THE SIX SIGMA HANDBOOK

FIFTH EDITION

A Complete Guide for Green Belts, Black Belts, and Managers at All Levels

THOMAS PYZDEK + PAUL KELLER

Mc Graw Hill Education

The Six Sigma Handbook

About the Authors

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PREFACE

Even a brief overview of Six Sigma literature will uncover more than a few approaches to implementing Six Sigma. Some have been remarkably unsuccessful, while others have provided the vision and means for the organization to prosper. Online chat groups provide a global sounding board for the discontented as well as the enthused. For some, Six Sigma is dead, and for those, perhaps it should be. They are ready to move on to the "next big thing."

What I tend to find most intriguing about these discussions are the details. What *specifically* failed in an implementation? Why didn't Six Sigma work? What alternative provides an improved approach? Invariably, the failures suffered from predictably flawed approaches, hampered by the usual suspects of implementation issues: lack of commitment and/or resources, and poor or misdirected focus. The fundamentals of the Six Sigma approach remain sound: Prioritize specific issues impacting customers, shareholders and/or employees, and problem-solve over a relatively rapid time frame using data-driven cross-functional project teams sponsored by the functional stakeholder groups. Effectively-managed projects will quickly identify organizational issues, highlighting the advantage of the project as the means to achieve manageable bites of improvement. Are there best practices that improve success rates? Absolutely! Best practices in Six Sigma are continuously evolving, just as Six Sigma itself evolved from earlier best practices in quality improvement. Those who truly "get it" know that Six Sigma will die only when organizations stop caring about their customers, employees and shareholders. Did Six Sigma really "kill innovation at XYZ Company?" Of course not! Can an overly bureaucratic approach to innovation stifle creativity? Yes, just as overzealous standardization emphasizes process consistency and internal productivity at the expense of an improved customer experience. These failures result from neglecting a key tenet of Six Sigma: customer focus.

This fifth edition addresses many of these challenges. If this is your first copy of *The Six Sigma Handbook*, you may find the implementation approach includes many of the practices advocated by "newer" disciplines, such as Business Process Management (BPM) or Business Process Improvement (BPI). The overall approach remains consistent with the earlier editions of the text, with elaboration and best practices added to more fully develop the approach in the reader's mind.

You'll notice many references to free online materials within the text, such as Excel file templates that can be used for analyzing projects, or videos that provide an in-depth narrative on specific topics. Additional links will be added over time to further extend the learning potential offered by the text, so be sure to regularly check back into the online site at www.mhprofessional.com/ssh5. We expect to offer additional learning options, some free and some at reasonable expense, based on reader feedback.

With well over 120,000 copies in print for its first four editions, *The Six Sigma Handbook* is well-established as a key reference guide for forward-thinking managers and customer-focused process improvement specialists alike. We'd like to thank our faithful readers who have made this work a lasting tribute to the concepts and techniques known as Six Sigma. We hope this fifth edition provides additional insight and direction to achieve ever-higher levels of value for your customers.

Paul Keller

PART I

Six Sigma Implementation and Management

CHAPTER 1

Building the Responsive Six Sigma Organization

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[1] 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.

The DMAIC methodology is discussed in detail in Part II.

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 that also reduce value and quality, Six Sigma identifies and eliminates costs that 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% of their revenues fixing problems. This is known as the cost of quality, or more accurately the cost of poor quality (COPQ). Companies operating at Six Sigma typically spend less than 5% 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). In today's competitive, global business climate, we cannot.

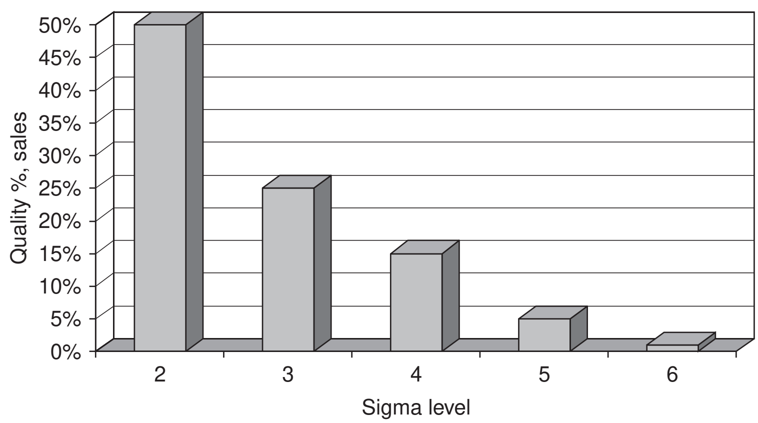

Figure 1.1 Cost of poor quality versus sigma level.

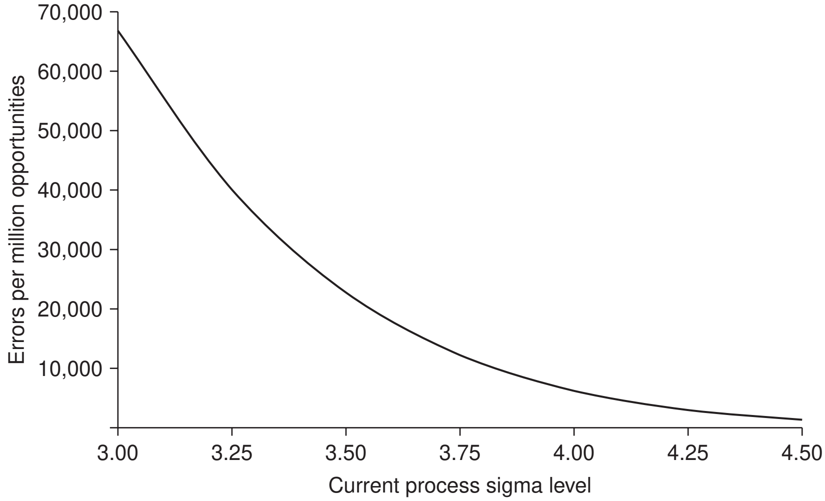

Figure 1.2 Error rate versus sigma level.

The Six Sigma Philosophy

Six Sigma is the application of the scientific method to the design and operation of management systems and business processes that 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 customers 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:

- It was applied only to manufacturing processes, while Six Sigma is applied to all important business processes.
- 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. (This assumption is further discussed in Chap. 7.) 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. (See rolled throughput yield calculations in the "Deliverables" section in Chap. 6.) 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. 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.
- Forty-three percent of managers think important decisions are delayed and the ability to make decisions is affected as a result of having too much information.
- Forty-four percent 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, 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:

- **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.
- **Change the norms**—Norms consist of standards, models, or patterns that 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.
- **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, makes 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.

