Second Edition

Statistical Thinking

Improving Business Performance

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PART ONE

Statistical Thinking Concepts

CHAPTER 1

Need for Business Improvement

If you don't keep doing it better—your competition will.

—Anonymous

In today's global marketplace success—even survival—hinges on an organization's ability to improve everything it does. In this chapter, we demonstrate why corporations need to improve how they run their businesses and how the use of statistical thinking can improve business operations. Statistical thinking can be applied to both business operations and methods of management.

The main objective of Chapter 1 is to better understand the effect of global competition on business and other organizations in our society and how this impact is forcing us to improve. You will become familiar with the various approaches to improvement and how statistical thinking plays a role in each of these methods. This will enable you to see how the broad use of statistical thinking can help businesses and other organizations improve.

We begin with a short case study. Generalizing from the case study, we then discuss today's business realities, the need to improve, and the recognition that improving how we work is part of the job. The need to improve while we accomplish our work is illustrated with an overall model for business improvement. We then briefly review some new management approaches. Common themes that run through these approaches are identified, and the role of statistical thinking in these themes, and hence in the improvement effort, is noted.

TODAY'S BUSINESS REALITIES AND THE NEED TO IMPROVE

Consider the following business scenario. A large publication corporation, Kowalski and Sons, is having trouble with their monthly billing process. They have discovered that it takes about 17 days to send bills out to customers. But there is a lot of variation from billing cycle to billing cycle, with some bills taking much longer than 17 days. Management's expectation is that the billing should be done in less than 10 days with minimal variation. This target is important from both the company's and the customers' point of view. A shorter cycle time for the bills would improve the company's cash flow, and it would allow customers to enter the billing information in their accounting systems promptly so they can close their monthly books sooner. The current situation results in numerous "late" payments, for which Kowalski and their customers often blame each other. Customers complain that other publishers are not as tardy in sending out bills.

Does this sound like a bad situation? Actually, this is a typical situation in many businesses. In fact, when one of the authors consulted on this problem and began to dig deeper, the situation became worse! Assessing the process revealed that three different departments were involved in billing. Each department worked separately, and no one understood the process from beginning to end. When problems occurred, there was a lot of finger pointing: "The problem is not with us, it's with them. If they would clean up their act, the billing process would be okay." Similarly, there were no standard operating procedures—that is, formal, agreed-upon methods of doing the job. Everybody did it their own way. This resulted in a lot of "fire fighting" to keep the bills going out—heroic efforts requiring long hours and shifting priorities.

The one clear advantage was that a quantitative measure to monitor performance did exist: the number of days required to send bills out. Without a clear measure of success, it is difficult—if not impossible—to effectively manage and improve a process.

Traditional business leaders faced with this situation might attempt to assign blame so the persons responsible could be reprimanded. The approach we recommend is just the opposite. Here is how we approached this problem: A systems map was created for the overall process, along with a flowchart of the critical process steps. The systems map identified the responsible departments and the information or materials that flowed back and forth between the groups. The flowchart was used to construct a production schedule for the monthly billing cycle. This schedule showed what had to be done each month by each group along with a timetable for doing so.

Next, critical subprocesses were identified and cycle time measurements were monitored for each of these critical subprocesses as well as for the overall process. These measurements highlighted key problem areas. Cross-functional teams were formed to troubleshoot the process daily and to review the billing process at the end of the cycle. These teams identified problems and suggested procedures for creating and implementing solutions.

Efforts were also made to document the process and the procedures used in its operation. This documentation helped reduce variation in the process and was central to training new employees. A process owner was also assigned. The process owner's job was to care for the "health" of the process by seeing that the various aspects of the process management system were used and improved to handle the changing conditions the process would experience.

Use of this statistical thinking approach significantly improved the billing process. Over a 5-month period, the monthly billing cycle time was reduced from an average of 17 days to about 9.5 days, with less variation. This resulted in annual savings of more than $2.5 million, more satisfied customers, and a less stressful work environment for employees.

The use of statistics in business has grown over the years as a result of political, social, technological, and economic forces that have affected our world economy. Each new force has created a new need for statistics that typically results in new concepts, methods, tools, and applications. For example, World War II created the need for statistical quality control: Munitions needed to be manufactured consistently to very tight tolerances. The need for statistical design of experiments resulted from the demand for major increases in farm production in the early 1900s, which required experimentation with new farming techniques.

This movement was accelerated both by the former Soviet Union's launch of the *Sputnik* satellite and by the increasing focus on research and development in the chemical and process industries during the 1950s and 1960s.

The U.S. Food, Drug, and Cosmetics Act and the U.S. Environmental Protection Act resulted in increased use of statistics in the pharmaceutical industry and in environmental studies in the 1970s. The advent of the computer also made statistical calculations easier and available to a broader range of people. The 1980s brought a new economic force—global competition—which has created the need to make major changes in how we run our businesses. The need for change is driven by increasing customer demands for more responsive companies and for higher quality products and services at lower costs.

