What Is Six Sigma?

Six Sigma is a rigorous, focused, and highly effective implementation of proven quality principles and techniques. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error-free business performance. Sigma, Σ, is a letter in the Greek alphabet used by statisticians to measure the variability in any process. A company’s performance is measured by the sigma level of their business processes. Traditionally companies accepted three or four sigma performance levels as the norm, despite the fact that these processes created between 6,200 and 67,000 problems per million opportunities! The Six Sigma standard of 3.4 problems-per-million opportunities* is a response to the increasing expectations of customers and the increased complexity of modern products and processes.

Despite its name, Six Sigma’s magic isn’t in statistical or high-tech razzle-dazzle. Six Sigma relies on tried and true methods that have been used for decades. By some measures, Six Sigma discards a great deal of the complexity that characterized Total Quality Management (TQM). Six Sigma takes a handful of proven methods and trains a small cadre of in-house technical leaders, known as Six Sigma Black Belts, to a high level of proficiency in the application of these techniques. To be sure, some of the methods Black Belts use are highly advanced, including up-to-date computer technology. But the tools are applied within a simple performance improvement model known as Define-Measure-Analyze-Improve-Control, or DMAIC. DMAIC is described briefly as follows:

D Define the goals of the improvement activity.
M Measure the existing system.
A Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal.
I Improve the system.
C Control the new system.

*Statisticians note: The area under the normal curve beyond Six Sigma is 2 parts-per-billion. In calculating failure rates for Six Sigma purposes we assume that performance experienced by customers over the life of the product or process will be much worse than internal short-term estimates predict. To compensate, a “shift” of 1.5 sigma from the mean is added before calculating estimated long-term failures. Thus, you will find 3.4 parts-per-million as the area beyond 4.5 sigma on the normal curve.
Why Six Sigma?

When a Japanese firm took over a Motorola factory that manufactured Quasar television sets in the United States in the 1970s, they promptly set about making drastic changes in the way the factory operated. Under Japanese management, the factory was soon producing TV sets with 1/20th as many defects as they had produced under Motorola's management. They did this using the same workforce, technology, and designs, and did it while lowering costs, making it clear that the problem was Motorola's management. It took a while but, eventually, even Motorola's own executives finally admitted "Our quality stinks" (Main, 1994).

It took until nearly the mid-1980s before Motorola figured out what to do about it. Bob Galvin, Motorola's CEO at the time, started the company on the quality path known as Six Sigma and became a business icon largely as a result of what he accomplished in quality at Motorola. Using Six Sigma Motorola became known as a quality leader and a profit leader. After Motorola won the Malcolm Baldrige National Quality Award in 1988 the secret of their success became public knowledge and the Six Sigma revolution was on. Today it's hotter than ever. Even though Motorola has been struggling for the past few years, companies such as GE and AlliedSignal have taken up the Six Sigma banner and used it to lead themselves to new levels of customer service and productivity.

It would be a mistake to think that Six Sigma is about quality in the traditional sense. Quality, defined traditionally as conformance to internal requirements, has little to do with Six Sigma. Six Sigma focuses on helping the organization make more money by improving customer value and efficiency. To link this objective of Six Sigma with quality requires a new definition of quality: the value added by a productive endeavor. This quality may be expressed as potential quality and actual quality. Potential quality is the known maximum possible value added per unit of input. Actual quality is the current value added per unit of input. The difference between potential and actual quality is waste. Six Sigma focuses on improving quality (i.e., reducing waste) by helping organizations produce products and services better, faster, and cheaper. There is a direct correspondence between quality levels and "sigma levels" of performance. For example, a process operating at Six Sigma will fail to meet requirements about 3 times per million transactions. The typical company operates at roughly four sigma, equivalent to approximately 6,210 errors per million transactions. Six Sigma focuses on customer requirements, defect prevention, cycle time reduction, and cost savings. Thus, the benefits from Six Sigma go straight to the bottom line. Unlike mindless cost-cutting programs which also reduce value and quality, Six Sigma identifies and eliminates costs which provide no value to customers: waste costs.

