The Seven Management and Planning Tools

ASQ Quality Press

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In 1976, the Union of Japanese Scientists and Engineers (JUSE) saw the need for tools to promote innovation, communicate information and successfully plan major projects. A team researched and developed the seven new quality control tools, often called the seven management and planning (MP) tools, or simply the seven management tools. Not all the tools were new, but their collection and promotion were.

The seven MP tools, listed in an order that moves from abstract analysis to detailed planning, are:

1. Affinity diagram: organizes a large number of ideas into their natural relationships.
2. Relations diagram: shows cause-and-effect relationships and helps you analyze the natural links between different aspects of a complex situation.
3. Tree diagram: breaks down broad categories into finer and finer levels of detail, helping you move your thinking step by step from generalities to specifics.
4. Matrix diagram: shows the relationship between two, three or four groups of information and can give information about the relationship, such as its strength, the roles played by various individuals, or measurements.
5. Matrix data analysis: a complex mathematical technique for analyzing matrices, often replaced in this list by the similar prioritization matrix. One of the most rigorous, careful and time-consuming of decision-making tools, a prioritization matrix is an L-shaped matrix that uses pairwise comparisons of a list of options to a set of criteria in order to choose the best option(s).
6. Arrow diagram: shows the required order of tasks in a project or process, the best schedule for the entire project, and potential scheduling and resource problems and their solutions.
7. Process decision program chart (PDPC):systematically identifies what might go wrong in a plan under development.

All material is excerpted from Nancy R. Tague's *The Quality Toolbox*, Second Edition, ASQ Quality Press, 2004.

1 – Affinity Diagram

Also called: affinity chart, K-J method
Variation: thematic analysis

Description

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

When to Use an Affinity Diagram

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

Typical situations are:

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

Affinity Diagram Procedure

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

1. Record each idea with a marking pen on a separate sticky note or card. (During a brainstorming session, write directly onto sticky notes or cards if you suspect you will be following the brainstorm with an affinity diagram.) Randomly spread notes on a large work surface so all notes are visible to everyone. The entire team gathers around the notes and participates in the next steps.

2. It is very important that no one talk during this step. Look for ideas that seem to be related in some way. Place them side by side. Repeat until all notes are grouped. It's okay to have "loners" that don't seem to fit a group. It's all right to move a note someone else has already moved. If a note seems to belong in two groups, make a second note.

3. You can talk now. Participants can discuss the shape of the chart, any surprising patterns, and especially reasons for moving controversial notes. A few more changes may be made. When ideas are grouped, select a heading for each group. Look for a note in each grouping that captures the meaning of the group. Place it at the top of the group. If there is no such note, write one. Often it is useful to write or highlight this note in a different color.

4. Combine groups into "supergroups" if appropriate.

Affinity Diagram Example

The ZZ-400 manufacturing team used an affinity diagram to organize its list of potential performance indicators. Figure 1 shows the list team members brainstormed. Because the team works a shift schedule and members could not meet to do the affinity diagram together, they modified the procedure.

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

Figure 1 Brainstorming for Affinity Diagram Example

They wrote each idea on a sticky note and put all the notes randomly on a rarely used door. Over several days, everyone reviewed the notes in their spare time and moved the notes into related groups. Some people reviewed the evolving pattern several times. After a few days, the natural grouping shown in figure 2 had emerged.