Global competition is affecting economies around the world; indeed we now have a global economy. Evidence of the effects of the global marketplace on the U.S. economy can be seen in the balance of trade and average wages (adjusted for inflation) shown in Figures 1.1 and 1.2. These plots indicate a robust U.S. economy in the 1950s and 1960s, but things clearly changed in the 1970s and 1980s. Global competition became a serious challenge to the U.S. economy. Figure 1.1 shows that the trade balance of goods and services (exports minus

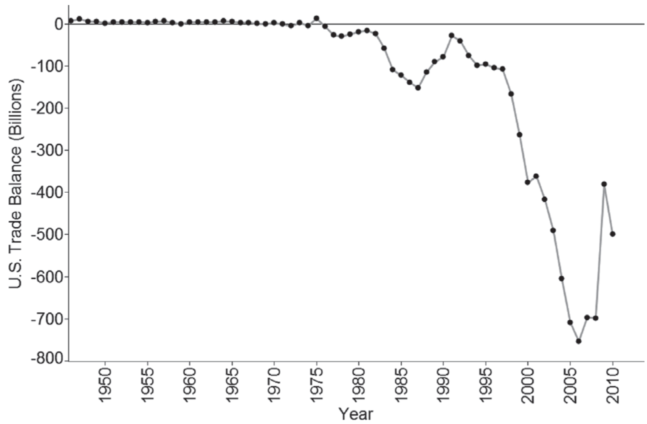

FIGURE 1.1 U.S. Balance of Trade, 1964–2010

imports) was positive until 1971, when it turned negative. Despite some positive upturns, it remained significantly negative in the 1980, 1990s, and into the twenty-first century. In Figure 1.2, we see that the U.S. average hourly earnings adjusted for inflation increased until 1973 and decreased after that date until the mid-1990s, when it began to increase. But as of 2010, U.S. hourly earnings had not reached the levels of the early 1970s. This indicates a declining standard of living for the United States as a whole.

Global competition has had an impact on the U.S. economy in other ways as well. Companies find it difficult to compete, which results in layoffs, downsizing, mergers, and bankruptcies. Many of 1960s Fortune 500 companies are not in business today. The General Electric Company is the only surviving corporation from the original members of the Dow Jones Industrial Average in

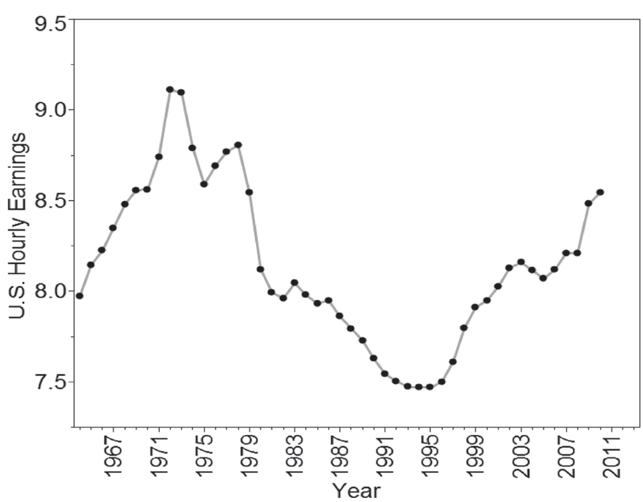

FIGURE1.2 U.S. Hourly Earnings, 1946–2010 (1982 dollars seasonally adjusted)

1896. In the new millennium, the Internet and social media are driving forces. Many "traditional" businesses are being replaced by digital competitors with a radically different business model, such as the Kindle and other electronic readers replacing physical books.

The changes taking place in U.S. business have ripple effects throughout society, including government, education, health care, and nonprofit organizations. For example, difficult economic times often result in reduced contributions to artistic, charitable, and religious groups. Poor business earnings and declining real wages reduce tax revenues to governments, and high unemployment demands greater expenditures by these same governments. Organizations are continually being asked to do more with less, to work in different ways, to be more responsive and caring, to provide better service, and so on. Those organizations that cannot keep up are left behind.

The increase in competition is in large part due to progress in the rest of the world, as opposed to changes in the United States alone. After World War II, the United States dominated the world's manufacturing capacity, being the only world economic power that did not suffer significant destruction during the war. The significant prewar economies of Germany and Japan were in shambles, and those of the United Kingdom, France, Italy, and many others suffered a great deal of damage. Over the years since 1945, these countries have regained their competitive edge, and developing countries are becoming players in the world market. Japan became a major player in the global economy in the 1980s, and India and China have more recently joined the group. The obvious result of these changes is that a healthy economy, abundant jobs, high wages, and the comfortable lifestyle desired by most people of the world cannot be taken for granted; they must be fought for and earned! So what should we do?

