CHAPTER 67

Quality Tools for Learning and Improvement

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1. MODEL FOR IMPROVEMENT

Improvement comes from the application of knowledge to relevant problems or opportunities. This knowledge may be knowledge of engineering, operations, complex theories, or simply experience of the way some activity is currently done. Generally, the more complete the appropriate knowledge, the better the improvements will be when applying the knowledge to making changes. Therefore, improvement must be based on building and applying knowledge. This view leads to the model for improvement in Figure 1 (Langley 1998). The model consists of three fundamental questions that define the opportunity and a method (the PDSA cycle) to increase the requisite knowledge.

This model provides a framework for a trial-and-learning approach to improvement. The word "trial" suggests a test of a change. The word "learning" implies that some criteria exist by which to study and learn from the trial. The focus on the questions accelerates the building of knowledge by emphasizing a framework for learning, the use of data, and the design of effective tests or trials. Learning from testing changes on a small scale is encouraged, rather than from extensive study of the problem before any changes are attempted. The PDSA (Plan, Do, Study, Act) cycle in the model provides the framework for an efficient trial-and-learning methodology. We refer to this cycle as the cycle for learning and improvement. The cycle begins with a plan and ends with action being taken based on the learning gained from the Plan, Do, and Study phases of the cycle.

Many improvement efforts can be successfully completed using only subject matter knowledge to answer the three questions of the model for improvement. In other cases, additional knowledge is needed to develop a change. What are some ways to obtain this knowledge? A number of different tools and methods are described in this Handbook and are summarized in this chapter. These methods and tools for improvement in this chapter are organized into five use categories:

1. Viewing Systems and Processes
2. Gathering Information
3. Organizing Information

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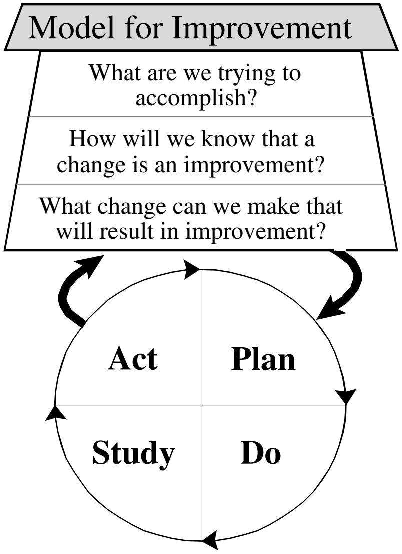

Figure 1 The Model for Improvement. (Copyright 1980–1998 Associates in Process Improvement)

4. Understanding Variation
5. Understanding Relationships

The 19 improvement tools and methods described in this chapter are summarized in Table 1. Note that these tools are sometimes called by slightly different names in other references.

Figures 2 through 20 show pictorial examples of these tools/methods. Each tool or method is considered in light of five questions about the tool:

1. *What* is this tool?
2. *Why* would someone choose to use this tool?
3. What are important considerations when *planning* to use this tool?
4. What *other tools* might be useful in conjunction with this tool?
5. What are the basic *mechanics* of using this tool?

A case study at the end of the chapter illustrates the use of the tools in an improvement project.

2. TOOLS FOR VIEWING SYSTEMS AND PROCESSES

- *What?* The flow diagram (often called flowchart) is a graphic representation of a series of activities that define a process.
- *Why?* This tool is useful when there is a need to describe how a process is being carried out or should be carried out. In particular, the flow diagram is very useful when a team needs to understand how the process works.
- *Planning:* The scope of the process (beginning and end) must be defined. The developers of the flow diagram must agree on the use of symbols and the level of detail needed. These choices will be guided by the purpose of the flowchart.
- *Other tools:* The flow diagram can help plan where to collect data. Use of the flow diagram may help initiate using the tools for organizing information, such as the cause-and-effect diagram.
- *Mechanics:* Decide on the process stop–start points, level of detail, and symbols. Have those knowledgeable about the process construct the chart. There are a number of special versions of

TABLE 1 Overview of Methods and Tools for Improvement

Use Category	Method or Tool	Typical Use of Method or Tool
Viewing systems and processes	1. Flow diagram	Develop a picture of a process. Communicate and standardize processes.
	2. Linkage of processes	Develop a picture of a system composed of processes linked together.
Gathering information	3. Form for collecting data	Plan and organize a data-collection effort
	4. Surveys	Obtain information from people.
	5. Benchmarking	Obtain information on performance and approaches from other organizations.
	6. Creativity methods	Develop new ideas and fresh thinking.
Organizing information	7. Affinity diagram	Organize and summarize qualitative information.
	8. Force field analysis	Summarize forces supporting and hindering change.
	9. Cause-and-effect diagram	Collect and organize current knowledge about potential causes of problems or variation.
	10. Matrix diagram	Arrange information to understand relationships and make decisions.
	11. Tree diagram	Visualize the structure of a problem, plan, or any other opportunity of interest.
	12. Quality function deployment (QFD)	Communicate customer needs and requirements through the design and production processes.
Understanding variation	13. Run chart	Study variation in data over time; understand the impact of changes on measures.
	14. Control chart	Distinguish between special and common causes of variation.
	15. Pareto chart	Focus on areas of improvement with greatest impact.
	16. Frequency plot	Understand location, spread, shape, and patterns of data.
Understanding relationships	17. Scatterplot	Analyze the associations or relationship between two variables; test for possible cause and effect.
	18. Two-way table	Understand cause and effect for qualitative variables.
	19. Planned experimentation	Design studies to evaluate cause-and-effect relationships and test changes.

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flow diagrams (for example, complexity flow diagram, deployment flowchart, and top-down flow diagram).

- *What?* The linkage of processes (LOP) is a method to describe a system composed of processes linked together to accomplish a common purpose.
- *Why?* The LOP can be used to develop a systems view of an organization or a group of processes. A LOP can be used to explore the interdependencies and complexities in a system or subsystem.
- *Planning:* The boundaries of the system must be defined; the level of process detail should be uniform. This will be determined by the purpose of the LOP. People knowledgeable about the entire system will be needed to build a LOP.
- *Other Tools:* The linkage can be used as a data collection form. Parts of a LOP can be expanded using flow diagrams. The LOP provides a structure for using the tools to organize information.
- *Mechanics:* Decide on purpose and system boundaries; define processes at a uniform level of detail (initially target about 20-80 processes); assemble related processes and show linkages between processes.

3. TOOLS FOR GATHERING INFORMATION

- *What?* The form for collection of data provides an organized method to record observations or measurements to be used in the process of analysis.

