the boundaries? How detailed should we be? Use flowcharts to identify the scope and to make sure every team member understands it in detail. (From here on, we'll use the word “scope” to mean the system, design, process or service that is the subject of your FMEA.)
3. Fill in the identifying information at the top of your FMEA form. Figure 1 shows a typical format. The remaining steps ask for information that will go into the columns of the form.
4. Identify the functions of your scope. Ask, “What is the purpose of this system, design, process or service? What do our customers expect it to do?” Name it with a verb followed by a noun. Usually you will break the scope into separate subsystems, items, parts, assemblies or process steps and identify the function of each.
5. For each function, identify all the ways failure could happen. These are potential failure modes. If necessary, go back and rewrite the function with more detail to be sure the failure modes show a loss of that function.
6. For each failure mode, identify all the consequences on the system, related systems, process, related processes, product, service, customer or regulations. These are potential effects of failure. Ask, “What does the customer experience because of this failure? What happens when this failure occurs?”
7. Determine how serious each effect is. This is the severity rating, or S. Severity is usually rated on a scale from 1 to 10, where 1 is insignificant and 10 is catastrophic. If a failure

mode has more than one effect, write on the FMEA table only the highest severity rating for that failure mode.

8. For each failure mode, determine all the potential root causes. Use tools classified as cause analysis tool, as well as the best knowledge and experience of the team. List all possible causes for each failure mode on the FMEA form.
9. For each cause, determine the occurrence rating, or O. This rating estimates the probability of failure occurring for that reason during the lifetime of your scope. Occurrence is usually rated on a scale from 1 to 10, where 1 is extremely unlikely and 10 is inevitable. On the FMEA table, list the occurrence rating for each cause.
10. For each cause, identify current process controls. These are tests, procedures or mechanisms that you now have in place to keep failures from reaching the customer. These controls might prevent the cause from happening, reduce the likelihood that it will happen or detect failure after the cause has already happened but before the customer is affected.
11. For each control, determine the detection rating, or D. This rating estimates how well the controls can detect either the cause or its failure mode after they have happened but before the customer is affected. Detection is usually rated on a scale from 1 to 10, where 1 means the control is absolutely certain to detect the problem and 10 means the control is certain not to detect the problem (or no control exists). On the FMEA table, list the detection rating for each cause.
12. (Optional for most industries) Is this failure mode associated with a critical characteristic? (Critical characteristics are measurements or indicators that reflect safety or compliance with government regulations and need special controls.) If so, a column labeled "Classification" receives a Y or N to show whether special controls are needed. Usually, critical characteristics have a severity of 9 or 10 and occurrence and detection ratings above 3.
13. Calculate the risk priority number, or RPN, which equals $S \times O \times D$. Also calculate Criticality by multiplying severity by occurrence, $S \times O$. These numbers provide guidance for ranking potential failures in the order they should be addressed.
14. Identify recommended actions. These actions may be design or process changes to lower severity or occurrence. They may be additional controls to improve detection. Also note who is responsible for the actions and target completion dates.
15. As actions are completed, note results and the date on the FMEA form. Also, note new S, O or D ratings and new RPNs.

3.2.4. FMEA Example

A bank performed a process FMEA on their ATM system. Figure 1 shows part of it—the function "dispense cash" and a few of the failure modes for that function. The optional "Classification" column was not used. Only the headings are shown for the rightmost (action) columns.

Notice that RPN and criticality prioritize causes differently. According to the RPN, "machine jams" and "heavy computer network traffic" are the first and second highest risks.

One high value for severity or occurrence times a detection rating of 10 generates a high RPN. Criticality does not include the detection rating, so it rates highest the only cause with medium to high values for both severity and occurrence: "out of cash." The team should use their experience and judgment to determine appropriate priorities for action.

FMEA #	Failure Mode	Potential Effects of Failure	S	Potential Causes of Failure	C	Current Process Controls	P	D	I	O	Frequency of Occurrence	Severity of Effect	Scenarios #					
													1	2	3	4		
001	Excess amount of water provided by customer	Water very hot, scalding, discomfort	6	Hot water	5	Water heater set at 160	5	100	100	100	100	100						
				Water heater set at 140		10											100	100
				Water heater set at 120														
002	Excess amount of water provided by customer	Water very hot, scalding, discomfort	6	Water heater set at 160	5	Water heater set at 140	5	100	100	100	100	100						
				Water heater set at 120														
003	Excess amount of water provided by customer	Water very hot, scalding, discomfort	6	Water heater set at 160	5	Water heater set at 140	5	100	100	100	100	100						
				Water heater set at 120														

FMEA Example

3.3. Mistake Proofing

Also called: poka-yoke, fail-safing

3.3.1. Description

Mistake proofing, or its Japanese equivalent poka-yoke (pronounced PO-ka yo-KAY), is the use of any automatic device or method that either makes it impossible for an error to occur or makes the error immediately obvious once it has occurred.

3.3.2. When to Use Mistake Proofing

- When a process step has been identified where human error can cause mistakes or defects to occur, especially in processes that rely on the worker’s attention, skill or experience.
- In a service process, where the customer can make an error which affects the output.
- At a hand-off step in a process, when output or (for service processes) the customer is transferred to another worker.
- When a minor error early in the process causes major problems later in the process.
- When the consequences of an error are expensive or dangerous.

3.3.3. Mistake-Proofing Procedure

1. Obtain or create a flowchart of the process. Review each step, thinking about where and when human errors are likely to occur.
2. For each potential error, work back through the process to find its source.
3. For each error, think of potential ways to make it impossible for the error to occur. Consider:
 - Elimination—eliminating the step that causes the error.
 - Replacement—replacing the step with an error-proof one.
 - Facilitation—making the correct action far easier than the error.
4. If you cannot make it impossible for the error to occur, think of ways to detect the error and minimize its effects. Consider inspection method, setting function and regulatory function.
5. Choose the best mistake-proofing method or device for each error. Test it, then implement it.

Three kinds of inspection methods provide rapid feedback:

- Successive inspection is done at the next step of the process by the next worker.
- Self-inspection means workers check their own work immediately after doing it.



- Source inspection checks, before the process step takes place, that conditions are correct. Often it's automatic and keeps the process from proceeding until conditions are right.

