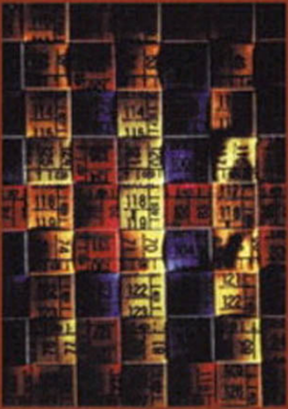
SEI SERIES IN SOFTWARE ENGINEERING

Measuring the Software Process



Statistical Process Control *for* Software Process Improvement

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Foreword by Watts S. Humphrey

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in 1943 [Ishikawa 1986]. They are also called *fishbone charts* because of their visual similarity to the skeleton of a fish.

When cause-and-effect diagrams are used to explore the behavior of a process, it is best if the diagrams are assembled by people who actually work in the process. When it comes to pinpointing problems and searching for root causes, there is no substitute for firsthand knowledge.

It is also wise to have people expert in different parts of the process participate. Diagrams drawn by one or two people are apt to be ineffective because they lack a sufficiently broad base of observational experience. For this reason, cause-and-effect diagrams are often drawn during brainstorming sessions that include people with differing viewpoints. Although cause-and-effect diagrams are (initially) subjective, they can be based on (and annotated to show) factual information such as measured values and dates of occurrences.

Cause-and-effect (CE) diagrams can be divided into three types [Ishikawa 1986]:

1. **Dispersion analysis type.** The dispersion analysis type of CE diagram is constructed by repeatedly asking the question, Why does this dispersion (or scatter) occur? Its strong point is that it helps organize and relate factors that cause variability in products and other process outcomes. Its weak points are that the form of the resulting diagram is dependent on the views of the people making it and that small causes may not get isolated or observed.
2. **Production process classification type.** The production process classification type of CE diagram is constructed by stepping mentally through the production process. This may be done in one of two ways: (1) by making the steps in the process the major ribs of a fishbone diagram or (2) by superimposing boxes on the backbone so that each box is a step in the production process. When the process steps are displayed along the backbone as illustrated in Figure 3.10), the causes are depicted on lines

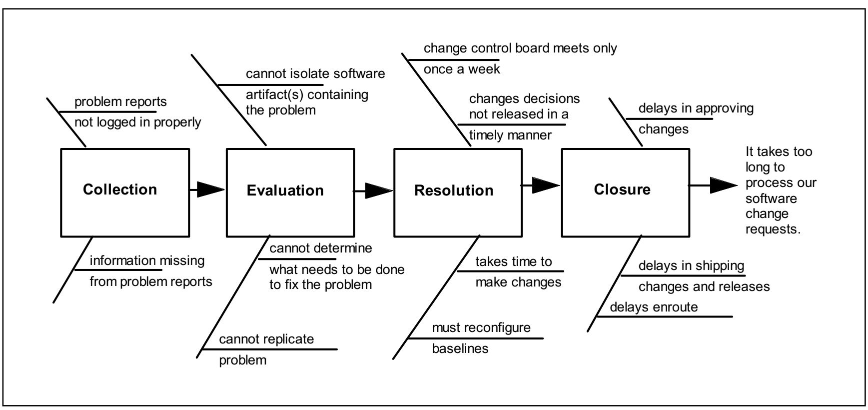

FIGURE 3.10 A Process Classification Cause-and-Effect Diagram

(ribs) that feed into either a box or one of the backbone segments that connects sequential boxes. The strength of this type of diagram is that it is easy to assemble and understand. The weaknesses are that similar causes often appear in more than one place and that problems resulting from combinations of more than one factor are difficult to illustrate.

3. **Cause enumeration type.** The cause enumeration type of CE diagram is generated by listing all possible causes and then organizing the causes to show their relationships to the aspect of product or process quality that is being examined [Ishikawa 1986]. Figure 3.11 shows a simple example. This type of cause-and-effect diagram can also be produced in brainstorming sessions where principal categories such as manpower, materials (inputs), methods, and machinery (tools) are used to prompt probing questions that uncover possible causes. The completed diagram may end up looking much like one produced by the dispersion analysis process, but it may not. The thought processes used to generate cause enumeration charts are (and should be) more free-form and less constrained than for dispersion analysis charts. The strength of the cause enumeration chart is that enumerating large numbers of likely causes reduces the probability of overlooking a major problem area. When done well, this tends to give a more complete picture than a chart produced by dispersion analysis. The weakness is that it may be hard to relate the twigs of the tree to the end result, which can make the diagram difficult to draw and to interpret.

