



7

BEYOND THE BASICS

Seven new quality tools
help innovate, communicate
and plan



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A MOVIE SEQUEL often can be as, if not more, captivating than the original. Take “The Godfather: Part II.” Remember “The Empire Strikes Back”? More recently, what about “The Lord of the Rings: The Two Towers”? Audiences everywhere couldn’t wait to get inside theaters on opening night to see what happened to the Corleone family, Luke Skywalker, and Frodo and Sam.

Essentially, a sequel builds on the original, continuing a journey with familiar characters and settings, developing ideas and unveiling more insight. In that spirit, we asked a supporting cast of QP contributors to help us write the script for the sequel to our January 2009 feature on Kaoru Ishikawa’s original seven quality tools.

Back then, we featured snapshots of each of the “old seven”—cause and effect diagrams, check sheets, control charts, histograms, Pareto analysis, scatter plots and stratification—offering the basics on what you need to understand about them and how they are used. This month, we’re throwing the spotlight on the seven management and planning tools, often referred to as the seven new quality tools: affinity diagrams, arrow diagrams, matrix data analysis, matrix diagrams, process decision program charts, relations diagrams and tree diagrams.

A team from the Union of Japanese Scientists and Engineers (JUSE) first collected these tools in 1976 to promote ways to innovate, communicate, and plan major and complex projects. At the time, some of the tools weren’t necessarily new, but their grouping and promotion were.

Not to spoil the ending, but 36 years later,

there’s nothing new or groundbreaking in this re-release of the newer seven. But we think this collection of articles about these new tools does what JUSE set out to do when it devised the collection of seven: promote ways to innovate, communicate and plan.

As noted in the original installment, our cast of contributors could have provided much, much more on each tool. Many of the tools include additional resources at the end of each article if you want to learn more.

You can also visit QP’s archives (www.qualityprogress.com) to access the original article (“Building From the Basics,” January 2009, pp. 18-29), as well as other articles on basic tools. ASQ’s website, too, has plenty of resources and publications (www.asq.org/books-and-publications.html) to help you learn about the basics of quality.

AFFINITY DIAGRAMS

The affinity diagram is a visual tool that allows an individual or a team to group a large number of ideas, issues, observations or items into categories for further analysis. The tool groups the ideas in a way that allows those with natural relationships or relevance to be placed together in the same group or category.¹

The affinity diagram partners well with the brainstorming tool to organize many ideas and issues. The tool also provides an opportunity to creatively identify categories of team observations or input. Often, it helps to overcome team paralysis by offering a step-by-step way to organize multitudes of options. Groups can use affinity diagrams:

As the next step in organizing the output of a brainstorming event into relevant themes or categories for analysis.

- To actively involve stakeholders in the specifics of a situation in which their understanding, experience, knowledge and support is required.
- As a vehicle for breakthrough thinking and creative association.
- To further analyze data, ideas or observations for eventual hypothesis testing, prioritization and decision making.²

To build an affinity diagram, clearly state the issue being explored. Gain consensus among group members on the issue statement, and brainstorm ideas related to the issue under consideration.

Write one idea each on a sticky note. Make sure the words are in large-enough print to be seen at least five feet away. Randomly place the notes on a board, wall or flip chart so they are visible to the whole group. Figure 1 shows an example of a list created by a group that was brainstorming its organization's community partners.

As a group, cluster the ideas into categories or themes suggested by the content in relation to the issue being explored. Figure 2 shows how the list of community partners can be organized through an affinity diagram.

If an idea logically fits within more than one thematic category, reproduce the note so it can be posted in all relevant areas. Sometimes, it may be necessary to isolate ideas that do not naturally fit into the categories identified by the group. These one-offs may provide valuable insight into additional analysis later.

Next, create an affinity card (or header card) for each group with a short statement describing the entire group of ideas. Review the resulting cluster themes for consensus.

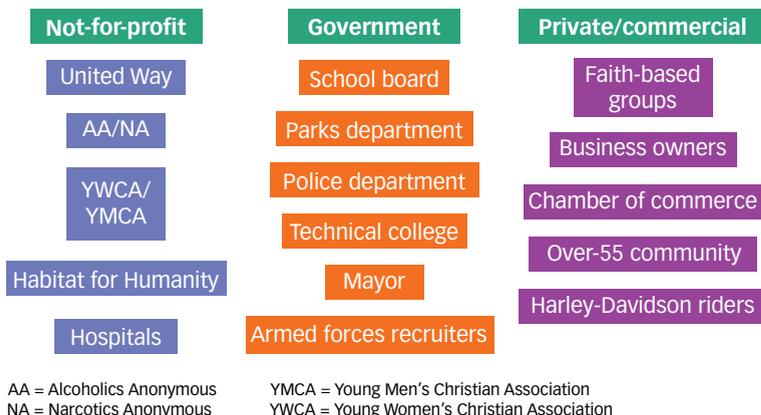
Two additional techniques can be used to encourage creativity among team members:

1. Allow no speaking among team members during the affinity categorization of the sticky notes. All associations of one idea with another should be done in silence.
2. Require team members to use their nondominant hand to move the sticky notes around during catego-

Community partners brainstorming list / FIGURE 1



Affinity diagram of community partners list / FIGURE 2



rization. In other words, a right-handed person should only use his or her left hand when moving ideas around the board, wall or flip chart. This simple exercise will encourage team members to be more deliberate and pay more attention to the decisions and moves they make.