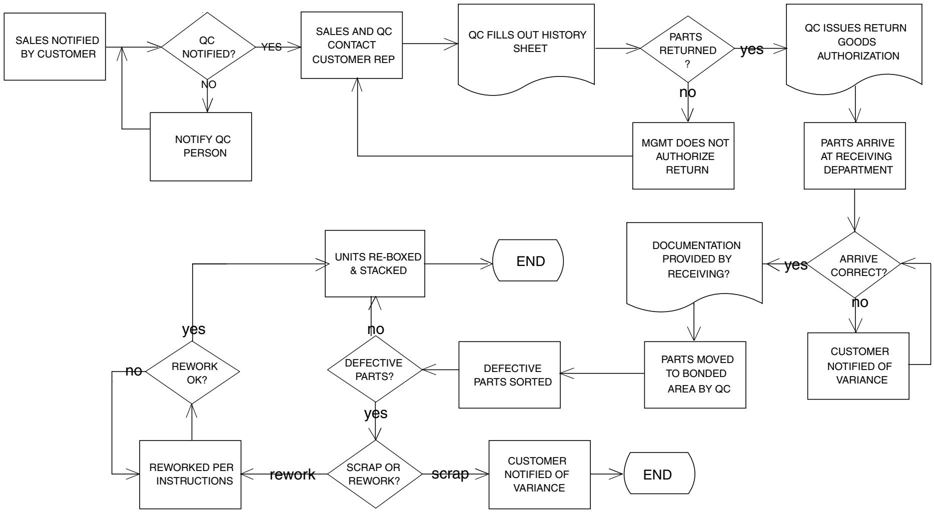

Figure 2 Flow Diagram. (Copyright 1980–1998 Associates in Process Improvement)

- *Why?* This tool is used to facilitate the recording of data and, in some cases, begin the analysis of data.
- *Planning:* It is important to have a clear understanding of what we want to learn from the data and who will collect and analyze it. The process of planning the form may force a more thorough consideration of the issues. Two types of forms are the check sheet and the recording form.
- *Other tools:* A form for collecting data is often built into other data analysis tools such as a control chart. All of the other data analysis tools will require some sort of data collection form for capturing observations or measurements.
- *Mechanics:* Decide on the questions to be answered. Decide on exactly what observations or data will be recorded and what format will be most useful. Operational definitions of terms can be important on a form for data collection.
- *What?* A survey is a method of collecting information directly from people about their feelings, motivations, plans, beliefs, experiences, and backgrounds.
- *Why?* As part of a PDSA cycle, a survey is a type of data-collection process that focuses on getting information from people to answer a question(s) posed in the planning phase of the cycle.
- *Planning:* Determine the objective of the survey. Consider why a survey is the most appropriate method for obtaining the desired information. Determine what questions are to be answered by the survey.
- *Other tools:* Any of the data-analysis tools may be used with data from surveys. Benchmarking is a special kind of survey. Surveys are required for a QFD analysis.
- *Mechanics:* Surveys can be administered in a number of ways: written surveys, personal interviews, group interviews, observations, and trading places.
- *What?* A process of measuring products, services, and business practices against the toughest competitors or those companies recognized as industry leaders.
- *Why?* Benchmarking, in its simplest form, is merely looking around at how others are doing things and trying to learn new approaches and possibilities. We can all benefit from doing this, and most organizations are already doing this on an informal basis. Benchmarking provides a formal method, with some structure, for making these observations and then using this information for improvement.
- *Planning:* Successful benchmarking efforts are organized using the PDSA cycle. A typical benchmarking exercise would be organized into four or five learning cycles.
- *Other tools:* Benchmarking is a type of survey. All of the other methods and tools can be used to organize and analyze data from benchmarking studies.
- *Mechanics:* The 10-step benchmarking process can be organized using the Model as a series of PDSA Cycles.

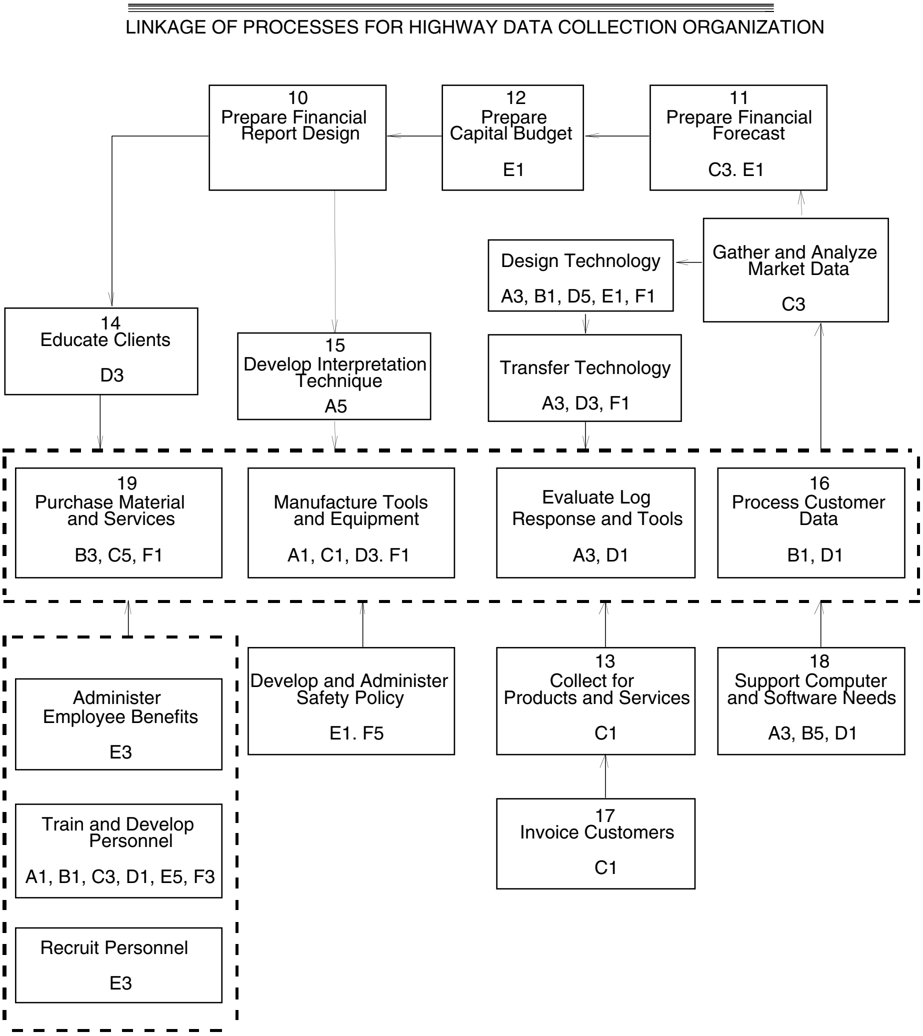

Figure 3 Linkage of Processes. (Copyright 1980–1998 Associates in Process Improvement)

- *What?* A collection of tools and methods (provocations, random entry, six thinking hats, concept triangle, etc.) based on creative thinking that fit with traditional quality improvement methods. The methods are serious, deliberate, and systematic; they do not rely on acting crazy or pure natural talent.
- *Why?* Based on theory and knowledge of how the brain works as an active, self-organizing information system, the lateral (creative) thinking tools are designed to allow people to deliberately produce thoughts that are outside their normal thinking patterns. This in turn greatly increases the chances of producing new ideas, new concepts, and new perceptions from old situations.
- *Planning:* The tools should be used when new ideas or concepts are required to accomplish the improvement initiative.
- *Other tools:* The creativity methods provide a refreshing alternative to the other methods to gather information. Tools for organizing information can be used with information collected using the creativity methods.

Problem	Occurrences				
	Monday	Tuesday	Wednesday	Thursday	Friday
Out of paper					
Out of toner					
Copies too light					
Sorter problems					
Document feeder					
Transparency feed					
Other:					
Copier stopped					
Panel won't clear					
No power					

Figure 4 Forms for Collection of Data. (Copyright 1980–1998 Associates in Process Improvement)

- *Mechanics:* Provocations seek to jolt us or start us outside of these mainstream patterns so that we can then increase the probability of connecting with other patterns to produce new ideas, concepts and perceptions.

