The Official
Council for Six Sigma Certification

Six Sigma
Yellow Belt Certification
Training Manual

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Chapter 1: What is Six Sigma?

Six Sigma, or 6σ, is both a methodology for process improvement and a statistical concept that seeks to define the variation inherent in any process. The overarching premise of Six Sigma is that variation in a process leads to opportunities for error; opportunities for error then lead to risks for product defects. Product defects—whether in a tangible process or a service—lead to poor customer satisfaction. By working to reduce variation and opportunities for error, the Six Sigma method ultimately reduces process costs and increases customer satisfaction.

Data Driven Processes and Decisions

In applying Six Sigma, organizations, teams, and project managers seek to implement strategies that are based on measurement and metrics. Historically, many business leaders made decisions based on intuition or experience. Despite some common beliefs in various industries, Six Sigma doesn't remove the need for experienced leadership, and it doesn't negate the importance of intuition in any process. Instead, Six Sigma works alongside other skills, experience, and knowledge to provide a mathematical and statistical foundation for decision making. Experience might say a process isn't working; statistics prove that to be true. Intuition might guide a project manager to believe a certain change could improve output; Six Sigma tools help organizations validate those assumptions.

Decision Making Without Six Sigma

Without proper measurement and analysis, decision making processes in an organization might proceed as follows:

- Someone with clout in the organization has a good idea or takes interest in someone else's idea.
- Based on past experience or knowledge, decision makers within an organization believe the idea will be successful.
- The idea is implemented; sometimes it is implemented in beta mode so expenses and risks are minimized.
- The success of the idea is weighed after implementation; problems are addressed after they impact products or processes in some way in the present or the future.

What is beta testing?

Beta testing is the act of implementing a new idea, system, or product with a select group of people or processes in as controlled an environment as possible. After beta testers identify potential problems and those problems are corrected, the idea, system, or product can be rolled out to the entire population of customers, employees, or processes. The purpose of beta testing is to reduce the risks and costs inherent in launching an unproven product or system to a widespread audience.

Beta testing is sometimes used in a Six Sigma approach, but the idea or change in question goes through rigorous analysis and data testing first. The disadvantage of launching ideas into beta—or to an entire population--without going through a Six Sigma methodology is that organizations can experience unintended consequences from changes, spend money on ideas that don't end up working out as planned, and impact customer perceptions through trial-and-error periods rife with opportunities for error. In many cases, organizations that don't rely on data make improvements without first understanding the true gain or loss associated with the change. Some improvements may appear to work on the surface without actually impacting customer satisfaction or profit in a positive way.

Decision Making With Six Sigma

The Six Sigma method lets organizations identify problems, validate assumptions, brainstorm solutions, and plan for implementation to avoid unintended consequences. By applying tools such as statistical analysis and process mapping to problems and solutions, teams can visualize and predict outcomes with a high-level of accuracy, letting leadership make decisions with less financial risk.

Six Sigma methods don't offer a crystal ball for organizations, though. Even with expert use of the tools described in this book, problems can arise for teams as they implement and maintain solutions. That's why Six Sigma also provides for control methods: once teams implement changes, they can control processes for a fraction of the cost of traditional quality methods by continuing the use of Six Sigma tools and statistics.

Defining 6σ

Six Sigma as a methodology for process improvement involves a vast library of tools and knowledge, which will be covered throughout this book. In this section, we'll begin to define the statistical concept represented by 6σ.

At the most basic definition, 6σ is a statistical representation for what many experts call a "perfect" process. Technically, in a Six Sigma process, there are only 3.4 defects per million opportunities. In percentages, that means 99.99966 percent of the products from a Six Sigma process are without defect. At just one sigma level below—5σ, or 99.97 percent accuracy--processes experience 233 errors per million opportunities. In simpler terms, there are going to be many more unsatisfied customers.

Real World Examples

According to the National Oceanic and Atmospheric Administration, air traffic controllers in the United States handle 28,537 commercial flights daily.[1] In a year, that is approximately 10.416 million flights. Based on a Five Sigma air traffic control process, errors of some type occur in the process for handling approximately 2,426 flights every year. With a Six Sigma process, that risk drops to 35.41 errors.

The CDC reports that approximately 51.4 million surgeries are performed in the United States in a given year.[2] Based on a 99.97 accuracy rate, doctors would make errors in 11,976 surgeries each year, or 230 surgeries a week. At Six Sigma, that drops to approximately 174 errors a year for the entire country, or

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[1]"Air Traffic," Science on a Sphere, National Oceanic and Atmospheric Administration. http://sos.noaa.gov/Datasets/dataset.php?id=44

[2] "Inpatient Surgery," FastStats, Centers for Disease Control and Prevention. http://www.cdc.gov/nchs/fastats/inpatient-surgery.htm

just over 3 errors each week. At Five Sigma, patients are 68 times more likely to experience an error at the hands of medical providers.

While most people accept a 99.9 percent accuracy rate in even the most critical services on a daily basis, the above examples highlight how wide the gap between Six Sigma and Five Sigma really is. For organizations, it's not just about the error rate—it's also about the costs associated with each error.

Consider an example based on Amazon shipments. On Cyber Monday in 2013, Amazon processed a whopping 36.8 million orders.[3] Let's assume that each order error costs the company an average of $35 (a very conservative number, considering that costs might include return shipping, labor to answer customer phone calls or emails, and labor and shipping to right a wrong order).

Cost of Amazon Order Errors, 5σ

Total Orders	Errors	Average Cost per Error	Total Cost of Errors
36.8 million	8574.4	$35	$300,104.00

Cost of Amazon Order Errors, 6σ

Total Orders	Errors	Average Cost per Error	Total Cost of Errors
36.8 million	125.12	$35	$4,379.20

For this example, the cost difference in sigma levels is still over $295,000 for the Cyber Monday business.

For most organizations, Six Sigma processes are a constant target. Achieving and maintaining Six Sigma "perfection" is difficult and requires continuous process improvement. But even advancing from lower levels of sigma to a Four or Five Sigma process has a drastic impact on costs and customer satisfaction. Let's look at the Amazon Cyber Monday example at other levels of sigma.

Sigma Level	Defects per Million Opportunities	Estimated Cyber Monday Defects	Total Cost (at $35 estimate per error)
One Sigma	690,000	25,392,000	$888,720,000
Two Sigma	308,000	11,334,400	$396,704,000
Three Sigma	66,800	2,458,240	$86,038,400
Four Sigma	6,200	228,160	$7,985,600
Five Sigma	233	8,574.4	$300,104

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[3] Siegel, Jacob, "Amazon sold 426 items per second during its 'best ever' holiday season," Boy Genius Reports, Dec. 26, 2013. http://bgr.com/2013/12/26/amazon-holiday-season-sales-2013/

Six Sigma	3.4	125.12	$4,379

At very low levels of sigma, any process is unlikely to be profitable. The higher the sigma level, the better the bottom line is likely to be.

Calculating Sigma Level

Organizations and teams can calculate the sigma level of a product or process using the equation below:

$$\left(\frac{\text{\# of opportunities - \# of defects)}}{\text{\# of opportunities}} \right) \times 100 = \text{Yield}$$

Consider a process in a marketing department that distributes letters to customers or prospects. For the purposes of the example, imagine that the process inserts 30,000 letters in preaddressed envelopes each day. In a given business week, the process outputs 150,000 letters.

The marketing department begins receiving complaints that people are receiving letters in envelopes that are addressed to them, but the letters inside are addressed to or relevant to someone else. The marketing department randomly selects 1,000 letters from the next week's batch and finds that 50 of them have errors. Applying that to the total amount, they estimate that as many as 7,500 letters could have errors. (Sampling and extrapolation are covered in depth in the advanced chapters on statistics.)

The letter process has 150,000 opportunities for error each week and an estimated 7,500 defects.

