Total Quality Tools

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Agenda

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3. Cause-and-Effect Diagrams
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7. Run Charts and Control Charts
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Total Quality Tools Defined

http://leanqcd.com/2010/08/factsheet-root-cause-analysis-2/

Writing about the use of statistical methods in Japan. Dr. Kaoru Ishikawa said:
"The above are the so-called seven indispensable tools . . . that are being used by everyone: company presidents, company directors, middle management, foremen, and line workers. These tools are also used in a variety of [departments], not only in the manufacturing [department] but also in the [departments] of planning, design, marketing, purchasing, and technology."

Total Quality Tools Defined

A tool, like a hammer, exists to help do a job. If the job includes continual improvement. problem solving, or decision making, the seven tools discussed in this chapter fit the definition. Each of these tools is some form of chart for the collection and display of specific kinds of data. Through the collection and display facility, the data become useful information—information that can be used to solve problems, enhance decision making, keep track of work being done, and even predict future performance and problems. The beauty of the charts is that they organize data so that we can immediately comprehend the message. This would be all but impossible without the charts, given the mountains of data flooding today's workplace.

Pareto Charts

The Pareto (pah-ray-toe) chart is a very useful tool wherever one needs to separate the important from the trivial. The chart, first promoted by Dr. Joseph Juran, is named after Italian economist and sociologist Vilfredo Pareto (1848—1923). He had the insight to recognize that in the real world a minority of causes lead to the majority of problems. This is known as the Pareto principle. Pick a category, and the Pareto principle will usually hold. For example, in a factory you will find that of all the kinds of problems you can name, only about 20% of them will produce 80% of the product defects: 80% of the cost associated with the defects will be assignable to only about 20% of the total number of defect types occurring. Examining the elements of this cost will reveal that once again 80% of the total defect cost will spring from only about 20% of the cost elements.

Pareto Charts

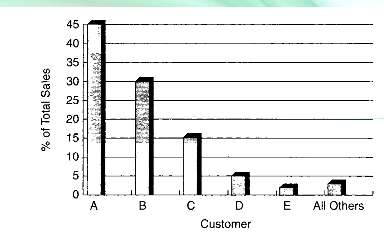


Figure 15–1
Pareto Chart: Percentage of Total Sales by Customer

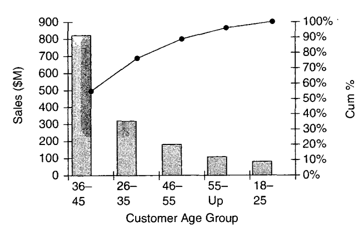


Figure 15–2
Swift V-12 Sales by Age Group

Pareto Charts

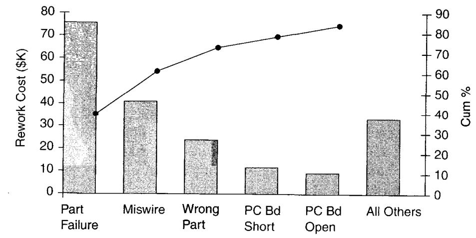


Figure 15–3
Top Five Detects by Rework Cost

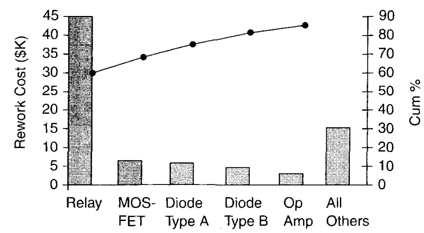


Figure 15–4
Rework Cost by Top Five Part Failure Categories

Pareto Charts

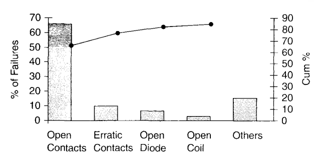
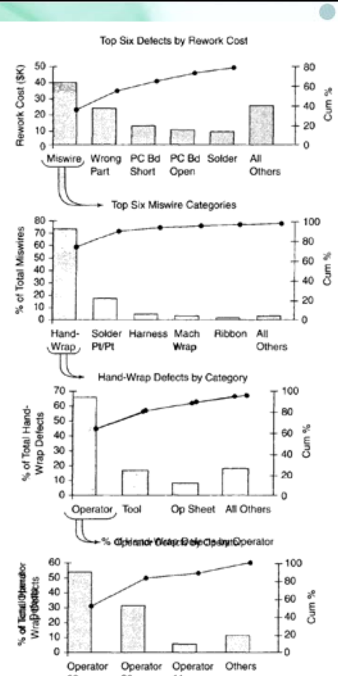


