

Statistical Process Control: Part 3, Pareto Analysis and Check Sheets

Scott Leavengood and James E. Reeb

Summary

Describes how to use Pareto analysis to identify and prioritize quality control problems in a manufacturing environment. Includes how to identify nonconformities, their frequency, and their impacts.

Part of the Performance Excellence in the Wood Products Industry publication series.

Part 1 in this series introduced the reader to Statistical Process Control, and Part 2 provided an overview of how and why SPC works. Part 3 begins the step-by-step process of building the practical skills necessary for hands-on implementation of SPC. This report discusses Pareto analysis, a tool we can use to help decide how and where to begin using SPC. We also discuss check sheets, which are data collection tools that may be used in Pareto analysis.

Part 4 discusses flowcharts. Other publications in the series discuss case histories of wood products firms using SPC, providing real-world evidence of the benefits of SPC and examining pitfalls and successful approaches.

Where to begin an SPC program?

Most manufacturing processes are sufficiently complex that at first glance it may seem impossible to decide where to begin using SPC techniques. SPC programs that attempt to monitor too many process variables are quickly overwhelmed by the time and labor required to collect, analyze, plot and interpret the data. In such cases, SPC seems too time consuming and expensive to be of any benefit.

The life expectancy of SPC in a company depends heavily on the results of the first few projects undertaken. With this kind of pressure, how do you decide where to begin?

Obviously, we cannot measure everything. We must focus initially on the most important quality problems to get the “biggest bang for the buck.” This is especially true in the early stages of an SPC program when personnel are likely to be skeptical of SPC and hesitant to make the necessary changes.

Prioritizing quality problems for the company is a good first step. Then, determine which projects will have the highest return on investment and therefore should be the initial focus of quality improvement programs. Pareto analysis enables us to do all this.

Pareto analysis

Pareto (pronounced “pah-RAY-toe”) analysis uses the Pareto principle, also called the 80:20 rule, to analyze and display data. Vilfredo Pareto was a 19th-century Italian economist who studied the distribution of income in Italy. He found that about 20% of the population controlled about 80% of the wealth.

Quality expert J.M. Juran applied the principle to quality control and found that 80% of problems stem from 20% of the possible causes. The numbers 80 and 20 are not meant to be absolutes. The main point, as Juran stated, is that we should focus on the “vital few” problems (those in the 20% category) rather than on the “trivial many” to make the most significant improvements in product quality.

Pareto charts are the graphical tool used in Pareto analysis. A Pareto chart is a bar chart that displays the relative importance of problems in a format that is very easy to interpret. The most important problem (for example, the one highest in cost, frequency, or some other measurement) is represented by the tallest bar, the next most important problem is represented by the next tallest bar, and so on. A check sheet is a useful tool for collecting data for Pareto charts.

Check sheets

Check sheets are relatively simple forms used to collect data. They include a list of nonconformities and a tally of nonconformities. Check sheets should also include the name of the project for which data is being collected, the shift when the items were produced, the names of persons collecting the data, dates of data collection and of production (if known), and the location of data collection (e.g., in-house or at a customer’s).

Check sheets aren’t mandatory to construct Pareto charts. However, because check sheets require you to standardize your list and definitions of nonconformities, they provide several benefits.

First, people often do not agree on the major categories of nonconformities. Therefore, developing a list of common nonconformities (i.e., quality problems) is not as easy as it sounds. A good way to develop this list is to brainstorm with production personnel, management, QC personnel, and, most important, your customers.

Second, people often do not agree on precisely what constitutes “nonconforming.” In other words, how bad does it have to be to get thrown in the scrap or rework pile?

Last, different people often will put a given item in different categories. For example, one person may call an item with torn grain a machining defect, another might call it fuzzy grain, and another may call it reaction wood. Without standard terminology and definitions, it becomes very difficult to conduct a Pareto analysis.

Nonconforming, not defective

A nonconforming product is one that fails to meet one or more specifications, and a nonconformity is a specific type of failure. A nonconforming product may be termed defective if it contains one or more defects that render it unfit or unsafe for use. Confusion of these terms has resulted in misunderstandings in product liability lawsuits. As a result, many companies have adjusted their internal terminology and now use the terms “nonconforming” and “nonconformity” in favor of “defect” and “defective.”