4. TOOLS FOR ORGANIZING INFORMATION

- *What?* The affinity diagram is a method to summarize qualitative data into groups with common themes.
- *Why?* The affinity diagram should be used when there are large amounts of qualitative data that must be summarized before proceeding. An example is the answers to open ended questions on a survey.
- *Planning:* Much will depend on the type of qualitative data. There may be many useful ways to group the data, so being creative and open-minded is helpful.

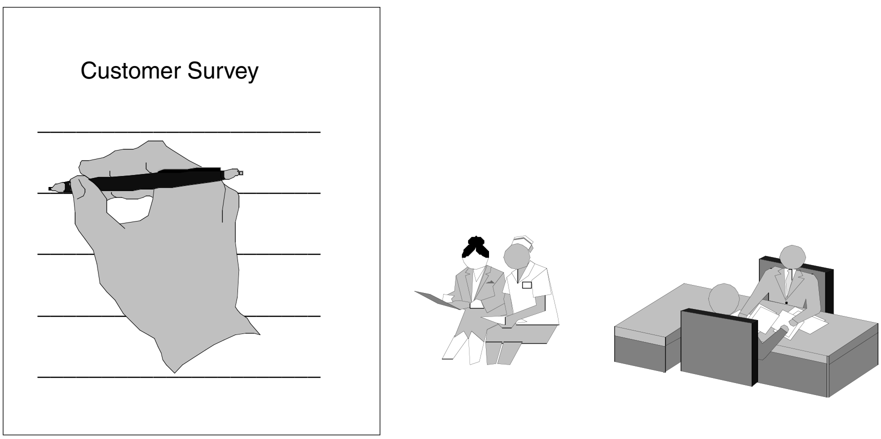

Figure 5 Surveys. (Copyright 1980–1998 Associates in Process Improvement)

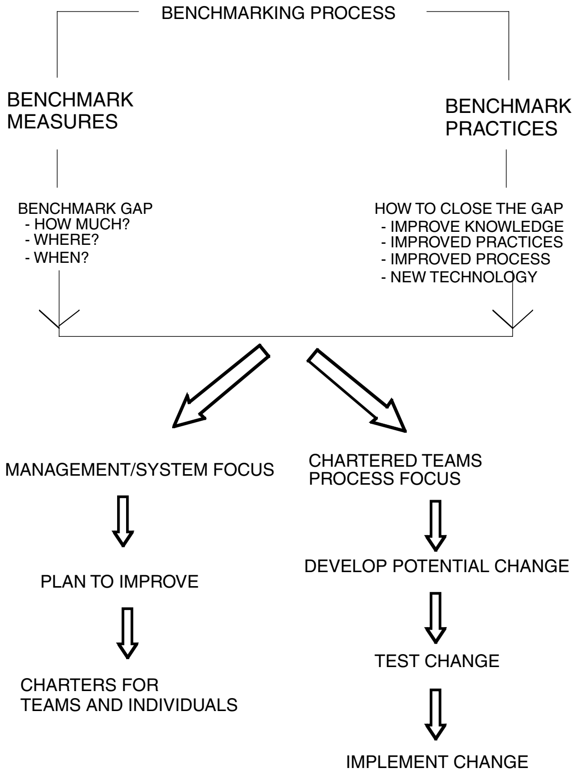

Figure 6 Benchmarking. (Copyright 1980–1998 Associates in Process Improvement)

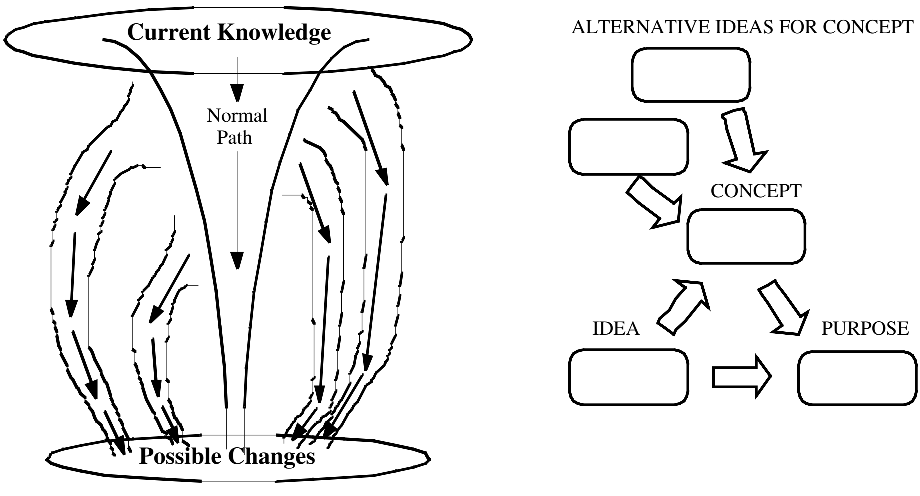

Figure 7 Creativity Methods. (Copyright 1980–1998 Associates in Process Improvement)

Each manager is doing the next level job	Products routinely miss the market window	Customer complaints about product consistency
Managers are task oriented	Increase in unprofitable products	Customer complaints about product consistency
Employee grievances have increased 14%	Change over from one product campaign to another is difficult and time consuming	Product variability causes downtime of equipment & maintenance PM time increase
Turnover rate is high - 23%	Costs associated with product introduction are typically 30% over estimates	Customer inspection results do not match our documented results
Decision making process is cumbersome		
Globalization of market requires managers that appreciate other cultures		

Figure 8 Affinity Diagram. (Copyright 1980–1998 Associates in Process Improvement)

- *Other tools:* Tools for gathering information that result in qualitative data can lead to an affinity analysis. After constructing an affinity diagram, the results may be summarized in a Pareto chart. Categories developed during an affinity analysis can be used for stratification with the other tools.
- *Mechanics:* Make a clear statement of the issue to be considered; record the qualitative data on cards; sort into related groups; create the main subgroup themes.
- *What?* The force field analysis is a method to analyze situations that support and inhibit a planned change.
- *Why?* The force field analysis is typically used in planning to overcome restraining forces and reinforce driving forces when implementing a change.
- *Planning:* Develop a clear definition of the planned change. The group will need knowledge of the organization as well as its outside environment.
- *Other tools:* The force field analysis is a planning tool. Information to do the analysis can come from any of the methods to gather information.

