Another mathematical analysis defines the *minimal cut set*, which is the smallest combination of causes that results in the top event. Use software for that analysis also.

Fault tree analysis shares features with the why–why diagram but is more structured. At each level of the fault tree, asking “Why?” leads to causes at the next lower level.

Fault tree analysis is a deductive method. You start with a failure event and work your way backward to specific causes. In contrast, failure modes and effects analysis is an inductive method. You start with specific failures and work your way forward to consequences of those failures. As a result, FMEA is a broader process, used for analyzing entire systems or processes. FTA is a narrower process, applied to one failure at a time. It can be used within the FMEA process to understand the causes of failure modes.

**fishbone diagram**

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

**Description**

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

**When to Use**

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

**Procedure**

*Materials needed:* flipchart or whiteboard, marking pens.

1. Agree on a problem statement (effect). Write it at the center right of the flipchart or whiteboard. Draw a box around it and draw a horizontal arrow running to it.

2. Brainstorm the major categories of causes of the problem. If there is difficulty here, use generic headings: methods, machines (equipment), people (manpower),
materials, measurement, environment. Write the categories of causes as branches from the main arrow.

3. Brainstorm all the possible causes of the problem. Ask “Why does this happen?” As each idea is given, the facilitator writes it as a branch from the appropriate category. Causes can be written in several places if they relate to several categories.

4. Ask again, “Why does this happen?” about each cause. Write subcauses branching off the causes. Continue to ask “Why?” and generate deeper levels of causes. Layers of branches indicate causal relationships.

5. When the group runs out of ideas, focus attention to places on the fishbone where ideas are few.

**Example**

Figure 5.59 is the fishbone diagram drawn by the ZZ-400 manufacturing team to try to understand the source of periodic iron contamination. This example is part of the ZZ-400 improvement story in Chapter 4. The team used the six generic headings to prompt ideas. Layers of branches show thorough thinking about the causes of the problem. For example, under the heading “Machines,” the idea “materials of construction” shows four kinds of equipment and then several specific machine numbers. Some ideas appear in two different places. “Calibration” shows up under “Methods,” as a factor in the analytical procedure, and also under “Measurement,” as a cause of lab error. “Iron tools”

![Fishbone Diagram Example](image-url)
can be considered a “Methods” problem when taking samples or a “Manpower” problem with maintenance personnel.

Also see the St. Luke’s Hospital story on page 72 for another example of a fishbone diagram used within the improvement process. See the Medrad story on page 61 for an example of a nontraditional way to conduct a fishbone exercise.

**cause enumeration diagram**

_Materials needed:_ sticky notes or cards, marking pens, large work surface (wall, table, floor), flipchart paper.

1. Agree on the problem statement.

2. Brainstorm all possible causes, using any brainstorming technique. (See _brainstorming_ and NGT.) Record on sticky notes or cards. Continue until the group has run out of ideas.

3. Using an affinity diagram, group the causes and determine headings.

4. Using the headings as main causes, arrange the ideas on a fishbone drawn on flipchart paper.

5. Use the fishbone to explore for additional ideas, especially where there are few ideas on the fishbone.

**process fishbone**

_Also called:_ production process classification diagram  
_Materials needed:_ flipchart paper, marking pens.

1. Identify the problem to be studied. Develop a flow diagram of the main steps of the process in which the problem occurs. There should be fewer than 10. Draw them as a series of boxes running horizontally across a flipchart page, with arrows connecting the boxes.

2. Draw a separate fishbone for each step of the process. Take each one in turn and brainstorm causes arising from each step. Also, consider the handoff from one step to another and the causes of quality problems that occur there.

3. Continue to brainstorm subcauses, as in the first procedure.

**time-delay fishbone**

_Materials needed:_ flipchart paper, marking pens, tape, large wall space.

1. Begin a fishbone as in steps 1 and 2 of the main procedure.