((150,000 – 7,500) / 150,000) * 100 = a yield of 99.5

Look up a yield of 99.5 in the Sigma table in the statistical appendix of this book and you'll see the process described above is currently between 4 and 4.1 sigma.

Sigma Level Is Not a Final Indicator

Sigma levels provide organization with a high-level look at how a process is performing, but comparing sigma levels between multiple processes doesn't always point to the particular process an organization should improve first. Leadership should also consider costs, resources, and the estimated impact of improvements.

For example, consider these processes that might be found in a food processing plant:

Process	Performance Metric(s)	Current Sigma Level
Attaching a decorative element to food item	Decorative touch is centered on food product and stable so it won't fall off in transit	2.2
Packing product	Product is sealed for freshness	3.1
Shipping of product	Product reaches the right	4.3

	customer in a timely manner	

A glance at sigma levels indicates that the process that attaches the decorative element is in most need of improvement. While that process has the highest rate of defects, leadership within the plant would have to ask themselves: How much does that matter to the customer, and what is the hit to the bottom line?

It's likely that most customers will notice most that the product is sealed for freshness and reaches the right location. Since bad product has to be thrown away, the most expensive errors might be associated with improper sealing during packing. The plant is likely to use resources to improve the packing process before addressing the decorative element issue.

After the packing process is improved, the plant might then consider whether to improve the decorating process or the shipping process. As part of that consideration, the company might conduct customer surveys to reveal that some customers have stopped buying the product because of the decorative element issue. An analyst estimates that the loss of sales related to that issue are costing the company $1,000 a week. Shipping issues are costing the company $500 a week.

Should the company address the costlier issue first? What if you were told that the shipping process could be improved with staff training sessions, while the decorative element issue required an expensive machinery update? Sometimes, organizations have to consider the expense of an improvement. Applying a Six Sigma project to all situations isn't financially lucrative since those improvements take time and money. A Six Sigma culture is about continuous improvement, which means teams consider all options before embarking on the most lucrative improvement measures.

Common Six Sigma Principles

Organizations can impact their sigma level by integrating core principles from the Six Sigma methodology into leadership styles, process management, and improvement endeavors. The principles of Six Sigma, and the tools used to achieve them, are covered in detail in various sections of this book, but some common ideas are introduced below.

Customer-Focused Improvement

In the illustration about the food plant, we saw that the Six Sigma process doesn't just make improvements for the sake of driving up sigma levels. A primary principle of the methodology is a focus on the customer. In Chapter 5, we'll look at the Voice of the Customer (VoC) and ways for establishing what the customer really wants from a product or process. By combining that knowledge with measurements, statistics, and process improvement methods, organizations increase customer satisfaction, ultimately bolstering profits, customer retention, and loyalty.

A detailed understanding of the customer and customer desires not only lets businesses customize product offerings and services, but it also lets organizations:

- Offer additional features customers want and are willing to pay for
- Prioritize product development to meet current needs
- Develop new ideas based on customer feedback

- Understand changing trends in the market
- Identify areas of concern
- Prioritize work on challenges based on how customers perceive various problems or issues
- Test solutions and ideas before investing time and money in them

Value Streams The value stream is the sequence of all items, events, and people required to produce an end result. For example, the value stream for serving a hotdog with ketchup to someone would include:

- A hotdog supplier
- A bun supplier
- A ketchup supplier
- Hotdogs
- Buns
- Ketchup
- A cooking procedure for the hotdog
- A pot
- Tongs
- Someone to do the cooking
- A plate
- Someone to put the hotdog into the bun
- Someone to put the ketchup on the hotdog
- Someone to put the completed hotdog onto a plate
- Someone to serve the hotdog to another

If you combine all of the above processes into a pictorial representation of exactly how these elements become the served hotdog, then you have a value stream map.

The purpose for determining a value stream for a process is that you can identify areas of concern, waste, and improvement. In the above process, are there four different people putting the hotdog together and serving it, or is one person doing all four of those tasks? Is the supplier a single grocery store, or are you shopping for items at various stores and why? Do you get savings benefits to offset the added time spent working with multiple suppliers? These are some examples of the questions you can reveal and answer during value stream mapping.

Continuous Process Improvement

Inherent in the Six Sigma method is *continuous* process improvement. An organization that completely adopts a Six Sigma methodology never stops improving. It identifies and prioritizes areas of opportunity on a continuous basis. Once one area is improved upon, the organization moves on to improving another area. If a process is improved from 4 Sigma to 4.4 Sigma, the organization considers ways to move the sigma level up further. The goal is to move ever closer to the "perfect" level of 99.99966 accuracy for all processes within an organization while maintaining other goals and requirements, such as financial stability, as quickly as possible.

Variation

One of the ways to continuously improve a process is to reduce the variation in the process. Every process contains inherent variation: in a call center with 20 employees, variation will exist in each phone

call even if the calls are scripted. Inflection, accents, environmental concerns, and caller moods are just some things that lead to variation in this circumstance. By providing employees with a script or suggested comments for common scenarios, the call center reduces variation to some degree.

Consider another example: A pizzeria. The employees are instructed to use certain amounts of ingredients for each size of pizza. A small gets one cup of cheese; a large gets two cups. The pizzeria owner notes a great deal of variation in how much cheese is on each pizza, and he fears it will lead to inconsistent customer experiences. To reduce variation, he provides employees with two measuring cups: a 1-cup container for small pizzas and a 2-cup container for large pizzas.

The variation is reduced, but it is still present. Some employees pour cheese into the cups and some scoop it. Some fill the cups just to the rim; others let the cheese create a mound above the rim. The owner acts to reduce variation again: he trains all employees to fill the cup over the rim and use a flat spatula to scrape excess cheese off. While variation will still exist due to factors such as air pockets or how cheese settles in the cup, it is greatly reduced, and customers experience more consistent pizzas.

Removing Waste
Remember the hotdog example for value streams? We asked the question: do four different people act to place the hotdog in the bun, put the ketchup on the hotdog, plate the hotdog, and serve it? If so, does the process take more time because the product has to be transferred between four people? Would it be faster to have one person perform all those actions? If so, then we've identified some waste in the process—in this case, waste of conveyance.

Removing waste—items, actions, or people that are unnecessary to the outcome of a process—reduces processing time, opportunities for errors, and overall costs. While waste is a major concern in the Six Sigma methodology, the concept of waste comes from a methodology known as Lean Process Management..

Equipping People
Implementing improved processes is a temporary measure unless organizations equip their employees working with processes to monitor and maintain improvements. In most organizations, process improvement includes a two-pronged approach. First, a process improvement team comprised of project management, methodology experts, and subject-matter experts define, plan, and implement an improvement. That team then equips the employees who work directly with the process daily to control and manage the process in its improved state.

Controlling the Process
Often, Six Sigma improvements address processes that are out of control. Out of control processes meet specific statistical requirements. The goal of improvement is to bring a process back within a state of statistical control. Then, after improvements are implemented, measurements, statistics, and other Six Sigma tools are used to ensure the process remains in control. Part of any continuous improvement process is ensuring such controls are put in place and that the employees who are hands-on with the process on a regular basis know how to use the controls.

Challenges of Six Sigma
Six Sigma is not without its own challenges. As an expansive method that requires commitment to continuous improvement, Six Sigma is often viewed as an expensive or unnecessary process, especially

for small or mid-sized organizations. Leadership at Ideal Aerosmith, a manufacturing and engineering company in Minnesota, was skeptical of Six Sigma ideas and the costs associated with implementing them. Despite reservations, the company waded into Six Sigma implementations, eventually seeing worthwhile results after only 18 months. Those results included a production improvement of 25 percent, a 5 percent improvement in profits within the first year, and a 30 percent improvement in timely deliverables.[4]

Some obstacles and challenges that often stand in the way of positive results from Six Sigma include lack of support, resources, or knowledge, poor execution of projects, inconsistent access to valid statistical data, and concerns about using the methodology in new industries.