The Transformation Process

Based on considerable research over a number of years, Kotter (1995) established a set of eight steps required to achieve organizational transformation. Kotter believes that change initiatives fail when management treat transformation as an event rather than a process. The successful transformation process occurs over a period of years, and steps are invariably skipped when pressure is exerted to speed up the process. Just as toxic to success is declaring victory prematurely, which saps momentum and can destroy the progress to date. Kotter considers the following eight steps necessary for success:

1. **Establish a sense of urgency**—Use market data, competitive analysis, or a convenient crisis (i.e., don't let a good crisis go to waste) to convince the broad majority of management (Kotter recommends 75% or more) that business as usual is riskier than the unknowns associated with the change. The head of the impacted area (the CEO for a company transformation, or a unit head for a business unit, for example) must certainly be onboard and advocate convincingly for the change (i.e., actions and words).
2. **Form a powerful guiding coalition**—Assemble a team of powerbrokers within the organization to lead the effort *as a team*. The involvement of these senior managers will certainly be needed at some point in the process, so charging them with leading the effort builds their buy-in and ensures the transformation will not be undermined by uninvolved senior managers. The executive council suggested earlier for managing Six Sigma in an organization would meet this condition. The team approach is necessary to maintain their active participation and also to prevent turf wars. (See Chap. 5 for further information on team development.)
3. **Create a vision**—How will the new organization differ from the current organization? Kotter emphasizes the need to simplify the vision into a coherent message that can be delivered in five minutes or less, yet generate interest and understanding from the audience.
4. **Communicate the vision**—Communication of the vision must be consistent and persistent, in both word and deed. The transformation will require employees to change behavior, which does not come easily and has at least perceived risk if not actual risk. These risks can only be overcome when the message is credible. Communication is a key aspect of building organizational buy-in. A DMAIC approach to building organizational buy-in is presented later in this chapter.
5. **Empower others to act on the vision**—The vision will only be realized when it becomes the new normal. To progress to that point may require identifying and

removing systems (or individuals) that serve as barriers to the new approach, or creating new systems that embody the new approach. A Six Sigma deployment achieves its objectives through a series of focused cross-functional projects sponsored by the manager(s) functionally responsible for the impacted area(s). The projects are deployed by teams, led by a trained Black Belt, that consist of local experts who perform the process activities daily. The sponsoring of the project by the functional managers ensures the team is empowered to affect change to the process. The oversight of the program by top management, and the alignment of the program with the strategic objectives, encourages the local managers to support the teams completely to achieve the project objectives. This system, discussed more completely in the next section, is critical to the success of the deployment effort.

6. **Plan for and create short-term wins**—A rational person does not decide to begin exercising as a New Year's resolution, then immediately embark on a 26-mile marathon or hike K2. Rather, success comes from setting and succeeding at smaller challenges, which builds expertise and confidence in the approach to apply for larger endeavors. It's the best of human nature to learn by doing. Typically, a successful Six Sigma deployment will seek to develop initial training projects that allow students to learn the techniques and apply them to familiar processes, with reasonable goals for improvement. This builds confidence for the teams as well as for the organization as whole. It is equally important for managers to become comfortable with their oversight responsibility. They must balance the empowerment given to the teams to affect change with the accountability of the teams to produce a meaningful, workable solution in a reasonable time frame.
7. **Consolidate improvements and produce more change**—For a Six Sigma deployment, as projects begin to impact change and produce results, management should celebrate the gains and congratulate the teams responsible. Use the early successes to build awareness throughout the organization, revise systems or policies that block effective change, and promote and develop employees with the skills needed to further affect change in the organization. Don't declare victory too soon. Instead, ramp up the efforts and build on the early success to gain critical mass and maintain momentum.
8. **Institutionalize new approaches**—Develop the leadership team and their practices to fully incorporate the change initiative into the organization's lifeblood. Constantly and consistently communicate the link between organization success and program success, and actively promote those responsible for the gains (at the expense of others who thought they could wait it out).

The approaches summarized above are more fully developed in the following section.

Implementing Six Sigma

After nearly three 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.

- **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.
- **Infrastructure**—Using their newly acquired knowledge, senior leaders direct the development and training of an infrastructure to manage and support Six Sigma.
- **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.
- **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 greater detail in Chap. 2.
- **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. 3.
- **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 management to achieve

business performance objectives linked to measurable financial results, as discussed in Chap. 4.

- **Project deployment**—Six Sigma projects are conducted by project teams lead by Black Belts (or by Green Belts with the technical assistance of Black Belts). Project deployment is discussed in detail in Part II of this book.

Timetable

Figure 1.3 shows a typical set of deployment activities to reach system maturity within two years. The resulting benefits are dependent on the rate of project deployment and the organization's initial quality levels. A typical goal is an improvement rate of approximately 10 times every two years, measured in terms of errors (or defects) per million opportunities (DPMO).[2] For example, an organization starting at a typical sigma level of 3.0 would seek to reduce their overall error rate from approximately 67,000 to about 6,700 (or about 4.0 sigma level) in two years time. Figure 1.4 provides a rough guideline for determining when you will reach Six Sigma based on the initial quality level, assuming the 10 times

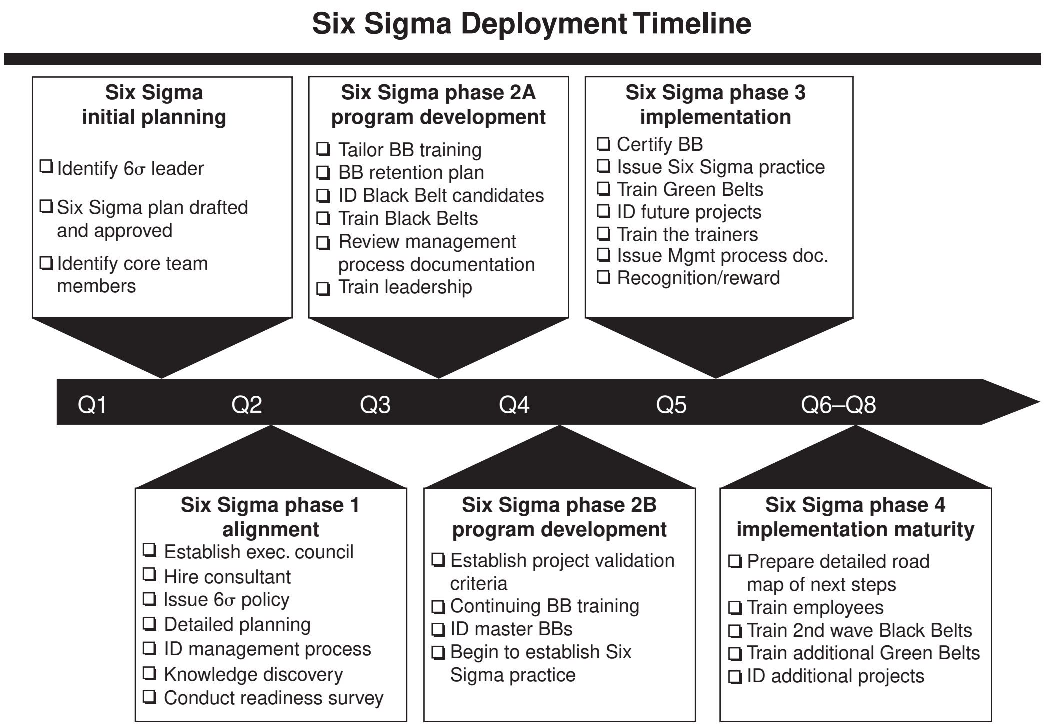

Figure 1.3 Typical deployment activities and timeline.