By using affinity diagrams, a group can move away

from idea paralysis and start its journey of exploring an issue or finding solutions to problems.

—Grace L. Duffy

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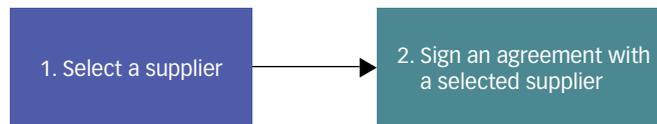
ARROW DIAGRAMS

The arrow diagram—also known as activity diagram, network diagram, activity chart, node diagram or critical path method chart—is used to illustrate the order of activities of a process or project. A basic example is shown in Figure 3.

The arrow diagram can be simple and straightforward, but over time its use has evolved to that of organizing and monitoring complex projects and situations. In the 1950s, two project management techniques—the program evaluation review technique (PERT) and the critical path method (CPM)—propelled the development of the arrow diagram to the next level.

The U.S Navy developed the techniques between 1956 and 1958 while developing its Polaris nuclear subma-

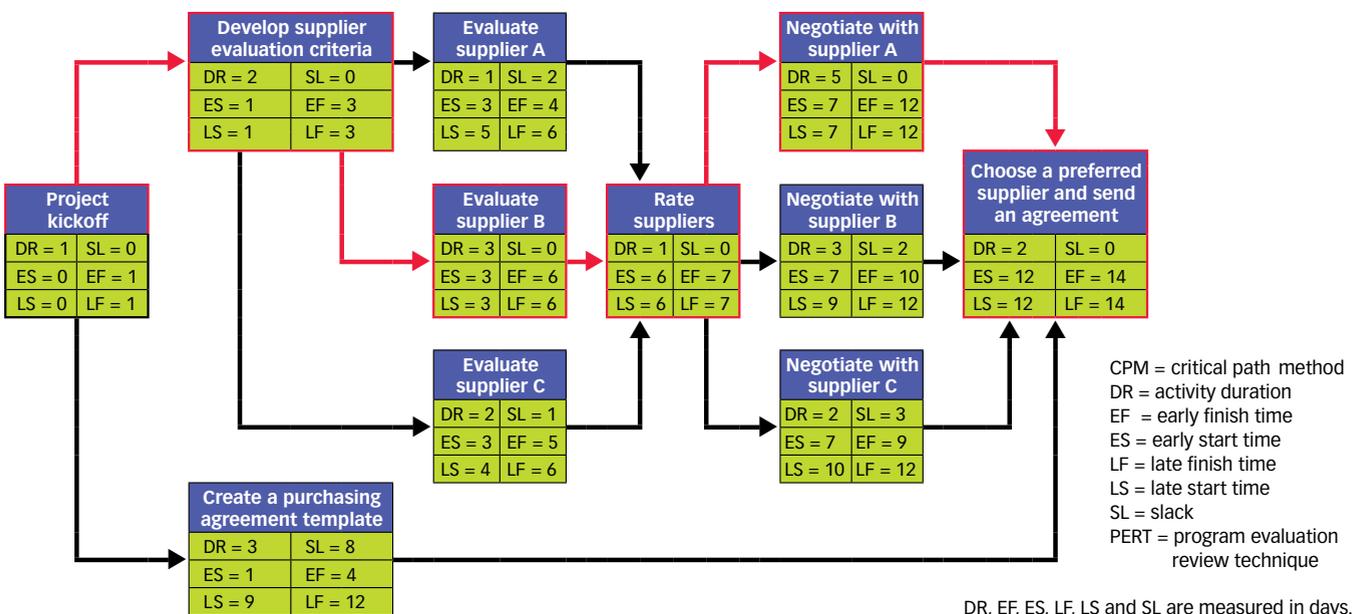
Simple arrow diagram / FIGURE 3



rine. E.I. Du Pont de Nemours Co., planning to construct major chemical plants in United States, also used these methods to plan, schedule and control its projects.

With PERT and CPM, the arrow diagram can include very specific scheduling and monitoring tasks by infusing additional information and details about each activity within a sometimes complex process or project being defined. Table 1 (p. 22) summarizes PERT and CPM

Arrow diagram using CPM and PERT / FIGURE 4



terminology. Figure 4 (p. 21) is an example of applying PERT and CPM to selecting a supplier and signing a purchasing agreement.