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

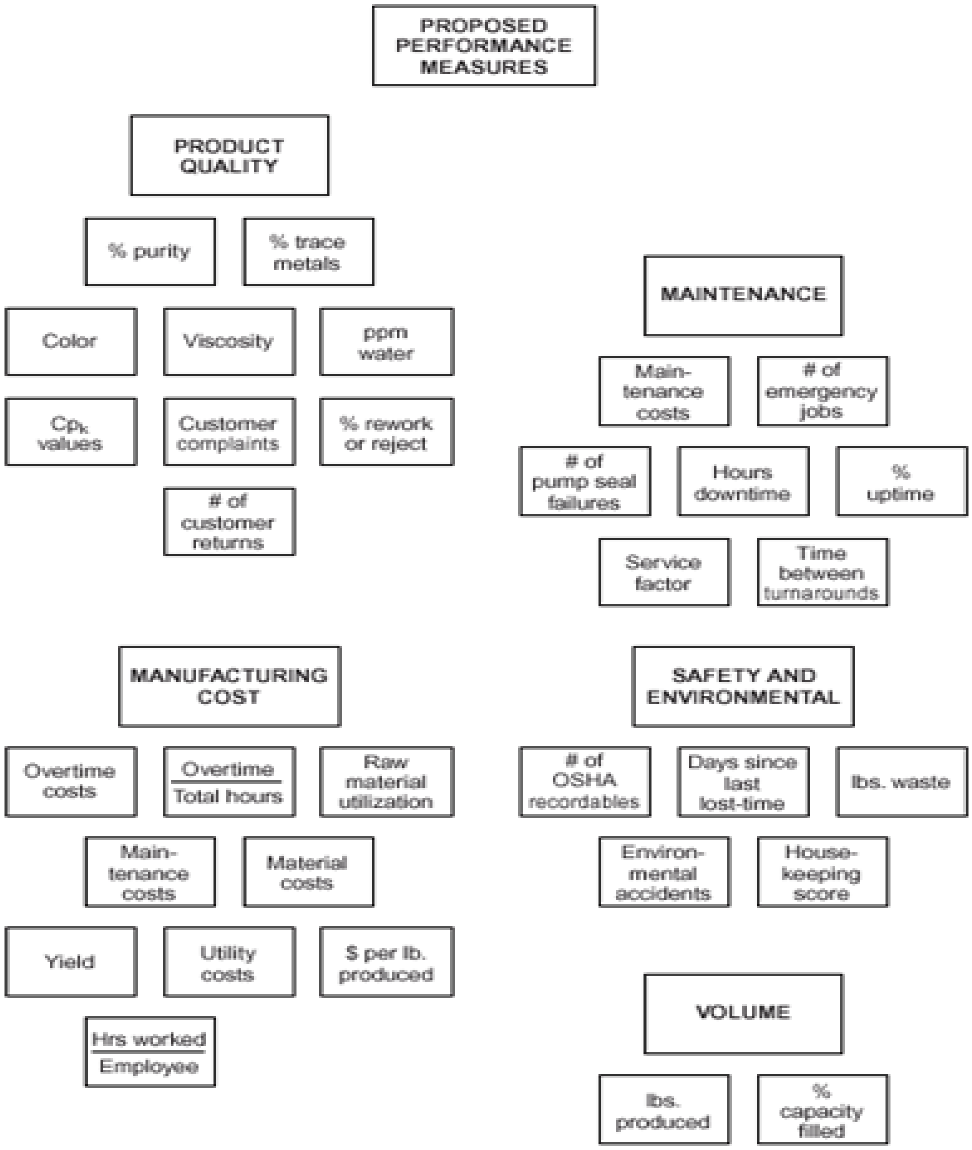


Figure 2 Affinity Diagram Example

Affinity Diagram Considerations

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

2 – Relations Diagram

Also called: interrelationship diagram or digraph, network diagram

Variation: matrix relations diagram

Description

The relations diagram shows cause-and-effect relationships. Just as importantly, the process of creating a relations diagram helps a group analyze the natural links between different aspects of a complex situation.

When to Use a Relations Diagram

- When trying to understand links between ideas or cause-and-effect relationships, such as when trying to identify an area of greatest impact for improvement.
- When a complex issue is being analyzed for causes.
- When a complex solution is being implemented.
- After generating an affinity diagram, cause-and-effect diagram or tree diagram, to more completely explore the relations of ideas.

Relations Diagram Basic Procedure

Materials needed: sticky notes or cards, large paper surface (newsprint or two flipchart pages taped together), marking pens, tape.

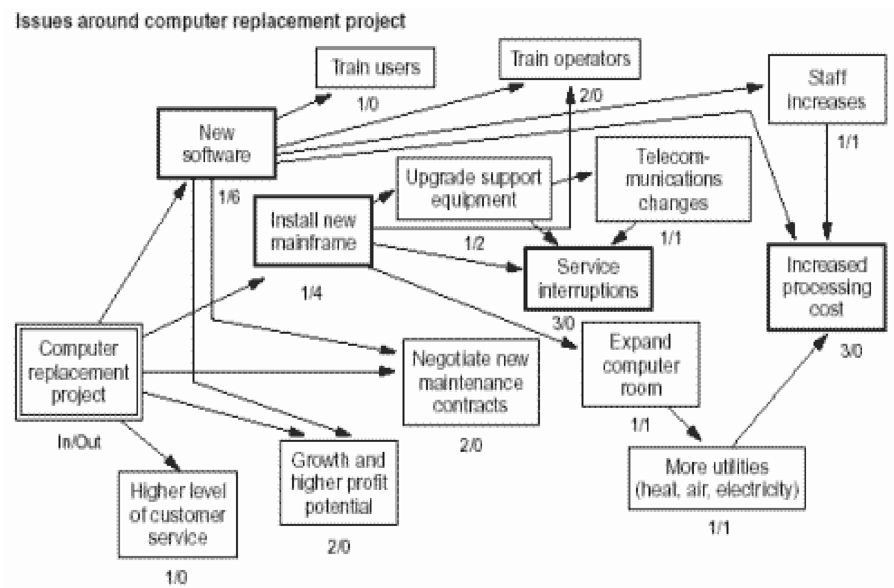
1. Write a statement defining the issue that the relations diagram will explore. Write it on a card or sticky note and place it at the top of the work surface.
2. Brainstorm ideas about the issue and write them on cards or notes. If another tool has preceded this one, take the ideas from the affinity diagram, the most detailed row of the tree diagram or the final branches on the fishbone diagram. You may want to use these ideas as starting points and brainstorm additional ideas.
3. Place one idea at a time on the work surface and ask: "Is this idea related to any others?" Place ideas that are related near the first. Leave space between cards to allow for drawing arrows later. Repeat until all cards are on the work surface.
4. For each idea, ask, "Does this idea cause or influence any other idea?" Draw arrows from each idea to the ones it causes or influences. Repeat the question for every idea.
5. Analyze the diagram:
    - Count the arrows in and out for each idea. Write the counts at the bottom of each box. The ones with the most arrows are the key ideas.