Figure 15–5
Relay Failure Categories



Cause-and-Effect Diagrams

A team typically uses a cause-and-effect diagram to identify and isolate causes of a problem. The technique was developed by the late Dr. Kaoru Ishikawa, a noted Japanese quality expert, so sometimes the diagram is called an Ishikawa diagram. It is also often called a fishbone diagram because that is what it looks like. In his book guide to quality Control, Ishikawa explains the benefits of using cause-and- effect diagrams as follows:

- ✓Creating the diagram itself is an enlightening, instructive process.
- ✓Such diagrams focus a group, thereby reducing irrelevant discussion.
- ✓Such diagrams separate causes from symptoms and force the issue of data collection.
- ✓Such diagrams can be used with any problem.

Cause-and-Effect Diagrams

The cause-and-effect diagram is the only tool of the seven tools that is not based on statistics. This chart is simply a means of visualizing how the various factors associated with a process affect the process's output. The same data could be tabulated in a list, but the human mind would have a much more difficult time trying to associate the factors with each other and with the total outcome of the process under investigation. The cause-and-effect diagram provides a graphic view of the entire process that is easily interpreted by the brain.

Cause-and-Effect Diagrams

Example:

machine	solderability	operator
solder	conveyer speed	temperature
preheat	materials	parts
operator attitude	operator attention	flux
conveyer angle	wave height	cleanliness
age of parts	age of boards	part preparation
parts vendors	board vendors	type of flux
specific gravity	machine maintenance	training
skill	vibration	storage
instruments	lighting	calibration
handling	wait-time	contamination
air quality	humidity	

Figure 15–7
Brainstormed List of Possible Causes for Solder Defects

Cause-and-Effect Diagrams

Example:

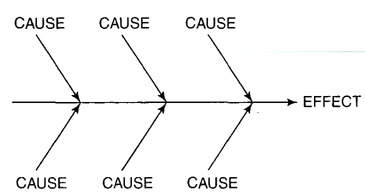


Figure 15–8
Basic Cause-and-Effect or Fishbone Diagram

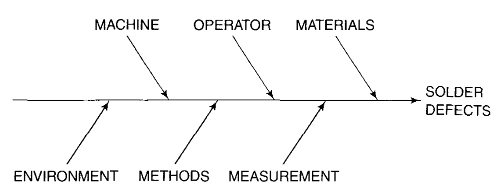


Figure 15–9
Cause-and-Effect Diagram with
Major Causes and Effect Assigned

Cause-and-Effect Diagrams

Example:

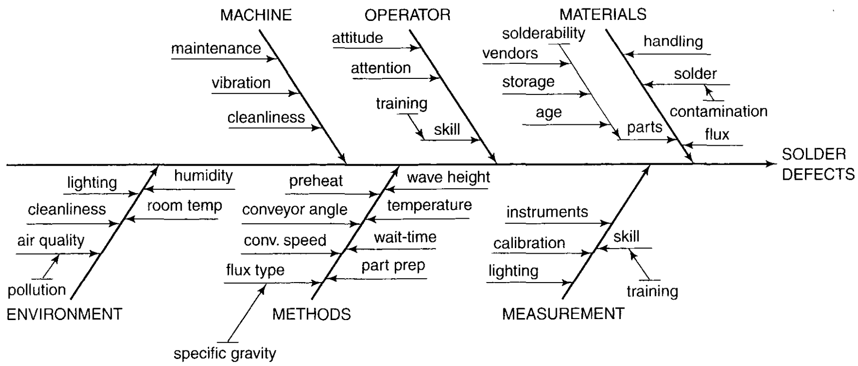


Figure 15–10
Completed Cause-and-Effect Diagram

Check Sheets

The check sheet is introduced here as the third of the seven tools. The fuel that powers the total quality tools is data. In many companies, elaborate systems of people, machines. and procedures exist for the sole purpose of collecting data. 1t times, this quest for data has become zealous to the point of obscuring the reason for data collection in the first place. Many organizations are literally drowning in their own data, while at the same time not knowing what is actually going on; they are “data rich and information poor.” With the advent of powerful desktop computers, information collection has become an end unto itself in many instances.

