GLOBAL EDITION

Operations Management

Sustainability and Supply Chain Management

FOURTEENTH EDITION

Jay Heizer • Barry Render • Chuck Munson

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Main Heading	Review Material	MyLab Operations Management
TOOLS OF TQM	TQM tools that generate ideas include the *check sheet* (organized method of recording data), *scatter diagram* (graph of the value of one variable vs. another variable), and *cause-and-effect diagram*. Tools for organizing the data are the *Pareto chart* and *flowchart*. Tools for identifying problems are the *histogram* (distribution showing the frequency of occurrences of a variable) and *statistical process control chart*. ■ **Cause-and-effect diagram**—A schematic technique used to discover possible locations of quality problems. (Also called an Ishikawa diagram or a fish-bone chart.) The 4 *M*s (material, machinery/equipment, manpower, and methods) may be broad "causes." ■ **Pareto chart**—A graphic that identifies the few critical items as opposed to many less important ones. ■ **Flowchart**—A block diagram that graphically describes a process or system. ■ **Statistical process control (SPC)**—A process used to monitor standards, make measurements, and take corrective action as a product or service is being produced. ■ **Control chart**—A graphic presentation of process data over time, with predetermined control limits.	Concept Questions: 4.1–4.6 Problems: 6.1, 6.3, 6.5, 6.8–6.14, 6.16–6.19 **ACTIVE MODEL 6.1** Virtual Office Hours for Solved Problem: 6.1
THE ROLE OF INSPECTION	■ **Inspection**—A means of ensuring that an operation is producing at the quality level expected. ■ **Source inspection**—Controlling or monitoring at the point of production or purchase: at the source. ■ **Poka-yoke**—Literally translated, "mistake proofing"; it has come to mean a device or technique that ensures the production of a good unit every time. ■ **Checklist**—A type of poka-yoke that lists the steps needed to ensure consistency and completeness in a task. ■ **Attribute inspection**—An inspection that classifies items as being either good or defective. ■ **Variable inspection**—Classifications of inspected items as falling on a continuum scale, such as dimension, size, or strength.	Concept Questions: 5.1–5.6 Problems: 6.20–6.21 **VIDEO 6.2** Quality Counts at Alaska Airlines
TQM IN SERVICES	Determinants of service quality: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding/knowing the customer, and tangibles. ■ **Service recovery**—Training and empowering frontline workers to solve a problem immediately. ■ **SERVQUAL**—A popular measurement scale for service quality that compares service expectations with service performance.	Concept Questions: 6.1–6.6 **VIDEO 6.3** Celebrity Cruises: A Premium Experience
ADDITIONAL MYLAB OPERATIONS MANAGEMENT RESOURCES	✔ Additional Case Studies (Westover Electrical, Inc. and Quality at the Ritz-Carlton Hotel Company) ✔ Southwestern University Case Studies are integrated in Chapters 3, 4, 6, 8, 12, and 13 and in Supplement 7 ✔ Multiple Choice Case Questions (Southwestern University (C) and Westover Electrical, Inc.) ✔ Quality Management Simulation	

Self Test

LO 6.1 In this chapter, *quality* is defined as:
- **a)** the degree of excellence at an acceptable price and the control of variability at an acceptable cost.
- **b)** how well a product fits patterns of consumer preferences.
- **c)** the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs.
- **d)** being impossible to define, but you know what it is.

LO 6.2 ISO 9000 is an international standard that addresses _____.

LO 6.3 A Six Sigma program:
- **a)** is a process that has a very high level of capability.
- **b)** is a program that focuses on customer satisfaction.
- **c)** uses a set of tools such as histograms and flowcharts.
- **d)** uses the DMAIC model.
- **e)** All of the above are features of a Six Sigma program.

LO 6.4 The process of identifying other organizations that are best at some facet of your operations and then modeling your organization after them is known as:
- **a)** continuous improvement.
- **b)** employee empowerment.
- **c)** benchmarking.
- **d)** copycatting.
- **e)** patent infringement.

LO 6.5 The Taguchi method includes all except which of the following major concepts?
- **a)** Employee involvement
- **b)** Remove the effects of adverse conditions
- **c)** Quality loss function
- **d)** Target specifications

LO 6.6 The seven tools of total quality management are _______, _______, _______, _______, _______, _______, and _______.

Answers: LO 6.1. c; LO 6.2. quality management systems; LO 6.3. e; LO 6.4. c; LO 6.5. a; LO 6.6. check sheets, scatter diagrams, cause-and-effect diagrams, Pareto charts, flowcharts, histograms, SPC charts.