Setting functions are the methods by which a process parameter or product attribute is inspected for errors:

- The contact or physical method checks a physical characteristic such as diameter or temperature, often using a sensor.
- The motion-step or sequencing method checks the process sequence to make sure steps are done in order.
- The fixed-value or grouping and counting method counts repetitions or parts or weighs an item to ensure completeness.
- A fourth setting function is sometimes added: information enhancement. This makes sure information is available and perceivable when and where required.

Regulatory functions are signals that alert the workers that an error has occurred:

- Warning functions are bells, buzzers, lights and other sensory signals. Consider using color-coding, shapes, symbols and distinctive sounds.
- Control functions prevent the process from proceeding until the error is corrected (if the error has already taken place) or conditions are correct (if the inspection was a source inspection and the error has not yet occurred).

3.3.4. Mistake-Proofing Example

The Parisian Experience restaurant wished to ensure high service quality through mistake-proofing. They reviewed the deployment chart (a detailed flowchart that shows who performs each step) of the seating process shown in the figure and identified human errors on the part of restaurant staff or customers that could cause service problems.



Restaurant's deployment chart

The first potential error occurs when customers enter. The maitre d' might not notice a customer is waiting if the maitred' is escorting other customers to their table, checking on table status or conferring with kitchen staff.

The mistake-proofing device is an electronic sensor on the entrance door. The sensor sends a signal to a vibrating pager on the maitre's belt to ensure that the maitre d' always knows when someone enters or leaves the restaurant. Other mistake-proofing methods replaced the process steps requiring the maitre d' to leave the front door to seat customers.

A possible error on the customers' part was identified at the step when diners are called from the lounge when their table is ready. They might miss the call if the lounge is noisy, if they are engrossed in conversation or if they are hard-of-hearing.

The mistake-proofing chosen by the team was to replace the step of the process in which the maitre d' called the customer's name over the loudspeaker. Instead, during the greeting step, the maitre d' notes a unique visual identifier of one or more members of the party. When the table is ready, the table busser notifies the waiter, who comes to the maitre d' and learns how to identify the customers. The waiter finds the customers in the lounge, escorts them to their table, gives them menus and takes additional drink orders.

Not only does this mistake-proofing method eliminate a customer-caused problem, it improves the restaurant ambiance by eliminating the annoying loudspeaker, keeps the maitre d' at the front door to greet customers, creates a sense of exceptional service when the waiter "magically" knows the customers and eliminates additional waiting time at the handoff between maitre d' and waiter.

4. CAUSE ANALYSIS TOOLS

Use these cause analysis tools when you want to discover the cause of a problem or situation:

Fishbone (Ishikawa) diagram: identifies many possible causes for an effect or problem and sorts ideas into useful categories.

Pareto chart: shows on a bar graph which factors are more significant.

Scatter diagram: graphs pairs of numerical data, with one variable on each axis, to help you look for a relationship.

4.1. Fishbone Diagram

Also Called: Cause-and-Effect Diagram, Ishikawa Diagram

Variations: cause enumeration diagram, process fishbone, time-delay fishbone, CEDAC (cause-and-effect diagram with the addition of cards), desired-result fishbone, reverse fishbone diagram

4.1.1. *Description*

The fishbone diagram identifies many possible causes for an effect or problem. It can be used to structure a brainstorming session. It immediately sorts ideas into useful categories.

4.1.2. *When to Use a Fishbone Diagram*

- When identifying possible causes for a problem.
- Especially when a team's thinking tends to fall into ruts.

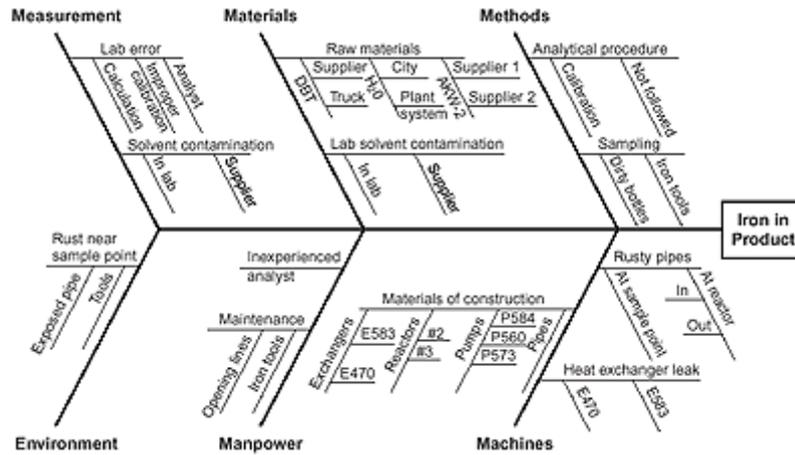
4.1.3. *Fishbone Diagram Procedure*

Materials needed: flipchart or whiteboard, marking pens.

1. Agree on a problem statement (effect). Write it at the center right of the flipchart or whiteboard. Draw a box around it and draw a horizontal arrow running to it.
2. Brainstorm the major categories of causes of the problem. If this is difficult use generic headings:
 - Methods
 - Machines (equipment)
 - People (manpower)
 - Materials
 - Measurement
 - Environment
3. Write the categories of causes as branches from the main arrow.
4. Brainstorm all the possible causes of the problem. Ask: "Why does this happen?" As each idea is given, the facilitator writes it as a branch from the appropriate category. Causes can be written in several places if they relate to several categories.
5. Again ask "why does this happen?" about each cause. Write sub-causes branching off the causes. Continue to ask "Why?" and generate deeper levels of causes. Layers of branches indicate causal relationships.
6. When the group runs out of ideas, focus attention to places on the chart where ideas are few.

4.1.4. 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.



Fishbone Diagram Example

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.

4.2. Pareto Chart

Also called: Pareto diagram, Pareto analysis

Variations: weighted Pareto chart, comparative Pareto charts

4.2.1. Description

A Pareto chart is a bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which situations are more significant.

4.2.2. When to Use a Pareto Chart

- When analyzing data about the frequency of problems or causes in a process.
- When there are many problems or causes and you want to focus on the most significant.
- When analyzing broad causes by looking at their specific components.
- When communicating with others about your data.