The critical path, marked in red on the arrow diagram in Figure 4, includes activities that should be conducted

without delay because they are critical to meeting the scheduled end date. All other activities can be conducted using a more flexible schedule.

The creation of a purchasing agreement template, for example, can start anytime between the first and the ninth day of the project, and it can take more than the anticipated three days if an early start day was chosen.

The example illustrates how the arrow diagram helps to balance project resources and identify activities that are critical for the completion of the project on time.

—Natalia Scriabina

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Arrow diagram acronyms / TABLE 1

Term and acronym	What is it?	How it is calculated?
Early start time (ES)	The earliest time a given task can start.	A duration of the activities leading into this one.
Early finish time (EF)	The earliest time a given task can be finished.	ES + a duration of this activity.
Late finish time (LF)	The latest time a given task can be finished and still keep the projection schedule.	A duration of the activities following this one.
Late start time (LS)	The latest time a given task can start and still keep the project on schedule.	LF – a duration of this activity.
Slack (SL)	The time this activity could be postponed without delaying the project schedule.	LS – ES or LF – EF.

MATRIX DATA ANALYSIS

Many of the seven new quality tools packaged and promoted by JUSE are referred to by names different from what JUSE originally called them, but only one has actually been modified through the years: matrix data analysis.

In its original form, matrix data analysis was heavy on mathematics. Sometimes, it has been replaced on this list by the similar prioritization matrix (see the online sidebar and five additional tables on this article's webpage at www.qualityprogress.com). There is very little reference material on matrix data analysis itself, but I have compiled the limited information and developed an example.

In more complex industrial problems, data are not necessarily one dimensional. Often, we get into analyzing data that have many possibilities. For example, auto-

mobiles are built with several features targeting different consumer demographics. Different demographic groups may react differently because the features and preferences vary. Younger consumers may pay more attention to design

style, while older consumers place greater emphasis on stability and safety of the design. Similarly, there may be preference discrepancies between men and women in terms of color and comfort.

To analyze this data, the traditional seven quality tools may not be adequate. The matrix data analysis method can be used to analyze the data arranged in matrix format. For example, you may want to analyze the customer responses to several attributes of a new product to form a smaller number of uncorrelated variables that are easier to interpret.

The matrix diagram arranges items in a column and row format, with the degree of correlation entered into the relevant columns using symbols or numerical values. This idea appears similar to the relationship matrix tool. In the matrix data analysis, however, the correlation coefficient is used to identify the relationship instead of symbols.

One type of matrix data analysis is principal component analysis. This technique is used in multivariate analysis. Principal component analysis is a selective measurement technique in which the representative characteristics can be mathematically calculated. Prin-

HEAR AND SEE MORE from the authors who contributed to this package featuring the seven new quality tools.

Find links to pre-recorded webcasts throughout April at www.qualityprogress.com.



principal components analysis can reduce your data and avoid multicollinearity, or a situation in which you have too many predictors relative to the number of observations. Principal components analysis often can uncover unsuspected relationships, allowing you to interpret data in a new way.

For the automobile example, 100 potential customers (both genders of various ages in urban and rural areas) were asked to score five automobile features. A score of one was the lowest preference score, and 10 was the highest. The following steps were used to construct and analyze data using matrix data analysis:

1. The scores were averaged and each data item was arranged in row and column format, as shown in Table 2.
2. The correlation coefficient matrix was calculated for each observed group. The example in Table 3 is the sex and age of the observed groups.
3. The characteristic values and vectors using the correlation matrix were calculated, as shown in Table 4 (p. 24). In our example, the first principal component has variance 7.607 (equal to the largest eigenvalue) and accounts for 0.634 (63.4%) of the total variation in the data. The second principal component (variance 3.608) accounts for 0.301 (30.1%) of the total data variation. The third principal component (variance 0.652) accounts for 0.054 (5.4%) of the total data variation. The first two principal components with variances equal to the eigenvalues greater than one represent 0.935 (93.5%) of the total

4. The degree of preference for each feature by demographics was reviewed. Such value expresses the degree of preference. The value of characteristics' vector changes from positive to negative in accordance with age for men and women (Figure 5, p. 24). General preference affected by demography, age and sex are calculated. This is graphically represented by the score plot and biplot in Figures 6 and 7. The score plot graphs the second principal component scores

Matrix data analysis / TABLE 2

Group	Feature one	Feature two	Feature three	Feature four	Feature five
United States: urban					
Men (age < 35)	7.5	7	8	9	6.5
Men (age 36-60)	5.5	8.8	8.5	7.5	6
Men (age > 60)	5	8	8.5	7	6.5
Women (age < 35)	8	5.5	8	9	6
Women (age 36-60)	8.5	6	7.5	8.5	7.5
Women (age > 60)	9	6.8	7	8	8
United States: rural					
Men (age < 35)	6	7.5	8.5	8.5	7
Men (age 36-60)	5.5	8.5	8	7.5	7.5
Men (age > 60)	5.5	8	8	7.5	8
Women (age < 35)	8.5	6.5	8.5	9	6.6
Women (age 36-60)	8.5	5.5	7.5	8.5	7.5
Women (> 60)	9	5	7	8	6