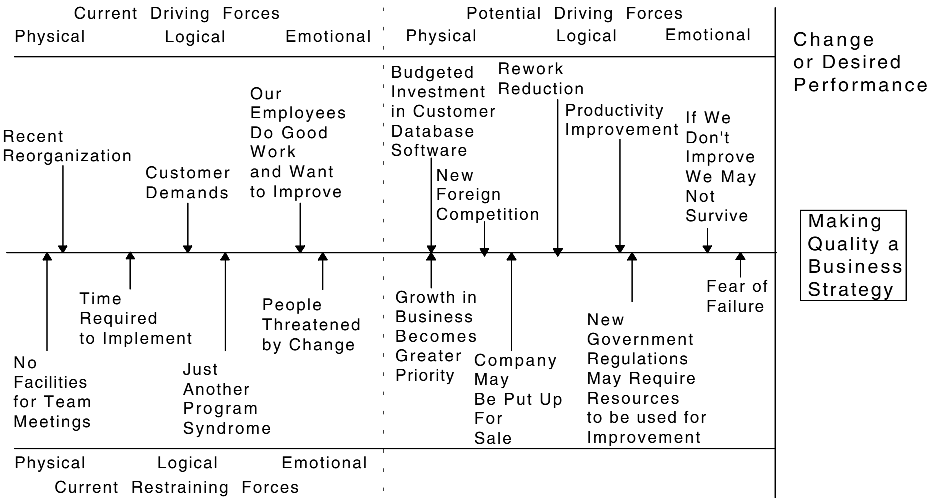

Figure 9 Force Field Analysis. (Copyright 1980–1998 Associates in Process Improvement)

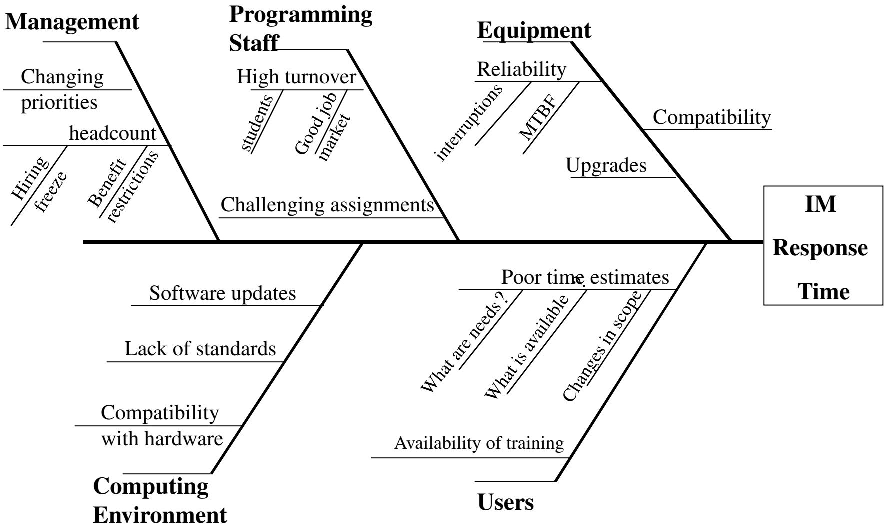

Figure 10 Cause-and-Effect Diagram. (Copyright 1980–1998 Associates in Process Improvement)

- *Mechanics:* Develop a clear statement of the change to be considered, brainstorm restraining, and reinforcing forces. Place these into categories, if useful.
- *What?* The cause-and-effect diagram (C&E) is a tool for organizing a group's current knowledge about causes of a problem or variation in a quality characteristic. The tool is also called a fishbone diagram or an Ishikawa diagram.
- *Why?* It is useful for a group to share knowledge when each member has a different perspective on a problem, e.g., management, operations, maintenance, and accounting. The C&E diagram can be updated and serve as a method to organize a team's current knowledge.
- *Planning:* It is important to define the problem or issue clearly. Putting the diagram together requires people with all of the knowledge relevant to the situation working together and sharing ideas.
- *Other tools:* Any of the data-analysis tools might be useful after it is decided what should be measured using the C&E diagram. Causes on the C&E are likely to show up on a flowchart as

	Criteria for Selection						
Computer Type	Disk size	Memory size	Processing speed	Features	Standard software	Costs	**Total Score**
Brand A	1	2	4	3.5	1	2.5	14
Brand B	4	4	3	3.5	3	2.5	20
Brand C	2	1	1	2	2	1	9
Brand D	3	3	2	1	4	4	18

Figure 11 Matrix Diagram. (Copyright 1980–1998 Associates in Process Improvement)

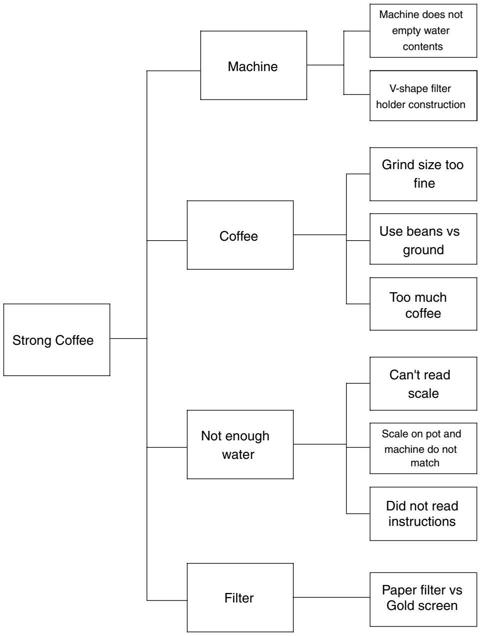

Figure 12 Tree Diagram. (Copyright 1980–1998 Associates in Process Improvement)

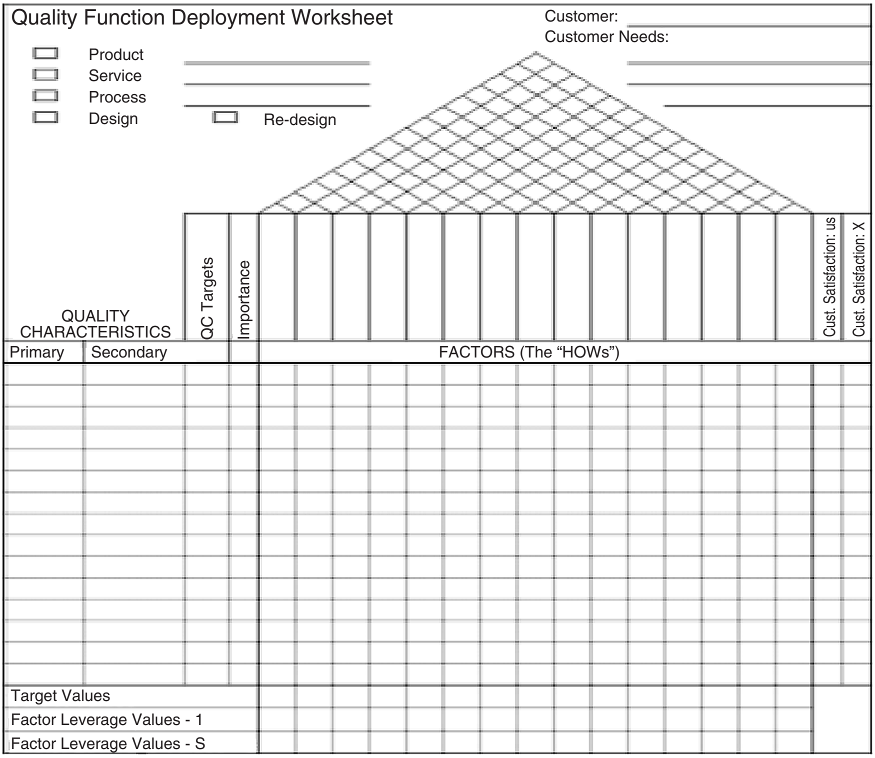

Figure 13 Quality Function Deployment. (Copyright 1980–1998 Associates in Process Improvement)

Figure 14 Run Chart (Trend Chart). (Copyright 1980–1998 Associates in Process Improvement)