4.2.3. Pareto Chart Procedure

1. Decide what categories you will use to group items.

2. Decide what measurement is appropriate. Common measurements are frequency, quantity, cost and time.
3. Decide what period of time the Pareto chart will cover: One work cycle? One full day? A week?
4. Collect the data, recording the category each time. (Or assemble data that already exist.)
5. Subtotal the measurements for each category.
6. Determine the appropriate scale for the measurements you have collected. The maximum value will be the largest subtotal from step 5. (If you will do optional steps 8 and 9 below, the maximum value will be the sum of all subtotals from step 5.) Mark the scale on the left side of the chart.
7. Construct and label bars for each category. Place the tallest at the far left, then the next tallest to its right and so on. If there are many categories with small measurements, they can be grouped as "other."

Steps 8 and 9 are optional but are useful for analysis and communication.

8. Calculate the percentage for each category: the subtotal for that category divided by the total for all categories. Draw a right vertical axis and label it with percentages. Be sure the two scales match: For example, the left measurement that corresponds to one-half should be exactly opposite 50% on the right scale.
9. Calculate and draw cumulative sums: Add the subtotals for the first and second categories, and place a dot above the second bar indicating that sum. To that sum add the subtotal for the third category, and place a dot above the third bar for that new sum. Continue the process for all the bars. Connect the dots, starting at the top of the first bar. The last dot should reach 100 percent on the right scale.

4.2.4. Pareto Chart Examples

Example #1 shows how many customer complaints were received in each of five categories.

Example #2 takes the largest category, "documents," from Example #1, breaks it down into six categories of document-related complaints, and shows cumulative values.

If all complaints cause equal distress to the customer, working on eliminating document-related complaints would have the most impact, and of those, working on quality certificates should be most fruitful.



Example #1



Example #2

4.3. Scatter Diagram

Also called: scatter plot, X-Y graph

4.3.1. Description

The scatter diagram graphs pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line.

4.3.2. When to Use a Scatter Diagram

- When you have paired numerical data.
- When your dependent variable may have multiple values for each value of your independent variable.
- When trying to determine whether the two variables are related, such as...
 - When trying to identify potential root causes of problems.
 - After brainstorming causes and effects using a fishbone diagram, to determine objectively whether a particular cause and effect are related.
 - When determining whether two effects that appear to be related both occur with the same cause.
 - When testing for autocorrelation before constructing a control chart.

4.3.3. Scatter Diagram Procedure

1. Collect pairs of data where a relationship is suspected.
2. Draw a graph with the independent variable on the horizontal axis and the dependent variable on the vertical axis. For each pair of data, put a dot or a symbol where the x-axis value intersects the y-axis value. (If two dots fall together, put them side by side, touching, so that you can see both.)
3. Look at the pattern of points to see if a relationship is obvious. If the data clearly form a line or a curve, you may stop. The variables are correlated. You may wish to use regression or correlation analysis now. Otherwise, complete steps 4 through 7.
4. Divide points on the graph into four quadrants. If there are X points on the graph,
 - Count X/2 points from top to bottom and draw a horizontal line.
 - Count X/2 points from left to right and draw a vertical line.
 - If number of points is odd, draw the line through the middle point.
5. Count the points in each quadrant. Do not count points on a line.
6. Add the diagonally opposite quadrants. Find the smaller sum and the total of points in all quadrants.

A = points in upper left + points in lower right
 B = points in upper right + points in lower left
 Q = the smaller of A and B
 N = A + B

7. Look up the limit for N on the trend test table.
 - If Q is less than the limit, the two variables are related.
 - If Q is greater than or equal to the limit, the pattern could have occurred from random chance.

Table 5.18 Trend test table.

N	Limit	N	Limit
1-8	0	51-53	18
9-11	1	54-55	19
12-14	2	56-57	20
15-16	3	58-60	21
17-19	4	61-62	22
20-22	5	63-64	23
23-24	6	65-66	24
25-27	7	67-69	25
28-29	8	70-71	26
30-32	9	72-73	27
33-34	10	74-76	28
35-36	11	77-78	29
37-39	12	79-80	30
40-41	13	81-82	31
42-43	14	83-85	32
44-46	15	86-87	33
47-48	16	88-89	34
49-50	17	90	35

4.3.4. Scatter Diagram Example

The ZZ-400 manufacturing team suspects a relationship between product purity (percent purity) and the amount of iron (measured in parts per million or ppm). Purity and iron are plotted against each other as a scatter diagram, as shown in the figure below.

There are 24 data points. Median lines are drawn so that 12 points fall on each side for both percent purity and ppm iron.

To test for a relationship, they calculate:

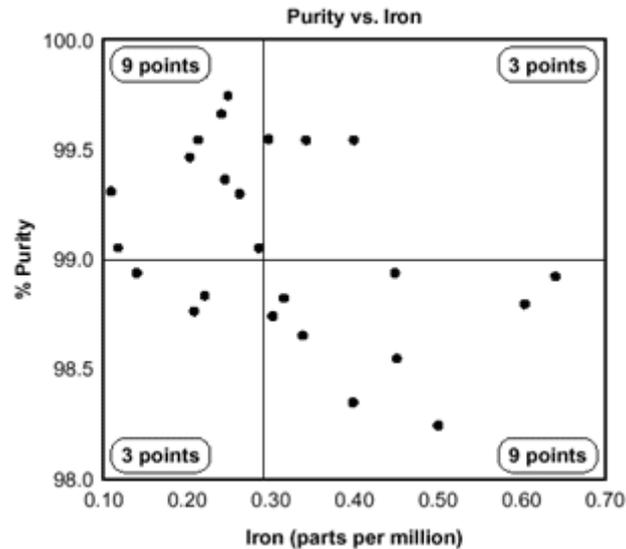
A = points in upper left + points in lower right = 9 + 9 = 18

B = points in upper right + points in lower left = 3 + 3 = 6

Q = the smaller of A and B = the smaller of 18 and 6 = 6

N = A + B = 18 + 6 = 24

Then they look up the limit for N on the trend test table. For N = 24, the limit is 6. Q is equal to the limit. Therefore, the pattern could have occurred from random chance, and no relationship is demonstrated.