- Note which ideas have primarily outgoing (from) arrows. These are basic causes.
- Note which ideas have primarily incoming (to) arrows. These are final effects that also may be critical to address.

Be sure to check whether ideas with fewer arrows also are key ideas. The number of arrows is only an indicator, not an absolute rule. Draw bold lines around the key ideas.

Relations Diagram Example

A computer support group is planning a major project: replacing the mainframe computer. The group drew a relations diagram (see figure below) to sort out a confusing set of elements involved in this project.



Relations Diagram Example

"Computer replacement project" is the card identifying the issue. The ideas that were brainstormed were a mixture of action steps, problems, desired results and less-desirable effects to be handled. All these ideas went onto the diagram together. As the questions were asked about relationships and causes, the mixture of ideas began to sort itself out.

After all the arrows were drawn, key issues became clear. They are outlined with bold lines.

- "New software" has one arrow in and six arrows out. "Install new mainframe" has one arrow in and four out. Both ideas are basic causes.
- "Service interruptions" and "increased processing cost" both have three arrows in, and the group identified them as key effects to avoid.

3 – Tree Diagram

Also called: systematic diagram, tree analysis, analytical tree, hierarchy diagram

Description

The tree diagram starts with one item that branches into two or more, each of which branch into two or more, and so on. It looks like a tree, with trunk and multiple branches.

It is used to break down broad categories into finer and finer levels of detail. Developing the tree diagram helps you move your thinking step by step from generalities to specifics.

When to Use a Tree Diagram

- When an issue is known or being addressed in broad generalities and you must move to specific details, such as when developing logical steps to achieve an objective.
- When developing actions to carry out a solution or other plan.
- When analyzing processes in detail.
- When probing for the root cause of a problem.
- When evaluating implementation issues for several potential solutions.
- After an affinity diagram or relations diagram has uncovered key issues.
- As a communication tool, to explain details to others.

Tree Diagram Procedure

1. Develop a statement of the goal, project, plan, problem or whatever is being studied. Write it at the top (for a vertical tree) or far left (for a horizontal tree) of your work surface.
2. Ask a question that will lead you to the next level of detail. For example:
   - For a goal, action plan or work breakdown structure: “What tasks must be done to accomplish this?” or “How can this be accomplished?”
   - For root-cause analysis: “What causes this?” or “Why does this happen?”
   - For gozinto chart: “What are the components?” (Gozinto literally comes from the phrase “What goes into it?”

Brainstorm all possible answers. If an affinity diagram or relationship diagram has been done previously, ideas may be taken from there. Write each idea in a line below (for a vertical tree) or to the right of (for a horizontal tree) the first statement. Show links between the tiers with arrows.

3. 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?
4. Each of the new idea statements now becomes the subject: a goal, objective or problem statement. For each one, ask the question again to uncover the next level of detail. Create

another tier of statements and show the relationships to the previous tier of ideas with arrows. Do a “necessary and sufficient check” for each set of items.