Check Sheets

Having access to data is essential. However, problems arise when trivial data cannot be winnowed from the important and when there is so much of it that it cannot be easily translated into useful information. Check sheets help deal with this problem. Check sheets can be valuable tools for converting data into useful and easy-to-use information. The key is teaching operators how to employ them and empowering them to do so.

Check Sheets

Shaft length: Week of 7/11 (Spec: 1.120–1.130")

Date	Length	Date	Length	Date	Length	Rem
11	1.124	11	1.128	11	1.123	
11	1.126	11	1.128	11	1.125	
11	1.119	11	1.123	11	1.122	
11	1.120	11	1.122	11	1.123	
12	1.124	12	1.126	12	1.125	
12	1.125	12	1.127	12	1.125	
12	1.121	12	1.124	12	1.125	
12	1.126	12	1.124	12	1.127	
13	1.123	13	1.125	13	1.121	
13	1.120	13	1.122	13	1.118	
13	1.124	13	1.123	13	1.125	
13	1.126	13	1.123	13	1.124	
14	1.125	14	1.127	14	1.124	
14	1.126	14	1.129	14	1.125	
14	1.126	14	1.123	14	1.124	
14	1.122	14	1.124	14	1.122	
15	1.124	15	1.121	15	1.123	
15	1.124	15	1.127	15	1.123	
15	1.124	15	1.122	15	1.122	
15	1.123	15	1.122	15	1.121	

Figure 15–11
Weekly Summary of Shaft Dimensional Tolerance Results
Note: This is *not* a check sheet.

Check Sheets

Check Sheet

Shaft length: Week of 7/11 (Spec: 1.120–1.130")

1.118**	13
1.119**	11
1.120	11 13
1.121	12 13 15 15
1.122	11 11 13 14 14 15 15 15
1.123	11 11 11 13 13 13 14 15 15 15
1.124	11 12 12 12 13 13 14 14 14 15 15 15
1.125	11 12 12 12 12 13 13 14 14
1.126	11 12 12 13 14 14
1.127	12 12 14 15
1.128	11 11
1.129	14
1.130	
1.131**	
1.132**	

** Out of Limits

Enter day of month for data point.

Figure 15–12
Check Sheet of Shaft Dimensional Tolerance Results

Check Sheets

Operator No.	Bench No.	11/2 AM	11/2 PM	11/3 AM	11/3 PM	11/4 AM	11/4 PM	11/5 AM	11/5 PM	11/6 AM	11/6 PM	Week Totals	
8	A3					●				○ □		○ - 1 ● - 1 □ - 1	3
10	A2			● ●			□					● - 2 □ - 1	3
11	B1	○						○				○ - 2	2
13	A1		○				△				□ □	○ - 1 △ - 1 □ - 2	4
28	C2	○ ● ○	○ △	○ ○ ○	△ ○ ○	○	○ ○	○ △	□ ○	○ ○	○ ● ○	○ - 17 ● - 2 △ - 3 □ - 1	23
33	C3	○ ○ ○ △ ○	● ○ ○ ○	○ △ ○ ○	○ ○ □	○ ●	□ ○ ○	△ ○ ○	○ ○	○ ○ ○ ○ △ ○	○ ○ ○ ○	○ - 28 ● - 2 △ - 4 □ - 2	36
40	B2	+							○ ●			○ - 1 ● - 1 + - 1	3
	Half-day totals	10	7	9	6	4	7	6	6	10	9	39	35
	Full-day totals	17		15		11		12		19		74	

LEGEND:
○ = Hand wrap
● = Solder point to point
△ = Harness
+ = Ribbon
□ = Other

Figure 15–13
Check Sheet: Defect Factors—Miswires

Histograms

Histograms are used to chart frequency of occurrence. How often does something happen? Any discussion of histograms must begin with an understanding of the two kinds of data commonly associated with processes: attributes and variables data. Although they were not introduced as such, both kinds of data have been used in the illustrations of this chapter. An attribute is something that the output product of the process either has or does not have. From one of the examples, either an electronic assembly had wiring errors or it did not. Another example shows that either an assembly had broken screws or it did not. These are attributes. The example of making shafts of a specified length was concerned with measured data. That example used shaft length measured in thousandths of an inch, but any scale of measurement can be used, as appropriate for the process under scrutiny. A process used in making electrical resistors would use the scale of electrical resistance in ohms, another process might use a weight scale, and so on. Variables data are something that results from measurement.