Scatter Diagram Example

4.3.5. Scatter Diagram Considerations

- Here are some examples of situations in which might you use a scatter diagram:
 - Variable A is the temperature of a reaction after 15 minutes. Variable B measures the color of the product. You suspect higher temperature makes the product darker. Plot temperature and color on a scatter diagram.
 - Variable A is the number of employees trained on new software, and variable B is the number of calls to the computer help line. You suspect that more training reduces the number of calls. Plot number of people trained versus number of calls.
 - To test for autocorrelation of a measurement being monitored on a control chart, plot this pair of variables: Variable A is the measurement at a given time. Variable B is the same measurement, but at the previous time. If the scatter diagram shows correlation, do another diagram where variable B is the measurement two times previously. Keep increasing the separation between the two times until the scatter diagram shows no correlation.
- Even if the scatter diagram shows a relationship, do not assume that one variable caused the other. Both may be influenced by a third variable.
- When the data are plotted, the more the diagram resembles a straight line, the stronger the relationship.
- If a line is not clear, statistics (N and Q) determine whether there is reasonable certainty that a relationship exists. If the statistics say that no relationship exists, the pattern could have occurred by random chance.
- If the scatter diagram shows no relationship between the variables, consider whether the data might be stratified.
- If the diagram shows no relationship, consider whether the independent (x-axis) variable has been varied widely. Sometimes a relationship is not apparent because the data don't cover a wide enough range.
- Think creatively about how to use scatter diagrams to discover a root cause.
- Drawing a scatter diagram is the first step in looking for a relationship between variables.

5. IDEA CREATION TOOLS

Use tools like these when you want to come up with new ideas or organize many ideas:

Affinity diagram: Organizes a large number of ideas into their natural relationships.

Benchmarking: A structured process for comparing your organization's work practices to the best similar practices you can identify in other organizations, and then incorporating the best ideas into your own processes.

Brainstorming: A method for generating a large number of creative ideas in a short period of time.

Nominal group technique: A structured method for group brainstorming that encourages contributions from everyone.

5.1. Affinity Diagram

Also called: affinity chart, K-J method

Variation: thematic analysis

5.1.1. *Description*

The affinity diagram organizes a large number of ideas into their natural relationships. This method taps a team's creativity and intuition. It was created in the 1960s by Japanese anthropologist Jiro Kawakita.

5.1.2. *When to Use an Affinity Diagram*

- When you are confronted with many facts or ideas in apparent chaos
- When issues seem too large and complex to grasp
- When group consensus is necessary

Typical situations are:

- After a brainstorming exercise
- When analyzing verbal data, such as survey results.

5.1.3. *Affinity Diagram Procedure*

Materials needed: sticky notes or cards, marking pens, large work surface (wall, table, or floor).

1. Record each idea with a marking pen on a separate sticky note or card. (During a brainstorming session, write directly onto sticky notes or cards if you suspect you will be following the brainstorm with an affinity diagram.) Randomly spread notes on a large work surface so all notes are visible to everyone. The entire team gathers around the notes and participates in the next steps.
2. It is very important that no one talk during this step. Look for ideas that seem to be related in some way. Place them side by side. Repeat until all notes are grouped. It's okay to have "loners" that don't seem to fit a group. It's all right to move a note someone else has already moved. If a note seems to belong in two groups, make a second note.
3. You can talk now. Participants can discuss the shape of the chart, any surprising patterns, and especially reasons for moving controversial notes. A few more changes may be made. When ideas are grouped, select a heading for each group. Look for a note in each grouping that captures the meaning of the group. Place it at the top of the group. If there is no such note, write one. Often it is useful to write or highlight this note in a different color.

4. Combine groups into "supergroups" if appropriate.

5.1.4. Affinity Diagram Example

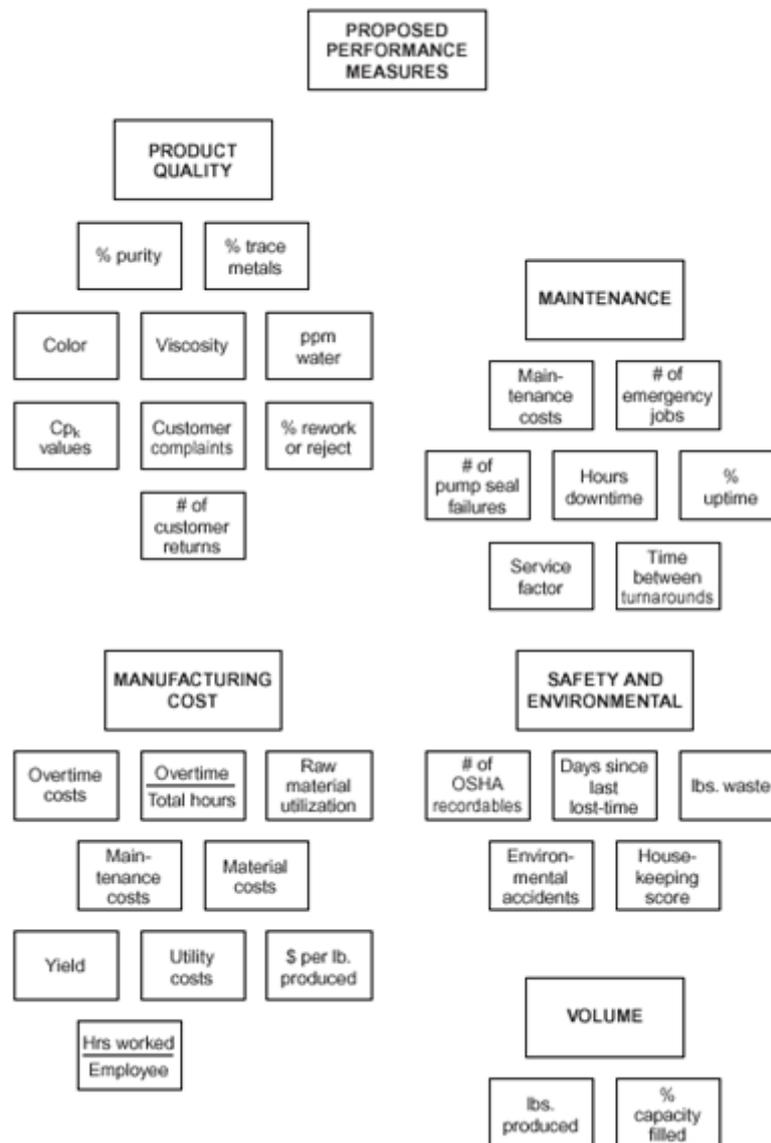
The ZZ-400 manufacturing team used an affinity diagram to organize its list of potential performance indicators. The figure below shows the list team members brainstormed. Because the team works a shift schedule and members could not meet to do the affinity diagram together, they modified the procedure.