Statistical Process Control

SUPPLEMENT 6

SUPPLEMENT OUTLINE

LEARNING OBJECTIVES

As part of its statistical process control system, Flowers Bakery, in Georgia, uses a digital camera to inspect just-baked sandwich buns as they move along the production line. Items that don't measure up in terms of color, shape, seed distribution, or size are identified and removed automatically from the conveyor.

Courtesy of Georgia Institute of Technology

Statistical Process Control (SPC)

Statistical process control (SPC)
A process used to monitor standards by taking measurements and corrective action as a product or service is being produced.

Control chart
A graphical presentation of process data over time.

In this supplement, we address statistical process control—the same techniques used at Flowers Bakery, Arnold Palmer Hospital, GE, and Southwest Airlines to achieve quality standards. **Statistical process control (SPC)** is the application of statistical techniques to ensure that processes meet standards. All processes are subject to a certain degree of variability. While studying process data in the 1920s, Walter Shewhart of Bell Laboratories made the distinction between the common (natural) and special (assignable) causes of variation. He developed a simple but powerful tool to separate the two—the **control chart**.

A process is said to be operating *in statistical control* when the only source of variation is common (natural) causes. The process must first be brought into statistical control by detecting and eliminating special (assignable) causes of variation.[1] Then its performance is predictable, and its ability to meet customer expectations can be assessed. The *objective* of a process control system is to *provide a statistical signal when assignable causes of variation are present*. Such a signal can quicken appropriate action to eliminate assignable causes.

Natural variations
Variability that affects every production process to some degree and is to be expected; also known as common cause.

Assignable variation
Variation in a production process that can be traced to specific causes.

Natural Variations

Natural variations affect almost every process and are to be expected. **Natural variations** are the many sources of variation that occur within a process, even one that is in statistical control. Natural variations form a pattern that can be described as a *distribution*.

As long as the distribution (output measurements) remains within specified limits, the process is said to be "in control," and natural variations are tolerated.

Assignable Variations

Assignable variation in a process can be traced to a specific reason. Factors such as machine wear, misadjusted equipment, fatigued or untrained workers, or new batches of raw material are all potential sources of assignable variations.

Natural and assignable variations distinguish two tasks for the operations manager. The first is to *ensure that the process is capable* of operating under control with only natural variation. The second is, of course, to *identify and eliminate assignable variations* so that the processes will remain under control.

Figure **S6.1**

Natural and Assignable Variation

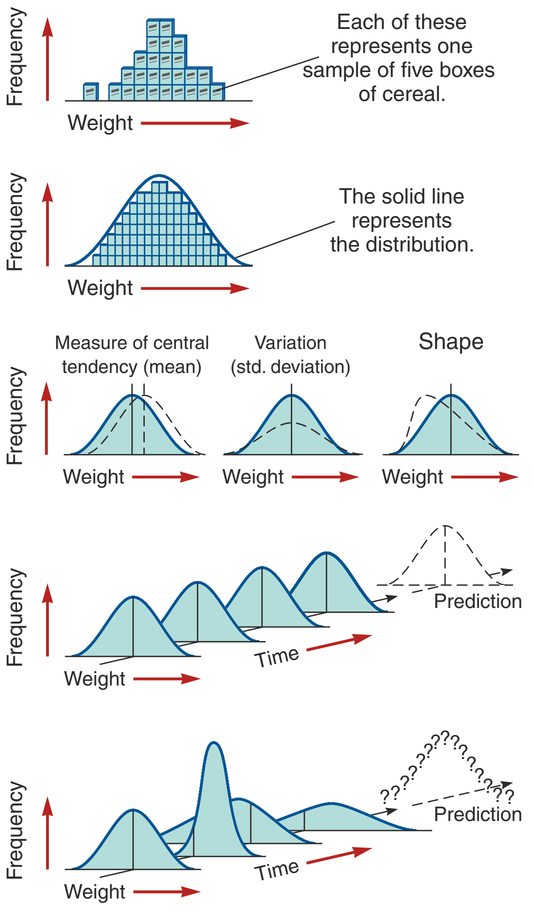
(a) Samples of the product, say five boxes of cereal taken off the filling machine line, vary from one another in weight.

(b) After enough sample means are taken from a stable process, they form a pattern called a *distribution*.

(c) There are many types of distributions, including the normal (bell-shaped) distribution, but distributions do differ in terms of central tendency (mean), standard deviation or variance, and shape.

(d) If only natural causes of variation are present, the output of a process forms a distribution that is stable over time and is predictable.