To get an idea of the effect on your company of lack of standardized terminology and definitions for nonconformities, try a simple experiment. Select several items at random and ask different people to examine them and record nonconformities item by item.

One experiment at a secondary wood products manufacturer involved five quality inspectors. The inspectors did not agree on the number of items that should be rejected due to quality problems (the scrap/rework rate varied from 34% to 49%) nor did they agree on the reasons for rejecting the products. Had we looked only at data collected by inspectors 1, 2 and 3, we would have concluded that torn grain and blue stain were the biggest quality problems. Had we looked only at data collected by inspectors 4 and 5, we would have concluded that dents (handling damage) and reaction wood were the biggest quality problems. Do not underestimate the importance of developing a standard list of nonconformities and precise definitions for each.

The following example demonstrates how to construct and interpret check sheets and Pareto charts.

Example

The Quality Improvement Team at a manufacturer of wood components visited a customer and examined items in the scrap and rework bins. After looking at each item and talking with the customer, the team agreed on categories of nonconformities and developed precise definitions for each category. They created a check sheet, then inspected each item and tallied the number of occurrences (frequency) for each cause of nonconformity. Figure 1 presents the results.

reworking costs approximately \$11 per item. Therefore, our estimate of the average scrap and rework cost for size out-of-specification is:

$$(\text{scrap cost}) \times (\% \text{ scrap}) + (\text{rework cost}) \times (\% \text{ rework}) = \text{scrap \& rework cost}$$

$$(\$20) \times (10\%) + (\$11) \times (90\%) = \$12$$

To account for frequency as well as scrap and rework costs, multiply relative frequency by cost to obtain relative cost. For example, we already determined that approximately 41% of nonconformities were size out-of-specification. Therefore, the relative cost due to size out-of-specification is:

$$0.41 \times \$12 = \$4.92$$

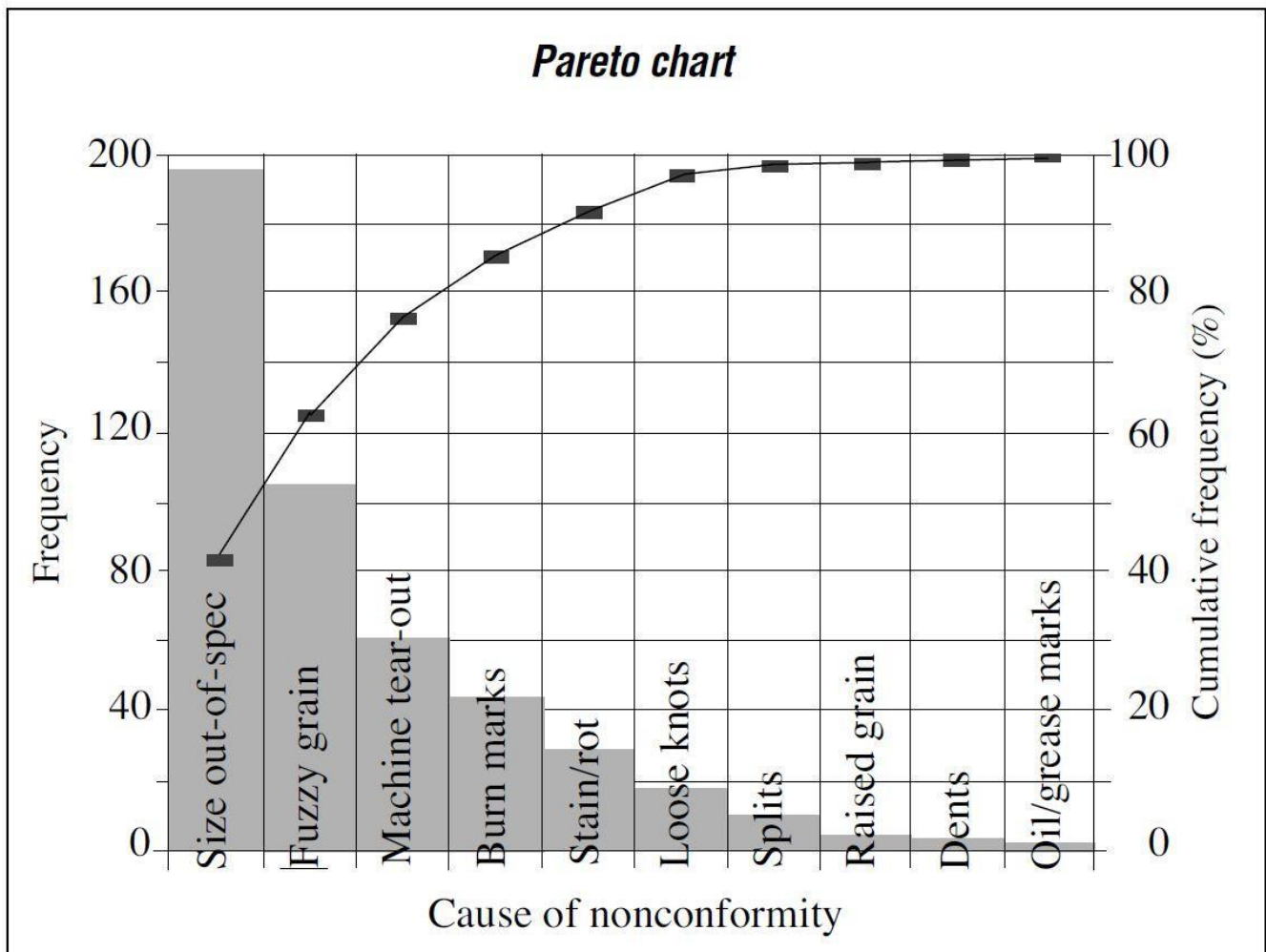


Figure 3: Pareto chart for the data in Figure 2.

Table 1 shows the relative costs, and Figure 4 shows the corresponding Pareto chart. We can see that size out-of-specification is the primary nonconformity from the standpoint of frequency (Figure 3) as well as relative cost to scrap or rework (Figure 4). Therefore, to get the “biggest bang for the buck,” it would be wise to begin the SPC program by focusing on problems that lead to size out-of-specification.

Table 1: Nonconformities and relative costs.

Nonconformity	Rel. Cost (\$)	Rel. Freq. (%)	Cum. Rel. Freq. (%)
Size out-of-spec.	4.92	38	38
Machine tear-out	2.34	18	56
Fuzzy grain	1.76	13	69
Stain/rot	1.75	13	82
Loose knots	1.00	8	90
Burn marks	0.72	6	96
Splits	0.32	2	98
Dents	0.09	0.7	98.7
Raised grain	0.06	0.5	99.2
Oil/grease marks	0.03	0.2	99.4
Total	12.99	99.4	