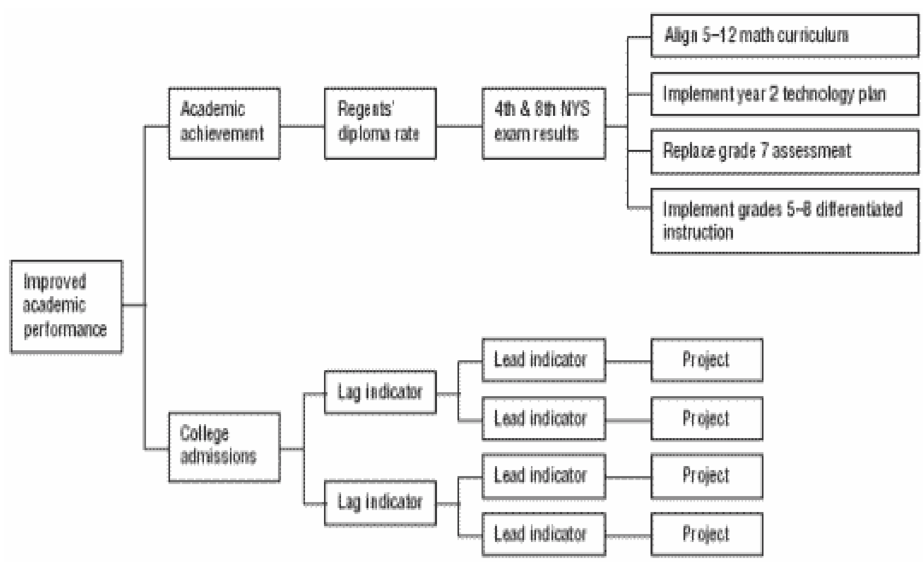
5. Continue to turn each new idea into a subject statement and ask the question. Do not stop until you reach fundamental elements: specific actions that can be carried out, components that are not divisible, root causes.

6. Do a “necessary and sufficient” check of the entire diagram. Are all the items necessary for the objective? If all the items were present or accomplished, would they be sufficient for the objective?

Tree Diagram Example

The Pearl River, NY School District, a 2001 recipient of the Malcolm Baldrige National Quality Award, uses a tree diagram to communicate how district-wide goals are translated into sub-goals and individual projects. They call this connected approach “The Golden Thread.”

The district has three fundamental goals. The first, to improve academic performance, is partly shown in the figure below. District leaders have identified two strategic objectives that, when accomplished, will lead to improved academic performance: academic achievement and college admissions.



Tree Diagram Example

Lag indicators are long-term and results-oriented. The lag indicator for academic achievement is Regents’ diploma rate: the percent of students receiving a state diploma by passing eight Regents’ exams.

Lead indicators are short-term and process-oriented. Starting in 2000, the lead indicator for the Regents’ diploma rate was performance on new fourth and eighth grade state tests.

Finally, annual projects are defined, based on cause-and-effect analysis, that will improve performance. In 2000–2001, four projects were accomplished to improve academic achievement. Thus this tree diagram is an interlocking series of goals and indicators, tracing the causes of systemwide academic performance first through high school diploma rates, then through lower grade performance, and back to specific improvement projects.

4 – Matrix Diagram and 5 – Matrix data analysis

Also called: matrix, matrix chart

Description

The matrix diagram shows the relationship between two, three or four groups of information. It also can give information about the relationship, such as its strength, the roles played by various individuals or measurements.

Six differently shaped matrices are possible: L, T, Y, X, C and roof-shaped, depending on how many groups must be compared.

When to Use Each Matrix Diagram Shape

Table 1 summarizes when to use each type of matrix. Also click on the links below to see an example of each type. In the examples, matrix axes have been shaded to emphasize the letter that gives each matrix its name.

- An L-shaped matrix relates two groups of items to each other (or one group to itself).
- A T-shaped matrix relates three groups of items: groups B and C are each related to A. Groups B and C are not related to each other.
- A Y-shaped matrix relates three groups of items. Each group is related to the other two in a circular fashion.
- A C-shaped matrix relates three groups of items all together simultaneously, in 3-D.
- An X-shaped matrix relates four groups of items. Each group is related to two others in a circular fashion.
- A roof-shaped matrix relates one group of items to itself. It is usually used along with an L- or T-shaped matrix.

Table 1: When to use differently-shaped matrices

L-shaped	2 groups	A ⇔ B (or A ⇔ A)
T-shaped	3 groups	B ⇔A ⇔ C but not B ⇔ C
Y-shaped	3 groups	A ⇔ B ⇔ C ⇔ A
C-shaped	3 groups	All three simultaneously (3-D)
X-shaped	4 groups	A ⇔ B ⇔ C ⇔ D ⇔ A but not A ⇔ C ⇔ or B ⇔ D
Roof-shaped	1 group	A ⇔ A when also A ⇔ B in L or T

L-Shaped Matrix Diagram

This L-shaped matrix summarizes customers' requirements. The team placed numbers in the boxes to show numerical specifications and used check marks to show choice of packaging. The L-shaped matrix actually forms an upside-down L. This is the most basic and most common matrix format.

Customer Requirements

	Customer *D*	**Customer *M***	**Customer *R***	**Customer *T***
Purity %	> 99.2	> 99.2	> 99.4	> 99.0
Trace metals (ppm)	< 5	—	< 10	< 25
Water (ppm)	< 10	< 5	< 10	—
Viscosity (cp)	20-35	20-30	10-50	15-35
Color	< 10	< 10	< 15	< 10
Drum		✔		
Truck	✔			✔
Railcar			✔	

T-Shaped Matrix Diagram

This T-shaped matrix relates product models (group A) to their manufacturing locations (group B) and to their customers (group C).