For non-Six Sigma companies, these costs are often extremely high. Companies operating at three or four sigma typically spend between 25 and 40 percent of their revenues fixing problems. This is known as the cost of quality, or more accurately the cost of poor quality. Companies operating at Six Sigma typically spend less than 5 percent of their revenues fixing problems (Fig. 1.1). COPQ values shown in Fig. 1.1 are at the lower end of the range of results reported in various studies. The dollar cost of this gap can be huge. General Electric estimated that the gap between three or four sigma and Six Sigma was costing them between $8 billion and $12 billion per year.

One reason why costs are directly related to sigma levels is very simple: sigma levels are a measure of error rates, and it costs money to correct errors. Figure 1.2 shows the relationship between errors and sigma levels. Note that the error rate drops exponentially as the sigma level goes up, and that this correlates well to the empirical cost data shown in Fig. 1.1. Also note that the errors are shown as errors per million opportunities, not as
percentages. This is another convention introduced by Six Sigma. In the past we could tolerate percentage error rates (errors per hundred opportunities) today we cannot.

**The Six Sigma Philosophy**

Six Sigma is the application of the scientific method to the design and operation of management systems and business processes which enable employees to deliver the greatest value to customers and owners. The scientific method works as follows:

1. Observe some important aspect of the marketplace or your business.
2. Develop a tentative explanation, or hypothesis, consistent with your observations.
3. Based on your hypothesis, make predictions.
4. Test your predictions by conducting experiments or making further careful observations. Record your observations. Modify your hypothesis based on the new facts. If variation exists, use statistical tools to help you separate signal from noise.

5. Repeat steps 3 and 4 until there are no discrepancies between the hypothesis and the results from experiments or observations.

At this point you have a viable theory explaining an important relationship in your market or business. The theory is your crystal ball, which you can use to predict the future. As you can imagine, a crystal ball is very useful for any organization. Furthermore, it often happens that your theory will explain phenomena other than that you initially studied. Isaac Newton’s theory of gravity may have begun with the observation that apples fell toward the earth, but Newton’s laws of motion explained a great deal about the way planets moved about the sun. By applying the scientific method over a period of years you will develop a deep understanding of what makes your customer and your business tick.

When this approach is applied across the organization, the political influence that stalls organizations is minimized and a “show me the data” attitude prevails. While corporate politics can never be eliminated where human beings interact, politics is much less an influence in Six Sigma organizations than in traditional organizations. People are often quite surprised at the results of this seemingly simple shift in attitude. The essence of these results is stated quite succinctly by “Pyzdek’s law”:

Most of what you know is wrong!

Like all such “laws,” this is an overstatement. However, you’ll be stunned by how often people are unable to provide data supporting positions on basic issues when challenged. For example, the manager of a technical support call center was challenged by the CEO to show that customers cared deeply about hold time. Upon investigation, the manager determined that customers cared more about the time it took to reach a technician and whether or not their issue was resolved. The call center’s information system measured hold time to include both the time until the technician first answered the phone and the time the customer was on hold while the technician researched the answer. The customer cared much less about this “hold time,” since they recognized the value it added in resolution of the issue. This fundamental change in focus made a great deal of difference in the way the call center operated.

**What we know**

We all know that there was a surge in births nine months after the November 1965 New York City power failure, right? After all, the New York Times said so in a story that ran August 8, 1966. If that’s not prestigious enough for you, consider that the source quoted in the Times article was the city’s Mt. Sinai Hospital, one of the best.

**What the data show**

The newspaper compared the births on August 8, 1965 with those on August 8, 1966. This one-day comparison did indeed show an increase year-over-year. However, J. Richard Udry, director of the Carolina Population Center at the University of North Carolina, studied birthrates at several New York City hospitals between July 27 and August 14, 1966. His finding: the birthrate nine months after the blackout was slightly below the five-year average.
The Six Sigma philosophy focuses the attention on the stakeholders for whom the enterprise exists. It is a cause-and-effect mentality. Well-designed management systems and business processes operated by happy employees cause customers and owners to be satisfied or delighted. Of course, none of this is new. Most leaders of traditional organizations honestly believe that this is what they already do. What distinguishes the traditional approach from Six Sigma is the degree of rigor and commitment to the core principles.