Whatever method you use for producing cause-and-effect diagrams, be on the lookout for diagrams with many major ribs and few twigs. This almost always indicates either that the understanding of the process was shallow or that the diagram is too generalized. Use care also when a diagram lists only five or six causes. This kind of diagram is usually inadequately penetrating, even though its form may be correct.

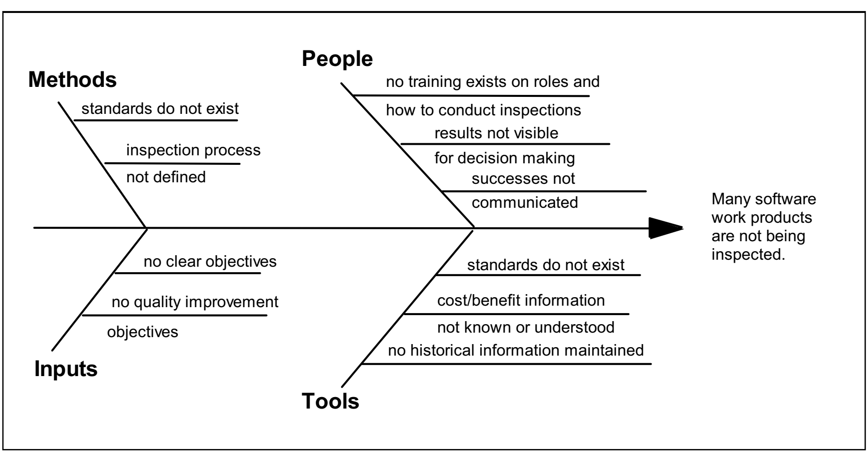

FIGURE 3.11 A Cause Enumeration Cause-and-Effect Diagram

3.5.4 HISTOGRAMS

A histogram takes measurement data and displays the distribution of the observed values. Histograms are created by grouping the results of measurement into "cells" and then counting the number in each cell. The cells are nonoverlapping, equal-width intervals along some continuous scale. The heights of the bars in histograms are proportional to the number of occurrences within each cell, as illustrated in Figure 3.12.

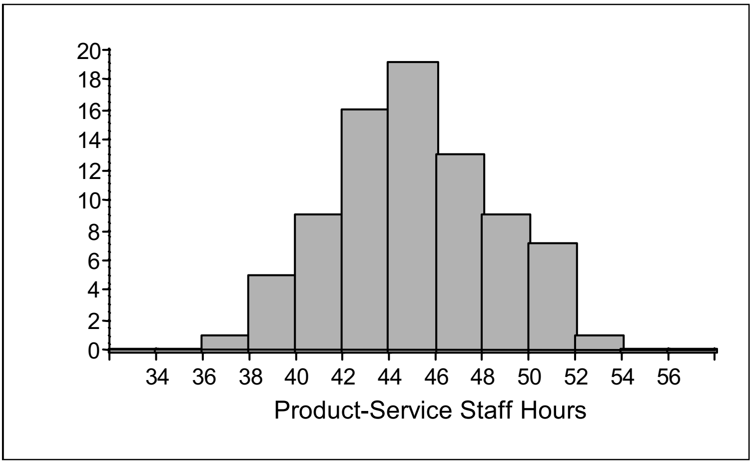

FIGURE 3.12 A Simple Histogram for Continuous Data

Histograms display frequency counts in ways that make it easy to compare distributions and see central tendencies and dispersions. As we will see in Chapters 5 and 7, histograms are useful for investigating and summarizing the performance of a process with respect to the specification limits that the process or its products must satisfy.