Histograms

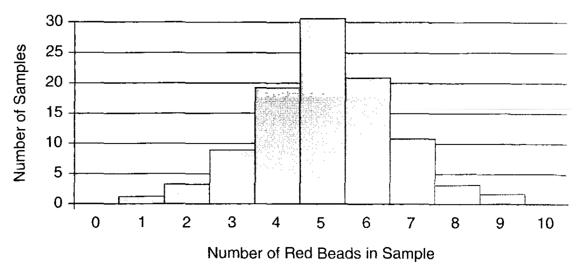


Figure 15–15
Frequency Distribution of Red Beads in Samples

Samples with 0 red beads	0
Samples with 1 red bead	1
Samples with 2 red beads	3
Samples with 3 red beads	9
Samples with 4 red beads	19
Samples with 5 red beads	31
Samples with 6 red beads	21
Samples with 7 red beads	11
Samples with 8 red beads	3
Samples with 9 red beads	2
Samples with 10 red beads	0
Total samples taken	100

Figure 15–16
Data on Red Beads in Samples

Histograms

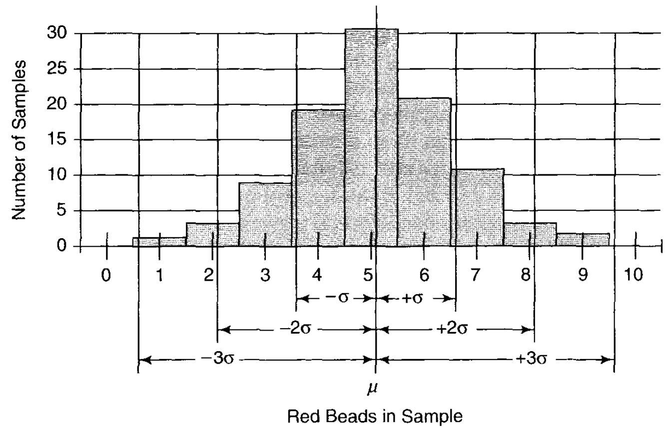


Figure 15–18
Application of Standard Deviation Calculations to Red Bead Histogram

Histograms

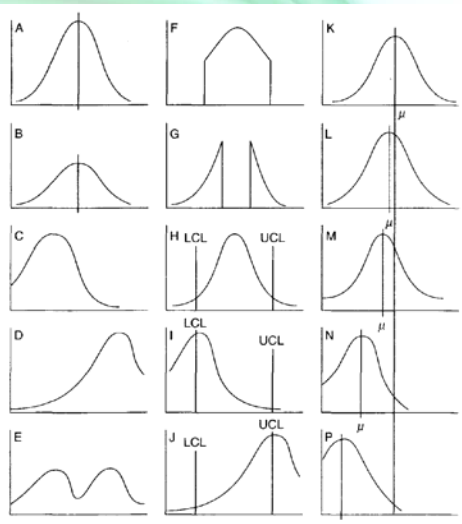


Figure 15–19
Histograms of Varying Shapes

Scatter Diagrams

The fifth of the seven tools is the scatter diagram. It is the simplest of the seven and one of the most useful. The scatter diagram is used to determine the correlation (relationship) between two characteristics (variables). Suppose you have an idea that there is a relationship between automobile fuel consumption and the rate of speed at which people drive. To prove. or disprove, such an assumption, you could record data on a scatter diagram that has miles per gallon (mpg) on the y-axis and miles per hour (mph) on the x-axis; mpg and mph are the two characteristics.