Possible Performance Measures	
% purity	# of OSHA recordables
% trace metals	# of customer returns
Maintenance costs	Customer complaints
# of emergency jobs	Overtime/total hours worked
lbs. produced	\$/lb. produced
Environmental accidents	Raw material utilization
Material costs	Yield
Overtime costs	Utility cost
# of pump seal failures	ppm water
Viscosity	Color
Cp _k values	Service factor
Safety	Time between turnarounds
Days since last lost-time	Hours worked/employee
% rework or reject	lbs. waste
Hours downtime	Housekeeping score
% uptime	% capacity filled

Brainstorming for Affinity Diagram Example

They wrote each idea on a sticky note and put all the notes randomly on a rarely used door. Over several days, everyone reviewed the notes in their spare time and moved the notes into related groups. Some people reviewed the evolving pattern several times. After a few days, the natural grouping shown in the next figure had emerged.

Notice that one of the notes, "Safety," has become part of the heading for its group. The rest of the headings were added after the grouping emerged. Five broad areas of performance were identified: product quality, equipment maintenance, manufacturing cost, production volume, and safety and environmental.



Affinity Diagram Example

5.1.5. Affinity Diagram Considerations

- The affinity diagram process lets a group move beyond its habitual thinking and preconceived categories. This technique accesses the great knowledge and understanding residing untapped in our intuition.
- Very important "Do not's": Do not place the notes in any order. Do not determine categories or headings in advance. Do not talk during step 2. (This is hard for some people!)
- Allow plenty of time for step 2. You can, for example, post the randomly-arranged notes in a public place and allow grouping to happen over several days.
- Most groups that use this technique are amazed at how powerful and valuable a tool it is. Try it once with an open mind and you'll be another convert.
- Use markers. With regular pens, it is hard to read ideas from any distance

5.2. Benchmarking

The benchmarking process consists of five phases:

1. Planning. The essential steps are those of any plan development: what, who and how.

- **What is to be benchmarked?** Every function of an organization has or delivers a “product” or output. Benchmarking is appropriate for any output of a process or function, whether it’s a physical good, an order, a shipment, an invoice, a service or a report.
- **To whom or what will we compare?** Business-to-business, direct competitors are certainly prime candidates to benchmark. But they are not the only targets. Benchmarking must be conducted against the best companies and business functions regardless of where they exist.
- **How will the data be collected?** There’s no one way to conduct benchmarking investigations. There’s an infinite variety of ways to obtain required data – and most of the data you’ll need are readily and publicly available. Recognize that benchmarking is a process not only of deriving quantifiable goals and targets, but more importantly, it’s the process of investigating and documenting the best industry practices, which can help you achieve goals and targets.

2. Analysis. The analysis phase must involve a careful understanding of your current process and practices, as well as those of the organizations being benchmarked. What is desired is an understanding of internal performance on which to assess strengths and weaknesses.

Ask:

- Is this other organization better than we are?
- Why are they better?
- By how much?
- What best practices are being used now or can be anticipated?
- How can their practices be incorporated or adapted for use in our organization?

Answers to these questions will define the dimensions of any performance gap: negative, positive or parity. The gap provides an objective basis on which to act—to close the gap or capitalize on any advantage your organization has.

3. Integration. Integration is the process of using benchmark findings to set operational targets for change. It involves careful planning to incorporate new practices in the operation and to ensure benchmark findings are incorporated in all formal planning processes.

Steps include:

- Gain operational and management acceptance of benchmark findings. Clearly and convincingly demonstrate findings as correct and based on substantive data.
- Develop action plans.
- Communicate findings to all organizational levels to obtain support, commitment and ownership.

4. Action. Convert benchmark findings, and operational principles based on them, to specific actions to be taken. Put in place a periodic measurement and assessment of achievement. Use the creative talents of the people who actually perform work tasks to determine how the findings can be incorporated into the work processes.

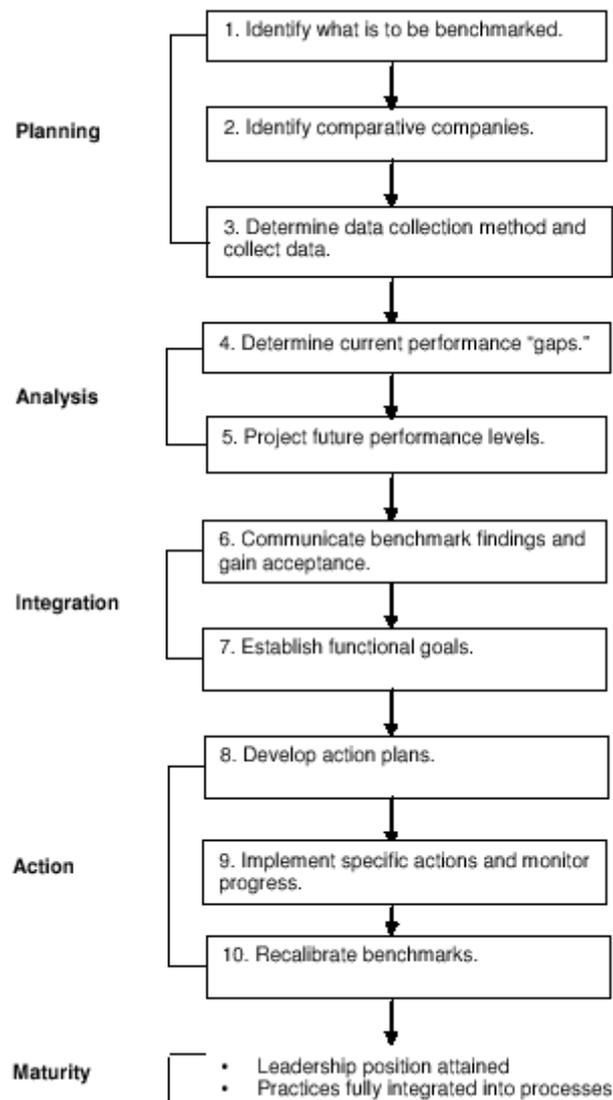
Any plan for change also should contain milestones for updating the benchmark findings, and an ongoing reporting mechanism. Progress toward benchmark findings must be reported to all employees.