Histograms can be helpful troubleshooting aids. Comparisons between histograms from different subprocesses, operators, vendors, or periods of time often provide insights that point to potential causes, trends, or needs for stratification. For example, twin peaks may indicate that the data have come from two different sources, each with its own distinct characteristics. If so, control charting and other interpretive or predictive applications would not be appropriate until the data have been stratified according to source.

3.5.5 BAR CHARTS

A bar chart, like a histogram, is used to investigate the shape of a data set. Figure 3.13 is an example. Bar charts are similar in many respects to histograms but are defined on sets of discrete values. Thus, they can display any numerical value, not just counts or relative frequencies. So, bar charts can be used to display data such as the total size, cost, or elapsed time associated with individual entities or with sets of products or process steps.

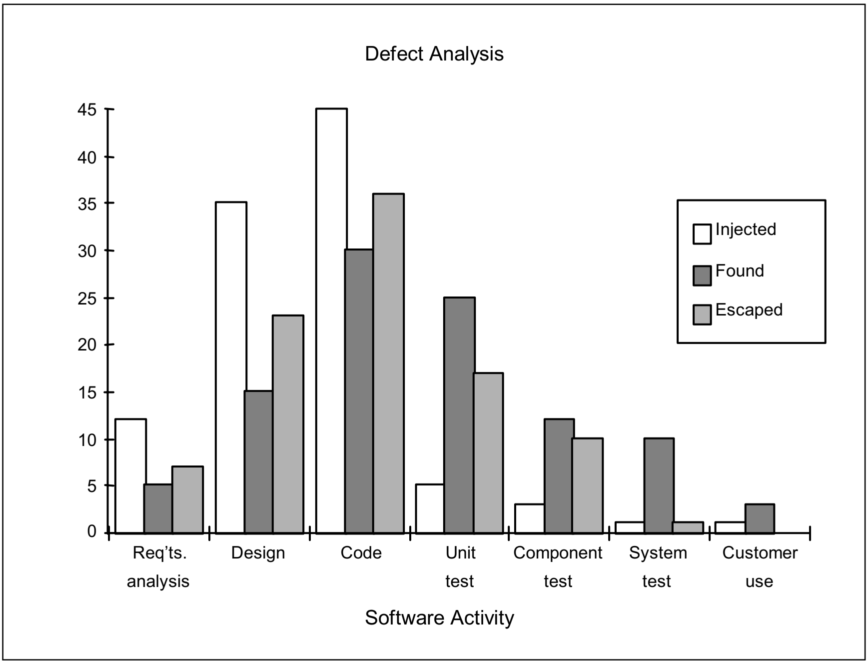

FIGURE 3.13 A Bar Chart That Compares Three Discrete Distributions

Because bar charts are defined on discrete scales, cell width is irrelevant, and there are always gaps between cells. You are free to use bars of any width you like. Bars of different widths, though, should be used only as one of several possible ways to distinguish between different data sets (coloring, shading, staggering, or labeling are usually preferable).

The concepts of average and standard deviation have no meaning for the independent variable in bar charts that are defined on discrete scales whose values are not equally spaced on the real number line. Medians, modes, and ranges, however, can be used with ordinal scales, even though the distance between cells has no meaning.

3.5.6 PARETO CHARTS

Pareto analysis is a process for ranking causes, alternatives, or outcomes to help determine which should be pursued as high-priority actions or opportunities for improvement. It is a useful technique for separating the "vital few" from the "trivial many" [Juran 1988]. A Pareto chart can be used at various stages in a quality improvement program to help select the steps to take next. Pareto charts can also be used to address questions such as these: On which types of defect should we concentrate our efforts? What parts of the process are the biggest contributors to the problem we are examining?

In their simplest forms, Pareto charts are essentially frequency counts or amounts displayed in descending order, as illustrated in Figure 3.14. In more sophisticated analyses, Pareto charts may rank causal factors or potential actions in decreasing order of their estimated economic costs or consequences.

Pareto charts may seem simple, and they are. Nevertheless, the benefits that this kind of visual display has over a table of numbers should not be underrated. As those who have succeeded in quality improvement can attest, much of the battle lies in getting everyone in a group—employees and managers alike—to share a common view of the problems faced and the actions needed.[5] Pareto charts help to create this common view.