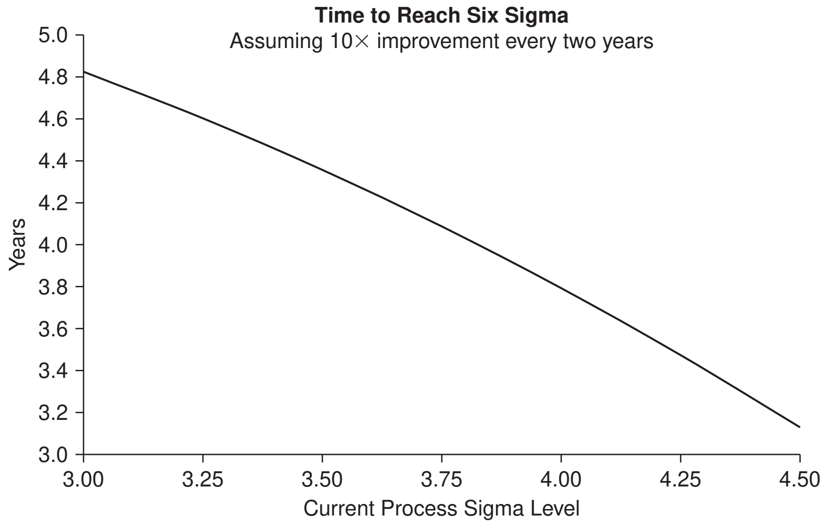

Figure 1.4 Time to reach Six Sigma performance levels.

improvement every two years. For the typical company starting at three sigma, Fig. 1.4 indicates they will reach Six Sigma levels of performance after approximately five years from the time they have deployed Six Sigma. Given the deployment timeline shown in Fig. 1.3, it will be approximately seven years from date of program initiation. Of course, results will begin to appear within a year of starting the deployment.

Yet, even when the enterprise reaches a performance level of five or Six Sigma overall, there may still be processes operating at poor sigma levels, demonstrating the fallibility of the DPMO metric, especially when interpreted across an entire organization. Individual customers judge your organization based on their individual experiences, and customer expectations are a moving target, as previously discussed.

Figure 1.5 shows General Electric's published data on their Six Sigma program. Note there was sufficient savings to cover costs during the first year. In the second and subsequent years the benefits outpaced the costs, with the benefit-to-cost ratio improving steadily as costs level out. These results are consistent with those reported by academic research for companies that successfully implemented TQM.

The annual savings achieved by a given organization is largely dependent on their initial quality, as well as their resource commitment. The number of full-time personnel devoted to Six Sigma is a relatively small percentage of the total work force. Mature Six Sigma programs, such as those of General Electric, Johnson & Johnson, AlliedSignal, and others, average about 1% of their workforce as Black Belts, with considerable variation in that number. There is usually about one Master Black Belt for every 10 Black Belts, or about one Master Black Belt per 1,000 employees. A Black Belt will typically complete

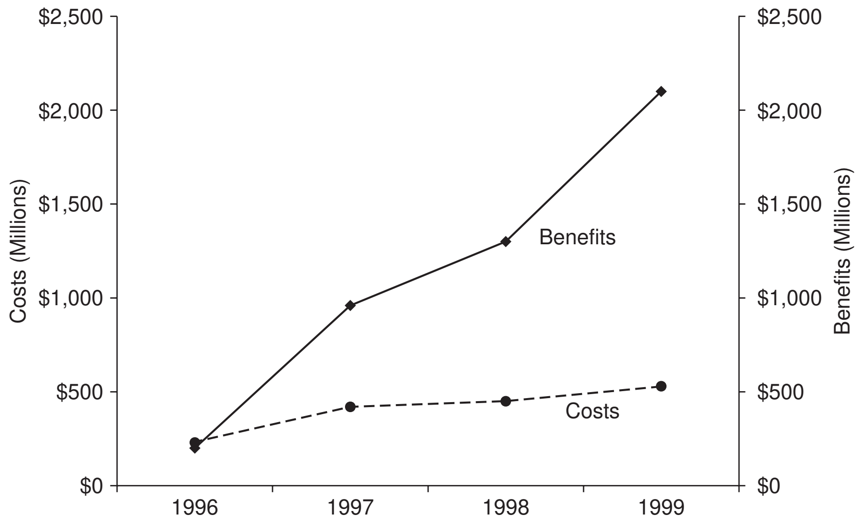

Figure1.5 GE's reported cost of Six Sigma versus benefits.

five to seven projects per year, usually working with teams. Project teams are led either by Black Belts or in some cases Green Belts, who, unlike Black Belts and Master Black Belts, are not engaged full time in the Six Sigma program. Green Belts usually devote between 5 and 10% of their time to Six Sigma project work.

Estimated savings per project vary from organization to organization, but average about $150,000 to $243,000 according to published figures. Some industries just starting their Six Sigma programs average as high as $700,000 savings per project, although these projects usually take longer. Note that these are not the huge megaprojects such as pursued by reengineering. Yet, by completing five to seven projects per year per Black Belt the company will add in excess of $1 million per year per Black Belt to its bottom line. For a company with 1,000 employees the resource requirement and estimated savings are shown in the following table:

Master Black Belts:	1
Black Belts:	10
Projects:	50 to 70 (5 to 7 per Black Belt)
Estimated saving:	$9 million to $14.6 million (i.e., $14,580 savings per employee)

Savings for your organization can be easily estimated the same way. Recall from Fig. 1.1 the potential savings (about 25% of revenue) that exists in a typical three sigma organization, and it's easy to see there are many potential projects available within a typical organization. Since Six Sigma savings—unlike traditional slash and burn cost cutting—impact only non-value-added costs, they flow directly to your company's bottom line. Traditional, income-statement-based cost cutting inevitably hurts value-adding activities. As a result, the savings seldom measure up to expectations, and revenues often suffer as well. The predicted bottom-line impact is not actually realized. Firms engaging in these activities hurt their prospects for future success and delay their recovery.

Infrastructure

A successful Six Sigma deployment demands an organizational infrastructure to manage and support the various activities summarized earlier in this chapter. Six Sigma is the primary strategy for enterprise-wide business process improvement; to ensure success it is necessary to institutionalize it as a way of doing business. It is not enough to train resources to act outside of the normal business functions. To the contrary, such a plan virtually guarantees failure by placing the Six Sigma activities somewhere other than the mainstream. Instead, process improvement must become an ongoing part of the business to meet the ever-changing market conditions and customer value definitions.

It's interesting to note that companies institutionalizing the principles of TQM obtained excellent results, which are comparable to the results reported by companies implementing Six Sigma. Those that didn't invariably failed to achieve lasting results. Six Sigma provides a quasi-standardized set of guidelines for deployment, resulting in a much higher success rate. Although each organization will develop its own unique approach to Six Sigma, it is helpful to review the practices of successful companies.

Most importantly, successful Six Sigma deployment is always a top-down affair. For Six Sigma to have a major impact on overall enterprise performance, it must be fully embraced and actively led by top management. Isolated efforts at division or department levels are doomed from the outset. Like flower gardens in a desert, they may flourish and produce a few beautiful results for a time, but sustaining the results requires immense effort by local heroes in constant conflict with the mainstream culture, placing themselves at risk. Sooner or later, the desert will reclaim the garden. Six Sigma shouldn't require heroic effort—there are never enough heroes to go around. Once top management has accepted its leadership responsibility the organizational transformation process can begin.