Lack of Support

Six Sigma requires support and buy-in at all levels of an organization. Leaders and executives must be willing to back initiatives with resources—financial and labor related. Subject-matter experts must be open to sharing information about their processes with project teams, and employees at all levels must embrace the idea of change and improvement and participate in training. Common barriers to support include:

- Leaders that are unfamiliar with or don't understand the Six Sigma process
- Leaders willing to pursue improvements initially but who lose interest in overseeing and championing projects before they are completed
- Staff that is fearful of change, especially in an environment when change has historically caused negative consequences for employees
- Employees who are resistant to change because they believe improvements might make them obsolete, drastically change their jobs, or make their jobs harder
- Department heads or employees who constantly champion their own processes and needs and are unwilling to enter into big-picture thinking

Lack of Resources or Knowledge

Lack of resources can be a challenge to Six Sigma initiatives, but they don't have to be a barrier. Lack of knowledge about how to use and implement Six Sigma is one of the first issues small- and mid-sized companies face. Smaller businesses can't always afford to hire dedicated resources to handle continuous process improvement, but the availability of resources and Six Sigma training makes it increasingly possible for organizations to use some of the tools without an expert or to send in-house staff to be certified in Six Sigma.

Poor Project Execution

Companies implementing Six Sigma for the first time, especially in a project environment, often turn away from the entire methodology if the first project or improvement falls flat. Proponents of Six Sigma within any organization really have to hit it out of the ballpark with the first project if leadership and others are on the fence about the methodology. Teams can help avoid poor project performance by taking extreme care to execute every phase of the project correctly. By choosing low-risk, high-reward improvements, teams can also stack the deck in their favor with first-time projects. The only

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[4] Gupta, Praveen and Schultz, Barb, "Six Sigma Success in Small Business," Quality Digest. http://www.qualitydigest.com/april05/articles/02_article.shtml

disadvantage with such a tactic is that it can be hard to duplicate the wow factor with subsequent improvements, making it important to remember that long-term implementation and commitment is vital in Six Sigma.

Data Access Issues

Data and analytics issues are a common challenge for organizations of all sizes. Gaining access to consistent and accurate data streams—and applying statistical analysis to that data in an appropriate manner—is difficult. Some data-related challenges include:

- Discovering that an important process metric is not being captured
- The use of manual data processes in many processes
- Automated data processes that capture enormous amounts and create scope challenges
- Data that is skewed due to assumptions, human interaction in the process, or incorrect capture
- Lengthy times between raw data capture and access
- Industry or company compliance rules that make it difficult to gain access to necessary data

Concerns about Using Six Sigma in a Specific Industry

Six Sigma originated in the manufacturing industry and many of the concepts and tools of the methodology are still taught in the context of a factory or industrial environment. Because of this, organizations often discount the methods or believe they will be too difficult to implement in other industries. In reality, Six Sigma can be customized to any industry.

Chapter 2: Six Sigma History and Application

While the roots of Six Sigma are commonly attributed to companies such as Toyota and Motorola, the methodology is actually grounded in concepts that date as far back as the 19th century. Before delving into the history of Six Sigma, it's important to understand the difference between traditional quality programs, such as Total Quality Management, and continuous process improvement methods, such as Six Sigma.

Most modern quality and improvement programs can be traced back to the same roots. Both quality programs and continuous process improvement methods look to achieve goals such as reducing errors and defects, making processes more efficient, improving customer satisfaction, and boosting profits. But quality programs are concerned with achieving a specific goal. The program either runs forever, constantly working toward the same goal, or it achieves the end goal and must be reset for a new goal.

Six Sigma seeks to instill a culture of *continuous* improvement and quality that optimizes performance of an organization from the inside out. It's the cultural element inherent in Six Sigma that lets organizations enact both small and sweeping improvements that drastically impact efficiencies and costs. Six Sigma does work toward individual goals with regard to each project, but the projects are part of the overall culture of improvement that, in practice, is never done. Six Sigma creates safeguards and tactics so that, even after a project is considered complete, controls are in place to ensure progress continues and it is impossible to revert to old ways.

The Development of Statistical Process Control

Six Sigma applies statistics to define, measure, analyze, verify, and control processes. In fact, Six Sigma teams usually use methodologies known as DMAIC or DMADV to accomplish improvements and develop controls for processes. DMAIC stands for Define, Measure, Analyze, Improve, and Control. These are the five phases of a Six Sigma project to improve a process that already exists. When developing a new process, teams use DMADV, which stands for Define, Measure, Analyze, Design, and Verify. Both methods are discussed in Chapter 11, and Unit 3 provides in-depth information about each phase of DMAIC.

The roots of statistical process control, which provide a backbone for Six Sigma methods, began with the development of the normal curve by Carl Friedrich Gauss in the 19th century. We know today that the normal curve is just one of several possible probability distribution models. It is perhaps the most widely used model, and the other models developed from the normal curve. Probability distribution models are discussed in later chapters on statistics
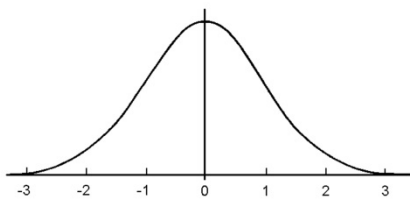
The Normal Curve

In the early part of the 20th century, statistical process control received another big boost thanks to contributions from an engineer and scholar named Walter Shewhart. Shewhart's contributions to quality are many, but two specific ideas stand out. First, Shewhart was the first person

to closely relate sigma level and quality. He defined a process in need of correction as one that is performing at three sigma. If you look back to Chapter 1 and the theoretical Amazon example, the cost difference between four sigma and three sigma is over $78 million; in comparison, the difference between five and four sigma is only approximately $7.6 million. Because errors and costs exponentially increase as sigma level decreases, Shewhart's definition has very practical applications in business. While Six Sigma as a method seeks to move ever toward less than 3.4 defects per million opportunities (dpmo), it is also true that if the quality of a process decreases, as it approaches three sigma, the costs associated with errors increase substantially.

Second, Shewhart is considered the father of control charts. Control charts, which are covered in depth in the chapters on advanced statistics, are a critical component of statistical process control that lets organizations maintain improved performance after a Six Sigma initiative. At a time when scholars were writing about the theoretical application of statistics in a growing number of fields, Shewhart developed ways to apply these concepts to manufacturing and industrial processes specifically.

During the same time period, W. Edwards Deming was working for the U.S. Department of Agriculture. A physicist and mathematician, Deming was in charge of teaching courses at the agency's graduate school and he arranged for Shewhart to come and speak there. Later, Deming brought Shewhart's statistical concepts to the United States Census Bureau, applying his theories outside of an industrial or manufacturing environment for possibly the first time.

One of Deming's ideas is called the PDCA cycle, or plan-do-check-act cycle. The idea is that improvement comes when you recognize there is a need for change and make a plan to create improvement. Next, you do something by testing your ideas. Using the results of the test, you check or verify that your improvements are working. Then you act, bringing your improvements to a production environment or scaling improvements outside of the test environment. The fact that PDCA is a cycle means it never ends; there are always improvements to be made. This is a core tenet of Six Sigma.
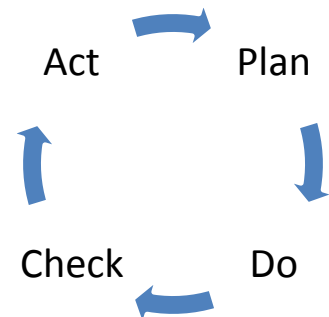
Following World War II, Deming worked in Japan on behalf of the United States government in several capacities. While in post-war Japan, Deming befriended statisticians and convinced at least one notable engineer that statistical process control was relevant to Japan's need to drastically drive economic and production performance to overcome damage from the war. In the end, Deming became a valued teacher and consultant to manufacturing companies in Japan, planting the ideas and concepts that would soon become the Toyota Production System, or Lean Six Sigma.