**Six Sigma versus Traditional Three Sigma Performance**

The traditional quality model of process capability differed from Six Sigma in two fundamental respects:

1. It was applied only to manufacturing processes, while Six Sigma is applied to all important business processes.
2. It stipulated that a “capable” process was one that had a process standard deviation of no more than one-sixth of the total allowable spread, where Six Sigma requires the process standard deviation be no more than one-twelfth of the total allowable spread.

These differences are far more profound than one might realize. By addressing all business processes Six Sigma not only treats manufacturing as part of a larger system, it removes the narrow, inward focus of the traditional approach. Customers care about more than just how well a product is manufactured. Price, service, financing terms, style, availability, frequency of updates and enhancements, technical support, and a host of other items are also important. Also, Six Sigma benefits others besides customers. When operations become more cost-effective and the product design cycle shortens, owners or investors benefit too. When employees become more productive their pay can be increased. Six Sigma’s broad scope means that it provides benefits to all stakeholders in the organization.

The second point also has implications that are not obvious. Six Sigma is, basically, a process quality goal, where sigma is a statistical measure of variability in a process. As such it falls into the category of a process capability technique. The traditional quality paradigm defined a process as capable if the process’s natural spread, plus and minus three sigma, was less than the engineering tolerance. Under the assumption of normality, this three sigma quality level translates to a process yield of 99.73%. A later refinement considered the process location as well as its spread and tightened the minimum acceptance criterion so that the process mean was at least four sigma from the nearest engineering requirement. Six Sigma requires that processes operate such that the nearest engineering requirement is at least Six Sigma from the process mean.

One of Motorola’s most significant contributions was to change the discussion of quality from one where quality levels were measured in percent (parts-per-hundred), to a discussion of parts-per-million (PPM) or even parts-per-billion. Motorola correctly pointed out that modern technology was so complex that old ideas about “acceptable quality levels” could no longer be tolerated. Modern business requires near perfect quality levels.

One puzzling aspect of the “official” Six Sigma literature is that it states that a process operating at Six Sigma will produce 3.4 parts-per-million nonconformances. However, if a special normal distribution table is consulted (very few go out to Six Sigma) one finds that the expected nonconformances are 0.002 PPM (2 parts-per-billion,
or PPB). The difference occurs because Motorola presumes that the process mean can drift 1.5 sigma in either direction. The area of a normal distribution beyond 4.5 sigma from the mean is indeed 3.4 PPM. Since control charts will easily detect any process shift of this magnitude in a single sample, the 3.4 PPM represents a very conservative upper bound on the nonconformance rate.

In contrast to Six Sigma quality, the old three sigma quality standard of 99.73% translates to 2,700 PPM failures, even if we assume zero drift. For processes with a series of steps, the overall yield is the product of the yields of the different steps. For example, if we had a simple two-step process where step #1 had a yield of 80% and step #2 had a yield of 90%, then the overall yield would be $0.8 \times 0.9 = 0.72 = 72\%$. Note that the overall yield from processes involving a series of steps is always less than the yield of the step with the lowest yield. If three sigma quality levels (99.97% yield) are obtained from every step in a 10-step process, the quality level at the end of the process will contain 26,674 defects per million. Considering that the complexity of modern processes is usually far greater than 10 steps, it is easy to see that Six Sigma quality isn’t optional, it’s required if the organization is to remain viable.

The requirement of extremely high quality is not limited to multiple-stage manufacturing processes. Consider what three sigma quality would mean if applied to other processes:

- Virtually no modern computer would function
- 10,800,000 mishandled healthcare claims each year
- 18,900 lost U.S. savings bonds every month
- 54,000 checks lost each night by a single large bank
- 4,050 invoices sent out incorrectly each month by a modest-sized telecommunications company
- 540,000 erroneous call detail records each day from a regional telecommunications company
- 270,000,000 (270 million) erroneous credit card transactions each year in the United States

With numbers like these, it’s easy to see that the modern world demands extremely high levels of error-free performance. Six Sigma arose in response to this realization.