A key decision is whether Black Belts will report to a central Six Sigma organization or to managers located elsewhere in the organization. The experience of most successful Six Sigma enterprises is that centralized reporting is best. Internal studies by one company that experimented with both types of reporting revealed the results shown in Table 1.1. The major reason for problems with the decentralized approach was disengaging people from routine work and firefighting. Six Sigma is devoted to change, and it seems change tends to take a back seat to current problems. To be sure, the Black Belt possesses a skill set that can be very useful in putting out fires. Black Belts also tend to excel at whatever they do. This combination makes it difficult to resist the urge to pull the Black Belt off of his or her projects "just for a while." In fact, some organizations have trouble getting the Black Belts out of their current department and into the central organization. In one case the CEO intervened personally on behalf of the Black Belts to break them loose. Such stories are testimony to the difficulties encountered in making drastic cultural changes.

Table 1.1 Black Belt Certification Versus Reporting Arrangement

Where Black Belt Reported	Black Belts Successfully Certified
Local organization	40%
Centralized Six Sigma organization	80%

The transformation process involves new roles and responsibilities on the part of many individuals in the organization. In addition, new change agent positions must be created. Table 1.2 lists some typical roles and responsibilities. In a Six Sigma organization, improvement and change are the full-time job of a small but critical percentage of the organization's personnel. These full-time change agents are the catalyst that institutionalizes change.

Education and training are important means of changing individual perceptions and behaviors. In this discussion, a distinction is made between training and education. *Training* refers to instruction and practice designed to teach a person how to perform one or more tasks. Training focuses on concrete tasks to be completed. *Education* refers to instruction in thinking. Education focuses on integrating abstract concepts into one's knowledge of the world. An educated person will view the world differently after being educated. This is an essential part of the process of change.

Six Sigma training is a subproject of the Six Sigma deployment plan, whose timetables must be tightly linked. Training provided too early or too late is a mistake. When training is provided too early, the recipient will forget much of what he has learned before it is needed. When it is provided too late, the quality of the employee's work will suffer. When it comes to training, just-in-time delivery is the goal.

Table 1.2 Six Sigma Roles and Responsibilities

Responsible Entity	Roles	Responsibilities
Executive Six Sigma Council	Strategic leadership	• Ensures Six Sigma goals are linked to enterprise goals • Develops new policies as required • Aligns process excellence efforts across the organization • Suggests high-impact projects • Approves project selection strategy
	Ensures progress	• Provides resources • Tracks and controls progress toward goals • Reviews improvement teams' results (BB, GB, Lean, Supply Chain, other) • Reviews effectiveness of Six Sigma deployment: systems, processes, infrastructure, etc.
	Cultural transformation	• Communicates vision • Removes formal and informal barriers • Commissions modification of compensation, incentive, reward, and recognition systems
Director, Six Sigma	Manages Six Sigma infrastructure and resources	• Six Sigma champion for ACME • Develops Enterprise Six Sigma deployment • Owns the Six Sigma project selection and prioritization process for ACME • Ensures Six Sigma strategies and projects are linked through quality function deployment to business plans • Achieves defect reduction and cost take-out targets through Six Sigma activities • Member of Executive Six Sigma Council • Leads and evaluates the performance of Black Belts and Master Black Belts • Communicates Six Sigma progress with customers, suppliers, and the enterprise • Champions Six Sigma reward and recognition, as appropriate
Six Sigma Certification Board	Certifies Black Belts Board representatives include Master Black Belts and key Six Sigma leaders	• Works with local units to customize Black Belt and Green Belt requirements to fit business needs • Develops and implements systems for certifying Black Belts and Green Belts • Certifies Black Belts

(continued on next page)

Table 1.2 Six Sigma Roles and Responsibilities (*continued*)

Responsible Entity	**Roles**	**Responsibilities**
Six Sigma Core Team	Cross-functional Six Sigma team Part-time change agent	• Provides input into policies and procedures for successful implementation of Six Sigma across ACME • Facilitates Six Sigma activities such as training, special recognition events, Black Belt testing, etc.
Master Black Belt	Enterprise Six Sigma expert Permanent full-time change agent Certified Black Belt with additional specialized skills or experience especially useful in deployment of Six Sigma across the enterprise	• Highly proficient in using Six Sigma methodology to achieve tangible business results • Technical expert beyond Black Belt level on one or more aspects of process improvement (e.g., advanced statistical analysis, project management, communications, program administration, teaching, project coaching) • Identifies high-leverage opportunities for applying the Six Sigma approach across the enterprise • Basic Black Belt training • Green Belt training • Coach/Mentor Black Belts • Participates on ACME Six Sigma Certification Board to certify Black Belts and Green Belts
Black Belt	Six Sigma technical expert Temporary, full-time change agent (will return to other duties after completing a two- to three-year tour of duty as a Black Belt)	• Leads business process improvement projects where Six Sigma approach is indicated • Successfully completes high-impact projects that result in tangible benefits to the enterprise • Demonstrated mastery of Black Belt body of knowledge • Demonstrated proficiency at achieving results through the application of the Six Sigma approach • Internal Process Improvement Consultant for functional areas • Coach/Mentor Green Belts • Recommends Green Belts for Certification

Responsible Entity	Roles	Responsibilities
Green Belt	Six Sigma project originator Six Sigma project leader Part-time Six Sigma change agent. Continues to perform normal duties while participating on Six Sigma project teams Six Sigma champion in local area	• Demonstrated mastery of Green Belt body of knowledge • Demonstrated proficiency at achieving results through the application of the Six Sigma approach • Recommends Six Sigma projects • Participates on Six Sigma project teams • Leads Six Sigma teams in local improvement projects • Works closely with other continuous improvement leaders to apply formal data analysis approaches to projects • Teaches local teams, shares knowledge of Six Sigma • Successful completion of at least one Six Sigma project every 12 months to maintain their Green Belt certification
Six Sigma Improvement Team	Primary ACME vehicle for achieving Six Sigma improvements	• Completes chartered Six Sigma projects that deliver tangible results • Identifies Six Sigma project candidates
ACME Leaders and Managers	Champions for Six Sigma	• Ensures flow-down and follow-through on goals and strategies within their organizations • Plans improvement projects • Charters or champions chartering process • Identifies teams or individuals required to facilitate Six Sigma deployment • Integrates Six Sigma with performance appraisal process by identifying measurable Six Sigma goals/objectives/results • Identifies, sponsors, and directs Six Sigma projects • Holds regular project reviews in accordance with project charters • Includes Six Sigma requirements in expense and capital budgets • Identifies and removes organizational and cultural barriers to Six Sigma success • Rewards and recognizes team and individual accomplishments (formally and informally) • Communicates leadership vision • Monitors and reports Six Sigma progress • Validates Six Sigma project results • Nominates highly qualified Black Belt and/or Green Belt candidates

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Table 1.2 Six Sigma Roles and Responsibilities (*continued*)

Responsible Entity	**Roles**	**Responsibilities**
Project Sponsor	Charters and supports Six Sigma project teams	• Sponsor is ultimately responsible for the success of sponsored projects • Actively participates in projects • Ensures adequate resources are provided for project • Personal review of progress • Identifies and overcomes barriers and issues • Evaluates and accepts deliverable
"Matrixed" Project Manager	Manages Six Sigma resources dedicated to a particular area (e.g., teams of Black Belts on special assignment) Champions Six Sigma Black Belt team	• Provides day-to-day direction for Six Sigma project Black Belt and team activities • Provides local administrative support, facilities, and materials • Conducts periodic reviews of projects • Provides input on Black Belt performance appraisals • Makes/implements decisions based on recommendations of Six Sigma Black Belts
Six Sigma Improvement Team Member	Learns and applies Six Sigma tools to projects	• Actively participates in team tasks • Communicates well with other team members • Demonstrates basic improvement tool knowledge • Accepts and executes assignments as determined by team

The cost of Six Sigma training should be included in the previously discussed estimates of Six Sigma cost-benefit ratios and include

- Trainer salaries
- Consulting fees
- Classroom space and materials
- Lost time from the job
- Staff salaries
- Office space of training staff

The estimated benefits of the training include the subsequent project deliverables, often on an annualized basis. Since trained Black Belts and Green Belts will often work on multiple projects during the year, it's best to consider these costs and benefits on a program-wide basis, rather than a per-class or per-project basis.