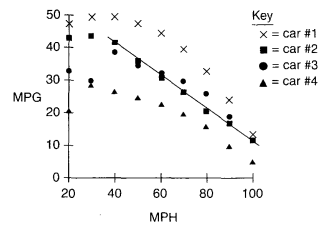


Figure 15–22
Scatter Diagram: Speed Versus Fuel Consumption for Four Automobiles

Scatter Diagrams

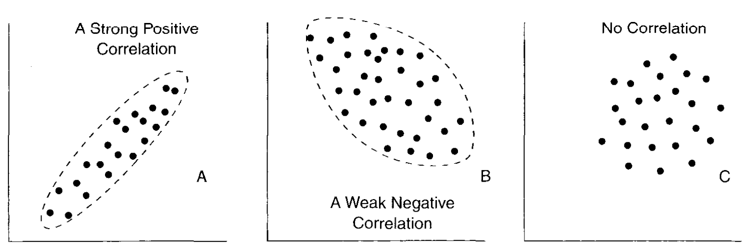


Figure 15–23
Scatter Diagrams of Various Correlations

Scatter Diagrams

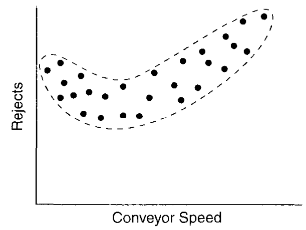


Figure 15–24
Scatter Diagram: Conveyor Speed Versus Rejects

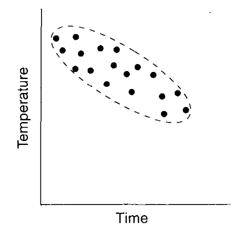


Figure 15–25
Scatter Diagram: Cleaning Solution Temperature Versus Cleaning Time

Run Charts and Control Charts

The run chart is straightforward, and the control chart is a much more sophisticated outgrowth of it. Therefore, the two are usually thought of together as a single tool. Both can be very powerful and effective for the tracking and control of processes, and they are fundamental to the improvement of processes.

Run Charts and Control Charts

Run Charts

The run chart records the output results of a process over time. The concept is strikingly simple, and, indeed, it has been used throughout modern times to track performance of everything from AAA membership to zwieback production. Because one axis (usually the x-axis) represents time, the run chart can provide an easily understood picture of what is happening in a process as time goes by. That is, it will cause trends to "jump" out at you. For this reason, the run chart is also referred to as a trend chart.

Run Charts and Control Charts

Run Charts

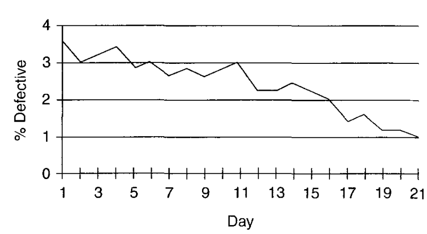


Figure 15–26
Run Chart: Pen Defect Rate for 21 Working Days

Run Charts and Control Charts

Control Charts

The problem with the run chart and, in fact, many of the other tools is that it does not help us understand whether the variation is the result of special causes—things such as changes in the materials used, machine problems, lack of employee training—or common causes that are purely random. Not until Dr. Walter Shewhart made that distinction in the 19205 was there a real chance of improving processes through the use of statistical techniques. Shewhart, then an employee of Bell Laboratories, developed the control chart to separate the special causes from the common causes.

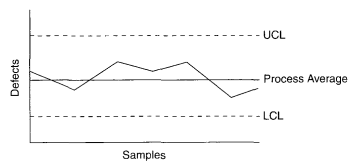


Figure 15–27
Basic Control Chart

Run Charts and Control Charts

Control Charts

In evaluating problems and finding solutions for them, it is important to distinguish between special causes and common causes. Data are plotted over time, just as with a run chart; the difference is that the data stay between the upper control limit (UCL) and the lower control limit (LCL) while varying about the center line or average only so long as the variation is the result of common causes (i.e., statistical variation). Whenever a special cause (nonstatistical cause) impacts the process, one of two things will happen: either a plot point will penetrate UCL or LCL, or there will be a "run" of several points in a row above or below the average line. When a penetration or a lengthy run appears, this is the control chart's signal that something is wrong that requires immediate attention.

Run Charts and Control Charts

Control charts are the appropriate tool to monitor processes. The properly used control chart will immediately alert the operator to any change in the process. The appropriate response to that alert is to stop the process at once, preventing the production of defective product. Only after the special cause of the problem has been identified and corrected should the process be restarted. Having eliminated a problem's root cause, that problem should never recur. (Anything less, however, and it is sure to return eventually.) Control charts also enable continual improvement of processes. When a change is introduced to a process that is operated under statistical process control charts, the effect of the change will be immediately seen. You know when you have made an improvement. You also know when the change is ineffective or even detrimental. This validates effective improvements, which you will retain. This is enormously difficult when the process is not in statistical control because the process instability masks the results, good or bad, of any changes deliberately made.