Continuous Process Improvement: Toyota and Lean

Deming's teachings and the need for Japanese industry to make a successful comeback following a catastrophic war combined to bear fruit for Toyota. Toyota's leadership had visited the concepts of quality prior to WWII, but improved performance and efficiency became a more critical goal given the nature of Japan's economy and resources in the 1940s and 50s. Taking manufacturing ideas attributed to Henry Ford, Toyota leaders applied statistics and new quality concepts to create a system they felt would increase production and allow for variable products while reducing costs and ensuring quality.

Several individuals were instrumental in the ultimate development of the Toyota Production System. They infused the process with automated machinery, quality controls to keep defects from occurring, and efficiency tools that had not yet been applied with such detail and consistency. One man, Kiichiro Toyoda, had previous factory experience. In his previous jobs, he added efficiencies to processes in textile mills through conveyor and other automated systems. Toyoda introduced the same concepts on certain lines in the Toyota manufacturing process. Later, Eiji Toyoda and Taiichi Ohno introduced concepts known as Just-in-Time and jidoka, which are the pillars of the Toyota Production System.

> **What is Jidoka?**
>
> Jidoka is a principle that creates control of defects inside a business process. Instead of identifying defects at the end of the production line and attempting to trace errors back to a source, jidoka demands that a process stop as soon as errors are detected so improvements or troubleshooting can happen immediately.
>
> For jidoka to work properly, machines are often equipped to recognize bad outputs from good outputs; the machines are also equipped with a notification of some type to spark human interaction in the process when things go awry.

The principles driving Toyota's system, and later, the foundation of Lean Process Management or Lean Six Sigma, include:

- Defining customer values
- Identifying the value stream for customer needs and desires
- Identifying waste in the process
- Creation of a continuous process flow
- Continually working to reduce the number of steps and time it takes to reach customer satisfaction

Lean management is highly concerned with removing waste from any process. Waste increases costs and time spent on a process, making it undesirable in any form.

Motorola's Focus on Defects

Though the basis for Six Sigma was laid in the late 19th and early 20th centuries, it wasn't until the mid-1980s that these concepts saw large-scale success in the United States. Decades after Toyota developed its system, engineers at Motorola began to question how effective their quality management programs were. Those questions first arose after a Japanese company took over a Motorola television

manufacturing plant. By applying Lean concepts, the new company began creating televisions that demonstrated 1/20th the amount of defects as Motorola's own television sets.

At the time, departments across Motorola measured defects as a ratio of a thousand opportunities. Bob Galvin, the CEO of Motorola, issued a challenge to his team. He wanted to see an improvement in quality and production—not just any improvement; he wanted a ten-fold improvement in half a decade. Engineer Bill Smith and a new addition to the Motorola team – Dr. Mikel Harry – began to work on the problem.

The team realized that measuring errors against a thousand opportunities didn't provide the level of detail needed for true statistical process control. Instead, the engineers wanted to measure defects against a million opportunities. We know that sigma levels were already defined and the idea of using sigma levels as a measure of quality began with Shewhart. It wasn't a long jump for the Motorola engineers to make from their desire for more accurate data to the basic concepts of Six Sigma as both a goal and a methodology.

Throughout the next two decades, Motorola worked to perfect its Six Sigma methodology, seeing positive results along the way. In addition to statistical tools, the team created a step-by-step process by which any team--in almost any industry--could make gains and improvements. For the first time, this type of statistical process control was taken out of the manufacturing environment on a large scale company-wide. Motorola applied the method to customer service, engineering, and technical support. It used the process to create a collaborative environment between stakeholders inside and outside of the organization. It was highly successful; according to Motorola, the company saved more than $16 billion as a result of continuous process improvement initiatives within 12 years.[5]

Motorola did more than improve its own systems and products, though. Galvin directed his team to share Six Sigma with the world. Motorola and its team published articles and books on the Six Sigma method and implemented efforts to train others. In this way, they created a methodology based on statistics that could be taught and implemented within any organization or industry.

ABB, Allied Signal, and General Electric

After leaving Motorola, Dr. Harry joined Asea Brown Boveri. At ABB, Harry worked with Richard Schroeder, who would also become a champion for Six Sigma. In fact, the two men later cofounded the Six Sigma Academy. At ABB, Harry came to realize a key idea in the evolution of Six Sigma: business, or profits, in some ways came before quality. Quality, in fact, was a driving factor of business. Customers didn't make purchases if quality was poor. Because the individuals with the ability to decide in favor of Six Sigma initiatives were highly motivated by dollars, Harry incorporated financial tactics into the Six Sigma methodology. For the first time, the method was focused on the bottom-line as a primary goal with other concerns and goals stemming from financially-led goals.

In 1993, both Schroeder and Harry changed jobs, joining the team at Allied Signal. Allied Signal's CEO at the time was Larry Bossidy. He was interested in Six Sigma but realized that executives and other high-level leaders experienced knowledge barriers while attempting to interact and collaborate with analysts, process engineers, and Six Sigma experts. Bossidy suggested that leadership at a company had to be

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[5] "The History of Six Sigma," iSixSigma. http://www.isixsigma.com/new-to-six-sigma/history/history-six-sigma/

well-versed in Six Sigma to pick the right projects for success and support those projects on a company-wide basis to ensure success.

Harry, who is sometimes referred to as the father of Six Sigma, created a system for educating executive leaders. In conjunction with others at Allied Signal, he developed systems that allowed Six Sigma to be effectively deployed by leadership throughout an organization in its entirety.

Around the same time, GE CEO Jack Welch entered into the Six Sigma arena. Prior to learning about Six Sigma, Welch had stated he was not a proponent of quality measures. He'd previously criticized quality programs as heavy-handed approaches that did little to deliver results. Welch invited Larry Bossidy to speak at a GE corporate meeting in 1995. He also requested an analysis regarding the benefits of implementing Six Sigma at GE. At that time, GE was performing at between three and four sigma. The potential savings should the company rise to six sigma were enormous; estimates were $7 to $10 billion.[6]

Welch is known as a champion of Six Sigma not because he contributed in major ways to the development of statistical process controls or the Six Sigma toolsets, but because he demonstrated exactly how leaders should approach Six Sigma. He also made GE a historically successful Six Sigma organization by tying Six Sigma goals to employee reward structures. Employees were no longer only compensated based on financial performance factors; they were also evaluated based on Six Sigma performance. Suddenly, employees at every level had a personal reason to become involved in continuous process improvement, and employees and managers were supplied with the Six Sigma training to succeed.

Continued Growth of Six Sigma

Following the success of corporations such as GE and Motorola, companies across the country rushed to implement Six Sigma. Unfortunately, in the rush to implement the process, many organizations executed improvements poorly or failed to gain an adequate understanding of statistical process control before moving forward with improvements. Although Six Sigma methods have been used by organizations to gain millions—even billions—in savings and efficiencies, some companies walked away with a bad taste for the process. That bad taste has resulted in the following misconceptions and myths that are still prevalent today in many industries:

- *Six Sigma is solely concerned with metrics and ignores common sense.* The opposite is actually true: Six Sigma often starts with traditional common sense ideas, often arrived at through brainstorming, and validates those assumptions with data. The reason for this myth is twofold. First, managers and others who are used to making calls without being questioned are suddenly questioned in a Six Sigma environment. Not only are they questioned, but hard data sometimes proves them wrong. Second, in some cases data is improperly used to support conclusions that are against common sense or tradition. When those conclusions turn out to be faulty, it's easy to blame the process of Six Sigma there is a lack of adequate understanding of the statistical theories involved.
- *Six Sigma is too expensive*. While enterprise-wide adoption of Six Sigma can be costly at first, due in part to training needs, slowly integrating the concepts into a company often costs very

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[6] "The Evolution of Six Sigma," PQA.net. http://www.pqa.net/ProdServices/sixsigma/W06002009.html

little in the long run. Organizations have to balance how they adopt Six Sigma with budgetary concerns—but when implemented correctly, Six Sigma generally leads to savings that more than cover its initial investment.