Correlation coefficient matrix / TABLE 3

		Urban						Rural				
		Men (< 35)	Men (36-60)	Men (> 60)	Women (< 35)	Women (36-60)	Women (> 60)	Men (< 35)	Men (36-60)	Men (> 60)	Women (< 35)	Women (36-60)
Urban	Men (age 36-60)	0.26										
	Men (age > 60)	0.142	0.937									
	Women (age < 35)	0.894	-0.125	-0.185								
	Women (age 36-60)	0.558	-0.635	-0.624	0.839							
	Women (age > 60)	0.064	-0.928	-0.967	0.41	0.803						
Rural	Men (age < 35)	0.613	0.761	0.818	0.318	-0.115	-0.664					
	Men (age 36-60)	-0.046	0.847	0.921	-0.421	-0.738	-0.944	0.724				
	Men (age > 60)	-0.108	0.671	0.842	-0.404	-0.608	-0.837	0.707	0.951			
	Women (age < 35)	0.881	-0.082	-0.163	0.99	0.795	0.379	0.29	-0.436	-0.448		
	Women (age 36-60)	0.531	-0.638	-0.596	0.826	0.996	0.782	-0.096	-0.716	-0.565	0.78	
	Women (age > 60)	0.223	-0.854	-0.783	0.6	0.933	0.906	-0.389	-0.839	-0.654	0.554	0.942

versus the first principal component scores. As in this example, if the first two components account for most of the variance in the data, you can use the score plot to assess the data structure and detect clusters, outliers and trends. For examples with multiple variables, the plot may reveal groupings of points, which may indicate two or more separate distributions in the data.

The biplot overlays the score and loading (prefer-

ence, importance) plots of the first two principal components. The second principal component scores are plotted versus the first principal component scores. The loadings for these two principal components are plotted on the same graph.

The plot may reveal groupings of points, which may indicate two or more separate distributions in the data. This may be evident with an example that uses hundreds of features. Only five features of the matrix data analysis technique have been mentioned for illustration purposes.

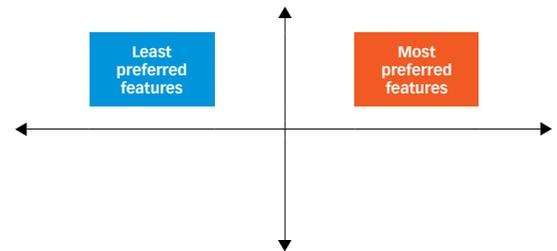
If the data follow a normal distribution and no outliers are present, the points are randomly distributed around zero. In the score plot diagram, the generally preferred features appear as you move right along the horizontal axis, and features that are not preferred move to the left.

With the exception of the youngest age group, the biplot (Figure 7) seems to indicate that rural and urban men have the same preferences, rural and urban women share the same preferences, and those under

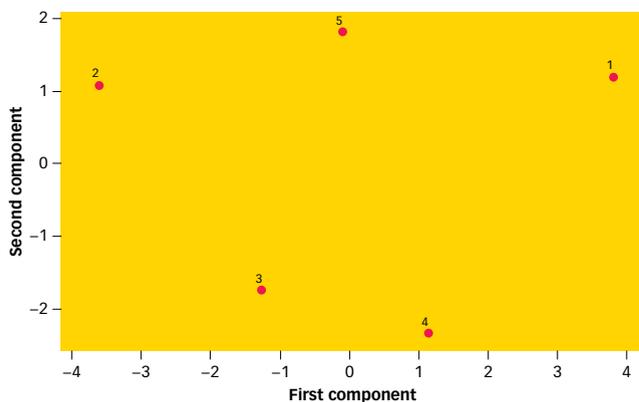
Characteristic values and vectors / TABLE 4

	Groups	First principal component	Second principal component	Third principal component
Urban	Men (age < 35)	0.102	-0.489	0.204
	Men (age 36-60)	-0.300	-0.257	0.343
	Men (age >60)	-0.314	-0.245	-0.038
	Women (age <35)	0.229	-0.405	0.099
	Women (age 36-60)	0.333	-0.187	-0.224
	Women (age > 60)	0.348	0.129	-0.059
Rural	Men (age < 35)	-0.179	-0.444	-0.260
	Men (age 36-60)	-0.342	-0.133	-0.244
	Men (age > 60)	-0.306	-0.116	-0.603
	Women (age < 35)	0.222	-0.399	0.240
	Women (age 36-60)	0.327	-0.187	-0.302
	Women (age > 60)	0.344	-0.014	-0.369
	Eigenvalue	7.607	3.608	0.652
	Proportion	0.634	0.301	0.054
	Cumulative	0.634	0.935	0.989