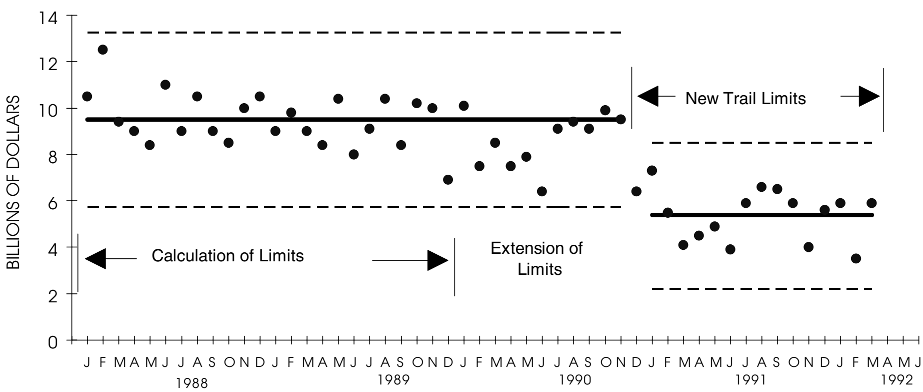

Figure 15 Control Chart (Shewhart Chart). (Copyright 1980–1998 Associates in Process Improvement)

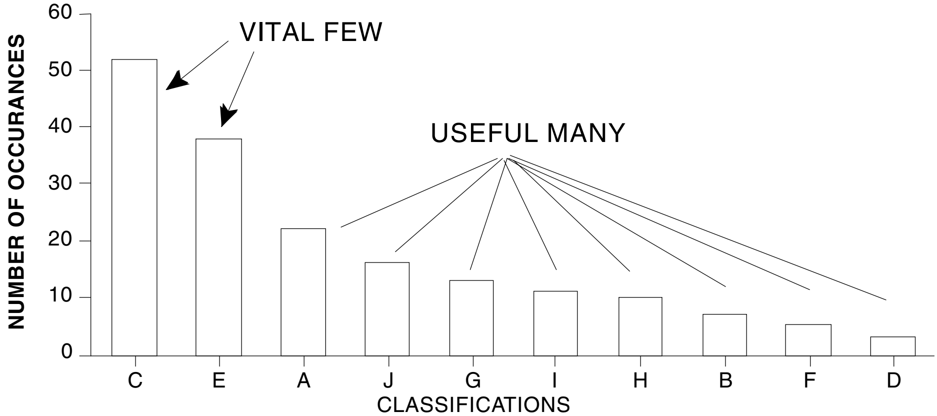

Figure 16 Pareto Chart. (Copyright 1980–1998 Associates in Process Improvement)

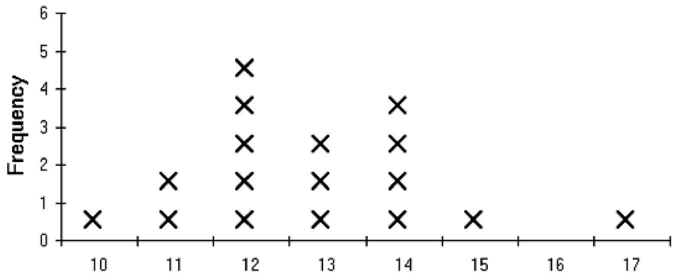

Figure 17 The Frequency Plot. (Copyright 1980–1998 Associates in Process Improvement)

complexity or awkward stages of a process. A C&E diagram is useful when planning an experiment to identify factors and background variables.

- *Mechanics:* Define the issue, brainstorm the causes, and organize the causes into categories. Display the categories on a diagram.
- *What?* A matrix diagram is a method used to arrange data to help the user understand important relationships. The diagram displays the relationship between two groupings (e.g., steps in a process and departments, customer needs and features offered with your service, vendors and selection criteria).
- *Why?* The matrix diagram has many uses in improvement efforts. It is especially useful for developing a change and deciding where to test it. Some of the typical uses include showing the changes planned for a process and where in the organization they will have an impact; summarizing information to help make a decision; and showing the relationship between factors and measure of quality in a planned experiment.
- *Planning:* Understand the information available and the relationships that are important.
- *Other tools:* Information from any of the methods for gathering information can be summarized using a matrix diagram.
- *Mechanics:* Establish lists of items whose relationship is under study. Place one list across the top of the matrix and the other down the side. Draw the matrix. Pick the data or relationship

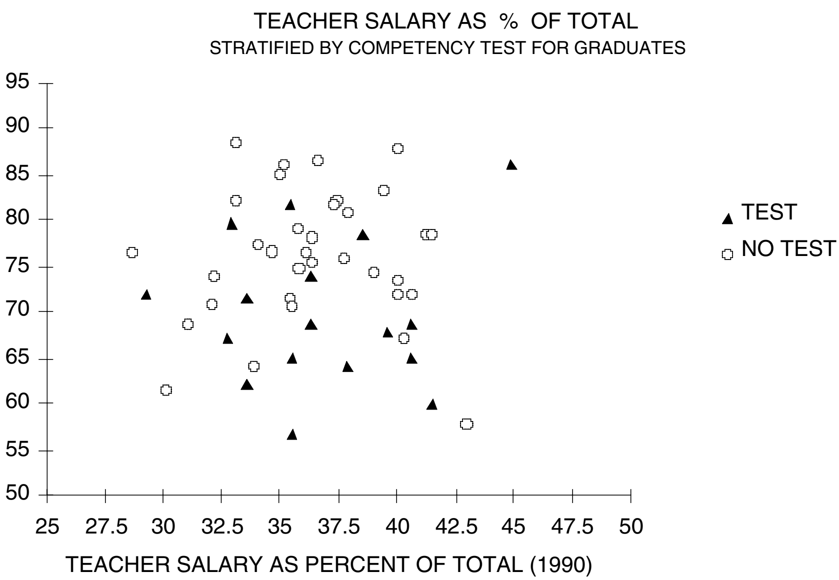

Figure 18 Scatterplot. (Copyright 1980–1998 Associates in Process Improvement)

	New System	
Current System	**on-time**	**late**
on-time	**28**	**2**
late	**16**	**4**

Figure 19 Two-Way Table. (Copyright 1980–1998 Associates in Process Improvement)

symbols to be used. Place the relevant symbols or data on the matrix that corresponds to the proper relationship.

- *What?* A tree diagram is used to visualize the structure of a problem, a plan, or any other opportunity of interest. The diagram helps you think systematically about each aspect of the problem. It has also been called a systematic diagram. The tree diagram allows the graphical view of different level of details about a problem.
- *Why?* The diagram allows a system of strategies for solving a problem or means of achieving an objective to be developed systematically and logically, making it less likely that any essential items will be omitted. The diagram facilitates dialogue and agreement among group members. Tree diagrams are convincing in presentations because they identify and clearly display the details of complex issues.
- *Planning:* Understand the information available and which of the many varieties of tree diagrams is appropriate for the opportunity of interest.
- *Other tools:* Information from any of the methods for gathering information can be summarized using a tree diagram. A tree diagram is similar to a cause-and-effect diagram when causes of an event are being evaluated. Standard symbols are used with tree diagrams for applications like fault tree analysis or failure mode and effects analysis (FMEA).
- *Mechanics:* A tree diagram is simple and natural to construct and thus is a common tool used to organize information. This is done by developing the branches on the tree into different levels of detail. The tree can be developed either horizontally or vertically on the page.
- *What?* Quality function deployment (QFD) is a tool for organizing information when designing a process or product.
- *Why?* QFD is especially useful as an interdisciplinary method that takes customer-centered marketing information and translates this into choices for the organization.
- *Planning:* The group developing the QFD will need marketing information on quality characteristics with customer weights. Also, operations knowledge will be needed to relate quality characteristics to process choices.
- *Other tools:* QFD is typically a jumping-off point for a new product or other major change. Often QFD will establish the need for planned experimentation or customer surveys.
- *Mechanics:* Create a matrix; enter quality characteristics on one side. Enter process choices on the other side; weight the effects. Identify interrelationships. Note where tests and new information are needed.