- *Six Sigma can fix anything.* Opposite the nay-sayers are Six Sigma cheerleaders who believe they can apply the method like a salve to any problem. While Six Sigma can be applied to any problem of process, it's not always relevant to problems of culture or people. If morale or other human resource problems are at the root of an issue, statistics can't help. However, if morale is low because a process is difficult to work with or is performing poorly, Six Sigma can be used to improve the process, thereby improving morale.

Applying Six Sigma Knowledge

Six Sigma is applied via a controlled project selection and management process. Once areas of concern are identified, leaders usually turn to analysts, Six Sigma experts, and subject-matter-experts for cost-benefit analyses. Six Sigma teams attempt to quantify how broken a process is (by calculating sigma level, costs of defects, downtime, and other metrics) and how much it might cost to address the problem. Problems are then prioritized according to severity as well as an organization's ability to address the issue. Teams begin working through the priority list, returning to the analysis from time to time to ensure the list has not changed. The majority of this book covers the methods by which teams identify and address problems using Six Sigma.

The Levels of Six Sigma Certification

Possessing a Six Sigma certification proves that an individual has demonstrated practical applications and knowledge of Six Sigma. Some organizations offer in-house certification processes. Most people seek certification by enrolling in online or onsite Six Sigma training course. Most organizations that offer Six Sigma education also offer a path to certification. You can take courses for certification at various levels; Six Sigma levels are differentiated by belt level.

White Belt

A certified Six Sigma White belt is familiar with the basic tenets of the Six Sigma methodology, though they aren't often regular members of process improvement teams. White belt training is a good introduction to Six Sigma for auxiliary staff members within an organization and can provide the information necessary for understanding why project teams do what they do. The training lets employees review project processes, understand information presented in milestone meetings, and better participate in project selection processes. White belt training can also be used across all levels of employees when organizations are attempting to implement a Six Sigma culture. It is worth noting that White Belt training usually only provides a very basic introduction and overview of Six Sigma, so much so that not all Six Sigma professionals recognize it as a true Six Sigma certification.

Yellow Belt

A yellow belt certification is a step above white belt: it is still considered a basic introduction to the concepts of Six Sigma, but a yellow belt learns basic information about the DMAIC method often used to improve processes. The following concepts are often included in Six Sigma yellow belt training:

- Six Sigma roles

- Team development and management
- Basic quality tools such as Pareto charts, run charts, scatter diagrams and histograms
- Common Six Sigma metrics
- Data collection
- Measurement system analysis
- Root cause analysis
- An introduction to hypothesis testing

At the yellow belt level, training is often geared toward understanding of the overall methodology and basic data collection. Yellow belts don't need to know how to conduct hypothesis testing, but they must understand the language of hypothesis testing and the conclusions that are drawn from such tests. Yellow belts are often employees who need to know about the overall process and why it is being implemented.

Green Belt

Certified green belts work within Six Sigma teams, usually under the supervision of a black belt or master black belt. In some cases, green belts might lead or handle smaller projects on their own. Green belts are generally equipped with intermediate statistical analysis capabilities; they might address data and analysis concerns, help Black Belts apply Six Sigma tools to a project, or teach others within an organization about the overall Six Sigma methodology.

Green Belts can be middle managers, business analysts, project managers, and others who have a reason to be involved regularly with process improvement initiatives but who might not be a full-time Six Sigma expert within an organization. Sometimes, Green Belts are considered the worker bees of the Six Sigma methodology because they undertake most of the statistical data collection and analysis under the supervision of certified Black Belts.

The following concepts are often included in Green Belt training:

- All of the information listed for yellow belt certification
- Failure mode and effects analysis
- Project and team management
- Probability and the Central Limit Theorem
- Statistical distributions
- Descriptive statistics
- How to perform basic hypothesis testing
- Waste elimination and Kaizen
- Basic control charts

Black Belt

A certified Six Sigma Black Belt usually works as the project leader on process improvement projects. They might also work within management, analyst, or planning roles throughout a company. Common minimum requirements for black belt certification include everything listed for yellow and green belts in addition to:

- Advanced project and team management skills

- Knowledge of the expansive list of Six Sigma brainstorming and project tools
- Intermediate to advanced statistics
- An understanding of other process improvement and quality programs, including Lean and Total Quality Management
- An ability to design processes
- Advanced capabilities for diagraming processes, including flow charts and value stream maps
- Use of software to conduct analysis, such as Excel or Minitab

Master Black Belt

A Master Black Belt is the highest certification level achievable for Six Sigma. Within a business organization, Master Black Belts usually manage Black Belts and Green Belts, consult on especially difficult project concerns, offer advice and education about challenging statistical concepts, and train others in Six Sigma methodology.

Certification Exams

Most certification programs require individuals to pass an exam for certification; some require that green and black belt candidates also demonstrate their knowledge in the form of Six Sigma project experience.

If an exam is required for white or yellow belt certification, it is usually fairly short and covers basic concepts about the methodology. Green belt exams are longer and might include questions about statistics and some basic calculations. Black belt exams often take up to four hours to complete; they test for understanding and application. Exams might include difficult statistical problems or questions about how a project leader might handle various situations. While exams differ by organization, this book is designed based on The Council for Six Sigma Certification's (CSSC) published body-of-knowledge requirements.

Chapter 3: Other Process Improvement and Quality Methods

By studying the history of Six Sigma, you've already realized that the methodology is closely related to a number of other quality-driven initiatives developed over the past century. This is true in part because all successful businesses ultimately seek to do the same thing: serve a customer a product or service they need while making as much profit as possible.

While Six Sigma encompasses all the tools you need to approach virtually any problem of process, familiarity with other types of process improvement and quality methods is important. Some of these methods, such as Lean and JumpStart, add value within a Six Sigma approach. Others might be used by outside resources alongside a Six Sigma project. Even if you don't use or work with some of these programs, you will need to communicate with leadership and business partners who are more familiar with other methods. The ability to frame Six Sigma concepts in a more global quality management approach can help you win support for your own projects.

Other Formal Quality or Process Improvement Programs

Lean Process Management

Lean principles often go hand-in-hand with Six Sigma principles. While Lean originally developed as a concept for reducing waste in a manufacturing environment, the ideas of Lean Process Management can be applied to any process that involves the movement or creation of goods or services. This is true even if those services are virtual or digital, such as in a computerized workflow process.

One of the ways that Lean is similar to Six Sigma is that it is concerned with continuous improvements; like Six Sigma, Lean provides waste-removal tools so daily control and improvements can be made to processes. In fact, one of Lean's continuous improvement tools is called Kaizen, a Japanese word that translates loosely to "change for the better." The purpose of every change in a Kaizen environment is to eliminate waste and/or create more value for the customer on a continuous basis.

Lean Process Management can be deployed within a project environment or in daily production. Like Six Sigma, Lean is more about an overall culture of quality than a single quality event. Many organizations use Lean principles to make improvements in processes. By simply instituting some of the Lean principles, managers can drastically increase production and reduce costs for their departments.

Because Lean principles are so effective and fit so well with Six Sigma principles, for the purpose of this book, we will often treat Lean as a part of the Six Sigma methodology.