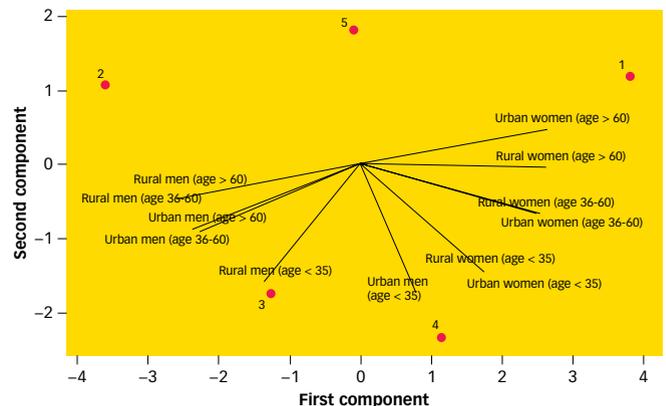
Vector changes / FIGURE 5



Score plot of evaluated groups / FIGURE 6



Biplot of evaluated groups / FIGURE 7



35 years old share the same preferences—regardless of gender.

This tool can be used to analyze market data, new product introduction and for narrowing down root cause analysis. Relationships among defects and their causes, location of defect occurrence or process step can be analyzed using the tool.

—Govind Ramu

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MATRIX DIAGRAMS

Knowing how to visually present data is absolutely critical in today's workplace, especially when you consider that visual representation of data is the only way you will reach some individuals. Matrix diagrams can be used to show the relationship between two, three or four groups of information.

There is a fundamental need for matrix diagram users to be familiar with data. To get started, you must determine ahead of time where the comparisons are going to be. The tool can be an excellent way to compare customers, associates in a call center, departments and processes, for example. The entities being compared are typically listed across the page (x axis). Features or aspects for comparison are listed going down the page (y axis).

Suppose a back-office processing area is scanning forms into a system. When you look at productivity data, you can quickly see there are two groups with distinctly different productivity.

List the names of the associates across the page, keeping in mind the total number of associates. If the number is small, you can list all the associates. If the number is large, you may need to create a composite employee, showing how typical high and low performers appear.

Brainstorm potential areas that participants say they think might be at the root of driving performance. The output of this activity would be listed down the page. Start filling in the matrix with the data you have. You will then have something to show management about how employees differ in performance and what may be causing the performances to be different.

One particular matrix diagram my organization uses on a regular basis is the 2 x 2 matrix (Figure 8). When we conduct workshops with clients, invariably a point is

reached at which we identify potential solutions. The 2 x 2 matrix helps the business partner differentiate the solutions.

This differentiation is centered on the effort required to implement a given solution and what the potential impact would be. Solutions are placed on the grid in response to the evaluation of the solution against a predefined set of criteria that defines effort and impact.

Potential solutions falling into the green block—high impact and low effort—are the targeted solutions. These are typically labeled as quick hits. Solutions falling into the red block—high effort and low impact—are prioritized lower on the list because more resources are required to implement a solution that will make less of an impact.

Using the two extremes as an example, the matrix diagram of impact and effort shows the relationship between the solutions by their positions on the grid. Using the predefined criteria enables a group to use this differentiation to make business decisions regarding which solutions to pursue.

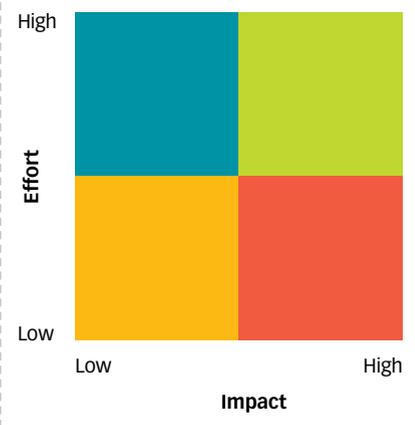
Matrix diagrams are a simple yet powerful means of understanding data. Perhaps more importantly, they are an effective way to convey information to decision makers.

—Keith Wagoner

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2 x 2 impact and effort grid / FIGURE 8



PROCESS DECISION PROGRAM CHARTS

The process decision program chart (PDPC) is an excellent tool for what can be called project risk management. Risk management involves looking ahead proactively during planning to identify potential future problems. PDPC provides a structure to identify what can go wrong and then plan what to do when the wrong things happen.

PDPC is a visual tool that combines and builds on elements of several other techniques. It may enhance a tree diagram in which an objective and one or two levels of activities or tasks already have been defined. It has some characteristics of failure mode and effects analysis, such as the identification of risks, consequences and mitigations.

The PDPC also can be described as a graphical version of the good project management practice of proactively identifying issues, risks and assumptions. Therefore, a PDPC is a nice tool to place into a project plan or charter.