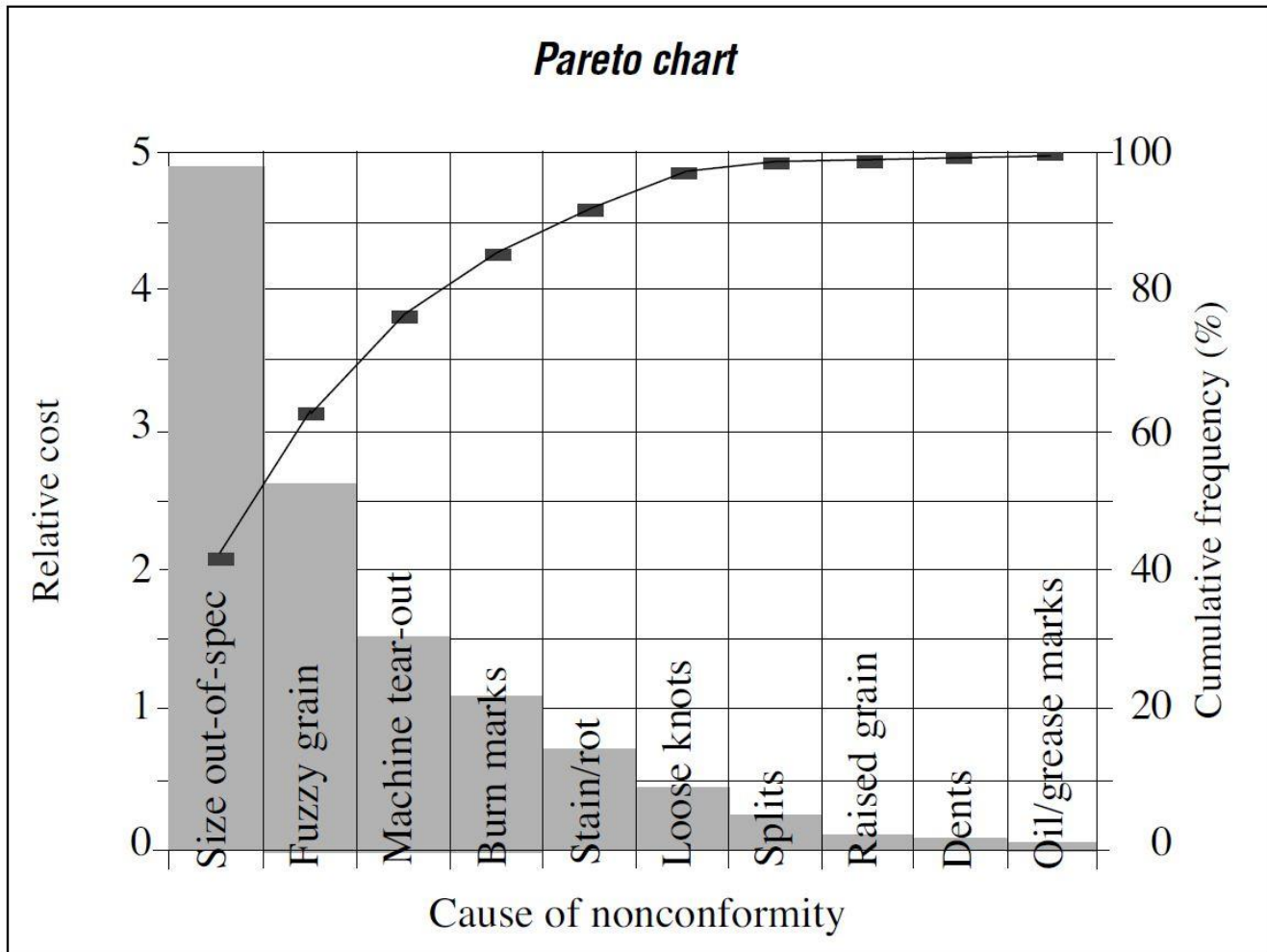


Figure 4: Pareto chart for the data in Table 1.

Summary

We now know the primary nonconformities and therefore where to focus initial efforts of an SPC program. We do not yet know, however, the specific processing steps that lead to a given nonconformity—that is, where and how the problem arises—and therefore we do not yet know where or what to monitor.

To help us discover the specific steps in the process that lead to a given nonconformity, it is helpful to develop a flowchart for the process. Flowcharts are the subject of the next report in this series.

For more information

Brassard, M., and D. Ritter. 1994. *The Memory Jogger II: A Pocket Guide of Tools for Continuous Improvement @ Effective Planning*. Salem, NH: Goal/QPC. <http://www.goalqpc.com/> (<http://www.goalqpc.com/>)

Grant, E.L., and R.S. Leavenworth. 1988. *Statistical Quality Control*, 6th ed. New York, NY: McGraw Hill.

Ishikawa, K. 1982. *Guide to Quality Control*. Tokyo, Japan: Asian Productivity Organization.

Montgomery, D.C. 1997. *Introduction to Statistical Quality Control*, 3rd ed. New York, NY: John Wiley & Sons.

Walton, M. 1986. *The Deming Management Method*. New York, NY: Putnam.

About this series

Publications in the Performance Excellence in the Wood Products Industry series address topics related to wood technology, marketing and business management, production management, quality and process control, and operations research.