Total Quality Management

Total Quality Management, or TQM, is a phrase well-known by anyone who worked in business in the last quarter of the 20th century. The TQM approach to quality is one of the first formal methods enacted in business environments in the United States. Originally developed in the 1950s, Total Quality

Management didn't become popular with companies across the country until the 80s. At one point, TQM was so popular with executives and other leaders that it actually became something of a joke among certain workforces who believed that much effort and expense was expended on quality without an equal resulting benefit. In fact, if you remember from the last chapter, Jack Welch at GE felt this way.

While Total Quality Management programs were often somewhat lackluster when it came to results, the method was an essential stepping point to current improvement and quality methods such as Six Sigma. TQM was not without its results: as with any method, results depended highly on the way the program was implemented and the culture of the organization. For this reason, TQM and its variations are still in play in many industries today. Some requirements for a successful TQM program include:

- A strict quality commitment at all levels of the organization, especially among leaders
- Empowered employees who can make quality decisions while working within the process without constantly seeking leadership approval for those decisions
- A reward and recognition structure to promote quality work so that employees have a reason to make quality-making decisions
- Strategic planning that takes quality and quality improvement goals into account when making long-term decisions
- Systems that let organizations make improvements and monitor quality

Successful TQM initiatives require eight key elements: ethics, integrity, trust, training, teamwork, leadership, recognition, and communication. You can view these elements as if they were part of the components needed to build a high-quality, lasting building. Ethics, integrity, and trust become the foundation for quality. Training, teamwork, and leadership are the bricks by which quality organizations are built. Honest, open, and concise communication is the mortar that binds everything else together, and recognition is the roof that covers everything, providing employees with a reason to seek and maintain quality.

One of the biggest advantages of the TQM mentality is that it began to force organizations to see themselves as one entity rather than a number of loosely related entities or departments. Prior to the quality methods developed in the last half of the 20th century, many organizations were run via heavily siloed departments. One department often did not understand what another was doing, which caused a great deal of rework and waste. Each department might seek higher quality levels or process improvements, but in the end, the organization was only as strong as the weakest element.

TQM began to change departmental thinking on a massive scale: organizations began to take enterprise approaches to decision making, quality, and customer service. Business leaders started to look at companies as a series of linked processes operating toward a single end goal. Within the bounds of TQM, the ideas for business process reengineering began to develop.

Organizations using TQM often experienced benefits such as:

- Improved employee engagement and morale
- A reduction in production or product costs
- Decreased cycle times
- More satisfied customers

Business Process Reengineering

Six Sigma, Lean and TQM are all concerned with making *continuous* changes on both a large and small scale that bring an organization ever closer to a model of perfection. In the case of Lean, that model is a process that has zero waste; in Six Sigma, the model is statistically 6 sigma. In TQM, organizations often define their own version of perfection before working toward it. Business Process Reengineering, or BPR, is less concerned with incremental quality wins and more concerned with a radical change across an entire organization or process architecture.

Business process reengineering, which is also called business process redesign, is most often concerned with the technical processes that occur throughout an organization. Those processes might include systems, software, data storage, cloud and web processes, and computer-based workflows operated and maintained by human users. Because of the intense integration of automation and computer elements into processes with BPR, organizations that enter BPR endeavors have to rely heavily on both inside and outside technical resources. Inside resources provide programming, integration, and troubleshooting services as processes are developed or redesigned. Outside resources can be BPR consultants, contracted programmers and developers, or vendors bringing new software products to the table.

As you can probably imagine, BPR initiatives can be costly, which is why they are often deployed only when an organization expects exponential gain or has determined that current processes are obsolete or badly broken.

BPR projects tend to follow a common map, though there isn't a defined set of principles as there is with Six Sigma. Most projects go through planning, design, and implementation phases. During planning, teams use process mapping and process architecture principles to define enterprise-wide processes in their current state. Teams look for opportunities for improvement and brainstorm new architectures for processes throughout the organization.

During the design phase, BPR teams use validation techniques 3 to ensure solutions they are planning will work within the enterprise structure. They also begin to build tools and programs to integrate the changes; technical teams might use the Scrum methods described later in this chapter at this point in the process.

Finally, organizations implement the changes they have made. Since changes are often programmatic in nature, implementation usually includes a rigorous change management and testing procedure. Testing in technical environments includes steps such as:

- Sandbox testing of basic functionality
- Quality assurance testing by trained technical resources
- Beta testing during which experienced subject matter experts vet all aspects of a program in a limited live environment
- A rollout of the program to the enterprise, often conducted in a phased approach during which technical resources are on call to immediately resolve troubleshooting issues
- A conversion to regular function where technical resources are available in a normal capacity to deal with occasional issues

Rummler-Brache

As process improvement methods became increasingly popular in the 1980s and later, individuals often took portions of one method or another and integrated it into new improvement or quality programs. In this manner, companies outside of the manufacturing industry began implementing bits and pieces of methods that incorporated Lean and Six Sigma elements. One such program is known as Rummler-Brache.

Rummler-Brache was pioneered in the 80s by Geary Rummler and Alan Brache. They developed what remains a proprietary program used by their own consulting firm, but details of the method have been published and used by others. The method seeks to affect positive change in processes and organizations by using a set of practical tools to address business issues and process problems.

One of the foundational components of Rummler-Brache is known as the Nine Boxes Model. The model is created by a matrix of three performance levels and three performance dimensions. Performance levels are the performer, the process, and the organization. Dimensions are management, design, and goal. When placed on a grid, the levels and dimensions form nine boxes, as seen below.

	Management	Design	Goals
Performer	Concerned with feedback, consequences, and rewards	Concerned with the tools and training needed to do the job as well as job documentation	Concerned with performance metrics and requirements at an individual level
Process	Concerned with who owns the process and how they might improve it	Concerned with the design of the process, work space, or system	Concerned with the requirements of the business and the customer
Organization	Concerned with overall leadership culture and the requirements of performance evaluation	Concerned with overall org charts and process architecture	Concerned with operating plans and top-level metrics

Rummler-Brache approaches improvement in six phases:

- **Improvement planning.** During the first phase, leadership and subject-matter-experts commit to making improvements and begin to identify opportunities for change.
- **Definition**. During the second phase, project goals and scopes are defined and teams are formed to create improvements.
- **Analysis and Design**. Teams use analysis to understand the current problem and to define and validate workable solutions.

- **Implementation**. Teams implement process changes. Depending on the type of change, this might include programming changes, retraining staff, changes in machinery or equipment, or policy changes.
- **Management of process**. Teams monitor the process during and immediately following the change to ensure improvements function as planned.
- **Processes are turned over to daily teams**. Management of the process is turned over to daily teams, often with some type of control in place to ensure continued success.

Scrum

Scrum is a project development method specific to Agile programming endeavors in technical departments. Scrum is used when teams want to create new technical products or integrate new developments on existing products within a short time frame. Commonly, Scrum projects last between two and four weeks, which is traditionally a very tight timeline for programming projects. Scrum was developed as programming and development teams needed a way to meet continuous technical design and improvement needs from other departments without substantially increasing programming, testing employee hours, or hiring more technical staff. Scrum can also be used to drive faster times to production or market for software and application products.

Scrum is a related concept to other process improvement initiatives discussed in the book because many projects today call for some type of technical resource or change. While project teams are working to validate and measure, technical departments often simultaneously deploy Scrum concepts to meet development needs for the improvement project by deadline.

Scrum projects feature three main phases:

- **The pregame**. Development teams analyze available data and business requirements. They use this information to come up with the concept for the new product or upgrade. Often, this involves translating business and process concepts into computer and technical concepts.
- **The game**. Teams begin to develop the product via programming sprints. Sprints are smaller phases of development that are completed in sequence, usually with a review and validation of the work before moving on to the next sprint. By validating work during development, teams are able to create working products faster.
- **The postgame**. Even though validation occurs during development, teams still have to follow quality assurance, testing, and change management procedures. Quality preparation for product release is handled in the final phase.