Stratification

Stratification is a simple tool in spite of its name. It involves investigating the cause of a problem by grouping data into categories. This grouping is called stratification. The groups might include data relative to the environment, the people involved, the machine(s) used in the process, materials, and so on. Grouping data by common element or characteristic makes it easier to understand the data and to pull insights from them.

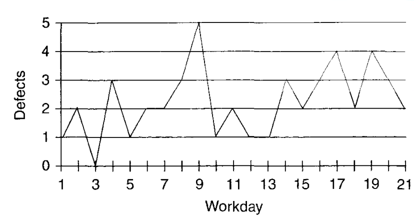


Figure 15–28
Chart of Operator Defects for November

Stratification

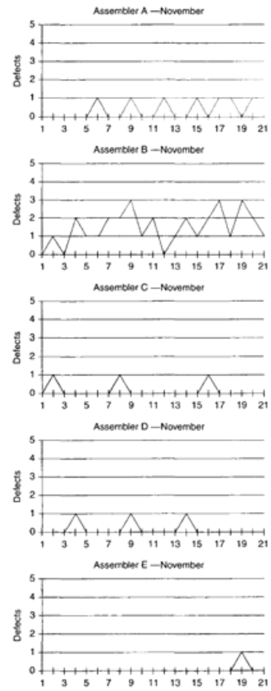


Figure 15–29
Stratified Charts for Each Operator

Stratification

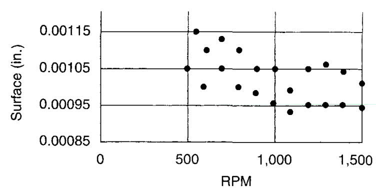


Figure 15–31
Scatter Diagram: Surface Flatness Versus Revolutions per Minute

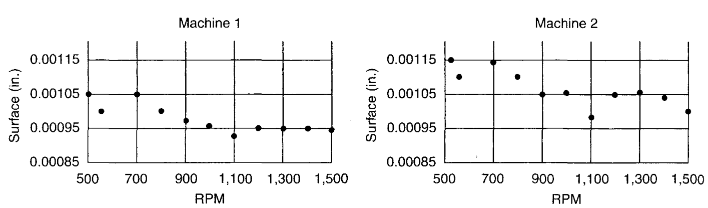


Figure 15–32
Stratified Scatter Diagrams: Surface Flatness Versus Revolutions per Minute

Some Other Tools Introduced

The preceding seven tools probably represent the seven basic methods most useful to all the people in the workplace. We recommend five more as necessary to complete the tool kit of any business enterprise, if not each of the players within the business:

✓Five-S
✓Flowcharts
✓Surveys
✓Failure mode and effects analysis (FMEA)
✓Design of experiments (DOE)

Some Other Tools Introduced

Five-S

Five-S is considered as essential to continual improvement. Its most significant proponent is Hiroyuki Hirano, author of 5 Pillars of the Visual Workplace, who claims that an organization that cannot implement five-S successfully will be unable to integrate any large-scale change. Hirano holds that TQM, JIT/Lean, and Kaizen are supported by the five pillars represented by the five S's and are probably unattainable without five-S. The authors heretofore have considered these five S's to be an integral part of TQM and JIT/Lean, but we have come to believe that they should be recognized as a tool that is separable from TQM but that may serve as an entry point for TQM in many organizations.

Some Other Tools Introduced

Five-S

Japanese Word	Translation	Action Implied	English Word for Five-S
Seiri	Organization	Sort useful from useless	Sort
Seiton	Neatness	Everything in its place	Store
Seiso	Cleaning	Workplace and equipment clean	Shine
Seiketsu	Standardization	Select the best practice	Standardize
Shitsuke	Discipline	Make sure rules are followed	Sustain

Some Other Tools Introduced

Flowcharts

Both W. Edwards Deming and Joseph Juran promote the use of flowcharts. A flowchart is a graphic representation of a process. P necessary step in improving a process is to flowchart it. In this way, all parties involved can begin with the same understanding of the process. It may be revealing to start the flowcharting process by asking several different team members who know the process to flowchart it independently. If their charts are not the same, one significant problem is revealed at the outset; there is not a common understanding of the way the process works. Another strategy is to ask team members to chart how the process actually works and then chart how they think it should work. Comparing the two versions can be an effective way to identify causes of problems and to suggest improvement possibilities.