WE NOW HAVE TWO JOBS: A MODEL FOR BUSINESS IMPROVEMENT

We used to have only one job—to do our work. We came to work, did our job, provided a product or a service, and our work was complete. There was no need to change how we did things because there was little competition. No one else was doing things differently. To survive and prosper in this new economic era, we have to make some changes. Now we must accept a second job—improving how we do our work.

Having two jobs means that we each must work to improve our personal knowledge and skills and how we do our jobs as well as get our daily work done. Managers must lead, plan, and manage how the organization can improve its performance as well as operate its day-to-day processes effectively and efficiently. This was illustrated in the billing scenario in the previous section, when Kowalski and Sons needed to improve the billing process to keep its current customers.

Organized team sports provide an excellent analogy to business because team sports operate in a competitive environment, have well-defined rules, use teamwork to succeed, and have clear measures of success (winning scores) that are monitored regularly. (We will present a statistical thinking case study involving a soccer team in Chapter 2.) The dual focus on "doing" and "improving" activities can be seen clearly in sports. For example, the "doing" work of baseball is playing the game itself. Professional baseball teams play 162 regular season games per year. But the work activities of baseball go way beyond showing up for each game, playing nine innings, and going home. The "improving" work of baseball is building individual and team skills.

The improvement cycle begins with spring training, where players get in shape and hone their skills. Players work on improving their hitting, running, and pitching. Pitchers work on controlling the curve ball, learning to throw a knuckle ball, and developing pitches they did not have before. Hitters work on hitting the curve ball or fast ball and other aspects of hitting. This work on improvement goes on all year: before the game, after the game, in the bullpen, viewing videotapes of pitching and hitting, and so on. In the off-season improvement activities involve weight training to build strength and speed or playing winter baseball. Coaches frequently state that star performers are not necessarily the most naturally talented but typically are those who work the hardest at improving their game.

Figure 1.3 shows that the amount of time and effort we spend on improving how we work will increase in the future. We will also be doing more work in the future, as depicted by the larger pie on the right side of the figure. Increasing the rate of improvement is key. If the competition is also improving, the organizations that succeed will be those with the fastest rate of improvement. It is likely that Kowalski and Sons' competitors are also improving; hence, they cannot view the improvements to the billing process as a one-time event but must make improvement part of the job. Companies must continually improve or go out of business.

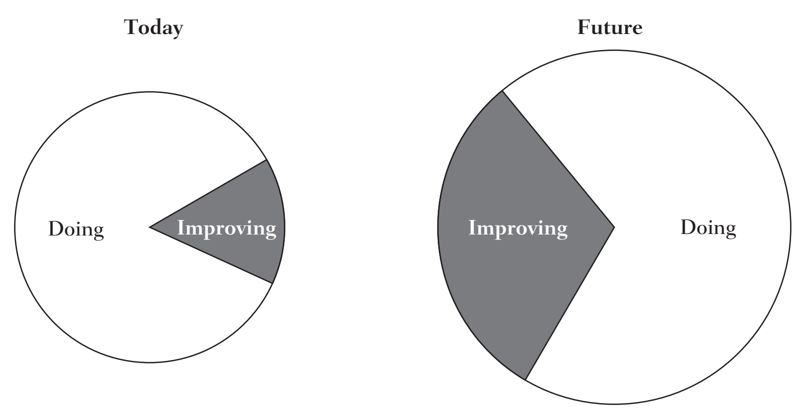

FIGURE 1.3 We Have Two Jobs: Doing and Improving

Government, health care, and nonprofit organizations also operate in this competitive environment. For example, states compete with one another and with foreign countries for investment from business and industry, which creates new jobs. States that can offer businesses the best-educated workforce and the best infrastructure (transportation, communication, etc.) at the lowest cost (taxes and regulations) tend to get new investments and jobs. The goal for all types of organizations must therefore be to improve faster than their competition.

Figure 1.4 depicts an overall model for business improvement. The doing activity is represented by the Business Process shown at the top. A series of activities, each with its own inputs and outputs, are done as a sequence of steps to produce the desired output for the customer. For example, Kowalski and Sons went through several processing steps to send out their monthly bills. The purpose, or aim, of the process is to provide a product or service of value to the customer. Note that a customer need not be someone outside the organization who purchases a product or service. A *customer* is anyone who uses the output of the process, whether within or outside the organization. Internal customers, the employees, are the key customers of the payroll process.