The Customer Experience Management Method (CEM)

Like Rummler-Brache, the Customer Experience Management Method, or CEM Method, was created by process improvement consultants to address needs in organizations outside of manufacturing. CEM combines some process improvement tools with customer relations management. It was developed in the 1990s by the Virgin Group and became popular throughout the 90s and early part of the 21st century.

The CEM Method takes an outside-in approach to process improvement, focusing on what the customer wants or needs and how each process in an organization serves that need. The primary purpose of CEM is to align processes throughout an organization with customer satisfaction goals. As such, even processes without a direct relation to customers are defined in terms of customers.

For example, shipping processes are obviously directly related to end customers, so it's easy to define how those processes can best serve customers. Shipments should arrive on time, be accurate to orders, and shipping costs should be affordable.

In-house human resource processes are harder to link to customer-facing goals. However, the morale and functionality of employees *is* directly related to how those employees can serve customers. You can make a customer-facing statement about almost any process in an organization in this manner. If organizations cannot link a process to the customer, then they must ask whether the process is necessary or broken.

Like Six Sigma, CEM relies heavily on data. Organizations can't make determinations about customer goals and the success of processes without collecting and analyzing customer feedback. The advantage of CEM is that organizations are able to deploy customer-facing tactics across the enterprise, which often results in enormous gains in customer satisfaction, loyalty, and spending. A disadvantage of this method is that traditionally inward-facing departments, such as human resources, legal, and accounting, often have a difficult time implementing customer-focused cultural change.

JumpStart

JumpStart differs from the other programs and methods described in this chapter in that it is a fast-paced method for identifying problems and solutions in a single session. JumpStart can be used within almost all of the other methods described in this book as a way to spark discussion regarding processes or to identify possible solutions. It can also be used as a management tool for helping teams come to tenable solutions outside of project environments or in the absence of project resources.

Because JumpStart doesn't take the time for rigorous verification or statistical analysis on its own, teams should not use this method to enact sweeping changes or attempt to improve processes that could seriously impact customer experience or the bottom line. One disadvantage of using JumpStart alone is that changes are sometimes made on a wait-and-see mentality, which is safe for many inner-team changes but often dangerous for department or enterprise-wide processes, or for making changes to processes that are closely tied to regulatory or compliance rules.

JumpStart usually begins when leaders at some level identify an area of concern or opportunity. The manager, supervisor, or other delegate identifies a team of employees who they believe would offer appropriate insight on the issue at hand. In most cases, JumpStart doesn't work to define the problem: the group is close enough to the issue that they already know what is wrong. Instead, the group spends several hours brainstorming root causes for the problem and coming up with possible solutions.

Six Sigma and other process improvement tools can be deployed during JumpStart sessions. Fishbone diagrams and solutions selections matrixes, both covered in later chapters, can be used to validate assumptions using only the knowledge of the people in the room and some quick research.

The benefit of JumpStart is that it lets teams create and implement small-scale solutions quickly, often providing problem resolution the same day. It also lets teams identify issues that need to be addressed in a more comprehensive project environment.

When to Use Six Sigma

Some organizations make use of various project improvement methods. As a Six Sigma expert, you might have to champion your own method on occasion. Here are some reasons to choose Six Sigma over other methods described in this chapter.

When facing the unknown

Six Sigma is designed so you can begin a project even when you don't know the cause of the problem. In some cases, teams aren't even sure what the exact problem is – they only know some metric is not performing as desired. For example, an organization might experience a drop in profits that doesn't correct itself in several consecutive quarters. Six Sigma methods can begin to seek the causes of the problem, prioritize them, and work toward solutions.

When problems are widespread and not defined

Even when a problem is understood, if it is wide in scope and not well defined, improvement projects that are not tightly managed can escalate in scope to a point that they become unmanageable. In this situation, teams attempt to solve increasingly bigger issues. As a result, no problem is ever completely solved. Six Sigma includes controls for avoiding such scope creep so teams can make incremental improvements that steadily improve a process over time. We'll talk about scope creep more in later chapters.

When solving complex problems

If processes are complex and feature many variables, it is difficult to determine how to approach a solution, much less define and measure success. Knowledge of statistical analysis and process control lets teams approach problems that involve enormous amounts of data and many variables. Through analysis and graphical representation, complex ideas can be distilled to specific hypotheses, premises, and conclusions.

When costs are closely tied to processes

Because Six Sigma's statistical process control component lets teams make more accurate assumptions than almost any other method, it is very appropriate for situations that are closely tied to revenue or cost. When a single tiny change can result in millions of dollars in gains or losses, teams must validate assumptions with an extremely small margin of error. Guesswork, basic research, and even years of experience cannot do that as accurately as properly implemented Six Sigma methods.

Chapter 4: Lean Concepts

We've discussed Lean concepts in the previous three chapters because most Six Sigma approaches today incorporate Lean concepts into problem solving and the control of a process. In fact, organizations often use the term Lean Six Sigma when describing a process improvement approach that incorporates tenants from both Six Sigma and Lean methodologies. This is a popular approach because the greatest results usually come when you improve a process so that both defects and waste are eliminated. That statement rings true whether you're measuring from a business-driven bottom-line or a customer-satisfaction approach.

A Six Sigma defect is a failure to meet a requirement in a process. We'll talk more about requirements in Chapter 8 when we define quality. For now, know that **defects** cost money because businesses have to replace parts, equipment, or products that are not perfect. Organizations also experience financial loss associated with defects when quality reputation is so low that customers choose not to return or purchase from the company. From a customer satisfaction standpoint, defects can increase the time it takes for a customer to get what they want or can cause the customer to be unhappy with the end product or service.

Waste costs money because it is unnecessary time, labor, or material in the process. Generally, waste is something that is used in the process that isn't required for a satisfactory outcome. In some cases, waste creates a customer satisfaction issue because it holds up the process or introduces undesirable elements or defects in the end product.

In this chapter, we'll look at some specific types of waste and how to avoid them as well as touch on some Lean concepts for creating the most efficient processes.

The Seven Muda

Muda is a Japanese word that translates to waste. It describes a concept of being useless, unnecessary, or idle. The concept that muda must be eliminated in a process is a driving concept of the Toyota Production System and Lean manufacturing. Muda is a non-value-added task (NVA) within a process. Some types of muda are easier to identify than others, which is why Lean Six Sigma deploys tools such as value stream mapping. By understanding a process at all levels, teams are more likely to identify various forms of muda. According to Taiicho Ohno, chief engineer for Toyota, there are seven muda, or resources that are commonly misused and mismanaged: overproduction, correction, inventory, motion, conveyance, over processing, and waiting.

Overproduction

Overproduction is one of the easiest forms of muda to spot, as it tends to result in what we commonly think of as waste. Overproduction means a product, part, or service was produced too fast, at the wrong time, or in too much quantity for the process. To understand the idea of overproduction, consider a basic fast food restaurant that offers hamburgers and French fries for lunch. The restaurant does not serve breakfast, and it opens its doors at 11:00 a.m. for the lunch crowd.

If the cooks light up the grill at 11:00 a.m., then they might start the day behind, as it is possible that several orders will be placed immediately. However, if the cooks start making hamburger patties at

10:30 a.m., they might have patties that sit for some time before being consumed, which leads to customer dissatisfaction or waste if the patties are thrown out. Making 10 patties every 10 minutes starting at 10:30 a.m. is overproduction—the patties are being made too soon.

What if the restaurant owners have done some research and they know the average number of orders between 11:00 and 11:15 a.m. on a Tuesday is 10 hamburgers? They might instruct the cooks to begin making patties at 10:50 a.m. and to make 5 patties every 10 minutes. The goal is to align patty-making with customer orders so that wait times are reduced but customers are still able to enjoy fresh patties.