Some Other Tools Introduced

Flowcharts

The most commonly used flowcharting method is to have the team, which is made up of the people who work within the process and those who provide input to or take output from the process, develop the chart. It is important to note that to be effective, the completed flowchart must accurately reflect the way the process actually works, not how it should work. After a process has been flowcharted, it can be studied to determine what aspects of it are problematic and where improvements can be made.

Some Other Tools Introduced

Flowcharts

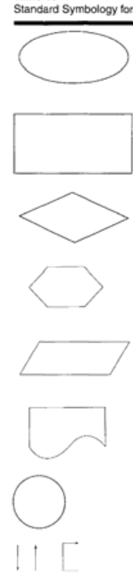


Table 15–1
Standard Symbology for Flowcharts

(oval)	An oval (or rectangle with rounded ends) is customarily used to denote the *start* or *finish* of a process.
(rectangle)	A rectangle is customarily used to denote a *process step*, an activity, or an operation. It may also represent an entire subprocess.
(diamond)	A diamond is always used to denote a *decision point*. This is usually a *yes* or *no* function but could also represent an *if/then* statement. The process flow branches off in two or more directions here. The branch followed depends on the decision.
(hexagon)	This symbol denotes preparation.
(parallelogram)	A parallelogram denotes an input or output.
(document)	This symbol represents *documentation* or paperwork produced or required by the process.
(circle)	A circle is used as a connector (from one chart or page to another, with numbers if necessary).
(arrows)	A line with an arrow always indicates the *path* and *direction* of flow in the process.

These are the symbols you will use most often, and they will fit virtually any situation.

Some Other Tools Introduced

Flowcharts

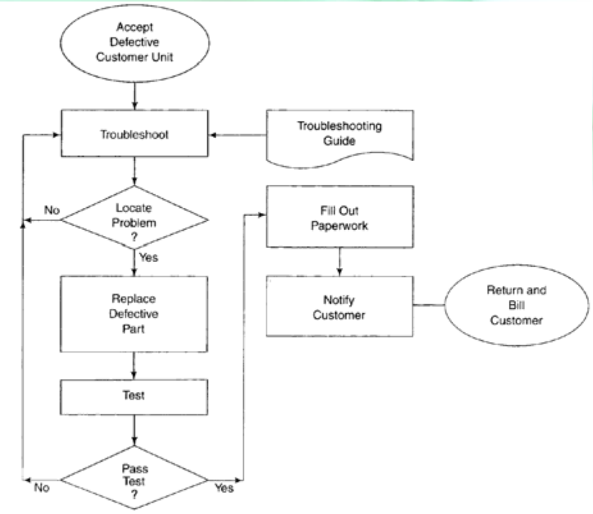


Figure 15–33
Typical Processes Flowchart

Some Other Tools Introduced

Surveys

At first glance, the survey may not seem to be indispensible. When you think about it, though, all of the tools are designed to present information—information that is pertinent, easily understood by all, and valuable for anyone attempting to improve a process or enhance the performance of some work function. The purpose of a survey is to obtain relevant information from sources that otherwise would not be heard from—at least not in the context of providing helpful data. Because you design your own survey, you can tailor it to your needs. We believe that the survey meets the test of being a total quality tool. Experience has shown that the survey can be very useful.

Some Other Tools Introduced

Surveys

Surveys can be conducted internally as a kind of employee feedback on problem areas or as internal customer feedback on products or services. They can also be conducted with external customers, your business customers, to gain information about how your products or services rate in the customers' eyes. The customer (internal or external) orientation of the survey is important because the customer, after all is said and done, is the only authority on the quality of your goods and services. Some companies conduct annual customer satisfaction surveys. These firms use the input from customers to focus their improvement efforts.

Some Other Tools Introduced

Failure Mode and Effects Analysis

Failure mode and effects analysis (FMEA) tries to identify all possible potential failures of a product or process, prioritize them according to their risk, and set in motion action to eliminate or reduce the probability of their occurrence. FMEA cannot by itself bring about this happy ending, since it is an analytical tool, not a problem solver. But it will point to the problems that must be solved through the use of the other tools.