For a complete list of titles, visit the Oregon State University Extension Catalog and search for “performance excellence”: <https://catalog.extension.oregonstate.edu/> (<https://catalog.extension.oregonstate.edu/>)

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Related publications



Part 1 in this series introduced Statistical Process Control (SPC). In Part 2, our goal is to provide information to increase managers' understanding of and confidence in SPC as a profit-making tool. It is unreasonable to expect managers to consent to and support SPC training and implementation if they do not understand what SPC is and how and why it works. Specifically, this publication describes the importance of understanding and quantifying process variation, and how that makes SPC work.

Part 3 in this series describes how to use check sheets and Pareto analysis to decide where to begin quality improvement efforts. Later publications in the series present additional tools such as flowcharts, cause-and-effect diagrams, designed experiments, control charts, and process capability analysis.

Beginning in Part 3, SPC tools and techniques are presented in the context of an example case study that follows a fictional wood products company's use of SPC to address an important quality problem.

For a glossary of common terms used in SPC, see Part 1.

Variation—it's everywhere

Variation is a fact of life. It is everywhere, and it is unavoidable. Even a brand new, state-of-the-art machine cannot hold perfectly to the target setting; there always is some fluctuation around the target. Attaining consistent product quality requires understanding, monitoring, and controlling process variability. Attaining optimal product quality requires a never-ending commitment to reducing variation.

Walter Shewhart, the man whose work laid the foundations for SPC, recognized that variability has two broad causes: **common causes** (also called chance, random, inherent, or unknown cause) and **special causes** (also called assignable cause).

Common causes are inherent in the process and can be thought of as the "natural rhythm of the process." Common causes result in a stable, repeating pattern of variation. Real quality improvement requires a continual focus on reducing common-cause variability.

It's difficult to give examples of common causes because what is typical for one process may not be typical for another. However, common causes might include things like normal tool wear; differences in wood density or moisture content; and normal, gradual changes in ambient temperature and humidity throughout the day.

Statistical Process Control: Part 2, How and Why SPC Works

(<https://extension.oregonstate.edu/catalog/pub/em-8733-statistical-process-control-part-2-how-why-spc-works>)

This publication provides information to help managers understand and be confident in using Statistical Process Control as a profit-making tool. It includes descriptions of basic statistical concepts and SPC tools. ...

Scott Leavengood, James E. Reeb | Jun 2023 | OSU EXTENSION CATALOG [Peer reviewed \(Orange level\)](#)

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Our focus for the first four publications in this series has been on introducing you to Statistical Process Control (SPC)—what it is, how and why it works, and then discussing some hands-on tools for determining where to focus initial efforts to use SPC in your company. Experience has shown that SPC is most effective when focused on a few key areas as opposed to the shotgun approach of measuring anything and everything. With that in mind, we presented check sheets and Pareto charts (Part 3) in the context of project selection. These tools help reveal the most frequent and costly quality problems. Flowcharts (Part 4) help to build consensus on the actual steps involved in a process, which in turn helps define precisely where quality problems might be occurring and what quality characteristics to monitor to help solve the problems.

In Part 5, we now turn our attention to cause-and-effect diagrams (CE diagrams). CE diagrams are designed to help quality improvement teams identify the root causes of problems. In Part 6, we will continue this concept of root cause analysis with a brief introduction to a more advanced set of statistical tools: Design of Experiments. It is important, however, that we do not lose sight of our primary goal: improving quality and in so doing, improving customer satisfaction and the profitability of the company.

We've identified the problem; now how can we solve it?

In previous publications in this series, we have identified the overarching quality problem we need to focus on and developed a flowchart identifying the specific steps in the process where problems may occur. We now need to narrow our focus so that we know what is causing the problem—and therefore how it can be solved.

Continuing our example from Parts 3 and 4, we determined that "size out of specification" for wooden handles was the most frequent and costly quality problem. The flowchart showed that part shape was inspected with a "go/no-go" gauge at the inlet to a machine that tapers the handles. The results of go/no-go inspection are either that the shape is acceptable ("go"), in which case the parts were loaded into the tapering machine, or that the shape is not acceptable ("no go"), in which case the parts are scrapped. However, customers are still indicating that the sizes of the handles are not meeting their specifications.