(e) If assignable causes of variation are present, the process output is not stable over time and is not predictable. That is, when causes that are not an expected part of the process occur, the samples will yield unexpected distributions that vary by central tendency, standard deviation, and shape.



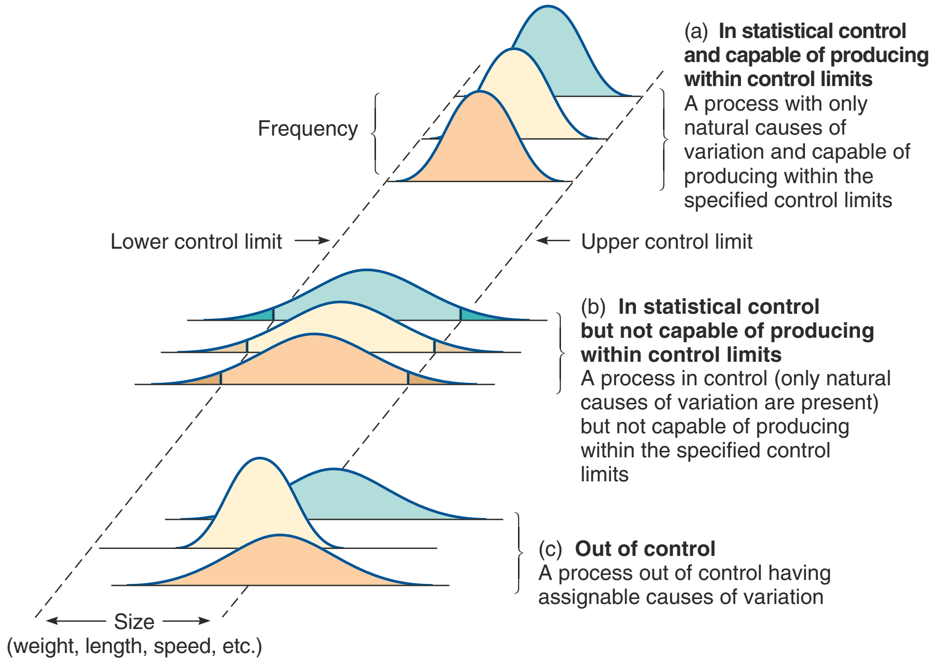


Figure **S6.2**

Process Control: Three Types of Process Outputs

Samples Because of natural and assignable variation, statistical process control uses averages of small samples (often of four to eight items) as opposed to data on individual parts. Individual pieces tend to be too erratic to make trends quickly visible.

Figure S6.1 provides a detailed look at the important steps in determining process variation. The horizontal scale can be weight (as in the number of ounces in boxes of cereal) or length (as in fence posts) or any physical measure. The vertical scale is frequency. The samples of five boxes of cereal in Figure S6.1 **(a)** are weighed, **(b)** form a distribution, and **(c)** can vary. The distributions formed in **(b)** and **(c)** will fall in a predictable pattern **(d)** if only natural variation is present. If assignable causes of variation are present, then we can expect either the mean to vary or the dispersion to vary, as is the case in **(e)**.

Control Charts The process of building control charts is based on the concepts presented in Figure S6.2. This figure shows three distributions that are the result of outputs from three types of processes. We plot small samples and then examine characteristics of the resulting data to see if the process is within "control limits." The purpose of control charts is to help distinguish between natural variations and variations due to assignable causes. As seen in Figure S6.2, a process is **(a)** in control *and the process is capable of producing within established control limits*, **(b)** in control *but the process is not capable of producing within established limits*, or **(c)** out of control. We now look at ways to build control charts that help the operations manager keep a process under control.

LO S6.1 *Explain* the purpose of a control chart

Control Charts for Variables

The variables of interest here are those that have continuous dimensions. They have an infinite number of possibilities. Examples are weight, speed, length, or strength. Control charts for the mean, $\bar{x}$ or x-bar, and the range, R, are used to monitor processes that have continuous dimensions. The **$\bar{x}$-chart** tells us whether changes have occurred in the central tendency (the mean, in this case) of a process. These changes might be due to such factors as tool wear, a gradual increase in temperature, a different method used on the second shift, or new and stronger materials. The ***R*-chart** values indicate that a gain or loss in dispersion has occurred. Such a change may be due to worn bearings, a loose tool, an erratic flow of lubricants to a machine, or to sloppiness on the part of a machine operator. The two types of charts go hand in hand when monitoring variables because they measure the two critical parameters: central tendency and dispersion.

$\bar{x}$-chart
A quality control chart for variables that indicates when changes occur in the central tendency of a production process.