Examining the matrix in different ways reveals different information. For example, concentrating on model A, we see that it is produced in large volume at the Texas plant and in small volume at the Alabama plant. Time Inc. is the major customer for model A, while Arlo Co. buys a small amount. If we choose to focus on the customer rows, we learn that only one customer, Arlo, buys all four models. Zig buys just one. Time makes large purchases of A and D, while Lyle is a relatively minor customer.

Products—Customers—Manufacturing

Texas plant	●		○	○
Mississippi plant		●		○
Alabama plant	○			●
Arkansas plant		○	●	
● Large volume ○ Small volume	Model A	Model B	Model C	Model D
Zig Corp.		●		
Arlo Co.	○	○	○	●
Lyle Co.			○	○
Time Inc.	●			●

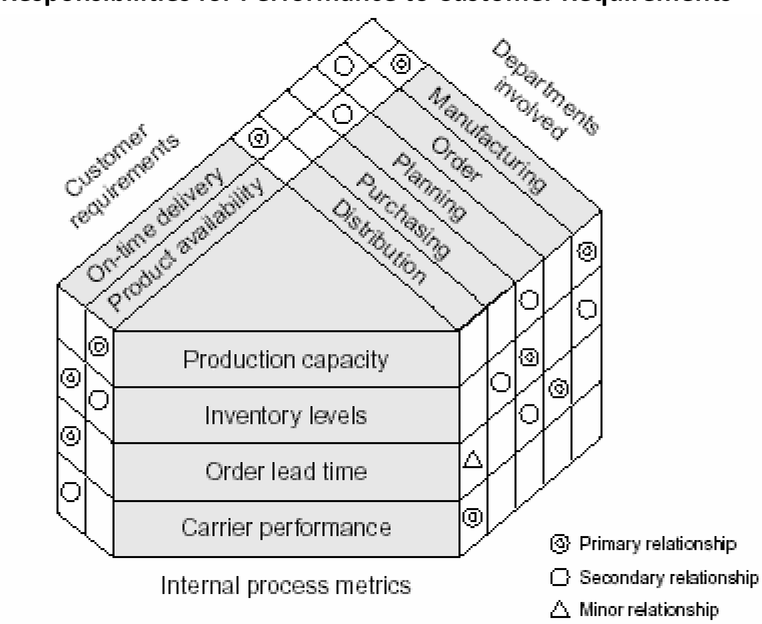
Locations

Y-Shaped Matrix Diagram

This Y-shaped matrix shows the relationships between customer requirements, internal process metrics and the departments involved. Symbols show the strength of the relationships: primary relationships, such as the manufacturing department's responsibility for production capacity; secondary relationships, such as the link between product availability and inventory levels; minor relationships, such as the distribution department's responsibility for order lead time; and no relationship, such as between the purchasing department and on-time delivery.

The matrix tells an interesting story about on-time delivery. The distribution department is assigned primary responsibility for that customer requirement. The two metrics most strongly related to on-time delivery are inventory levels and order lead time. Of the two, distribution has only a weak relationship with order lead time and none with inventory levels. Perhaps the responsibility for on-time delivery needs to be reconsidered. Based on the matrix, where would you put responsibility for on-time delivery?

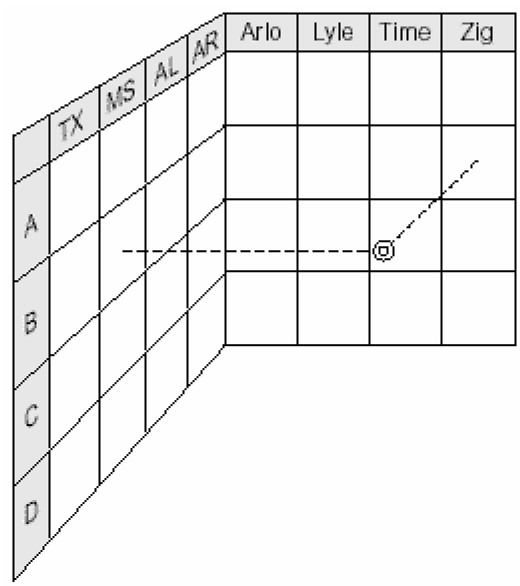
Responsibilities for Performance to Customer Requirements



C-Shaped Matrix Diagram

Think of C meaning "cube." Because this matrix is three-dimensional, it is difficult to draw and infrequently used. If it is important to compare three groups simultaneously, consider using a three-dimensional model or computer software that can provide a clear visual image.

This figure shows one point on a C-shaped matrix relating products, customers and manufacturing locations. Zig Company's model B is made at the Mississippi plant.