The improving activity is shown at the bottom of the figure. There are many different approaches to improvement, but we will focus on two types of improvement: process improvement and problem solving. *Process improvement* is a series of activities aimed at fundamentally improving the performance of the process. Some typical process improvement activities are:

- Flowcharting the process to understand it better
- Collecting data to assess the current performance
- Identifying areas where the process could be fundamentally improved

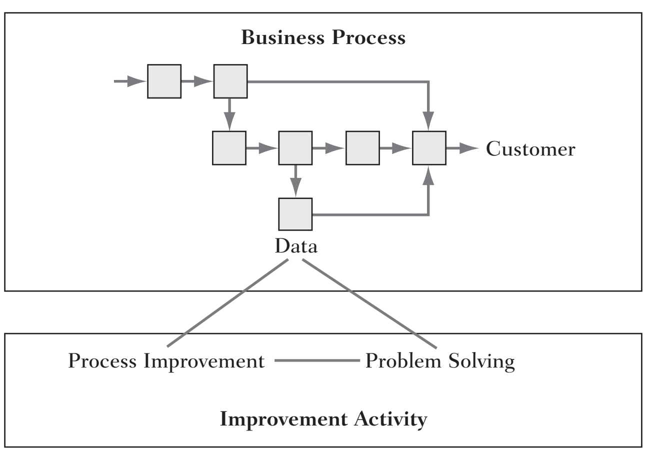

FIGURE 1.4 Improvement Model

- Changing the process to implement improvement ideas
- Checking the impact of improvement efforts
- Making the improvements part of the standard way of doing business

Problem solving addresses specific problems that are not part of the normal behavior of the process. These issues are often discovered in the process improvement analysis and can be resolved without fundamentally changing the process. For example, if only one customer's bill was a problem at Kowalski and Sons, they would investigate what happened to that particular bill rather than change the whole billing process. Problem solving usually involves significantly less time and cost investment than that required for true process improvement. The basic problem-solving steps are:

Step 1. Document the scope of the problem.

Step 2. Identify the root causes.

Step 3. Select, implement, and standardize corrections.

A company may go through the process improvement and problem-solving cycle many times in the course of improving a process. Problem-solving strategies and tools will be discussed in greater detail in Chapters 4 and 5. Kowalski and Sons used the process improvement model, which can require significant time and effort. If the process needs to be completely redesigned from scratch, the redesign activity is often called *reengineering.* (Reengineering is briefly outlined in Appendix H.)

Data are the connectors or links between the doing and improving activities. Data fuel process improvement and problem-solving activities and increase their effectiveness. Data help us document process performance, identify problems, and evaluate the impact of proposed solutions. This was certainly the case at Kowalski and Sons. But *data* is not synonymous with *information.* For example, we presented average times for bills to be sent out, but the actual time varies from bill to bill. How should we interpret this variation? Customers do not care about average time; they only care about their bill. Therefore, we need both theoretical understanding and practical experience to properly translate these data into actionable information. A thorough conceptual understanding of statistical thinking provides us with the theoretical understanding we need, and a personal project (see Chapter 2) will help provide the experience.

NEW MANAGEMENT APPROACHES REQUIRE STATISTICAL THINKING

New demands to improve have created the need for new management approaches, and a wide range of approaches on how to change have been proposed. Among these approaches are:

- Reengineering
- Total quality management
- Learning organizations
- Self-managed work teams
- Benchmarking
- Six Sigma and Lean Manufacturing

In addition to this list are the philosophies proposed by Peter Drucker, Stephen Covey, W. Edwards Deming, Joseph Juran, Tom Peters, Peter Senge, and many others. As you can see, management has many choices in today's business climate. Let us look at a few of these approaches in more detail.

Reengineering is "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed."[1] The approach is to "start with a clean sheet of paper" and redesign critical processes and the business as a whole, if needed, to become and remain competitive. The key distinction of this approach is to replace rather than improve key business processes, often utilizing information technology.

Total quality management (TQM), as generally practiced, is a broader, less radical approach to business improvement.[2] The basic elements of TQM are to focus on improving the quality of all aspects of the business to better satisfy the needs of customers. This involves cooperative efforts from all employees, from the chief executive officer (CEO) to those sweeping the floor, and typically stresses data-based decisions and use of statistical tools to reduce process variation.

Learning organizations create change and improvement by learning how to work in more effective and efficient ways.[3] This includes both individual learning and learning by the organization. Learning how to view the organization as a system of interconnected processes is key to this approach. The focus is on improving the system as a whole rather than looking at problems of individual departments. This approach requires an open mind and routine gathering of data, both quantitative and qualitative, from which to learn.

Self-managed work teams were created in response to the need to reduce layers of management and to empower the workforce. In self-managed work teams employees work as a team without direct supervision from management, using principles and guidelines developed jointly with management. A key rationale for this approach is a belief that those who work with the process every day understand it best and therefore should make most of the day-to-day decisions.[4]

Benchmarking is the process of improvement that finds the best practices in other organizations and adapts those practices to make improvements.[5] The best practices are often identified in outside industries. Examples could include the billing process, approaches to new product development, compensation plans, organizational structure, and so on. This approach avoids the problem of “reinventing the wheel.” Internal benchmarking, identifying and using the best practices of one department in others, also helps reduce variation from department to department.