5. Maturity. Maturity will be reached when best industry practices are incorporated in all business processes, thus ensuring superiority.

Tests for superiority:

- If the now-changed process were to be made available to others, would a knowledgeable businessperson prefer it?
- Do other organizations benchmark your internal operations?

Maturity also is achieved when benchmarking becomes an ongoing, essential and self-initiated facet of the management process. Benchmarking becomes institutionalized and is done at all appropriate levels of the organization, not by specialists.



Benchmarking process steps

5.3. Brainstorming

Variations: There are many versions of brainstorming, including round-robin brainstorming, wildest-idea brainstorming, double reversal, starbursting and the charette procedure. The basic version described below is sometimes called free-form, freewheeling or unstructured brainstorming.

See also: [nominal group technique](#) and [fishbone diagram](#)

5.3.1. Description

Brainstorming is a method for generating a large number of creative ideas in a short period of time.

5.3.2. *When to Use Brainstorming*

- When a broad range of options is desired.
- When creative, original ideas are desired.
- When participation of the entire group is desired.

5.3.3. *Brainstorming Procedure*

Materials needed: flipchart, marking pens, tape and blank wall space.

1. Review the rules of brainstorming with the entire group:
 - No criticism, no evaluation, no discussion of ideas.
 - There are no stupid ideas. The wilder the better.
 - All ideas are recorded.
 - Piggybacking is encouraged: combining, modifying, expanding others' ideas.
2. Review the topic or problem to be discussed. Often it is best phrased as a "why," "how," or "what" question. Make sure everyone understands the subject of the brainstorm.
3. Allow a minute or two of silence for everyone to think about the question.
4. Invite people to call out their ideas. Record all ideas, in words as close as possible to those used by the contributor. No discussion or evaluation of any kind is permitted.
5. Continue to generate and record ideas until several minutes' silence produces no more.

5.3.4. *Brainstorming Considerations*

- Judgment and creativity are two functions that cannot occur simultaneously. That's the reason for the rules about no criticism and no evaluation.
- Laughter and groans are criticism. When there is criticism, people begin to evaluate their ideas before stating them. Fewer ideas are generated and creative ideas are lost.
- Evaluation includes positive comments such as "Great idea!" That implies that another idea that did not receive praise was mediocre.
- The more the better. Studies have shown that there is a direct relationship between the total number of ideas and the number of good, creative ideas.
- The crazier the better. Be unconventional in your thinking. Don't hold back any ideas. Crazy ideas are creative. They often come from a different perspective.
- Crazy ideas often lead to wonderful, unique solutions, through modification or by sparking someone else's imagination.
- Hitchhike. Piggyback. Build on someone else's idea.
- When brainstorming with a large group, someone other than the facilitator should be the recorder. The facilitator should act as a buffer between the group and the recorder(s), keeping the flow of ideas going and ensuring that no ideas get lost before being recorded.
- The recorder should try not to rephrase ideas. If an idea is not clear, ask for a rephrasing that everyone can understand. If the idea is too long to record, work with the person who suggested the idea to come up with a concise rephrasing. The person suggesting the idea must always approve what is recorded.
- Keep all ideas visible. When ideas overflow to additional flipchart pages, post previous pages around the room so all ideas are still visible to everyone.

5.4. Nominal Group Technique (NGT)

5.4.1. *Description*

Nominal group technique (NGT) is a structured method for group brainstorming that encourages contributions from everyone.

5.4.2. *When to Use Nominal Group Technique*

- When some group members are much more vocal than others.
- When some group members think better in silence.
- When there is concern about some members not participating.
- When the group does not easily generate quantities of ideas.
- When all or some group members are new to the team.
- When the issue is controversial or there is heated conflict.

5.4.3. *Nominal Group Technique Procedure*

Materials needed: paper and pen or pencil for each individual, flipchart, marking pens, tape.

1. State the subject of the brainstorming. Clarify the statement as needed until everyone understands it.
2. Each team member silently thinks of and writes down as many ideas as possible in a set period of time (5 to 10 minutes).
3. Each member in turn states aloud one idea. Facilitator records it on the flipchart.
 - No discussion is allowed, not even questions for clarification.
 - Ideas given do not need to be from the team member's written list. Indeed, as time goes on, many ideas will not be.
 - A member may "pass" his or her turn, and may then add an idea on a subsequent turn.

Continue around the group until all members pass or for an agreed-upon length of time.

4. Discuss each idea in turn. Wording may be changed only when the idea's originator agrees. Ideas may be stricken from the list only by unanimous agreement. Discussion may clarify meaning, explain logic or analysis, raise and answer questions, or state agreement or disagreement.
5. Prioritize the ideas using multivoting or list reduction.

5.4.4. *Nominal Group Technique Considerations*

- Discussion should be equally balanced among all ideas. The facilitator should not allow discussion to turn into argument. The primary purpose of the discussion is clarification. It is not to resolve differences of opinion.
- Keep all ideas visible. When ideas overflow to additional flipchart pages, post previous pages around the room so all ideas are still visible to everyone.
- See brainstorming for other suggestions to use with this tool.

6. EVALUATION & DECISION – MAKING TOOLS

Use evaluation and decision-making tools when you want to narrow a group of choices to the best one, or when you want to evaluate how well you've done something. This includes evaluating project results.

Decision matrix: Evaluates and prioritizes a list of options, using pre-determined weighted criteria.

Multivoting: Narrows a large list of possibilities to a smaller list of the top priorities or to a final selection; allows an item that is favored by all, but not the top choice of any, to rise to the top.

6.1. Decision Matrix

Also called: Pugh matrix, decision grid, selection matrix or grid, problem matrix, problem selection matrix, opportunity analysis, solution matrix, criteria rating form, criteria-based matrix.