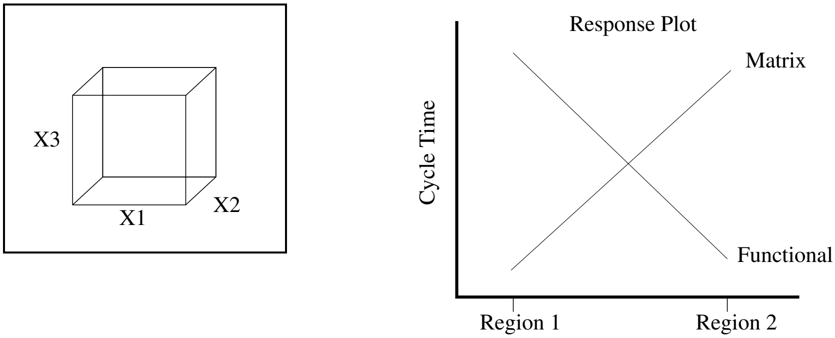

Figure 20 Planned Experimentation. (Copyright 1980–1998 Associates in Process Improvement)

5. TOOLS FOR UNDERSTANDING VARIATION

- *What?* The run chart is a graphical record of a quality characteristic measured over time.
- *Why?* The run chart is useful when it is important to study variation over time. Studying the order of the data enables important information to be learned from measurements.
- *Planning:* Scale the chart appropriately for the variation of interest. Choose a useful interval of time.
- *Other tools:* A run chart can be converted into a control chart after sufficient data have been collected. A run chart can be collapsed into a frequency plot to study the spread and shape of the data.
- *Mechanics:* Scale the chart such that the expected variation will take up about 75% of the chart. (Sometimes this will not be possible on the first try if not much is known about the variation in the process.) Record the measurements directly on the chart in the time order they are generated.
- *What?* A control chart is a tool for studying variation in data, distinguishing between common cause and special cause variation.
- *Why?* To decide on a course of action for improving a process and learn about the extent of variation and its degree of predictability; to evaluate the effectiveness of a change; and study dynamic complexity of a system.
- *Planning:* What subgrouping strategy will help us to learn the most about a process? How often should measurements be made? What is our reaction plan for out-of-control points?
- *Other tools:* A frequency plot would yield useful information about the spread and shape of the data. The flowchart might be helpful in understanding where the measurement was taken, and for what purpose. The cause-and-effect diagram of the process might help in understanding causes of variation. A scatter plot can be used to study measurements from different control charts.
- *Mechanics:* Define the variable and subgrouping; collect and plot the data; calculate control limits; identify special causes and learn from them.
- *What?* The Pareto chart is a tool for helping to focus our efforts by identifying the relative importance of certain categories of events.
- *Why?* This tool should be used when we want to focus an improvement effort on those areas that will have the greatest impact.
- *Planning:* Develop useful definitions for the categories of observations. Select the number of occurrences of each category or another useful measure (time, cost, etc.) of importance.
- *Other tools:* The cause-and-effect diagram may give useful information regarding which categories to measure. A Pareto chart is often used to analyze further a characteristic evaluated using an attribute control chart.
- *Mechanics:* The *X*-axis categories of the chart need to be well defined and useful. The *Y*-axis should be a measure of what is most important. Often this is frequency of occurrence, but it may be time, cost, or other meaningful measures.
- *What?* The frequency plot (or histogram) is a tool to display data. It presents to the user basic information about the location, shape, and spread of a set of data. The frequency plot is similar to the Pareto chart. The frequency plot displays quantitative data, while the Pareto chart displays categorical data.
- *Why?* This tool should be used when there is a need to understand the spread, location, and/or shape of the data. It is useful for summarizing a large amount of data.
- *Planning:* Have a clear objective for constructing the plot. What is the likely spread of the data? Is your scale appropriate?
- *Other tools:* A control chart provides important information about the stability of the process and should always be used when interpreting a frequency plot.
- *Mechanics:* The scale for the horizontal measure needs to be developed. Sometimes groupings of the values need to be determined. Individual values can be recorded or bars can be used to represent the frequency.

6. TOOLS FOR UNDERSTANDING RELATIONSHIPS

- *What?* The scatterplot is a tool for analyzing associations or relationships between two quantitative variables.
- *Why?* If a cause-and-effect relationship exists between the variables, the scatter plot will show this relationship.

- *Planning:* Which two variables may be associated? What is the range of data for both variables? Consider whether there might be a third variable causally related to one or more variables on the chart. Are the processes delivering the data stable?
- *Other tools:* Run charts and control charts would be important to determine whether the data is stable or trending. The cause-and-effect diagram could give insights as to which variables should be plotted together.
- *Mechanics:* Select the two variables. Record pairs of measures. Plot the data on a scale such that the range of variation takes up the full range of data. The axes should be of approximately equal length for each variable.
- *What?* The two-way table is a tabular representation of the relationship between pairs of variables or categories. (Similar to scatter plot.)
- *Why?* If a cause-and-effect relationship exists between the variables, the two-way table will show this relationship.
- *Planning:* Which two variables are associated? What are the levels of the two variables? Consider whether there might be a third variable causally related to one or both variables on the chart. Are the processes delivering the data stable?
- *Other tools:* The scatterplot can be used instead of a two-way table when quantitative data are available. Run charts and control charts would be important to determine whether the data are stable or trending. The cause-and-effect diagram could give insights as to which variables should be on a table together.
- *Mechanics:* Select the two variables. Record events. Develop range of the data or categories for the table. Place the data into the table. Evaluate the ratios across the tables.
- *What?* Planned experimentation is a set of tools for understanding the causes of variation in a variable of interest. It is of particular interest when there are several factors that all contributed considerably to the variation under study.
- *Why?* To study the important common causes of variation in a process. Planned experimentation is most effective when we want to learn about the effects of numerous factors in a study.
- *Planning:* What subject matter knowledge is available? How much time and expense can we devote to the study? Are the processes that are part of the study stable? How will the various variables in the process be treated during the study?
- *Other tools:* Control charts, cause-and-effect diagrams, scatter plots, matrices, run charts, and frequency plots are used to analyze data from planned experiments.
- *Mechanics:* Variables are classified as response variables, factors, or background variables. A design matrix is created for the factors. Background variables are held constant or grouped in blocks. Randomization and replication are used to minimize the impact of unknown variables. Graphical methods are used to summarize the response variables.

7. INTEGRATION OF THE TOOLS FOR IMPROVEMENT

When working with the tools used in improvement, it should be kept in mind that they form a set of tools. Sometimes a single tool will answer all of the important questions, but more often several tools may be needed together. It is a common mistake to reach for the ''favorite tool'' and expect it to be useful in all situations. One of the particularly useful aspects of using the model for improvement to guide the improvement effort is that it will encourage the careful consideration of the questions to be answered. Choosing the correct tool or tools to use will follow naturally from asking the right questions.