X-Shaped Matrix Diagram

This figure extends the T-shaped matrix example into an X-shaped matrix by including the relationships of freight lines with the manufacturing sites they serve and the customers who use them. Each axis of the matrix is related to the two adjacent ones, but not to the one across. Thus, the product models are related to the plant sites and to the customers, but not to the freight lines.

A lot of information can be contained in an X-shaped matrix. In this one, we can observe that Red Lines and Zip Inc., which seem to be minor carriers based on volume, are the only carriers that serve Lyle Co. Lyle doesn't buy much, but it and Arlo are the only customers for model C. Model D is made at three locations, while the other models are made at two. What other observations can you make?

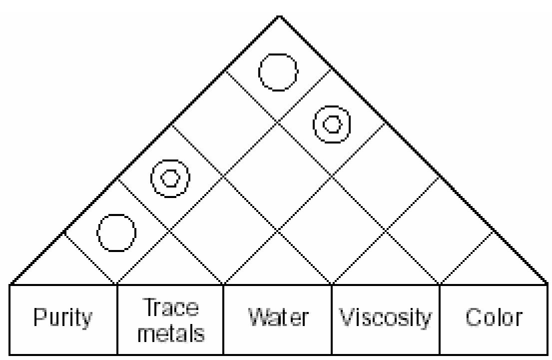
Manufacturing Sites—Products—Customers—Freight Lines

○		●	○	Texas plant	●		○	○
	○	●	●	Mississippi plant		●		○
		●	●	Alabama plant	○			●
○	○		○	Arkansas plant		○	●	
Red Lines	Zip Inc.	World-wide	Trans South		Model A	Model B	Model C	Model D
		●	○	Zig Corp.		●		
			●	Arlo Co.	○	○	○	●
○	○			Lyle Co.			○	○
	○	●		Time Inc.	●			●

● Large volume
○ Small volume

Roof-Shaped Matrix Diagram

The roof-shaped matrix is used with an L- or T-shaped matrix to show one group of items relating to itself. It is most commonly used with a house of quality, where it forms the “roof” of the “house.” In the figure below, the customer requirements are related to one another. For example, a strong relationship links color and trace metals, while viscosity is unrelated to any of the other requirements.



Frequently Used Matrix Diagram Symbols

◎ Strong relationship ○ Moderate relationship △ Weak or potential relationship No relationship	+ Positive relationship ○ Neutral relationship – Negative relationship
S Supplier C Customer D Doer O Owner	↑ Item on left influences item at top ← Item at top influences item on left The arrows usually are placed next to another symbol indicating the strength of the relationship.

6 – Arrow Diagram

Also called: activity network diagram, network diagram, activity chart, node diagram, CPM (critical path method) chart

Variation: PERT (program evaluation and review technique) chart

Description

The arrow diagram shows the required order of tasks in a project or process, the best schedule for the entire project, and potential scheduling and resource problems and their solutions. The arrow diagram lets you calculate the "critical path" of the project. This is the flow of critical steps where delays will affect the timing of the entire project and where addition of resources can speed up the project.

When to Use an Arrow Diagram

- When scheduling and monitoring tasks within a complex project or process with interrelated tasks and resources.
- When you know the steps of the project or process, their sequence and how long each step takes, and.
- When project schedule is critical, with serious consequences for completing the project late or significant advantage to completing the project early.

Arrow Diagram Procedure

Materials needed: sticky notes or cards, marking pens, large writing surface (newsprint or flipchart pages)

Drawing the Network

1. List all the necessary tasks in the project or process. One convenient method is to write each task on the top half of a card or sticky note. Across the middle of the card, draw a horizontal arrow pointing right.
2. Determine the correct sequence of the tasks. Do this by asking three questions for each task:
    - Which tasks must happen before this one can begin?
    - Which tasks can be done at the same time as this one?
    - Which tasks should happen immediately after this one?

It can be useful to create a table with four columns —prior tasks, this task, simultaneous tasks, following tasks.

3. Diagram the network of tasks. If you are using notes or cards, arrange them in sequence on a large piece of paper. Time should flow from left to right and concurrent tasks should be vertically aligned. Leave space between the cards.

4. Between each two tasks, draw circles for “events.” An event marks the beginning or end of a task. Thus, events are nodes that separate tasks.

5. Look for three common problem situations and redraw them using “dummies” or extra events. A dummy is an arrow drawn with dotted lines used to separate tasks that would otherwise start and stop with the same events or to show logical sequence. Dummies are not real tasks.

Problem situations:

- Two simultaneous tasks start and end at the same events.**Solution:** Use a dummy and an extra event to separate them. In Figure 1, event 2 and the dummy between 2 and 3 have been added to separate tasks A and B.
- Task C cannot start until both tasks A and B are complete; a fourth task, D, cannot start until A is complete, but need not wait for B. (See Figure 2.) **Solution:** Use a dummy between the end of task A and the beginning of task C.
- A second task can be started before part of a first task is done.**Solution:** Add an extra event where the second task can begin and use multiple arrows to break the first task into two subtasks. In Figure 3, event 2 was added, splitting task A.