6.1.1. *Description*

A decision matrix evaluates and prioritizes a list of options. The team first establishes a list of weighted criteria and then evaluates each option against those criteria. This is a variation of the L-shaped matrix.

6.1.2. *When to Use a Decision Matrix*

- When a list of options must be narrowed to one choice.
- When the decision must be made on the basis of several criteria.
- After the list of options has been reduced to a manageable number by list reduction.

Typical situations are:

- When one improvement opportunity or problem must be selected to work on.
- When only one solution or problem-solving approach can be implemented.
- When only one new product can be developed.

6.1.3. *Decision Matrix Procedure*

1. Brainstorm the evaluation criteria appropriate to the situation. If possible, involve customers in this process.
2. Discuss and refine the list of criteria. Identify any criteria that must be included and any that must not be included. Reduce the list of criteria to those that the team believes are most important. Tools such as list reduction and multivoting may be useful here.
3. Assign a relative weight to each criterion, based on how important that criterion is to the situation. Do this by distributing 10 points among the criteria. The assignment can be done by discussion and consensus. Or each member can assign weights, then the numbers for each criterion are added for a composite team weighting.
4. Draw an L-shaped matrix. Write the criteria and their weights as labels along one edge and the list of options along the other edge. Usually, whichever group has fewer items occupies the vertical edge.
5. Evaluate each choice against the criteria. There are three ways to do this:

Method 1: Establish a rating scale for each criterion. Some options are:

1, 2, 3:	1 = slight extent, 2 = some extent, 3 = great extent
1, 2, 3:	1 = low, 2 = medium, 3 = high
1, 2, 3, 4, 5:	1 = little to 5 = great

1, 4, 9: 1 = low, 4 = moderate, 9 = high

Make sure that your rating scales are consistent. Word your criteria and set the scales so that the high end of the scale (5 or 3) is always the rating that would tend to make you select that option: most impact on customers, greatest importance, least difficulty, greatest likelihood of success.

Method 2: For each criterion, rank-order all options according to how well each meets the criterion. Number them with 1 being the option that is least desirable according to that criterion.

Method 3, Pugh matrix: Establish a baseline, which may be one of the alternatives or the current product or service. For each criterion, rate each other alternative in comparison to the baseline, using scores of worse (-1), same (0), or better (+1). Finer rating scales can be used, such as 2, 1, 0, -1, -2 for a five-point scale or 3, 2, 1, 0, -1, -2, -3 for a seven-point scale. Again, be sure that positive numbers reflect desirable ratings.

6. Multiply each option’s rating by the weight. Add the points for each option. The option with the highest score will not necessarily be the one to choose, but the relative scores can generate meaningful discussion and lead the team toward consensus

6.1.4. Decision Matrix Example

The figure below shows a decision matrix used by the customer service team at the Parisian Experience restaurant to decide which aspect of the overall problem of “long wait time” to tackle first. The problems they identified are customers waiting for the host, the waiter, the food, and the check.

The criteria they identified are “Customer pain” (how much does this negatively affect the customer?), “Ease to solve,” “Effect on other systems,” and “Speed to solve.” Originally, the criteria “Ease to solve” was written as “Difficulty to solve,” but that wording reversed the rating scale. With the current wording, a high rating on each criterion defines a state that would encourage selecting the problem: high customer pain, very easy to solve, high effect on other systems, and quick solution.

Decision Matrix: Long Wait Time

Criteria →	Customer pain 5	Ease to solve 2	Effect on other systems 1	Speed to solve 2	
↑ Problems					
Customers wait for host	High—Nothing else for customer to do $3 \times 5 = 15$	Medium—Involves host and bussers $2 \times 2 = 4$	High—Gets customer off to bad start $3 \times 1 = 3$	High—Observations show adequate empty tables $3 \times 2 = 6$	28
Customers wait for waiter	Medium—Customers can eat breadsticks $2 \times 5 = 10$	Medium—Involves host and waiters $2 \times 2 = 4$	Medium—Customer still feels unattended $2 \times 1 = 2$	Low—Waiters involved in many activities $1 \times 2 = 2$	18
Customers wait for food	Medium—Ambiance is nice $2 \times 5 = 10$	Low—Involves waiters and kitchen $1 \times 2 = 2$	Medium—Might result in extra trips to kitchen for waiter $2 \times 1 = 2$	Low—Kitchen is design/space limited $1 \times 2 = 2$	16
Customers wait for check	Low—Customers can relax over coffee, mints $1 \times 5 = 5$	Medium—Involves waiters and host $2 \times 2 = 4$	Medium—Customers waiting for tables might notice $2 \times 1 = 2$	Low—Computerized ticket system is needed $1 \times 2 = 2$	13

Figure 5.50 Decision matrix example.

Decision Matrix Example

“Customer pain” has been weighted with 5 points, showing that the team considers it by far the most important criterion, compared to 1 or 2 points for the others.

The team chose a rating scale of high = 3, medium = 2, and low = 1. For example, let’s look at the problem “Customers wait for food.” The customer pain is medium (2), because the restaurant



ambiance is nice. This problem would not be easy to solve (low ease = 1), as it involves both waiters and kitchen staff. The effect on other systems is medium (2), because waiters have to make several trips to the kitchen. The problem will take a while to solve (low speed = 1), as the kitchen is cramped and inflexible. (Notice that this has forced a guess about the ultimate solution: kitchen redesign. This may or may not be a good guess.)

Each rating is multiplied by the weight for that criterion. For example, "Customer pain" (weight of 5) for "Customers wait for host" rates high (3) for a score of 15. The scores are added across the rows to obtain a total for each problem. "Customers wait for host" has the highest score at 28. Since the next highest score is 18, the host problem probably should be addressed first.

6.1.5. *Decision Matrix Considerations*

- A very long list of options can first be shortened with a tool such as list reduction or multivoting.
- Criteria that are often used fall under the general categories of effectiveness, feasibility, capability, cost, time required, support or enthusiasm of team and of others (Always important in CTS). Here are other commonly used criteria:

For selecting a problem or an improvement opportunity:

- Within control of the team
- Financial payback
- Resources required (for example; money and people)
- Customer pain caused by the problem
- Urgency of problem
- Team interest or buy-in U
- Effect on other systems
- Management interest or support
- Difficulty of solving
- Time required to solve.