**Just Do It!**

It’s important to note that Six Sigma organizations are not academic institutions. They compete in the fast-paced world of business, and they don’t have the luxury of taking years to study all aspects of a problem before deciding on a course of action. A valuable skill for the leader of a Six Sigma enterprise, or for the sponsor of a Six Sigma project, is to decide when enough information has been obtained to warrant taking a particular course of action. Six Sigma leadership should be conservative when spending the shareholders’ dollars. As a result, project research tends to be tightly focused on delivering information useful for management decision-making. Once a level of confidence is achieved, management must direct the Black Belt to move the project from the Analyze phase to the Improve phase, or from the Improve phase to the Control phase. Projects are closed and resources moved to new projects as quickly as possible.
Six Sigma organizations are not infallible; they make their share of mistakes and miss opportunities. Yet, research has shown they make fewer mistakes than their traditional counterparts and perform significantly better in the long run. Their systems incorporate the ability to learn from these mistakes, with resulting systematic improvements.

**What’s Important?**
While working with an aerospace client, I was helping an executive set up a system for identifying potential Six Sigma projects in his area. I asked “What are your most important metrics? What do you focus on?” “That’s easy,” he responded. “We just completed our monthly ops review so I can show you.”

He then called his secretary and asked that she bring the ops review copies. Soon the secretary came in lugging three large, loose-leaf binders filled with copies of PowerPoint slides. This executive and his staff spend one very long day each month reviewing all of these metrics, hoping to glean some direction to help them plan for the future. This is not focusing, it’s torture!

Sadly, this is not an isolated case. Over the years I’ve worked with thousands of people in hundreds of companies and this measurement nightmare is commonplace, even typical. The human mind isn’t designed to make sense of such vast amounts of data. Crows can track three or four people, beyond that they lose count. Like crows, we can only hold a limited number of facts in our minds at one time. We are simply overwhelmed when we try to retain too much information. One study of information overload found the following (Waddington, 1996):

- Two-thirds of managers report tension with work colleagues, and loss of job satisfaction because of stress associated with information overload.
- One-third of managers suffer from ill health, as a direct consequence of stress associated with information overload. This figure increases to 43% among senior managers.
- Almost two-thirds (62%) of managers testify that their personal relationships suffer as a direct result of information overload.
- 43% of managers think important decisions are delayed, and the ability to make decisions is affected as a result of having too much information.
- 44% believe the cost of collating information exceeds its value to business.

Clearly, more information isn’t always better.

When pressed, nearly every executive or manager will admit that there are a half-dozen or so measurements that really matter. The rest are either derivatives or window dressing. When asked what really interested him, my client immediately turned to a single slide in the middle of one of the binders. There were two “Biggies” that he focused on. The second-level drill down involved a half-dozen major drivers. Tracking this number of metrics is well within the abilities of humans, if not crows! With this tighter focus the executive could put together a system for selecting good Six Sigma projects and team members.

Six Sigma activities focus on the few things that matter most to three key constituencies: customers, shareholders, and employees. The primary focus is on customers,

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but shareholder interests are not far behind. The requirements of these two groups are determined using scientific methods, of course. Yet the science of identifying customer and shareholder desires is not fully mature, so the data are supplemented with a great deal of personal contact at all levels of the organization. Employee requirements are also aggressively sought. Well-treated employees stay longer and do a better job.

Focus comes from two perspectives: down from the top-level goals and up from problems and opportunities. The opportunities meet the goals at the Six Sigma project, whose selection and development become critical aspects of meeting organizational objectives. Six Sigma projects link the activities of the enterprise to its improvement goals. The linkage is so tight that in a well-run enterprise people working on Six Sigma projects can tell you which enterprise objectives will be impacted by their project, and senior leaders are able to measure the impact of Six Sigma on the enterprise in clear and meaningful terms. The costs and benefits of Six Sigma are monitored using enterprise-wide tracking systems that can slice and dice the data in many different ways. At any point in time an executive can determine if Six Sigma is pulling its weight. In many TQM programs of the past people were unable to point to specific bottom-line benefits, so interest gradually waned and the programs were shelved when times got tough. Six Sigma organizations know precisely what they’re getting for their investment.

Six Sigma also has an indirect and seldom measured benefit to an enterprise: its impact on human behavior. Six Sigma doesn’t operate in a vacuum. When employees observe Six Sigma’s dramatic results, they naturally modify how they approach their work. Seat-of-the-pants management doesn’t sit well (pardon the pun!) in Six Sigma organizations that have reached “critical mass.” Critical mass occurs when the organization’s culture has changed as a result of Six Sigma’s successful deployment across a large segment of the organization. The initial clash of cultures has worked itself out, and those opposed to the Six Sigma way have either left, converted, or learned to keep quiet.