Figure 1: Dummy separating simultaneous tasks

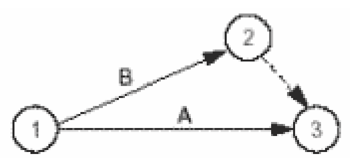


Figure 2: Dummy keeping sequence correct

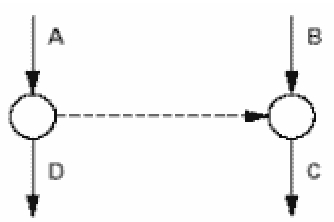
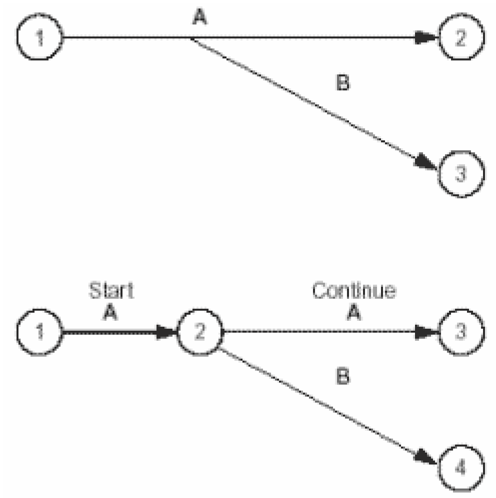


Figure 3: Using an extra event



6. When the network is correct, label all events in sequence with event numbers in the circles. It can be useful to label all tasks in sequence, using letters.

Scheduling: Critical Path Method (CPM)

7. Determine task times—the best estimate of the time that each task should require. Use one measuring unit (hours, days or weeks) throughout, for consistency. Write the time on each task's arrow.

8. Determine the "critical path," the longest path from the beginning to the end of the project. Mark the critical path with a heavy line or color. Calculate the length of the critical path: the sum of all the task times on the path.

9. Calculate the earliest times each task can start and finish, based on how long preceding tasks take. These are called earliest start (ES) and earliest finish (EF). Start with the first task, where ES = 0, and work forward. Draw a square divided into four quadrants, as in Figure 4. Write the ES in the top left box and the EF in the top right.

For each task:

- Earliest start (ES) = the largest EF of the tasks leading into this one
- Earliest finish (EF) = ES + task time for this task

Figure 4: Arrow diagram time box

ES Earliest start	**EF** Earliest finish
LS Latest start	**LF** Latest finish

10. Calculate the latest times each task can start and finish without upsetting the project schedule, based on how long later tasks will take. These are called latest start (LS) and latest finish (LF). Start from the last task, where the latest finish is the project deadline, and work backwards. Write the LS in the lower left box and the LF in the lower right box.

    - Latest finish (LF) = the smallest LS of all tasks immediately following this one
    - Latest start (LS) = LF – task time for this task

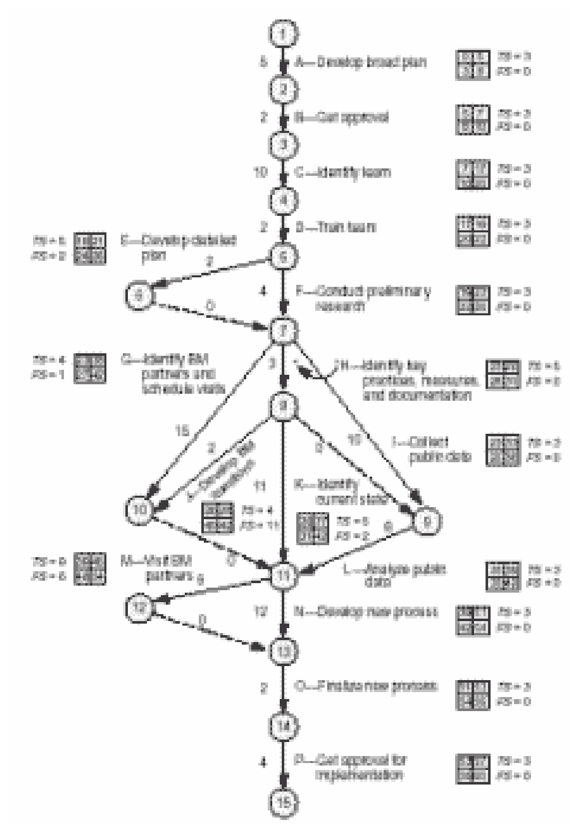
11. Calculate slack times for each task and for the entire project.