Some Other Tools Introduced

Failure Mode and Effects Analysis

Failure mode and effects analysis—the name itself is enough to scare off the unfamiliar. So you don't give up on FMEA before we get into it, let's simplify the concept. FMEA just tries to identify all the possible types (modes) of failures that could happen to a product or a process before they happen. Once the possible "failure modes" have been identified, the "effects analysis" kicks in and studies the potential consequences of those failures. Next the consequences of each potential failure are ranked by

- ✓ Seriousness to the customer
- ✓ Probability of the fault's occurrence
- ✓ Probability of the fault's detection by the systems responsible for defect prevention or detection

Some Other Tools Introduced

Failure Mode and Effects Analysis

When to Use FMEA

FMEA should be employed at the following points:

- ✓ During the design or redesign of a process, product, or service
- ✓ When improvements are needed or planned for existing processes, products, or services
- ✓ When existing processes, products, or services are to be used in a new way
- ✓ During after-the-fact failure analysis
- ✓ When safety or health is an issue

Some Other Tools Introduced

Design of Experiments

Design of experiments (DOE) is a very sophisticated method for experimenting with processes with the objective of optimizing them. If you deal with complicated processes that have multiple factors affecting them, DOE may be the only practical way of bringing about improvement. Such a process might be found in a wave soldering machine, for example. Wave solder process factors include these:

Solder type	Conveyor speed	Flux specific gravity
Solder temperature	Conveyor angle	Wave height
Preheat temperature	PC board layer count	Flux type
PC board groundplane mass		

Some Other Tools Introduced

Design of Experiments

These 10 factors influence the process, often interacting with one another. The traditional way to determine the proper selection or setting was to vary one factor while holding all others fixed. That kind of experimentation led to making hundreds of individual runs for even the simplest processes. With that approach, it is unusual to arrive at the optimum setup because a change in one factor frequently requires adjustment of one or more of the other factors for best results.

Some Other Tools Introduced

Design of Experiments

DOE reduces the number of runs from hundreds to tens as a rule, or by an order of magnitude. This means of process experimentation allows multiple factor adjustment simultaneously, shortening the total process, but equally as important, revealing complex interaction among the factors. A well-designed experiment can be concluded on a process such as wave soldering in 30—40 runs and will establish the optimum setting for each of the adjustable parameters for each of the selected factors. For example, optimal settings for conveyor speed, conveyor angle, wave height, preheat temperature, solder temperature, and flux specific gravity will be established for each PC board type, solder alloy, and so on.

Management's Role in Tool Deployment

- ✓Communicate. Let everyone know what is going on and what the results are. Help them understand why it is good for them, for the whole enterprise, and, yes, even for the nation.
- ✓Never assume that you know it all. The people who live with the processes day in and day out know far more about what is wrong with them and how to improve them than any manager. Never delude yourself that you have learned all you need to know about total quality. It will never happen because total quality is a dynamic and ever-expanding concept.

Management's Role in Tool Deployment

- ✓Start slowly. Don't try to organize an entire factory or office complex into improvement teams and train everyone in sight on day one. Take it one or two steps at a time, training as you go. Be careful to pick early projects that have high prospects for success.
- ✓But start. The worst choice a manager could make today is to decide that total quality is not for his or her business. It is for every conceivable kind of business, whether large or small, whether public, private, military, civilian, mass production, job shop, classroom, or office. It would be a tragedy to decide not to start this journey when so much is at stake.

Selecting the Right Tool for the Job

Table 15–2
Functionality Matrix: Quality Tools

	Cause & Effect Diagram	Check Sheet	Control Chart	Design of Experiments	Five-S	Flowchart	FMEA	Histogram	Pareto Chart	Run Chart	Scatter Diagram	Stratification	Survey
Alert operator to change in process			X							X			
Alert operator to special cause			X										
Analyze by sorting into categories												X	
Analyze potential causes	X					X			X		X	X	
Collect data from targeted groups													X
Determine relationships between variables (correlation)				X							X		
Experiment with a process				X		X							
Find patterns in data										X		X	
Frequency distribution (frequency of values to occur)								X					
Identify possible causes	X					X			X			X	
Improve/sustain work efficiency					X								
Investigate causes	X					X			X		X	X	
Monitor a process (continuing)		X	X							X			
Observe results over time			X							X			
Present information while collecting data		X							X	X			
Process analysis	X	X	X	X		X	X		X	X	X	X	
Process capability			X					X					
Process optimization				X		X		X			X		
Rank potential product/process failures for elimination							X						
Separate significant from trivial									X				
Study a process	X	X				X	X	X					
View process over time			X							X			

References

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Total Quality Tools

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