Six Sigma is a business improvement approach that seeks to find and eliminate causes of mistakes or defects in business processes.[6] Six Sigma is a statistical term that roughly translates to only 3.4 defects per million opportunities. The Six Sigma approach emphasizes understanding and documenting the business process, developing metrics and hard data, and reducing variation. This approach uses a breakthrough strategy that consists of four process improvement phases: Measure, analyze, improve, and control. The goal is to improve the process in such a way that customer satisfaction increases and there is a positive impact on the bottom line.

The Six Sigma approach was originally pioneered in 1987 by Motorola, which focused primarily on manufacturing, and was later applied by other companies including Allied Signal and General Electric (GE), which broadened the approach to include general business activities such as financial services. Use of the Six Sigma approach expanded rapidly in the United States and around the world. The Six Sigma breakthrough strategy is discussed in greater detail in Chapter 4.

The Six Sigma methodology continues to be developed. In the late 1990s GE added the project definition phase to the methodology, creating DMAIC (Define, Measure, Analyze, Improve, and Control). In the early 2000s Lean Six Sigma was created by adding lean manufacturing concepts, methods, and tools to more effectively improve the flow of information and materials through the process, thereby increasing process speed.[7]

Each of these approaches and philosophies is useful, and the best aspects of each can be integrated with the management approach an organization is currently using. The result is a new management approach that helps the organization better serve the needs of its customers and compete effectively in the marketplace. Three common themes run through these management approaches:

1. Viewing work as a process
2. Using data to guide decisions
3. Responding wisely to variation

These three items are part of the body of knowledge known as statistical thinking. This body of knowledge and its associated skills are essential to the successful management and improvement of any business. Statistical thinking is a philosophy of learning and action based on these fundamental principles:[8]

- All work occurs in a system of interconnected processes.
- Variation exists in all processes.
- Understanding and reducing variation are keys to success.

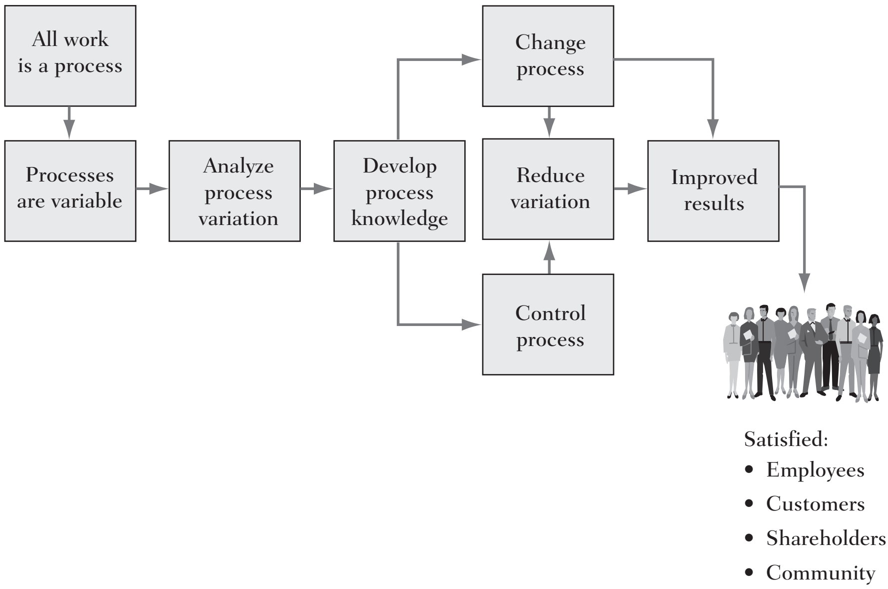

FIGURE 1.5 Steps in Implementing Statistical Thinking

These principles work together to create the power of statistical thinking. The steps in implementing statistical thinking are shown in Figure 1.5. We begin by recognizing that all work is a process and all processes are variable. We must analyze the process variation to develop knowledge of the process. You cannot improve a process that you do not understand. Note that these core principles are similar to the common themes of recent management improvement efforts presented earlier. With knowledge of the process, we are in a position to take action to improve that process.

From a statistical point of view improvement activity—both fundamental process improvement and problem solving—can be viewed as working on either of two process characteristics: (1) reducing variation through tighter control of the process or (2) improving the overall level (average value) by changing the process target, which may also result in reduced variation. For example, the primary objective of Kowalski and Sons' billing efforts was to reduce the average time to get bills out. They also wanted to reduce the variation from bill to bill. The end result of using statistical thinking is business performance that satisfies the stakeholders: customers, employees, the community in which the business operates, and the shareholders.

The terms *average* and *variation* are critical to applying statistical thinking. For most processes the average is the central value around which the process varies. Variation results when two or more measures of the process are different, which is the rule rather than the exception.