Champions and Sponsors

Six Sigma champions are high-level individuals who understand Six Sigma and are committed to its success. In larger organizations Six Sigma will be led by a full-time, high-level champion, such as an executive vice president. In all organizations, champions also include informal leaders who use Six Sigma in their day-to-day work and communicate the Six Sigma message at every opportunity. Sponsors are owners of processes and systems that help initiate and coordinate Six Sigma improvement activities in their areas of responsibilities.

Leaders should receive guidance in the art of "visioning." Visioning involves the ability to develop a mental image of the organization at a future time; without a vision, there can be no strategy.

Leaders need to be masters of communication. Fortunately, most leaders already possess outstanding communication skills; few rise to the top without them. However, training in effective communication is still wise, even if it is only refresher training. When large organizations are involved, communications training should include mass communication media, such as video, radio broadcasts, and print media. Communicating with customers, investors, and suppliers differs from communicating with employees and colleagues, and special training is often required.

Finally, leaders should demonstrate strict adherence to ethical principles. Leadership involves trust, and trust isn't granted to one who violates a moral code that allows people to live and work together. Honesty, integrity, and other moral virtues should be second nature to the leader.

Black Belts

Candidates for Black Belt status are technically oriented individuals held in high regard by their peers. They should be actively involved in the process of organizational change and development. Candidates may come from a wide range of disciplines and need not be formally trained statisticians or analysts. However, because they are expected to master a wide variety of technical tools in a relatively short period of time, Black Belt candidates will probably possess a background in college-level mathematics, the basic tool of quantitative analysis. Coursework in statistical methods should be considered a strong plus or even a prerequisite. Black Belts receive from three to six weeks of training in the technical tools of Six Sigma. Three-week curricula are usually given to Black Belts working in service or transaction-based businesses, administrative areas, or finance. Four-week programs are common for manufacturing environments. Six weeks of training are provided for Black Belts working in R&D or similar environments. Figure 1.6 shows the curriculum used for courses in General Electric for personnel with finance backgrounds who will be applying Six Sigma to financial, general business, and e-commerce processes. Figure 1.7 shows GE's curriculum for the more traditional manufacturing areas.

Although some training companies offer highly compressed two-week training courses, these are not recommended. Even in a six-week course, students receive the equivalent of two semesters of college-level applied statistics in just a few days. Humans require a certain "gestation period" to grasp challenging new concepts; providing too much material in too short a time period is counterproductive. Successful candidates will be comfortable with computers. At a minimum, they should be proficient with one or more operating systems, spreadsheets, database managers, presentation programs, and word processors. As part of their training they will also be required to become proficient in the use of one or more advanced statistical analysis software packages and probably simulation software. Six Sigma Black Belts work to extract actionable knowledge from an organization's information warehouse. To ensure access to the needed information, Six Sigma activities should be closely integrated with the information systems of the organization. Obviously, the skills and training of Six Sigma Black Belts must be enabled by an investment in software and hardware. It makes no sense to hamstring these experts by saving a few dollars on computers or software.

As a full-time change agent, the Black Belt needs excellent interpersonal skills. In addition to mastering a body of technical knowledge, Black Belts must

- Communicate effectively verbally and in writing
- Communicate effectively in both public and private forums
- Work effectively in small group settings as both a participant and a leader
- Work effectively in one-on-one settings
- Understand and carry out instructions from leaders and sponsors

Week 1

The DMAIC and DFSS (design for Six Sigma) improvement strategies

Project selection and “scoping” (define)

QFD (quality function deployment)

Sampling principles (quality and quantity)

Measurement system analysis (also called “Gage R&R”)

Process capability

Basic graphs

Hypothesis testing

Regression

Week 2

Design of experiments (DOE) (focus on two-level factorials)

Design for Six Sigma tools

Requirements flowdown

Capability flowup (prediction)

Piloting

Simulation

FMEA (failure mode and effects analysis)

Developing control plans

Control charts

Week 3

Power (impact of sample size)

Impact of process instability on capability analysis

Confidence intervals (vs. hypothesis tests)

Implications of the Central Limit Theorem

Transformations

How to detect “lying with statistics”

General linear models

Fractional factorial DOEs

Figure 1.6 Sample curriculum for finance Black Belts. (From Hoerl, 2001, p. 395. Reprinted by permission of ASQ.)

Context[1]

- Why Six Sigma
- DMAIC and DFSS processes (sequential case studies)
- Project management fundamentals
- Team effectiveness fundamentals

Define[1]

- Project selection
- Scoping projects
- Developing a project plan
- Multigenerational projects
- Process identification (SIPOC)

Measure[1]

- QFD
- Developing measurable CTQs
- Sampling (data quantity and data quality)
- Measurement system analysis (not just gage R&R)
- SPC Part I
  - The concept of statistical control (process stability)
  - The implications of instability on capability measures
- Capability analysis

Analyze[2]

- Basic graphical improvement tools ("Magnificent 7")
- Management and planning tools (Affinity, ID, etc.)
- Confidence intervals (emphasized)
- Hypothesis testing (de-emphasized)
- ANOVA (de-emphasized)
- Regression
- Developing conceptual designs in DFSS

Improve[3,4]

- DOE (focus on two-level factorials, screening designs, and RSM)
- Piloting (of DMAIC improvements)
- FMEA
- Mistake-proofing
- DFSS design tools
  - CTQ flowdown
  - Capability flowup
  - Simulation

Control[4]

- Developing control plans
- SPC Part II
  - Control charts
- Piloting new designs in DFSS

Figure 1.7 Sample curriculum for manufacturing Black Belts. (The week in which the material appears is noted as a superscript. From Hoerl, 2001, p. 399. Reprinted by permission of ASQ.)

A change agent deficient in these soft skills will nearly always be ineffective. They are usually frustrated and unhappy souls who don't understand why their technically brilliant case for change doesn't cause instantaneous compliance by all parties. The good news is that if the person is willing to apply as much time and effort to soft-skill acquisition and mastery as they applied to honing their technical skills, they will be able to develop proficiency.