When deploying Six Sigma, it’s important not to stifle creativity for the sake of operational efficiencies. For example, successful Research and development (R&D) involves a good deal of original creative thinking. Research may actually suffer from too much rigor and focus on error prevention. Cutting-edge research is necessarily trial and error and requires a high tolerance for failure. The chaos of exploring new ideas is not something to be managed out of the system; it is expected and encouraged. To the extent that it involves process design and product testing, including the concept of manufacturability, Six Sigma will certainly make a contribution to the development part of R&D. The objective is to selectively apply Six Sigma to those areas where it provides benefit.

Taking a broader view, a business is a complex undertaking, requiring creativity, innovation, and intuition for successful leadership. While it’s good to be “data-driven,” leaders need to question data effectively, especially since some of the most important components of success in business are unmeasured and perhaps immeasurable. Challenge counterintuitive data and subject it to a gut check. It may be that the counterintuitive result represents a startling breakthrough in knowledge, but it may simply be wrong.

Consider this example. A software client had a technical support call center to help their customers solve problems with the software. Customer surveys were collected and the statistician made an amazing discovery, hold time didn’t matter! The data showed that customer satisfaction was the same for customers served immediately and
for those on hold for an hour or more. Discussions began along the lines of how many fewer staff would be required due to this new information. Impressive savings were forecast.

Fortunately, the support center manager hadn’t left his skepticism at the front door. He asked for additional data, which showed that the abandon rate increased steadily as people were kept on hold. The surveys were given only to those people who had waited for service. These people didn’t mind waiting. Those who hung up the phone before being served apparently did. In fact, when a representative sample was obtained, excessive hold time was the number one complaint.

The Change Imperative

In traditional organizations the role of management is to design systems to create and deliver value to customers and shareholders. Unfortunately, however, too many of these organizations fail to recognize that this is a never-ending task. Competitors constantly innovate in an attempt to steal your customers. Customers continuously change their minds about what they want. Capital markets offer investors new ways to earn a return on their investment. The result is an imperative to constantly change management systems.

Despite the change imperative, most enterprises resist change until there are obvious signs that current systems are failing one or more stakeholder groups. Perhaps declining market share makes it clear that your products or services are not as competitive as they once were. Customers may remain loyal, but complaints have reached epidemic proportions. Or share price, the perceived market value of your business, may be trending ominously downward. Traditional organizations watch for such signs and react to them. Change occurs, as it must, but it does so in an atmosphere of crisis and confusion. Substantial loss may result before the needed redesign is complete. People may lose their jobs or even their careers. Many organizations that employ these reactionary tactics don’t survive the shock.

Sadly, as this page is written, the U.S. automobile industry is reeling from the combined effects of global competition, a worldwide credit crisis, and an extended period of high fuel costs. While arguments can be made as to the predictability of these events, it is clear that the strength of their competitors lies primarily in their ability to adapt. A recent poll found that more than 60% of global respondents agreed that the ability to change is an organization’s main competitive advantage (Blauth, 2008). The ability to respond to customer demand, whether that demand is stagnant or dynamic, is a key focus of Six Sigma projects. Applied at a process level, the Lean principles deployed within these projects stress reduced inventories with decreased cycle times to quickly satisfy shifts in customer demand. As an organizational strategy, these principles result in agile organizations that invest in adaptability rather than volume efficiencies. Resources are deployed only when needed, so they can be constantly refocused to meet the current customer value definitions.

In this way, the Six Sigma enterprise proactively embraces change by explicitly incorporating change into their management systems. Full- and part-time change agent positions are created with a supporting infrastructure designed to integrate change into the routine. Systems are implemented to monitor changing customer, shareholder, and employee inputs, and to rapidly integrate the new information into revised business processes. The approach may employ sophisticated computer modeling, or more basic statistical analysis, to minimize unneeded tampering by separating signal from noise.
These analytical techniques are applied to stakeholder inputs and to enterprise and process metrics at all levels.

The intended consequence of deploying Six Sigma is a change in behavior, as well as the more obvious organizational effectiveness and efficiencies. Conventional wisdom is respectfully questioned: the phrase “How do you know?” is heard repeatedly.