As simple as Pareto charts are, there are some points that should not be overlooked. In particular, the frequencies or other values plotted on a Pareto chart almost always have a time period associated with them. This time period should be made explicit so that viewers of the chart can attach correct interpretations to the rankings that are displayed.

One effective use of Pareto charts is to compare the before and after states related to improvement actions. This can give a quick visual appreciation of the effectiveness and progress (or lack thereof) related to actions that have been taken. Formal methods exist for testing whether or not differences between successive Pareto charts may be due solely to chance so that inappropriate conclusions will not be drawn [Kenett 1991].

One caution: If the processes that produced the data are not stable, Pareto charts easily lead to erroneous conclusions and improper actions. This is especially true when the chart shows frequencies of occurrence for different types of problems, some of which may have assignable causes. Assignable causes mean uncontrolled

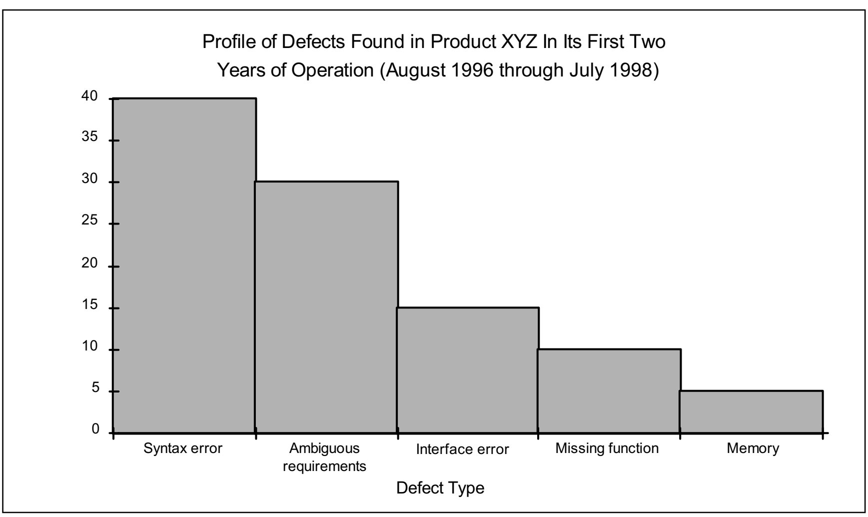

FIGURE 3.14 Example of a Pareto Chart

[5] For example, that it is easier and more consequential to reduce a tall bar by half than to reduce a short bar to zero.

variation, and these causes come and go. Frequencies associated with assignable causes have little meaning since there is no single distribution that underlies them. When a process is not in statistical control, the Pareto chart can easily look radically different from month to month, even when no action is taken.

3.6 Summary

In this chapter, we focused our attention to collecting and retaining process management data. The operational activities of measurement begin with collecting data. The procedures that you define for collecting and retaining data need to be integrated into your software processes and made operational. This means putting the right people, sensors, tools, and practices into the processes in the right places. It also means capturing and storing the data for subsequent use in analysis and process improvement.

The principal tasks associated with collecting and retaining data for process management are as follows:

- Designing the methods and obtaining the tools that will be used to support data collection and retention.
- Obtaining and training the staff that will execute the data collection procedures.
- Capturing and recording the data for each process that is targeted for measurement.
- Using defined forms and formats to supply the collected data to the individuals and groups who perform analyses.
- Monitoring the execution (compliance) and performance of the activities for collecting and retaining data.

Collecting data is more than just making measurements. It involves identifying the responsible persons and organizations; specifying where, when, and how measurements will be made; defining the procedures to be used for recording and reporting results; and providing standard "fill-in-the-blank" forms to simplify manual recording of the data.

Retaining data inherently involves creating and using one or more databases to organize and save the data for later use. Depending on the nature of your measurement activities, this may be a reasonably simple task or a very complex and technically demanding one. In either case, it is important to give serious consideration to the data retention system that will be employed.

And finally, as you collect data to visualize your process or to investigate assignable causes and potential improvements, you will often face the need to organize and summarize your data and look for patterns, trends, and relationships. Tools such as scatter diagrams, run charts, cause-and-effect diagrams, histograms, bar charts, and Pareto charts can assist you with these analyses.