In general, Black Belts are hands-on oriented people selected primarily for their ability to get things done. Tools and techniques are provided to help them do this. The training emphasis is on application, not theory. In addition, many Black Belts will work on projects in an area where they possess a high degree of subject-matter expertise. Therefore, Black Belt training is designed around projects related to their specific work areas. This requires Master Black Belts or trainers with very broad project experience to answer application-specific questions. When these personnel aren't available, examples are selected to match the Black Belt's work as closely as possible. For example, if no trainer with human resource experience is available, the examples might be from another service environment; manufacturing examples would be avoided. Another common alternative is to use consultants to conduct the training. Consultants with broad experience within the enterprise as well as with other organizations can sometimes offer insights.

Black Belts must work on projects while they are being trained. Typically, the training classes are conducted at monthly intervals and project work is pursued between classes. One of the critical differences between Six Sigma and other initiatives is the emphasis on using the new skills to get tangible results. It is relatively easy to sit in a classroom and absorb the concepts well enough to pass an exam. It's another thing entirely to apply the new approach to a real-world problem. The Black Belt has to be able to use change agent skills to recruit sponsors and team members and to get these people to work together on a project with a challenging goal and a tight timetable. While the instructors can provide coaching and project-specific training and advice, there's no better time to initiate the process than during the training.

The process for selecting Black Belts should be clearly defined. This ensures consistency and minimizes the possibility of bias and favoritism. Figure 1.8 provides a list of seven success factors, with their relative importance weights, that can be used to compare Black Belt candidates.

The weights are, of course, subjective and only approximate, and are based on an exercise with a group of consultants and Master Black Belts. Organizations can easily identify their own set of criteria and weights, such as shown by Keller (2005). The important thing is to determine the criteria and then develop a method of evaluating candidates on each criterion. The sum of the candidate's criterion score times the criterion weight will give you an overall numerical assessment for ranking the Black Belt candidates. Of course,

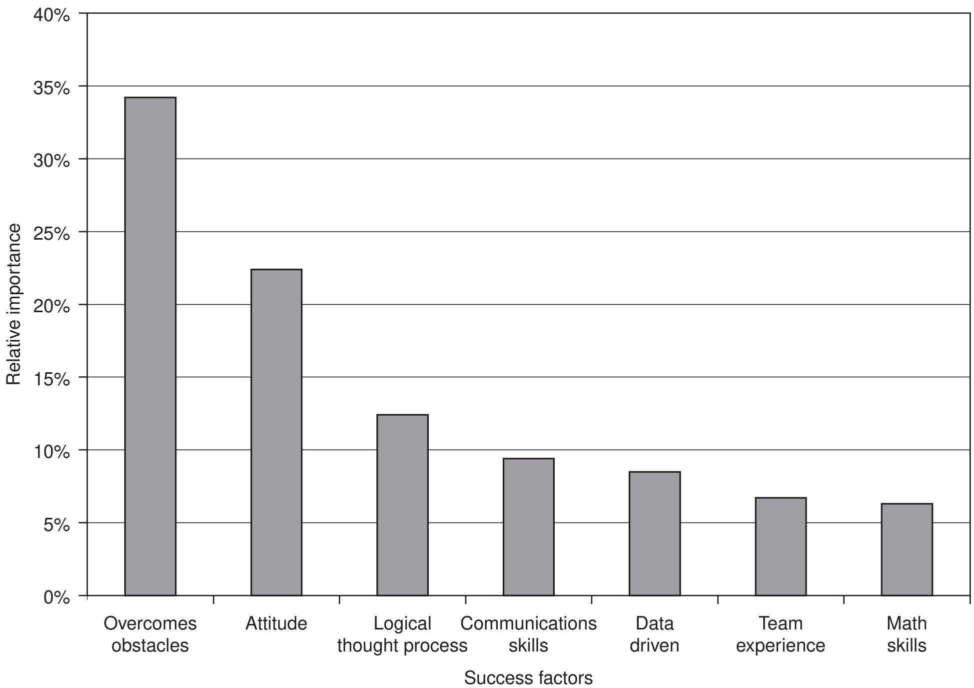

Figure 1.8 Black Belt success factors and importance weights.

the numerical assessment is not the only input into the selection decision, but it is a very useful one.

Notice the relatively low weight given to math skills. The rationale is that Black Belts will receive 200 hours of training, much of it focused on the practical application of statistical techniques using computer software and requiring very little actual mathematics. Software automates the analysis, making math skills less necessary. The mathematical theory underlying a technique is not discussed beyond the level necessary to help the Black Belt properly apply the tool. Black Belts who need help with a particular tool have access to Master Black Belts, other Black Belts, consultants, professors, and a wealth of other resources. Most statistical techniques used in Six Sigma are relatively straightforward and often graphical; spotting obvious errors is usually not too difficult for trained Black Belts. Projects seldom fail due to a lack of mathematical expertise. In contrast, the Black Belts will often have to rely on their own abilities to deal with the obstacles they will inevitably encounter. Failure to overcome the obstacle will often spell failure of the entire project.

Figure 1.9 provides a sample of the selection process for a Black Belt candidate at a particular firm.

Minimum Criteria

Education—Bachelors degree, minimum.

Work Experience—At least three years of business, technical, or managerial experience plus technical application of education and experience as a member or leader of functional and cross-functional project teams.

Technical Capability—Project management experience is highly desired. Understanding of basic principles of process management. Basic college algebra proficiency as demonstrated by exam.

Computer Proficiency—MS Office Software Suite.

Communication—Demonstrate excellent oral and written communication skills.

Team Skills—Ability to conduct meetings, facilitate small groups, and successfully resolve conflicts. Ability to mentor and motivate people.

Final Candidate Selection

To ensure that the Black Belts will be able to address enterprise-wide issues and processes, the Director of Six Sigma and the Executive Six Sigma Council will determine the number of Black Belts to be trained in each functional area, division, department, etc. Black Belt candidates are ranked using a system of points assigned during the screening process. Rank-ordered lists of Black Belt candidates are prepared for designated areas and presented to the senior management of the area for final selection. Area management nominates candidates from their list in numbers sufficient to fill the spaces allocated by the Director of Six Sigma and the Executive Six Sigma Council.

Commitment to Black Belt Assignment

Selected candidates are required to attend 200 hours of Black Belt training (see Chap. 4 for the training content). Within one year of completing training, the Black Belt candidate is required to become certified by passing a written examination and successfully completing at least two major projects. (See Appendix 15 for detailed Black Belt certification process information.) The Black Belt is assigned to Six Sigma full time as a Black Belt for a minimum period of two full years, measured from the time he or she is certified as a Black Belt.

Reintegration of Black Belts into the Organization

Black Belts are employed in the Black Belt role for two or three years. After that time they leave the Six Sigma organization and return to other duties. Accomplishing this transition is the joint responsibility of the Black Belt, the Director of Six Sigma, and the management of the Black Belt's former department. Collectively this group comprises the "Transition Team" for the Black Belt. However, senior leadership must accept ultimate responsibility for assuring that Black Belts are not "homeless" after completing their Black Belt tour of duty.

The Director of Six Sigma will inform the Black Belt at least six months prior to the scheduled return. Black Belts should maintain contact with their "home" organization during their tenure in Six Sigma. If it appears that there will be a suitable position available at approximately the time the Black Belt is scheduled to return, arrangements should be made to complete or hand off the Black Belt's Six Sigma projects in preparation for his return. If no suitable openings will be available, the Transition Team needs to develop alternative plans. Alternatives might include extending the Black Belt's term of service in Six Sigma, looking for openings in other areas, or making temporary arrangements.