Many levels of planning could benefit from the PDPC. The top level is strategic planning, for which the PDPC

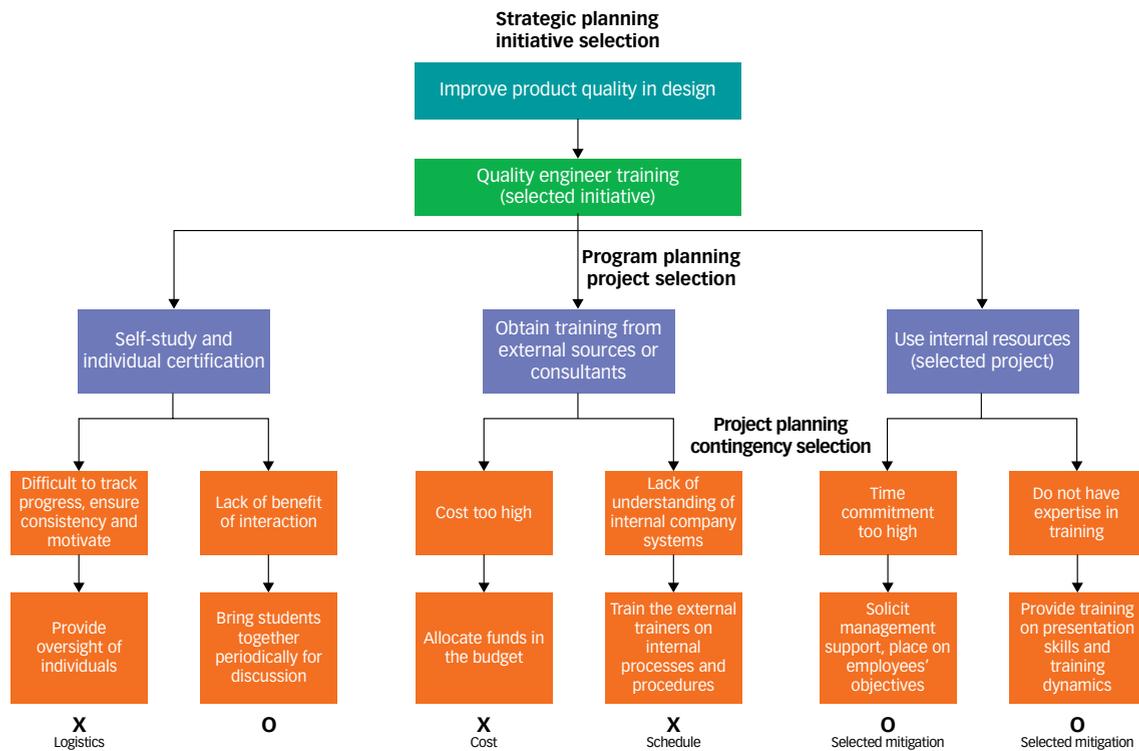
could be used to help select key initiatives or programs from several alternatives. A second level is program planning. “Program” means a portfolio of projects or a group of interrelated activities with specific endpoints.

A PDPC can be used to help select the projects or approaches that are most likely to succeed and weed out those that are not feasible because of high risk or unavailability of resources. After a specific project has been chosen, the PDPC can be used in its most basic form for detailed contingency analysis within the scope of project planning.

Figure 9 is a simplified example of a PDPC with information from program and project planning. The initiative of training quality engineers was chosen as a way to support the strategy of improving product quality in design. Alternative projects addressing different methods to deliver the training were evaluated. The concept of using internal resources was chosen as the preferred strategy.

Then, within the scope of this project, several risks

Process decision program chart example / FIGURE 9

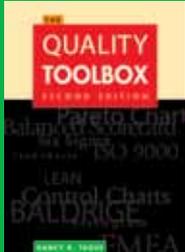


were identified and mitigations developed during the planning phase. Throughout the process, decisions were made by considering the potential risks at each step and eliminating the activities for which risk mitigations or countermeasures were not considered practical.

Figure 9 also shows the common PDPC practice of denoting impractical countermeasures with an X and practical countermeasures with an O. Identification of countermeasures deemed impractical was based on constraints in the project cost, schedule or logistics.

Ultimately, using the PDPC thought process facilitates project planning, identifies risks and mitigations, and helps secure approval to execute a project based on the

MANY OF THE AUTHORS drew from Nancy R. Tague's *The Quality Toolbox* (ASQ Quality Press, 2005) to develop the summaries of the seven management and planning tools. For more about the book and to read a sample chapter, visit <http://asq.org/quality-press/display-item/index.html?item=H1224> (case sensitive).



best benefit and risk ratio, and likelihood of success. The process decision program chart is, therefore, very deserving of its accurate and descriptive long name.

—Scott Laman

RELATIONS DIAGRAMS

A relations diagram is a graphical representation of the relationship between cause and effect or a given outcome, and all the factors that influence or contribute to that outcome. Figure 10 shows an example of a relations diagram, which is a variation of a typical fishbone or cause and effect diagram.