- “Nice report on on-time deliveries, Joan, but show me why you think this is important to the customer. If it is, I want to see a chart covering the last 52 weeks, and don’t forget the control limits.”
- “This budget variance report doesn’t distinguish between expected variation and real changes to the system! I want to see performance across time, with control limits, so we know how to effectively respond.”
- “Have these employee survey results been validated? What is the reliability of the questions? What are the main drivers of employee satisfaction? How do you know?”
- “How do these internal dashboards relate to the top-level dashboards that are important to shareholders?”

Yet, the act of challenging accepted practices poses risk. The challenger may feel isolated; those being challenged may feel threatened. These represent behavioral costs to the change effort. The net result of the challenge, ultimately, is the need for further information, which comes at a monetary cost and opportunity risk to the organization. These risks and costs must be effectively managed.

**Managing Change**

Three goals of change may be summarized as follows:

1. Change the way people in the organization think. Helping people modify their perspective is a fundamental activity of the change agent. All change begins with the individual, at a personal level. Unless the individual is willing to change his behavior, no real change is possible. Changing behavior requires a change in thinking. In an organization where people are expected to use their minds, people’s actions are guided by their thoughts and conclusions. The change agent’s job starts here.

2. Change the norms. Norms consist of standards, models, or patterns which guide behavior in a group. All organizations have norms or expectations of their members. Change cannot occur until the organization’s norms change. In effective Six Sigma organizations, the desired norm is data-driven decision making focused on providing maximum value to key stakeholders.

3. Change the organization’s systems or processes. This is the “meat” of the change. Ultimately, all work is a process and quality improvement requires change at the process and system level. However, this cannot occur on a sustained basis until individuals change their behavior and organizational norms are changed.

Change agents fundamentally accomplish these goals by building buy-in within the key stakeholder groups affected by the change. While this is challenging at the process level, it is considerably more so at the organizational level, as is discussed in the next section.
The press of day-to-day business, combined with the inherent difficulties of change, make it easy to let time slip by without significant progress. Keeping operations going is a full-time job, and current problems present themselves with an urgency that meeting a future goal can’t match. Without the constant reminders from change agents that goals aren’t being met, the leadership can simply forget about the transformation. It is the change agent’s job to become the “conscience” of the leadership and to challenge them when progress falls short of goals.

Implementing Six Sigma

After nearly two decades of Six Sigma experience, there is now a solid body of scientific research that successful deployment involves focusing on a small number of high-leverage items. The activities and systems required to successfully implement Six Sigma are well documented.

1. Leadership. Leadership’s primary role is to create a clear vision for Six Sigma success and to communicate their vision clearly, consistently, and repeatedly throughout the organization. In other words, leadership must lead the effort. Their primary responsibility is to ensure that Six Sigma goals, objectives, and progress are properly aligned with those of the enterprise as a whole. This is done by modifying the organization such that personnel naturally pursue Six Sigma as part of their normal routine. This requires the creation of new positions and departments, and modified reward, recognition, incentive, and compensation systems. These key issues are discussed throughout this chapter. The Six Sigma deployment will begin with senior leadership training in the philosophy, principles, and tools they need to prepare their organization for success.

2. Infrastructure. Using their newly acquired knowledge, senior leaders direct the development and training of an infrastructure to manage and support Six Sigma.

3. Communication and awareness. Simultaneously, steps are taken to “soft-wire” the organization and to cultivate a change-capable environment where innovation and creativity can flourish. A top-level DMAIC project is focused on the change initiative and the communication required to build buy-in of the initiative, as outlined later in this chapter.

4. Stakeholder feedback systems. Systems are developed for establishing close communication with customers, employees, and suppliers. This includes developing rigorous methods of obtaining and evaluating customer, owner, employee, and supplier input. Baseline studies are conducted to determine the starting point and to identify cultural, policy, and procedural obstacles to success. These systems are discussed in more detail later in this chapter.

5. Process feedback systems. A framework for continuous process improvement is developed, along with a system of indicators for monitoring progress and success. Six Sigma metrics focus on the organization’s strategic goals, drivers, and key business processes, as discussed in Chap. 2.

6. Project selection. Six Sigma projects are proposed for improving business processes by people with process knowledge at various levels of the organization. Six Sigma projects are selected based on established protocol by senior