Figure 1.9 Black Belt candidate selection process and criteria.

Past improvement initiatives, such as TQM, shared much in common with Six Sigma. TQM also had management champions, improvement projects, sponsors, etc. One of the main differences in the Six Sigma infrastructure is the creation of more formally defined change agent positions. Some observers criticize this practice as creating corps of "elites," especially Black Belts and Master Black Belts. Let's examine the commonly proposed alternatives to creating a relatively small group of highly trained technical experts:

- **Train the masses**—This is the "quality circles" approach, where people in the lowest level of the organizational hierarchy are trained in the use of basic tools and set loose to solve problems without explicit direction from leadership. When this approach was actually tried in America in the 1970s the results were disappointing. The originators of the quality circles idea, the Japanese, reported considerably greater success with the approach. This was no doubt due to the fact that Japanese circles were integrated into decades-old, company-wide process improvement activities, while American firms typically implemented circles by themselves. Indeed, when Six Sigma deployments reach a high level of maturity, more extensive training is often successful.
- **Train the managers**—This involves training senior and middle management in change agent skills. This isn't a bad idea in itself. However, if the basic structure of the organization doesn't change, there is no clear way to apply the newly acquired skills. Training in and of itself does nothing to change an organization's environment. Historically, trained managers return to pretty much the same job. As time goes by their skills atrophy and their self-confidence wanes. If opportunities to apply their knowledge do arise, they often fail to recognize them or, if they do recognize them, fail to correctly apply the approach. This is natural for a person trying to do something different for the first time. The full-time change agents in Six Sigma learn by doing. By the end of their tenure, they can confidently apply Six Sigma methodology to a wide variety of situations.
- **Use the experts in other areas**—The tools of Six Sigma are not new. In fact, Industrial Statisticians, ASQ Certified Quality Engineers, Certified Reliability Engineers, Certified Quality Technicians, Systems Engineers, Industrial Engineers, Manufacturing Engineers, and other specialists already possess a respectable level of expertise in many Six Sigma tools. Some have a level of mastery in some areas that exceeds that of Black Belts. However, being a successful change agent involves a great deal more than mastery of technical tools. Black Belts, Green Belts, and Master Black Belts learn tools and techniques in the context of following the DMAIC approach to drive organizational change. This is very different than using the same techniques in routine daily work. Quality analysts, for example, generally work in the quality department as permanent, full-time employees. They report to a single boss and have well-defined areas of responsibility. Black Belts, in contrast, go out and seek projects

rather than work on anything routine. They report to many different people, who use different criteria to evaluate the Black Belt's performance. They are accountable for delivering measurable, bottom-line results. Obviously, the type of person who is good at one job may not be suitable for the other.

- **Create permanent change agent positions**—Another option to the Black Belt position is to make the job permanent. After all, why not make maximum use of the training by keeping the person in the Black Belt job indefinitely? Furthermore, as Black Belts gain experience they become more proficient at completing projects. There are, however, arguments against this approach. Having temporary Black Belts allows more people to go through the position, thus increasing the number of people in management with Black Belt experience. Since Black Belts work on projects that impact many different areas of the enterprise, they have a broad, process-oriented perspective that is extremely valuable in top management positions. The continuous influx of new blood into Black Belt and Green Belt positions keeps the thinking fresh and prevents the "them-versus-us" mentality that often develops within functional units. New Black Belts have different networks of contacts throughout the organization, which leads to projects in areas that might otherwise be missed. Permanent Black Belts would almost certainly be more heavily influenced by their full-time boss than temporary Black Belts, thus leading to a more provincial focus.

Green Belts

Green Belts are Six Sigma project leaders capable of forming and facilitating Six Sigma teams and managing Six Sigma projects from concept to completion. Green Belt training consists of five days of classroom training and is conducted in conjunction with Six Sigma projects. (In some cases a ten-day course is offered to increase the time allotted for software training and exercises.) Training covers project management, quality management tools, quality control tools, problem solving, and descriptive data analysis. Six Sigma champions should attend Green Belt training. Usually, Six Sigma Black Belts help Green Belts define their projects prior to the training, attend training with their Green Belts, and assist them with their projects after the training.

Green Belts are change agents who work part time on process improvement. The bulk of the Green Belt's time is spent performing their normal work duties. Although most experts advocate that the Green Belt spend 10 to 20% of their time on projects, in most cases it is only 2 to 5%. A Green Belt will usually complete one or two major projects per year, usually as a team member rather than a team leader. Since a Green Belt is not trained in all the tools needed in the DMAIC cycle, when they lead projects they must be actively supported by a Black Belt. Few Green Belt projects cover enterprise-wide processes. However, since there are usually more Green Belts than Black Belts (by a factor of

Minimum Criteria

Education—High school or equivalent.

Work Experience—At least three years of business, technical, or managerial experience.

Technical Capability—High school algebra proficiency as demonstrated by a passing grade in an algebra course.

Computer Proficiency—Word processing, presentation, and spreadsheet software.

Team Skills—Willingness to lead meetings, facilitate small groups, and successfully resolve conflicts. Ability to mentor and motivate people.

Final Candidate Selection

Based on the organizational need for Green Belts, as determined by the Director of Six Sigma and the Executive Six Sigma Council, Green Belt training allotments are provided to Master Black Belts, Black Belts, and/or General Managers. Green Belt candidacy requires the consent of the candidate's management.

Commitment

Each Green Belt candidate selected will be required to complete a 40-hour Green Belt training course, and to lead at least one successful Six Sigma project every 12 months, or participate on at least two successful Six Sigma projects every 12 months. Green Belt certification is accomplished as described in Appendix 16.

Figure 1.10 Green Belt candidate selection process and criteria.

2 to 5), Green Belt projects can have a tremendous impact on the enterprise. Figure 1.10 provides an overview of a process for the selection of Green Belt candidates.

Master Black Belts

This is the highest level of technical and organizational proficiency. Master Black Belts provide technical leadership of the Six Sigma program. They must be thoroughly familiar with the Black Belt Body of Knowledge, as well as additional skills including the mathematical theory that forms the basis of the statistical methods, project management, coaching, teaching, and program organization at the enterprise level. Master Black Belts must be able to assist Black Belts in applying the methods correctly in unusual situations. Whenever possible, statistical training should be conducted only by qualified Master Black Belts or equivalently skilled consultants. If it becomes necessary for Black Belts and Green Belts to provide training, they should only do so under the guidance of Master Black Belts. Otherwise the familiar "propagation of error" phenomenon will occur; that is, Black Belt trainers pass on errors to Black Belt trainees who pass them on to Green Belts, who pass on greater errors to team members. Because of the nature of the Master's duties, all Master Black Belts must possess excellent communication and teaching skills.

Master Black Belts are recruited from the ranks of Black Belts. The process is usually less formal and less well defined than that for Black Belts or Green Belts and there is a great deal of variability between companies. Master Black Belt candidates usually make their interest known to Six Sigma leadership. Leadership selects candidates based on the needs of the enterprise and Six Sigma's role in meeting those needs. For example, in the early stages of deployment Master Black Belt candidates with excellent organizational skills and the ability to communicate the leadership's Six Sigma vision may be preferred. Intermediate deployments might favor candidates who excel at project selection and Black Belt coaching. Mature Six Sigma programs might look for Master Black Belts with training ability and advanced statistical know-how. Master Black Belts often have advanced technical degrees and extensive Black Belt experience. Many organizations provide Master Black Belts with additional training. Certification requirements for Master Black Belts vary with the organization. Many organizations do not certify Master Black Belts.