Developing a relations diagram is a structured approach to problem solving. The diagram also can be used to learn more about the problem being addressed, because it can clarify thinking about how various factors are related or contribute to the problem being addressed.

After you know these factors, you can address each one, depending on its importance in terms of severity of effect and the cost of addressing it or not.

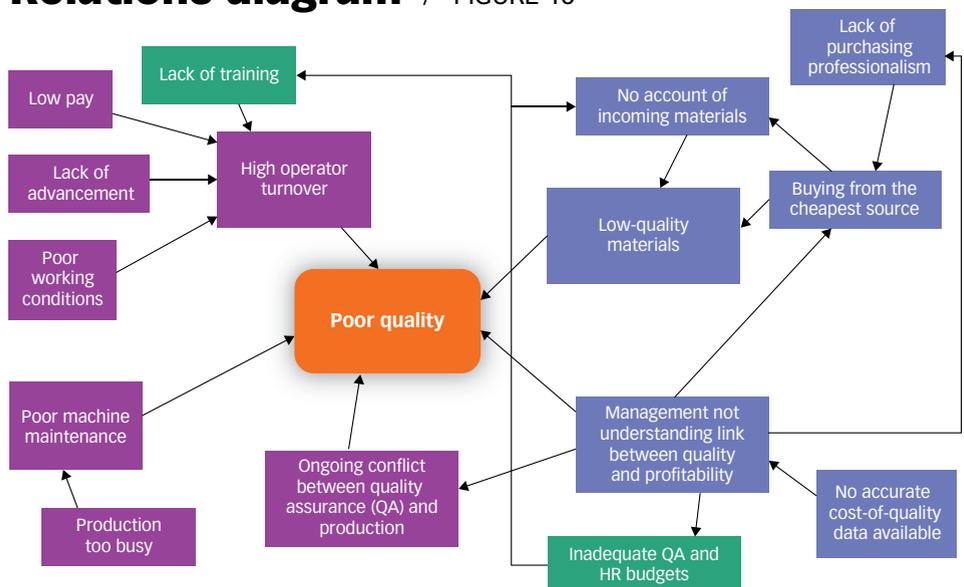
Developing a relations diagram involves brainstorming and organizing thoughts as explained in the following five steps:

1. Identify a group of people—usually no more than five or seven—to participate in developing a relations diagram about a problem. Include people from various departments and people with different perspectives.
2. Distribute a clear problem statement to be reviewed at least a day or two in advance of the first

meeting so group members have a chance to think about it and come to the meeting somewhat prepared.

3. Ask everyone to write on a sticky note one factor they think contributes to the problem. Collect the notes and place them on a wall or a board. Do this a second or third time, or until all factors are covered. These notes do not need to be placed in any order—placing them randomly is fine.
4. Write the problem statement on another wall, board or a flip chart. Then, take one of the notes and discuss whether it is a contributing factor and whether the

Relations diagram / FIGURE 10



group agrees it is. Place it near the problem statement, and draw an arrow from this note to the problem statement. Repeat the same process with another note (factor). Continue this and a relations diagram will emerge, as shown in Figure 10. If one factor contributes to more than one outcome, you can have arrows starting from a factor leading to several outcomes, as shown in the figure.

- Schedule a relations diagram session for no more than one hour because of the fatigue factor. If necessary,

hold more than one session.

Looking at Figure 10, it is clear the lack of management understanding about the link between quality and profitability contributes to many factors leading to poor quality. However, there are no cost-of-quality data available, so the link between quality and profitability cannot be explained.

Therefore, to address poor quality, the first step must be to collect cost-of-quality data for a certain period. After sufficient data are collected and analyzed, a presentation on the subject can be made to management. Ideally, after management understands the link between quality and profitability, it will support quality efforts and also look into the professionalism of the procurement and purchasing function.

Before the relations diagram was developed, the normal tendency for everyone in an organization was to blame poor quality on high operator turnover, poor-quality materials or poor machine maintenance. The relations diagram clarifies what ultimately drives those factors, which in turn helps address the root cause of poor quality.

—Pradip Mehta

CHECK OUT THE ARTICLE that inspired this month's sequel. "Building From the Basics" appeared in the January 2009 edition of QP and continues to receive rave reviews from readers. You can find the open-access article at <http://asq.org/quality-progress/2009/01/basic-quality/building-from-the-basics.html>. Share the link with colleagues through email, Twitter or Facebook. Also find templates for most of the seven basic tools at ASQ's Quality Tools & Templates corner of its website at <http://asq.org/learn-about-quality/tools-templates.html>.



TREE DIAGRAMS

A tree diagram allows you to detail a conceptual or high-level goal into more operational tasks to achieve the desired result. The tree diagram starts with one item that branches into two or more branches, each of which branches into two or more, and so on.