***R*-chart**
A control chart that tracks the "range" within a sample; it indicates that a gain or loss in uniformity has occurred in dispersion of a production process.

The Central Limit Theorem

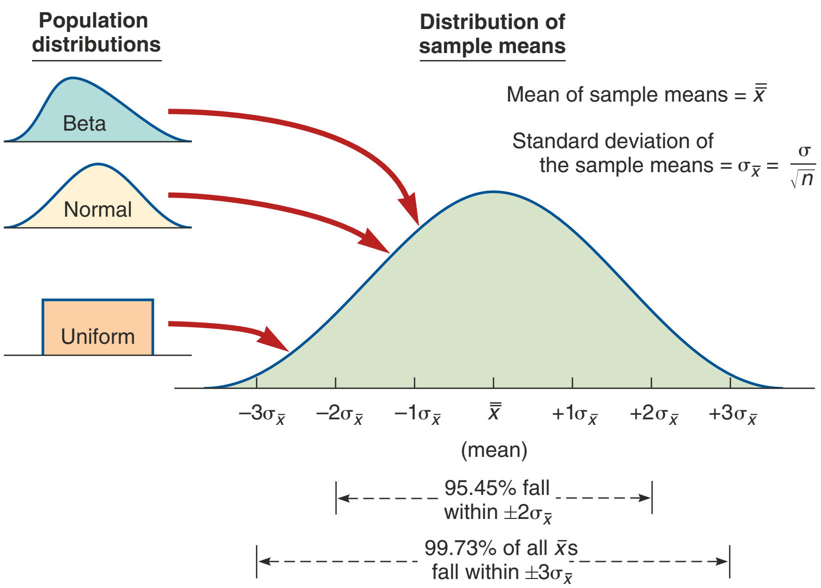
The theoretical foundation for $\bar{x}$-charts is the **central limit theorem**. This theorem states that regardless of the distribution of the population, the distribution of $\bar{x}$ s (each of which is a mean of a sample drawn from the population) will tend to follow a normal curve as the number of samples increases. Fortunately, even if each sample (n) is fairly small (say, 4 or 5), the distributions of the

Central limit theorem
The theoretical foundation for $\bar{x}$-charts, which states that regardless of the distribution of the population of all parts or services, the distribution of $\bar{x}$ s tends to follow a normal curve as the number of samples increases.

Figure **S6.3**

The Relationship Between Population and Sampling Distributions

Even though the population distributions will differ (e.g., normal, beta, uniform), each with its own mean (μ) and standard deviation (σ), the distribution of sample means always approaches a normal distribution.



averages will still roughly follow a normal curve. The theorem also states that: (1) the mean of the distribution of the $\bar{x}$ s (called $\bar{\bar{x}}$) will equal the mean of the overall population (called μ); and (2) the standard deviation of the *sampling distribution*, $\sigma_{\bar{x}}$, will be the *population (process) standard deviation*, divided by the square root of the sample size, *n*. In other words:[2]

LO S6.2 *Explain* the role of the central limit theorem in SPC

$$\bar{\bar{x}} = \mu \tag{S6-1}$$

and

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \tag{S6-2}$$

Figure S6.3 shows three possible population distributions, each with its own mean, μ and standard deviation, σ. If a series of random samples ($\bar{x}_1$, $\bar{x}_2$, $\bar{x}_3$, $\bar{x}_4$, and so on), each of size *n*, is drawn from any population distribution (which could be normal, beta, uniform, and so on), the resulting distribution of $\bar{x}_i$s will approximate a normal distribution (see Figure S6.3).

Moreover, the sampling distribution, as is shown in Figure S6.4(a), will have less variability than the process distribution. Because the sampling distribution is normal, we can state that:

- 95.45% of the time, the sample averages will fall within $\pm 2\sigma_{\bar{x}}$ if the process has only natural variations.
- 99.73% of the time, the sample averages will fall within $\pm 3\sigma_{\bar{x}}$ if the process has only natural variations.