It may be helpful, when learning the tools and methods, to consider not only what each tool tells us but also how another tool might give us information that would complement that given by the first tool. For example, a flow diagram can give us useful information about how a process works and may suggest where improvements can be made. It may also show us where complexity in the process might be causing difficulties. We may see more clearly where data could be collected to learn about the process. This is all very useful information, but what other types of information might be helpful? The flowchart gives us no quantitative information from which we might learn. If it were important to understand the variation in a process, we might need to make use of control charts, scatter diagrams, histograms, or Pareto charts. One or several of these might be useful to answer questions about the performance of the process.

Stratifying the data may also enhance the tools of data analysis—that is, separating the data according to some logical grouping, such as by machine, shift, supplier, or method of operation.

There are some particularly strong connections between some of the tools that deserve special mention. The Pareto diagram should only be used with adequate knowledge about the stability of the characteristic being measured. If the process is stable, the Pareto diagram displays the important failure modes or problem classifications produced by the common cause system. If the process is unstable, then stratification of the data should be performed to separate the data obtained when special causes were present from data produced by common causes.

A similar issue arises with histograms. Adequate knowledge of stability is necessary to interpret the histogram. It is a common misuse of a histogram to display data that have a symmetric ‘‘normal’’ shape and imply that the data came from a stable process. An unstable process can also appear as a ‘‘normal’’ distribution on a frequency plot.

As you gain experience using the tools, it will become clear that the tools actually just formalize ways of thinking that we often use in ordinary life. For example, we all have some idea of how we go about a task, such as coming to work in the morning. If we were to write down the steps, using some agreed-upon symbols, we would have a flowchart. A similar statement could be made regarding each of the tools presented, even those requiring calculations. A control chart could be used to chart your arrival time at work. Special causes could be learned from, and the extent of common cause variation could be seen. Yet you probably already have some mental estimate of these, along with some reaction plan.

By using the tools, we will apply some formality and will be more effective in learning and making changes. Also, we will have a ready means to share the information with others. This is one of the great benefits of using the improvement tools, particularly in combination; they put information into a form that can be effectively shared and acted upon.

8. CASE STUDY: USING THE TOOLS TO IMPROVE

The following example illustrates how several of the tools can be used together, along with stratification, to improve a process. The ABC Distribution Company delivered several different types of products mostly within a five-state region. Discussions with the customers showed that on-time delivery and complete orders were their main concern. On-time generally meant that the delivery should arrive on the agreed-upon day. If, for some reason, the delivery could not be made as scheduled, the customers wanted to know ahead of time, if possible. One major customer was a grocery store that expressed a desire for the shipments to arrive within a window of ± two hours. This standard had not been met consistently. At the company’s planning session, management decided that improving arrival time would be a way of differentiating themselves from competitors.

Using the model for improvement as a guide, the team decided to try to improve the processes affecting delivery. To find out how the delivery processes had performed in the past, they gathered some historical data from recent shipments and constructed the frequency plot shown in Figure 21. From this chart it can be seen that although most of the shipments were close to the target time, there are nonetheless a considerable number of deliveries that strayed from target. The frequency plot gives the following information about the historical performance: (1) average, (2) spread, and (3) shape. This chart gives only a summary of what happened in the past.

The next question that the team asked was: How had the delivery performance at ABC varied over time? There was quite a lot of disagreement among the team members over this. Some remembered a day when ‘‘everything seemed to work better.’’ Others thought the problems had always been there but had just floated from one place to another. Fortunately, time order of the

Figure 21 Frequency Plot of Time from Target. (Copyright 1980–1998 Associates in Process Improvement)

recent data used to construct the frequency plot had been retained. A run chart (Figure 22) was constructed using the same data as in the frequency plot from both warehouses over the last 46 deliveries.

There seemed to be a slight trend, and some of the team members thought there might be some increase in variation. In deciding what to do next, the team asked the question: What are some factors that could be contributing to variation in delivery performance?

The ABC business consisted of two warehouses located about 200 miles apart. Each carried about the same line of products, although there were some differences and some seasonal variations. Some of the team members thought the locations might be performing a little differently. It was decided to construct a run chart of the data but to stratify the data by warehouse 1 and 2. This run chart with stratification is shown in Figure 23.

A trend upward is visible from warehouse 2. The team decided to construct control charts to answer the question: Are the deliveries stable? The team was fairly sure about the trend in warehouse 2, but there was considerable uncertainty about warehouse 1. Control charts were constructed for each location. These are shown in Figures 24 and 25.

The trend seen in the run chart is clearly visible with the special cause signal, while warehouse 1 appears to be stable. The center lines for the two warehouses are also different. The team also constructed a scatterplot to see whether the results from the two warehouses on any particular week were related. The scatterplot in Figure 26 showed no relationship in results.

The team then more thoroughly considered the factors that might be affecting the delivery performance. There were several opinions that generally reflected the experience of the individual drivers and shipping personnel. One interesting theory was that the minor sideline-type products were a major source of delay in getting off on a run. When the run started late, more problems were likely to creep into the delivery, such as traffic delays and slow unloading. These sidelines were deliveries that were not part of the main customer deliveries and were things shipped only on some trips. These included some types of machinery, special building materials, and some clothing. The team decided to use a two-way table to investigate whether these deliveries might be tied to the late deliveries in a systematic manner. Figure 27 shows these data.

From this two-way table, it can be seen that these sideline deliveries are strongly associated with late deliveries. This can be seen by looking at the ratios across the table. For the on-time deliveries, 1 out of 16 were associated with special deliveries; for the late deliveries, 19 out of 30 were associated with special deliveries. Furthermore, the team looked into the portion of these deliveries from each warehouse and saw that location 2 had experienced an increase in these kinds of shipments, while location 1 had seen no change recently.

The team was now ready to make, develop, and test some changes. Management agreed that generally these sideline items were less time sensitive than the mainstay deliveries. This was verified in discussions with these customers. It was decided to split these types of deliveries into separate, smaller deliveries to be made in smaller trucks. For the test cycle, these trucks would be rented to try out this system. A month after the change was implemented, an updated control chart of the ABC delivery performance was constructed. Figure 28 shows the impact of these changes.

From this example, it can be appreciated that we need to be very careful about falling into the habit of trying to use only one tool to answer all questions. There should be no great difficulty

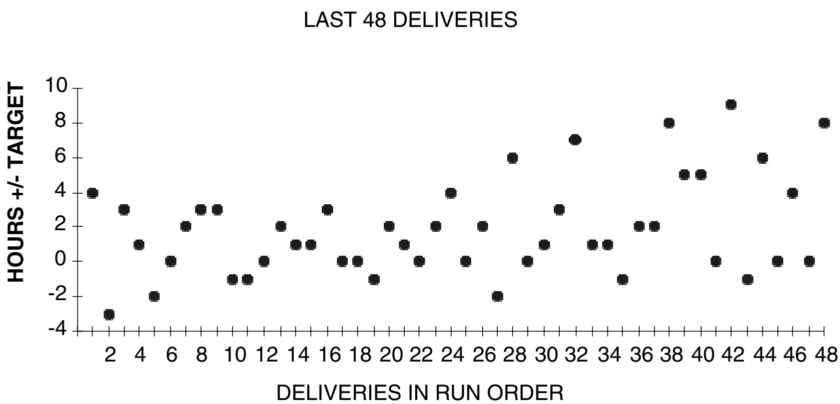

Figure 22 Run Chart of Delivery Data. (Copyright 1980–1998 Associates in Process Improvement)