In short, our prior efforts have helped us identify what the problem is and where it

Statistical Process Control: Part 5, Cause-and-Effect Diagrams

<https://extension.oregonstate.edu/catalog/pub/em-8984-statistical-process-control-part-5-cause-effect-diagrams>

Describes how cause-and-effect diagrams can help quality improvement teams identify the root causes of problems. Part of the Performance Excellence in the Wood Products Industry publication series.

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Our focus for the first five publications in this series has been on introducing you to Statistical Process Control (SPC)—what it is, how and why it works, and how to determine where to focus initial efforts to use SPC in your company. Experience has shown that SPC is most effective when focused on a few key areas as opposed to measuring anything and everything. With that in mind, we described how tools such as Pareto analysis and check sheets (Part 3) help with project selection by revealing the most frequent and costly problems. Then we emphasized how constructing flowcharts (Part 4) helps build consensus on the actual steps involved in a process, which in turn helps define where quality problems might be occurring. We also showed how cause-and-effect diagrams (Part 5) help quality improvement teams identify the root cause of problems.

In Part 6, we continue the discussion of root cause analysis with a brief introduction to design of experiments (DOE). We have yet to cover the most common tool of SPC: control charts.

It is important, however, to not lose sight of the primary goal: Improve quality, and in so doing, improve customer satisfaction and the company's profitability.

We've identified potential causes, but what's the true cause?

In an example that continues throughout this series, a quality improvement team from XYZ Forest Products Inc. (a fictional company) identified an important quality problem, identified the process steps where problems may occur, and brainstormed potential causes. They now need to know how specific process variables (e.g., feed speed, wood moisture, wood species, or tooling) influence the problem. In short, they need to filter the list to see which potential causes have a significant impact on the problem.

They determined that size out of specification for wooden handles (hereafter called out-of-spec handles) was the most frequent and costly quality problem (Part 3). A flowchart (Part 4) showed that part size and shape were inspected with a go/no-go (i.e., acceptable/unacceptable) gauge at the inlet to a machine that tapers the handles. Despite this inspection step, customers still indicated that handle sizes were not meeting their specifications. The team constructed a cause-and-effect diagram (Part 5) to brainstorm a list of potential causes for the problem, but they don't yet know which potential cause is

Statistical Process Control: Part 6, Design of Experiments

<https://extension.oregonstate.edu/catalog/pub/em-9045-statistical-process-control-part-6-design-experiments>

Focuses on how design of experiments can help companies solve problems in manufacturing. Part of the Performance Excellence in the Wood Products Industry publication series.

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Our focus for the prior publications in this series has been on introducing you to Statistical Process Control (SPC)—what it is, how and why it works, and how to use various tools to determine where to focus initial efforts to use SPC in your company. SPC is most effective when focused on a few key areas as opposed to measuring anything and everything. With that in mind, we described how to:

- Use Pareto analysis and check sheets to select projects (Part 3)
- Construct flowcharts to build consensus on the steps involved and help define where quality problems might be occurring (Part 4)
- Create cause-and-effect diagrams to identify potential causes of a problem (Part 5)
- Design experiments to hone in on the true cause of the problem (Part 6)

Now, in Part 7, we describe the primary SPC tool: control charts. Assuming our experiment helped identify target values for key processes, we are ready to focus on day-to-day control and monitoring to ensure the process remains stable and predictable over time.

It is important, however, to not lose sight of the primary goal: Improve quality, and in so doing, improve customer satisfaction and the company's profitability.

How can we be sure our process stays stable through time?

In an example that continues throughout this series, a quality improvement team from XYZ Forest Products Inc. (a fictional company) determined that size out of specification for wooden handles (hereafter called out-of-spec handles) was the most frequent and costly quality problem. The team identified the process steps where problems may occur, brainstormed potential causes, and conducted an experiment to determine how specific process variables (wood moisture content, species, and tooling) influenced the problem. Assuming the team makes a process change, they next need to (1) verify that the change actually produces the desired beneficial result and (2) ensure the process remains stable through time. In other words, they need to sustain the gains they've made.

Statistical Process Control: Part 7, Variables Control Charts

<https://extension.oregonstate.edu/catalog/pub/em-9109-statistical-process-control-part-7-variables-control-charts>

Describes control charts, the primary tools used in statistical process control. Part of the Performance Excellence in the Wood Products Industry publication series. The supplemental example spreadsheet below includes all data and charts from this publication.