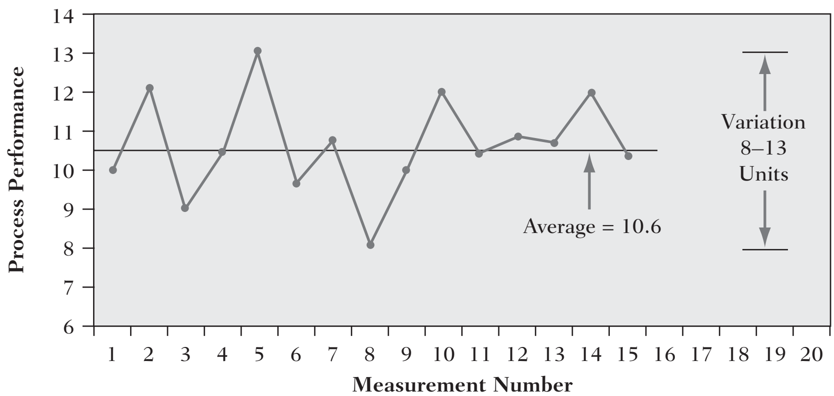

FIGURE 1.6 Process Average and Variation

Figure 1.6 illustrates these concepts by plotting 15 consecutive process measurements. Although any units could be used here, as an example, let us use monthly gross sales. The process is centered between $10,000 and $11,000, with an average value of $10,600. The average value is computed by adding the values to get the total and then dividing by the number of values—that is, 159,000/15 = 10,600 in this case. The observed variation in the process is from about $8,000 to $13,000, resulting in a range of about $5,000. Another common measure of variation is called the *standard deviation,* which can be thought of as the "typical" deviation of individual data points from the average. (See the box on standard deviation.)

With an understanding of the meaning of statistical thinking, we can now discuss the principles underlying statistical thinking.

STANDARD DEVIATION

The standard deviation is an overall measure of how far individual data points vary about the average. Most data points will fall within 1 standard deviation of the average. The standard deviation can be thought of as the typical (average) deviation. It is calculated by taking the deviation of each data point from the average, squaring these deviations (so they are all positive), averaging the squared deviations, and then taking the square root to go back to the original units; that is, the standard deviation = square root of the sum of squared deviations divided by *n,* where *n* is the number of data points. For example, to calculate the standard deviation of 1, 3, 5, 7, and 9, we first calculate the average, (1 + 3 + 5 + 7 + 9)/5, then we subtract the deviations of each value from 5, 1 – 5 = – 4, 3 – 5 = – 2, 5 – 5 = 0, 7 – 5 = 2, and 9 – 5 = 4. Next we square the deviations to get 16, 4, 0, 4, and 16. The average of these values is 8, and the standard deviation is 2.83. Note that in most cases we divide the sum of the squared deviations by *n* – 1 rather than by *n* when calculating the standard deviation. The reasons for this are discussed in Chapter 9.

PRINCIPLES OF STATISTICAL THINKING

The first principle of statistical thinking is that *all work occurs in a system of interconnected processes.* This principle provides the context for understanding the organization, improvement potential, and sources of variation mentioned in the second and third principles. A process is one or more connected activities in which *inputs* are transformed into *outputs* for a specific purpose. This is illustrated in Figure 1.7. For example, mailing bills requires that records are kept on charges (inputs). These records must be processed (aggregated for a month, reduced by payments made, checked for accuracy and applicable discounts, and so on), often with the aid of computer systems, into a monthly bill. Any discrepancies or errors must be resolved, often through a manual process. These bills must then be physically printed and stuffed into the appropriately addressed envelopes (or sent to appropriate electronic addresses) and delivered to the desired mailing system (U.S. Postal Service, Federal Express, United Parcel Service, etc.). The bill a customer receives is the output of the process. For a simpler example, the series of activities one goes through to get to work or school in the morning (getting out of bed, bathing, dressing, eating, and driving or riding) can be thought of as a process. Any activity in which a change of state takes place is a process, as depicted in Figure 1.7.

We encourage people to "blame the process, not the people" when working on improvement. Joseph M. Juran pointed out that the source of most problems is in the process we use to do our work. He discovered the "85/15 rule," which states that 85% of the problems are in the process and the remaining 15% are due to the people who operate the process. W. Edwards Deming states that the true figure is more like 96/4.[9] We may debate the correct figure, but it is clear that the vast majority of problems are in the process. Businesses and other organizations are made up of a collection of processes. Business processes interconnect and interact to form a system that typically provides a product or service for a customer (the person who receives the output of the system). Viewing business as a collection of processes is discussed in detail in Chapter 3. Some typical business processes are:

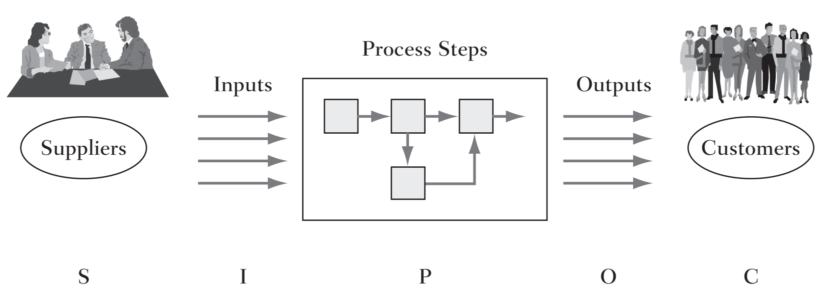

FIGURE 1.7 SIPOC: A Process View of Work

- Customer service
- Business planning
- New product development
- Employee recruiting and orientation
- Company mail delivery
- Manufacturing
- Equipment procurement
- Patent application
- Accounting
- Laboratory measurement

The second principle of statistical thinking is that *variation exists in all processes*. This provides the focus for improvement work. Variation is the key. If there were no variation:

- Processes would run better.
- Products would have the desired quality.
- Service would be more consistent.
- Managers would manage better.

Focusing on variation is a key strategy to improve performance. Of course, in certain situations variation is desirable, such as wanting variety in menu items in a restaurant, valuing diversity among team members, and so on. Intended or desirable variation is valuable and should be promoted. It is unintended variation that we will focus on here.

Variation is a fact of life. Variation is all around us. It is present in everything we do, in all the processes we operate, and in all the systems we create. Variation results when two or more things, which we may think are exactly the same, turn out to be different. Some examples are:

- Restaurant service time varies from day to day and from customer to customer.
- Tires wear at different rates.
- Tomatoes of the same variety vary in weight.
- Shirts of the same size fit differently.
- Cars of the same model perform differently.

To understand and improve a process we must take variation into account. Variation creates the need for statistical thinking. If there were no variation, there would be little need to study and use statistical thinking.

The third principle of statistical thinking is that *understanding and reducing variation are keys to success*. The focus is on unintended variation and how it is analyzed to improve performance. First we must identify, characterize, and quantify variation to understand both the variation and the process that produced it. With this knowledge we work to change the process (e.g., operate it more consistently) to reduce its variation.

The average performance of any process (e.g., average time in days to get bills out, average waiting time in minutes to be served in a restaurant, or average pounds of waste of a printing process) is a function of various factors involved in the operation of the process. When we understand the variation in the output of the process, we can determine which factors within the process influence the average performance. We can then attempt to modify these factors to move the average to a more desirable level.

Businesses, as well as customers, are interested in the variation of the process output around its average value. Typically, consistency of product and service is a key customer requirement. For example, customers of a shipping company do not want shipments to arrive sometimes in a day and other times in a week. Such variation would make it difficult to plan when to actually ship goods. Similarly, in accounts payable, we do not want to pay bills too late because we may lose discounted terms (often a 2% discount for prompt payment). If we pay too early, however, we lose interest on the cash. If we can reduce the variation in the process, we can consistently pay right at the due date and receive discounted terms and minimize loss of interest. This results in many improvement efforts that focus on reducing variation, for example, reducing restaurant waiting time from 0 to 10 minutes to 0 to 5 minutes, reducing the variation in real estate sales from 20 to 40 units/month to 25 to 30 units/month, or reducing bill mailing time from 10 ± 4 days to 10 ± 1 days. Low variation is important to customers, and they will sometimes accept less desirable "average performance" to obtain better consistency.

Two types of variation that we may need to reduce are "special cause" and "common cause." *Special-cause variation* is outside the normal or typical variation a process exhibits. Normal or typical variation is called *common-cause variation*. The distinction between these types of variation will be discussed in more detail in Chapter 2. The result of special-cause variation may be unpredictable or unexpected values that are too high or too low for the customer. Some examples include waiting for service for 30 minutes when 10 minutes or less is typical performance for a particular restaurant, a real estate sales office selling 10 units this month when typical sales are 20 to 40 units, or a printing press running at 10% waste this month when typical waste varies from 1 to 3%.

Because special-cause variation is atypical, we can often eliminate the root causes without fundamentally changing the process. Using a problem-solving approach, we identify what was different in the process when it produced the unusual result. For example, in the printing press scenario they may have purchased their raw paper stock from a new supplier that month. A hypothetical example is shown in Figure 1.8. The two points that clearly stick out from the rest are due to special causes. There should be a specific, identifiable reason these waste values were so high. Even if we eliminate the causes for these points through problem solving, however, we are left with the normal level of waste due to common causes. To make further improvement, we need to fundamentally change the system; that is, we need to improve the overall process.

Reducing the inherent common-cause variation typically requires studying the process as a whole because there are no unusual results to investigate. In other words, there is no single, identifiable reason waste was high one day and low the next. Using a process improvement approach, we study the normal variation and try to discover the input and process factors that are the largest sources of variation. Knowledge and understanding of common-cause variation is best obtained using a statistical approach and planned experiments. Historical process data analysis can also be helpful but is not as effective as planned experiments. Once the primary sources of variation are identified, we can determine how to modify the process to eliminate or mitigate their effects. Using the printing press example, we could experiment to find optimal combinations of paper stock, ink, and printing conditions, which would result in the fundamental improvement of the process.