Tree diagrams can be used to break down broad categories into finer levels of detail and can be adapted for a wide variety of uses.¹ Developing the tree diagram helps move team thinking from generalities to specifics. The tree diagram is a generic tool that can be adapted for a wide variety of purposes:

- Developing logical steps to attain a specific result.
- Conducting a five whys analysis to explore a root cause.
- Communicating to encourage involvement in the development of a jointly supported result.
- Drilling down to more detailed levels of a process flow.
- Graphically representing a hierarchical progression, such as a genealogy or classification scheme.

The structure of the tree diagram represents the hierarchical nature of a structure in a graphical form. It is

called a tree structure because the classic representation resembles a tree, even though the chart is generally upside down compared with the shape of an actual tree.

Some quality improvement teams often represent the tree from left to right, with the root at the left and the increasing levels of detail branching out to the right.

Every completed tree diagram has a root or root node, which also can be thought of as the starting node. The lines connecting elements are called branches, and the elements themselves are called nodes. Nodes without children are called leaf nodes, end-nodes or leaves.²

To construct a tree diagram, begin with the root node. Develop a short statement of the goal, issue or item being broken down. Locate the root node either at the top or far left of the diagram. Brainstorm what will take the hierarchy to the next level of detail. For an action plan, this may be the next steps to be taken. For an organization chart, it's the person who reports to the next level of the organization.

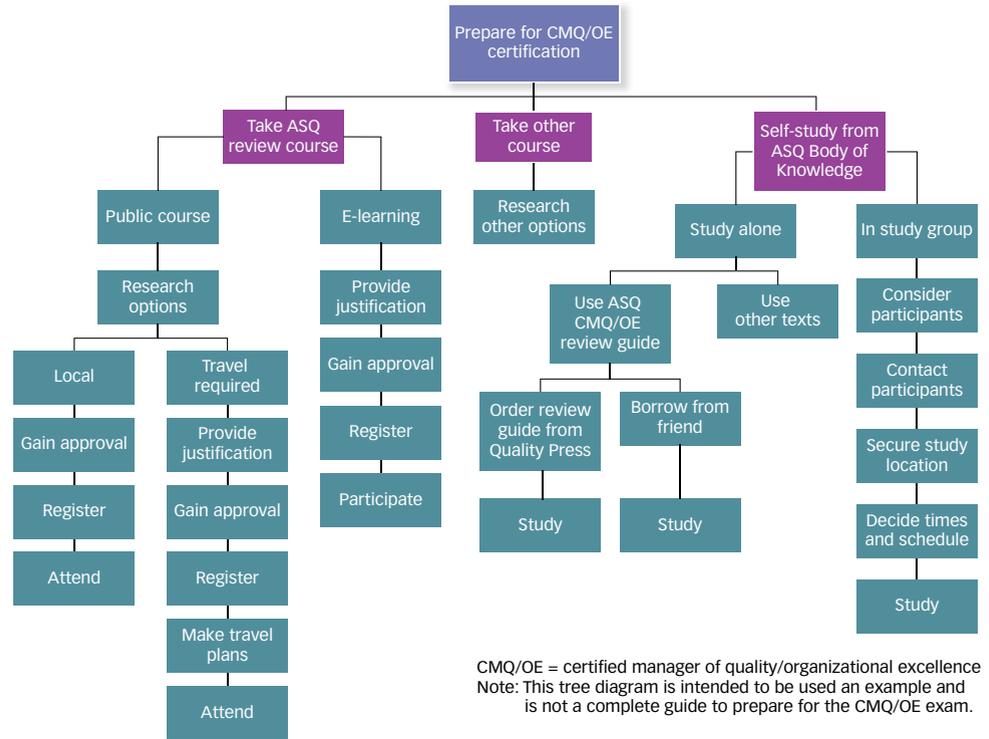
Brainstorm all possible items for each level until there

is no item or action available at a finer level of description. For a vertical tree, write each idea in a line below the branch. For a horizontal tree, write it to the right of the first statement. Do a “necessary and sufficient” check. Are all the items at this level necessary for the one on the level above? If all the items at this level were present or accomplished, would they be sufficient for the one on the level above?³

Figure 11 shows an example of a tree diagram that illustrates how to prepare for ASQ’s manager of quality/organizational excellence (CMQ/QE) certification. “Prepare for CMQ/QE” represents the goal, or root, of the tree diagram, while “Take ASQ review course,” “Take another course” and “Self-study from ASQ Body of Knowledge” are the next level of details, or nodes, that branch from the root. Further activities and descriptions below each of these three nodes continue until options and ideas seem exhausted.

—Grace L. Duffy

Tree diagram to prepare for CMQ/OE exam / FIGURE 11



CMQ/OE = certified manager of quality/organizational excellence
 Note: This tree diagram is intended to be used as an example and is not a complete guide to prepare for the CMQ/OE exam.

REFERENCES

1. Nancy R. Tague, *The Quality Toolbox*, second edition, ASQ Quality Press, 2004, p. 501.
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