Change Agent Compensation and Retention

Experienced Black Belts and Master Black Belts are in great demand throughout the manufacturing and services sectors.[3] Given their proven talent for effecting meaningful change in a complex environment, this is no surprise. Since organizations exist in a competitive world, steps must be taken to protect the investment in these skilled change agents, or they will be lured away by other organizations, perhaps even competitors. The most common (and effective) actions involve compensation and other financial incentives, such as:

- Bonuses
- Stock options
- Results sharing
- Payment of dues to professional societies
- Pay increases

There are also numerous nonfinancial and quasi-financial rewards. For example, Black Belts reentering the workforce after their tour of duty often enter positions that pay significantly higher than the ones they left when becoming Black Belts. In fact, in some companies the Black Belt position is viewed as a step on the fast track to upper management positions. Also, change is "news" and it is only natural that the names of Master Black Belts and Black Belts involved in major change initiatives receive considerable publicity on company Web sites as well as in newsletters, recognition events, project fairs, etc. Even if they don't receive formal recognition, Six Sigma projects often generate a great deal of internal excitement and discussion. The successful Black Belt usually finds that his work has earned him a reputation that makes him a hot commodity when it's time to end his Black Belt career.

There are, of course, innumerable complexities and details to be decided and worked out. Usually these issues are worked out by a team of individuals with members from Human Resources, the Six Sigma Core Team, and other areas of the organization. The team will address such issues as:

- What pay grade is to be assigned to the Black Belt and Master Black Belt positions?
- Should the pay grade be determined by the pay grade of the candidate's job prior to becoming a Black Belt?
- Should the Black Belt pay grade be guaranteed when the Black Belt leaves the Black Belt position to return to the organization?
- How do we determine eligibility for the various rewards? For example, are there key events such as acceptance as a Black Belt candidate, completion of training, completion of first project, successful certification, and so forth?
- What about Black Belts who were certified by other organizations or third parties?
- Do we provide benefits to Green Belts as well? If so, what and how?
- Who will administer the benefits package?

The plan will be of great interest to Black Belt candidates. If not done properly, the organization will find it difficult to recruit the best people.

Integrating Six Sigma and Related Initiatives

At any given time most companies have numerous activities underway to improve their operations. For example, the company may have functional areas devoted to Lean Implementation, Continuous Improvement, or Business Process Reengineering, as well as those tasked to more traditional quality functions of quality assurance and quality control. Collectively, these functions are often known as the *quality function* of an organization.

The Quality Function[4]

Juran and Gryna (1988, p. 2.6) define the quality function as "the entire collection of activities through which we achieve fitness for use, no matter where these activities are performed." Quality is thus influenced by, if not the responsibility of, many different departments. In most cases, the quality department serves a secondary, supporting role. While the quality department is a specialized function, quality activities are dispersed throughout the organization. The term "quality function" applies to those activities, departmental and companywide, that collectively result in product or service quality. An analogy can be made with the finance department. Even though many specialized finance and accounting functions are managed by the finance department, every employee in the organization is expected to practice responsible management of his or her budgets and expenditures.

Juran and Gryna (1988) grouped quality activities into three categories, sometimes referred to as the Juran Trilogy: planning, control, and improvement. *Quality planning* is the activity of developing the products and processes required to meet customers' needs. It involves a number of universal steps (Juran and DeFeo, 2010):

- Define the customers.
- Determine the customer needs.
- Develop product and service features to meet customer needs.
- Develop processes to deliver the product and service features.
- Transfer the resulting plans to operational personnel.

Quality control is the process used by operational personnel to ensure that their processes meet the product and service requirements (defined during the planning stage). It is based on the feedback loop and consists of the following steps:

- Evaluate actual operating performance.
- Compare actual performance to goals.
- Act on the difference.

Quality improvement aims to attain levels of performance that are unprecedented—levels that are significantly better than any past level. The methodologies recommended for quality improvement efforts utilize Six Sigma project teams, as described in Chap. 4. Notably, whereas earlier versions of Juran's *Quality Handbook* did not specifically advocate cross-functional project-based teams for quality improvement efforts, the most recent sixth edition (2010) clearly prescribes their use.

The mission of the quality function is companywide quality management. Quality management is the process of identifying and administering the activities necessary to achieve the organization's quality objectives. These activities will fall into one of the three categories in Juran's Trilogy.

Since the quality function transcends any specialized quality department, extending to all the activities throughout the company that affect quality, the primary role in managing the quality function is exercised by senior leadership. Only senior leadership can effectively manage the necessary cross-functional activities.

Leadership must give careful thought as to how the various overlapping activities can best be organized to optimize their impact on performance and minimize confusion over jurisdiction, resources, and authority. An "umbrella concept" often provides the needed guidance to successfully integrate the different but related efforts, resulting in the Process Enterprise.

The Six Sigma Process Enterprise

Organizations are typically designed along functional lines, with functions such as engineering, marketing, accounting, and manufacturing assigned responsibility for specific tasks often corresponding closely to university degree programs. Persons with higher education in a specific discipline specialize in the work assigned to that function. Resources are allocated to each function based on the needs of the enterprise.

If the enterprise is to be successful, the "needs of the enterprise" must be based on the needs of its customers. However, customers obtain value from products or services created by the cooperative efforts and resources of many different functional areas. Most customers couldn't care less about how the enterprise creates the values they are purchasing.[5] A similar discussion applies to owners and shareholders. There is a substantial body of opinion among management experts that focusing internally on functional concerns can be detrimental to the enterprise as a whole. Deming (1986) explained the risks of departmental improvements at the expense of the system as a whole. An alternative is a holistic focus on the process or value stream that creates and delivers value.

A process focus means that stakeholder values are determined and activities are classified as either relating to the creation of the final value (value-added activity) or not (non-value-added activity). Processes are evaluated on how effectively and efficiently they create value. *Effectiveness* is defined as delivering what the customer requires, or exceeding the requirements; it encompasses quality, price, delivery, timeliness, and everything else that goes into perceived value. *Efficiency* is defined as being effective using a minimum of resources; more of an owner's perspective. Excellent processes are those that are both effective and efficient.

Processes Are the Fundamental Activities of a Business. There is a tendency to narrowly interpret the term "process" as a manufacturing operation to convert raw materials into finished products. Throughout this book it has a much broader meaning, referring to any activity or set of activities that transform inputs to create values for stakeholders. The inputs can be labor, expertise, raw materials, products, transactions, information, or services that someone is willing to pay more for than they cost to create. In other words, the process adds value to the inputs. Said another way, *the process is the act of creating value*. The value can be a cured disease, a tasty banana split, a great movie, a successfully completed credit card transaction, or a cold soda purchased at a convenience store.

Reengineering, the process redesign fad so popular in the early 1990s, has become associated in the minds of many with brutal downsizing. Many academics condemned it as heartless and cold in its implementation. Yet the problem wasn't caused by reengineering in itself. The proper implementation of reengineering (and Six Sigma) focuses attention on broken and inefficient processes, enabling companies to operate faster and