For selecting a solution:

- Root causes addressed by this solution
- Extent of resolution of problem
- Cost to implement (for example, money and time)
- Return on investment; availability of resources (people, time)
- Ease of implementation
- Time until solution is fully implemented
- Cost to maintain (for example, money and time)
- Ease of maintenance
- **Support or opposition to the solution**
- **Enthusiasm by team members**
- Team control of the solution
- Safety, health, or environmental factors
- Training factors
- Potential effects on other systems
- Potential effects on customers or suppliers
- Value to customer
- Potential problems during implementation
- Potential negative consequences.

- This matrix can be used to compare opinions. When possible, however, it is better used to summarize data that have been collected about the various criteria.
- Sub-teams can be formed to collect data on the various criteria.
- Several criteria for selecting a problem or improvement opportunity require guesses about the ultimate solution. For example: evaluating resources required, payback, difficulty to solve, and time required to solve. Therefore, your rating of the options will be only as good as your assumptions about the solutions.
- It's critical that the high end of the criteria scale (5 or 3) always is the end you would want to choose. Criteria such as cost, resource use and difficulty can cause mix-ups: low cost is highly desirable! If your rating scale sometimes rates a desirable state as 5 and sometimes

as 1, you will not get correct results. You can avoid this by rewording your criteria: Say "low cost" instead of "cost"; "ease" instead of "difficulty." Or, in the matrix column headings, write what generates low and high ratings. For example:

Importance	Cost	Difficulty
low = 1 high = 5	high = 1 low = 5	high = 1 low = 5

- When evaluating options by method 1, some people prefer to think about just one option, rating each criterion in turn across the whole matrix, and then doing the next option and so on. Others prefer to think about one criterion, working down the matrix for all options, then going on to the next criterion. Take your pick.
- If individuals on the team assign different ratings to the same criterion, discuss this so people can learn from each other's views and arrive at a consensus. Do not average the ratings or vote for the most popular one.
- In some versions of this tool, the sum of the unweighted scores is also calculated and both totals are studied for guidance toward a decision.
- When this tool is used to choose a plan, solution, or new product, results can be used to improve options. An option that ranks highly overall but has low scores on criteria A and B can be modified with ideas from options that score well on A and B. This combining and improving can be done for every option, and then the decision matrix used again to evaluate the new options.

6.2. Multivoting

Also called: NGT voting, nominal prioritization

Variations: sticking dots, weighted voting, multiple picking-out method (MPM)

6.2.1. *Description*

Multivoting narrows a large list of possibilities to a smaller list of the top priorities or to a final selection. Multivoting is preferable to straight voting because it allows an item that is favored by all, but not the top choice of any, to rise to the top.

6.2.2. *When to Use Multivoting*

- After brainstorming or some other expansion tool has been used to generate a long list of possibilities.
- When the list must be narrowed down, and.
- When the decision must be made by group judgment.

6.2.3. *Multivoting Procedure*

Materials needed: flipchart or whiteboard, marking pens, 5 to 10 slips of paper for each individual, pen or pencil for each individual.

- Display the list of options. Combine duplicate items. [Affinity diagrams](#) can be useful to organize large numbers of ideas and eliminate duplication and overlap. List reduction may also be useful.
- Number (or letter) all items.
- Decide how many items must be on the final reduced list. Decide also how many choices each member will vote for. Usually, five choices are allowed. The longer the original list, the more votes will be allowed, up to 10.
- Working individually, each member selects the five items (or whatever number of choices is allowed) he or she thinks most important. Then each member ranks the choices in order of priority, with the first choice ranking highest. For example, if each member has five votes,

the top choice would be ranked five, the next choice four, and so on. Each choice is written on a separate paper, with the ranking underlined in the lower right corner.

- Tally votes. Collect the papers, shuffle them, then record on a flipchart or whiteboard. The easiest way to record votes is for the scribe to write all the individual rankings next to each choice. For each item, the rankings are totaled next to the individual rankings.
- If a decision is clear, stop here. Otherwise, continue with a brief discussion of the vote. The purpose of the discussion is to look at dramatic voting differences, such as an item that received both 5 and 1 ratings, and avoid errors from incorrect information or understandings about the item. The discussion should not result in pressure on anyone to change their vote.
- Repeat the voting process in steps 4 and 5. If greater decision-making accuracy is required, this voting may be done by weighting the relative importance of each choice on a scale of 1 to 10, with 10 being most important.

6.2.4. *Multivoting Example*

A team had to develop a list of key customers to interview. First, team members brainstormed a list of possible names. Since they wanted representation of customers in three different departments, they divided the list into three groups. Within each group, they used multivoting to identify four first-choice interviewees. This example shows the multivoting for one department.

Fifteen of the brainstormed names were in that department. Each team member was allowed five votes, giving five points to the top choice, four to the second choice, and so on down to one point for the fifth choice. The votes and tally are shown in the figure below. (The names are fictitious, and any resemblance to real individuals is strictly coincidental.) Although several of the choices emerge as agreed favorites, significant differences are indicated by the number of choices that have both high and low rankings. The team will discuss the options to ensure that everyone has the same information, and then vote again.

Votes in rank order: Rhonda's votes: 4, 9, 12, 2, 8 Terry's votes: 6, 10, 12, 9, 15 Pete's votes: 2, 9, 14, 4, 6		Martha's votes: 10, 8, 15, 12, 11 Al's votes: 8, 6, 11, 10, 4	
1. Buddy Ellis	6. Albert Stevens 5 + 1 + 4 = 10	11. Mike Frost 1 + 3 = 4	
2. Susan Legrand 2 + 5 = 7	7. Greg Burgess	12. Luke Dominguez 3 + 3 + 2 = 8	
3. Barry Williams	8. Joan McPherson 1 + 4 + 5 = 10	13. Joe Modjeski	
4. Lisa Galmon 5 + 2 + 1 = 8	9. Donald Jordan 4 + 2 + 4 = 10	14. Paul Moneaux 3	
5. Steve Garland	10. Sam Hayes 4 + 5 + 2 = 11	15. Chad Rusch 1 + 3 = 4	

Multivoting Example