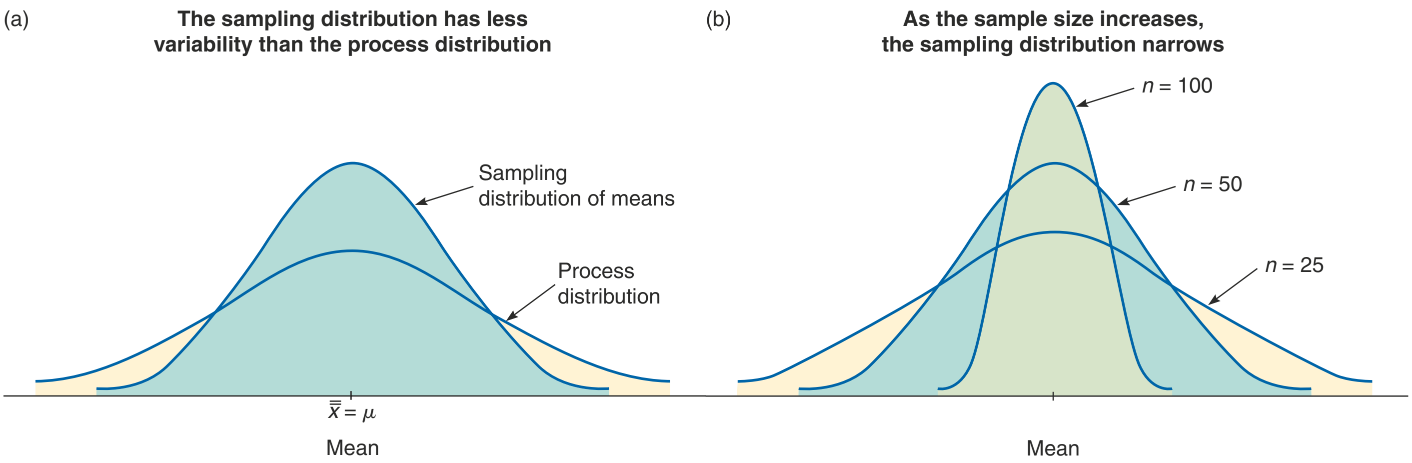


Figure **S6.4**

The Sampling Distribution of Means Is Normal

The process distribution from which the sample was drawn was also normal, but it could have been any distribution.

If a point on the control chart falls outside of the $\pm 3\sigma_{\bar{x}}$ control limits, then we are 99.73% sure the process has changed. Figure S6.4(b) shows that as the sample size increases, the sampling distribution becomes narrower. So the sample statistic is closer to the true value of the population for larger sample sizes. This is the theory behind control charts.

Setting Mean Chart Limits ($\bar{X}$-Charts)

If we know, through past data, the standard deviation of the population (process), σ, we can set upper and lower control limits[3] by using these formulas:

$$\text{Upper control limit (UCL)} = \bar{\bar{x}} + z\sigma_{\bar{x}} \tag{S6-3}$$

$$\text{Lower control limit (LCL)} = \bar{\bar{x}} - z\sigma_{\bar{x}} \tag{S6-4}$$

LO S6.3 *Build* $\bar{x}$-charts and *R*-charts

where

$\bar{\bar{x}}$ = mean of the sample means or a target value set for the process
z = number of normal standard deviations (2 for 95.45% confidence, 3 for 99.73%)
$\sigma_{\bar{x}}$ = standard deviation of the sample means = $\sigma/\sqrt{n}$
σ = population (process) standard deviation
n = sample size

Example S1 shows how to set control limits for sample means using standard deviations.

Example S1

SETTING CONTROL LIMITS USING SAMPLES

The weights of boxes of Oat Flakes within a large production lot are sampled each hour. Managers want to set control limits that include 99.73% of the sample means.

APPROACH ▶ Randomly select and weigh nine ($n = 9$) boxes each hour. Then find the overall mean and use Equations (S6-3) and (S6-4) to compute the control limits. Here are the nine boxes chosen for Hour 1:

STUDENT TIP If you want to see an example of such variability in your supermarket, go to the soft drink section and line up a few 2-liter bottles of Coke or Pepsi.

SOLUTION ▶

$$\text{The average weight in the first hourly sample} = \frac{17+13+16+18+17+16+15+17+16}{9}$$
$$= 16.1 \text{ ounces.}$$

Also, the *population (process)* standard deviation (σ) is known to be 1 ounce. We do not show each of the boxes randomly selected in hours 2 through 12, but here are all 12 hourly samples:

	WEIGHT OF SAMPLE		WEIGHT OF SAMPLE		WEIGHT OF SAMPLE
HOUR	(AVG. OF 9 BOXES)	HOUR	(AVG. OF 9 BOXES)	HOUR	(AVG. OF 9 BOXES)
1	16.1	5	16.5	9	16.3
2	16.8	6	16.4	10	14.8
3	15.5	7	15.2	11	14.2
4	16.5	8	16.4	12	17.3

The average mean $\bar{\bar{x}}$ of the 12 samples is calculated to be exactly 16 ounces $\left[\bar{\bar{x}} = \dfrac{\sum_{i=1}^{12}(\text{Avg. of 9 Boxes})}{12}\right]$.