Total slack is the time a job could be postponed without delaying the project schedule.

Total slack = LS – ES = LF – EF

Free slack is the time a task could be postponed without affecting the early start of any job following it.

Free slack = the earliest ES of all tasks immediately following this one – EF



Arrow Diagram Example

7 – Process Decision Program Chart

Also called: PDPC

Description

The process decision program chart systematically identifies what might go wrong in a plan under development. Countermeasures are developed to prevent or offset those problems. By using PDPC, you can either revise the plan to avoid the problems or be ready with the best response when a problem occurs.

When to Use PDPC

- Before implementing a plan, especially when the plan is large and complex.
- When the plan must be completed on schedule.
- When the price of failure is high.

PDPC Procedure

1. Obtain or develop a tree diagram of the proposed plan. This should be a high-level diagram showing the objective, a second level of main activities and a third level of broadly defined tasks to accomplish the main activities.
2. For each task on the third level, brainstorm what could go wrong.
3. Review all the potential problems and eliminate any that are improbable or whose consequences would be insignificant. Show the problems as a fourth level linked to the tasks.
4. For each potential problem, brainstorm possible countermeasures. These might be actions or changes to the plan that would prevent the problem, or actions that would remedy it once it occurred. Show the countermeasures as a fifth level, outlined in clouds or jagged lines.
5. Decide how practical each countermeasure is. Use criteria such as cost, time required, ease of implementation and effectiveness. Mark impractical countermeasures with an X and practical ones with an O.

Here are some questions that can be used to identify problems:

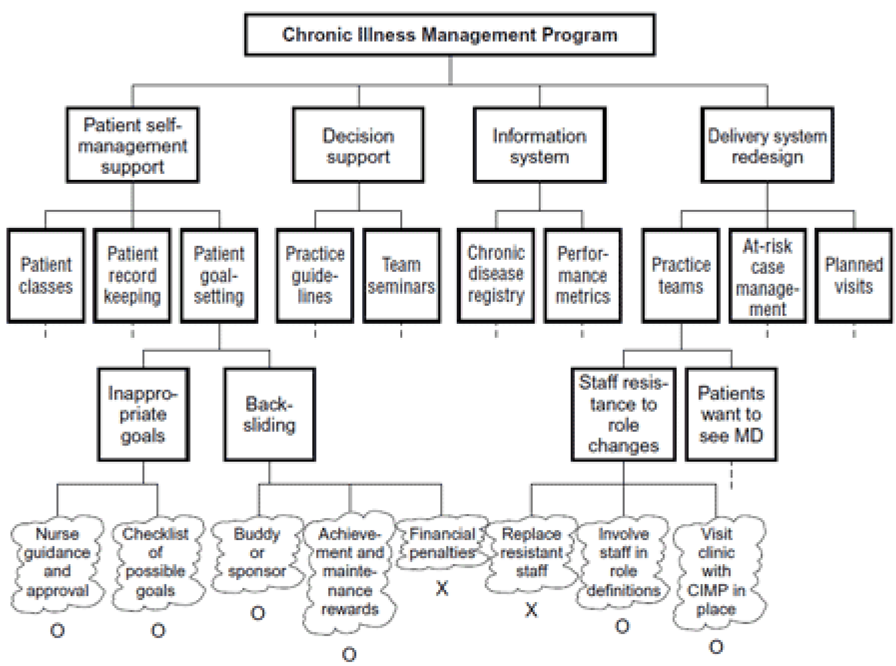
- What inputs must be present? Are there any undesirable inputs linked to the good inputs?
- What outputs are we expecting? Might others happen as well?
- What is this supposed to do? Is there something else that it might do instead or in addition?

- Does this depend on actions, conditions or events? Are these controllable or uncontrollable?
- What cannot be changed or is inflexible?
- Have we allowed any margin for error?
- What assumptions are we making that could turn out to be wrong?
- What has been our experience in similar situations in the past?
- How is this different from before?
- If we wanted this to fail, how could we accomplish that?

PDPC Example

A medical group is planning to improve the care of patients with chronic illnesses such as diabetes and asthma through a new chronic illness management program (CIMP). They have defined four main elements and, for each of these elements, key components. The information is laid out in the process decision program chart below.

Dotted lines represent sections of the chart that have been omitted. Only some of the potential problems and countermeasures identified by the planning team are shown on this chart.



Process Decision Program Chart Example

For example, one of the possible problems with patients' goal-setting is backsliding. The team liked the idea of each patient having a buddy or sponsor and will add that to the program design. Other areas of the chart helped them plan better rollout, such as arranging for all staff to visit a clinic with a CIMP program in place. Still other areas allowed them to plan in advance for problems, such as training the CIMP nurses how to counsel patients who choose inappropriate goals.