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Our focus for the prior publications in this series has been on introducing you to Statistical Process Control (SPC)—what it is, how and why it works, and how to use various tools to determine where to focus initial efforts to use SPC in your company. SPC is most effective when focused on a few key areas as opposed to measuring anything and everything. With that in mind, we described how to:

- Use Pareto analysis and check sheets to select projects (Part 3)
- Construct flowcharts to build consensus on the steps involved and help define where quality problems might be occurring (Part 4)
- Create cause-and-effect diagrams to identify potential causes of a problem (Part 5)
- Design experiments to hone in on the true cause of the problem (Part 6)
- Use the primary SPC tool—control charts—for day-to-day monitoring of key process variables to ensure the process remains stable and predictable over time (Part 7)

Variables control charts are useful for monitoring variables data—things you measure and express with numbers, such as length, thickness, moisture content, glue viscosity, and density. However, not all quality characteristics can be expressed this way. Sometimes, quality checks are simply acceptable/unacceptable or go/no-go. For these situations, we need to use attributes control charts.

It is important, however, to not lose sight of the primary goal: Improve quality, and in so doing, improve customer satisfaction and the company's profitability.

How can we be sure our process stays stable through time?

In an example that continues throughout this series, a quality improvement team from XYZ Forest Products Inc. (a fictional company) determined that size out of specification for wooden handles (hereafter called out-of-spec handles) was the most frequent and costly quality problem. The team identified the process steps where problems may occur, brainstormed potential causes, and conducted an experiment to determine how specific process variables (wood moisture content, species, and tooling) influenced the problem. The team's experiment revealed that moisture content as well as an interaction between

Statistical Process Control: Part 8, Attributes Control Charts

<https://extension.oregonstate.edu/catalog/pub/em-9110-statistical-process-control-part-8-attributes-control-charts>

Part of the Performance Excellence in the Wood Products Industry publication series, this publication and supplemental spreadsheet describes attributes control charts, a tool used in statistical process control.

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Our focus for the prior publications in this series has been on introducing you to Statistical Process Control (SPC)—what it is, how and why it works, and how to use various tools to determine where to focus initial efforts to use SPC in your company. Through this series, we described a variety of quality tools in terms of how they support implementation and use of SPC. The two primary SPC tools are control charts and process capability analysis.

A quick recap of this publication series: Parts 1 and 2 introduced SPC what it is and how it works. In Parts 3 through 8, we walked through an example from XYZ Forest Products Inc. (a fictional company), following along as the company's quality improvement team began using SPC in response to customer complaints about size of wooden handles being out of specification (hereafter called out-of-spec handles). We described how the team:

- Used Pareto charts and check sheets to decide where to focus efforts (Part 3)
- Constructed flowcharts to build consensus on the steps involved and help define where quality problems might be occurring (Part 4)
- Created cause-and-effect diagrams to identify potential causes of a problem (Part 5)
- Designed an experiment to hone in on the true cause of the problem (Part 6)
- Used the primary SPC tools—variables and attributes control charts—to first assess stability of the process and then monitor key variables to ensure the process remains stable and predictable over time (Parts 7 and 8)

It is important to not lose sight of the primary goal of SPC: Improve quality, and in so doing, improve customer satisfaction and the company's profitability.

We've spent considerable effort identifying XYZ's most important quality problems, determining how to solve them, and then ensuring the process remains stable. Now we need to step back and ask how well the new and improved process is able to meet customer expectations. In short, we must shift our focus from stability to capability.

Our focus on customers in process capability analysis is not limited to external customers. Internal customers (that is, processes down the line) are important, too. In our XYZ example, external customer expectations are related to the size of wooden handles. However, the designed experiment (Part 6) revealed that controlling moisture content is

Statistical Process Control: Part 9, Process Capability Analysis

<https://extension.oregonstate.edu/catalog/pub/em-9111-statistical-process-control-part-9-process-capability-analysis>

Describes process capability analysis, a method for comparing the variability of a process relative to desired specifications. Part of the Performance Excellence in the Wood Products Industry publication series.

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