APPLICATIONS OF STATISTICAL THINKING

Statistical thinking can be used in all parts of an organization and in all job functions. For example, the job of the manager is to lead the organization in a common direction. The manager must gain agreement on the desired direction and get employees to align all their activities with this common direction.

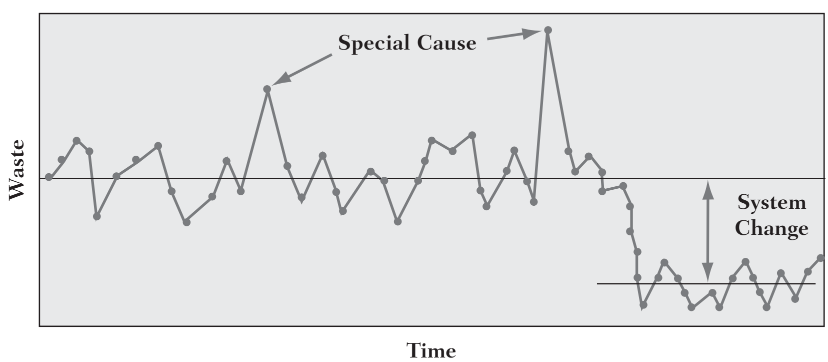

FIGURE 1.8 Special-Cause and Common-Cause Variation

The result of this reduced variation in activity is less wasted effort, less rework, reduced costs, and faster improvement of organizational performance. An engineer in a factory may want to reduce the variation in a product characteristic to meet customers' specifications a higher percentage of the time. This may require using a better process control procedure or developing a deeper understanding of the process so that fundamental changes can be made to better operate the process.

A business analyst may wish to find ways to change the "closing" process (calculating final profit and loss for a specific time period, such as quarterly or annually) so that, on average, the accounting books are "closed" in 2 days rather than the current 15-day average, thereby reducing overtime work required and increasing customer satisfaction (customers would include corporate management and the financial community). This objective will likely require a better understanding of how the closing process works and what persons and groups are involved. Armed with this knowledge, we can find ways to improve the process to meet business needs.

A restaurant manager may want to understand why it is taking a long time to serve some customers. Data on customer service time is needed to document current performance and to determine whether newly introduced procedures are working. Properly collected data are also useful in identifying causes of poor performance and possible solutions.

All of the problems identified in these examples can be addressed using statistical thinking. As noted earlier, statistical thinking also applies to various kinds of work in all organizations and functions, including:

Type of Organization	**Type of Function**
Manufacturing	Marketing
Financial services	Sales
Education	Manufacturing
Government	Research and development
Health care	Engineering
Retail sales	Human resources
Transportation	Information systems
Software	Purchasing
Restaurants	Finance

Statistical thinking is also useful in the management of organizations. We noted earlier that the job of the manager is to move the organization in a common direction. To do this the manager must gain agreement among the employees regarding the direction the organization should go. This will reduce variation in employee actions.

Similarly, many organizations have reduced the number of their suppliers. This action is based on the fact that a large number of suppliers increases the variation in incoming supplies, which in turn increases the variation in the output of the organization. Customers want consistent products and services. When a company decreases the number of suppliers, the company generally decreases the variation in their product or service.

Any time you improve a process, product, or management system you are requiring the involved employees to change how they work and the design of the processes they use to do their work. Such actions require a leader to help the organization make the needed changes. Such leaders can be anywhere in the organization, including scientists, engineers, financial analysts, managers, and others. Statisticians and quality professionals often serve in leadership roles as well.[10]

SUMMARY

In this chapter, we have discussed today's business realities and the need for businesses to improve, a model for business improvement, some new management approaches that have been proposed, and principles and applications of statistical thinking. The following is a list of the most important ideas and conclusions addressed in this discussion:

- Global competition has forced U.S. companies and organizations around the world to change.
- Improvement is needed for an organization to survive.
- We now have two jobs: to do our work and to improve on how we do our work.
- The U.S. system of management is changing, and many new approaches have been proposed.
- Statistical thinking is an integral part of the common themes that run through these new approaches.
- Statistical thinking is based on three principles: All work occurs in a system of interconnected processes, variation exists in all processes, and understanding and reducing variation are keys to success.
- Broad use of statistical thinking can help an organization improve operations and its management system.

NOTES

1. M. Hammer and J. Champy, *Reengineering the Corporation* (New York: HarperCollins, 1993), 32.
2. T. H. Berry, *Managing the Total Quality Transformation* (New York: McGraw-Hill, 1991).
3. P. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization* (New York: Doubleday/Currency, 1990).