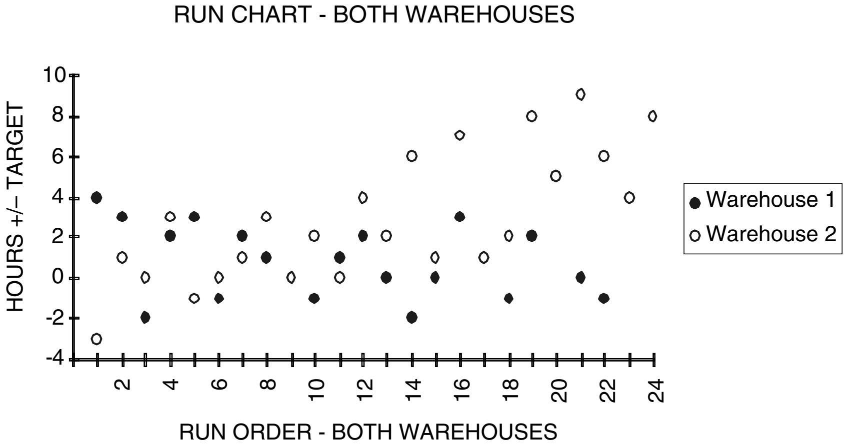

Figure 23 Run Chart Stratified by Location (Warehouse). (Copyright 1980–1998 Associates in Process Improvement)

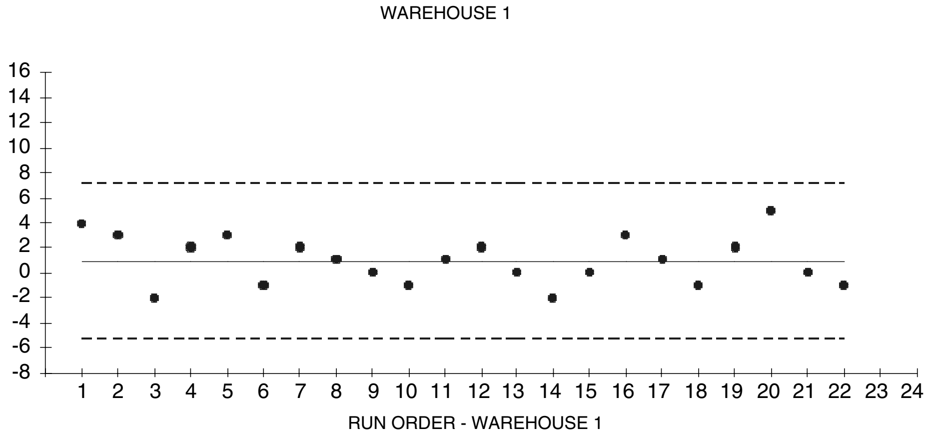

Figure 24 Control Chart of Warehouse 1. (Copyright 1980–1998 Associates in Process Improvement)

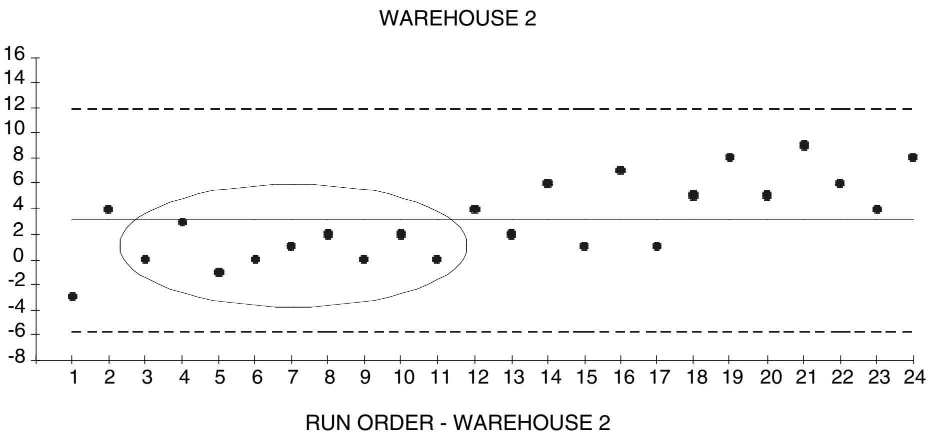

Figure 25 Control Chart of Warehouse 2. (Copyright 1980–1998 Associates in Process Improvement)

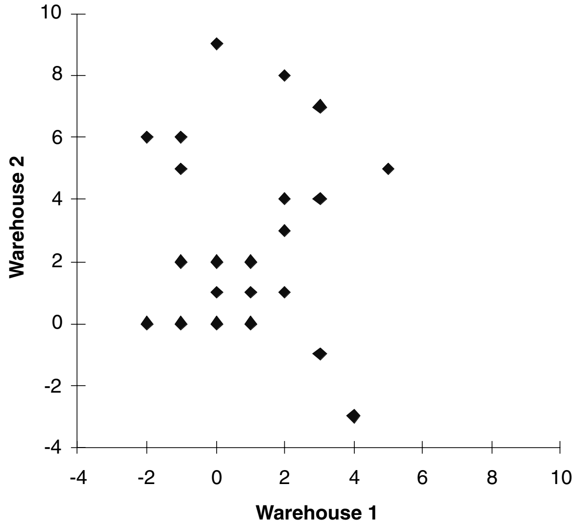

Figure 26 Scatterplot of Delivery Performance for the Two Warehouses. (Copyright 1980–1998 Associates in Process Improvement)

	Special Delivery	No Special Delivery	
On-Time	1	15	16
Late	19	11	30
	20	26	46 = total

Figure 27 Two-Way Table of Deliveries and Special Products. (Copyright 1980–1998 Associates in Process Improvement)

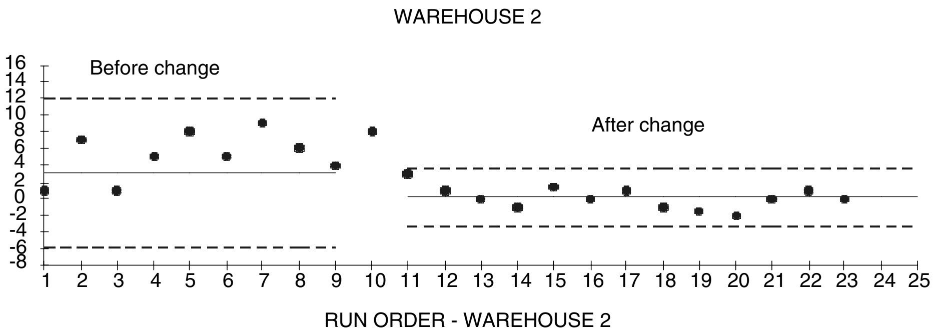

Figure 28 Control Chart of Deliveries after the Changes. (Copyright 1980–1998 Associates in Process Improvement)

imagining situations in which practically any combination of the tools would be used together. It is your subject matter knowledge of your business, along with knowledge of the tools, that will guide you to select the best tool for your situation. Using the model for improvement will also provide a helpful discipline and assist in selecting the best tool when help is needed to answer the three fundamental questions for improvement.

ADDITIONAL READING

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