By noon, the owners know orders tend to come in quickly, so they ask the cooks to make 15 patties every 10 minutes. By 2:00 p.m., however, the order traffic usually drops to 10 hamburgers an hour. If the cooks are still making 15 every 10 minutes, then the process suffers from overproduction.

At some point, the traffic in the restaurant may call for made-to-order grilling—a process where the cook only makes hamburger patties as they are ordered to avoid wasting any materials. By understanding the traffic trends in their restaurant, the owners are able to estimate needs and create processes that reduce the amount of waste made in the kitchen while still meeting the quality demands of customers.

Overproduction is most often associated with tangible outcomes from a process, though these outcomes don't have to be final, or "end products" of said processes. Consider a business that prints business cards, stationary, invitations, and other documents. Perhaps this business offers a printing and mailing service; to complete this service, the company uses a machine-driven process that prints, folds, and stuffs mailings. The printer is capable of delivering 1,000 pages an hour, but the folding machine is only able to fold 800 pages an hour.

Even if a customer wants 1,000 pages printed and mailed, the printer is overproducing if the first machine is set to operate at maximum speed. The process will take longer than one hour because it is contingent upon the slowest machine. Since the overproduction doesn't result in tangible waste – the printed pages will eventually be folded and mailed – the company's process owners have to consider other factors in order to decide if the temporary overproduction is detrimental to the process. Does the stacking of extra paper before the folding process create an extra risk for error? Does operating the printing machine at maximum capacity without necessity put unnecessary strain or wear and tear on it? If the answer is yes to either question, then there exists waste that should be eliminated from the process.

Overproduction can also exist with regard to reporting, digital assets, and preparation for processes. Almost anyone working in a business environment is familiar with reporting requirements—just as almost anyone who has created reports knows the unfortunate truth that the information often goes unread. Creating reports no one reads—or creating highly detailed reports when an overview would suffice—is overproduction.

Preparing equipment that isn't used in a process is also overproduction. Surgery centers often prepare machines, equipment trays, and operating rooms before shifts begin. The goal is to create efficient processes for any patient operation; staff must also be able to access equipment quickly if issues arise during procedures. Preparing 20 trays of equipment on a day when only 10 surgeries are scheduled might be considered overproduction if there is no use for the extra trays.

In some situations, such as the medical example above, processes might call for slight overproduction. If 10 surgeries are scheduled, staff might prepare 13 or 14 equipment trays. This way, if an emergency surgery arrives, or if an issue comes up with an existing tray, stand-by equipment is available. By understanding nuances within processes and requirements, Six Sigma teams can better identify muda of overproduction versus overproduction that might be required by regulation or problem-solving policies.

The key to eliminating overproduction is planning. In the examples above, you'll note that each solution came when the process operator understood the needs inherent within the process. When the owners knew how many orders were likely, they were able to plan to reduce waste. When the printer knows the capability of each machine in the process, he or she can plan for the most efficient printing run.

Correction

Also known as muda of rework, this form of waste often plagues organizations that are keen on traditional quality programs. In a desire to eliminate defects from the end product, organizations institute in-process quality checks that route work with defects back for correction. While rework might be necessary in some cases, especially if materials are particularly valuable and work is worth saving rather than scrapping, it is still waste in the process that should be identified and analyzed.

When rework occurs, it increases overall process time and uses additional labor and materials to create a smaller amount of products or outputs. Let's look at an example that might be found in the call center for a large automobile insurance company. Some of the calls coming into the center are from individuals who have sustained damage to vehicles in an accident. Consider the following process for handling such calls:

- The caller reports damage to the car.
- The representative records information in a computer form.
- The representative makes a decision based on the information provided by the caller:
  - The claim is routed for immediate handling if it is deemed an emergency
  - The claim is routed to team A if it is a single-car or act-of-God incident
  - The claim is routed to team B if it is a multi-car accident

Now, imagine a claim that arrives in the work queue for an employee working on team B. The information entered into the computer is incomplete, so the employee cannot determine for sure if the claim is related to a multi-car accident. The employee might send the claim back to the original queue, which means a call-center employee would have to call the insured back to gather additional information. The claim would then be routed again, according to the new information, and would wait in a work queue again.

One of the biggest problems with muda of correction is that a case can often be made that the processing is necessary. Perhaps team B is not equipped to deal with single-car incidents, so the work has to be rerouted if the claim is to be completed. But why not equip down-line team members to handle any claim, or create a process for rerouting claims to the correct team without sending the work back to the original queue?

Correction, or rework, can occur in any type of process. Manufacturing processes cull out defective parts and products; sometimes materials are reworked for a better outcome and sometimes they are scrapped—also a form of waste. Call centers and digital work queues are famous for rework, as it's easy

to send work back and forth in a digital format. In some cases, rework occurs not because of correction, but simply because departmental or worker responsibilities overlap.

To eliminate rework or correction, organizations must use a twofold approach. First, the root cause of the rework—that which is causing the errors—must be addressed. Is further employee training required? Could a process be changed to make it more mistake proof? In some cases, the principles discussed in later units on process control, including a strategy called a poka yoke, can be deployed to make it more difficult to create defects than to not create defects during a process. When defects are avoided, rework is also avoided.

In addition to addressing the root cause of errors, organizations should create quality steps that reduce rework waste. In the example about the insurance company call center, we noted that it would be more efficient for the down-line worker to reroute the claim to the correct team than to return it to the original team. This method sometimes causes a problem of culture, though; there is a feeling among leaders and staff that the first team or first team member should be held accountable for the error. One way of seeking accountability is to have that person correct his or her mistake. While reworking errors can be a good training method when time and resources allow, it isn't always feasible and doesn't make for an efficient daily process. Instead, employees might be more efficiently held accountable through goal-setting and metrics for the greater good of the organization as a whole.

Inventory

Muda of inventory is similar to muda of overproduction; in fact, overproduction can cause a waste of inventory. Muda of inventory occurs when materials or inputs stack up before a step in the process; this phenomenon is also called a bottleneck. Remember the printing example for overproduction? If the first machine is set to the highest production level, it will generate 1,000 pages an hour. The folding machine can only handle 800 pages an hour, so you would have an inventory of 200 pages created every hour. If both machines ran at highest production for four hours, the process would have developed an inventory of 800 pages. Until and unless the folding process becomes faster, then those extra pages are wasted inventory and will continue to pile up.

Inventory waste can occur when items are purchased or created before they are needed in a manufacturing or service process. Inventory can also occur in work queues, digital data queues, or even email inboxes. If you receive 300 emails a day and you are only handling 30 of them on a regular basis, you have a process problem with your communications.

While inventory waste can occur in any process, it is especially common in processes that operate in batches. Traditional lean wisdom says to avoid batch process – processes that involve creating a certain number of products or outputs before pushing them down the line. Reducing batch size lowers lead times—the time it takes to deliver the end product. It also reduces the amount of inventory that occurs before each step of the process.

While Lean mindsets usually push a batching-is-bad mentality, you can't always avoid it—and reduced lead times on individual outputs aren't always a primary goal of a process. Consider a baker who is preparing an order of one dozen cupcakes. He could prepare the order as a batch, or he could prepare each cupcake separately. Obviously, mixing the ingredients and baking the cupcakes as a batch makes more sense. Decorating them as a batch also works well—the baker might frost all of the cupcakes, add piping to all the cupcakes, and then top all the cupcakes with a candy. Batching works for the baker

because the first cupcake is not going to leave the bakery before the 12th is finished—they all move together because they are considered a unit.

You can also reduce waste of inventory by understanding a process and basing inventory decisions on historic metrics. A shipping center that processes between 50,000 and 100,000 boxes a week wouldn't place an order for 300,000 boxes if they only wanted to have a week's supply on hand. A baker doesn't whip cream for seven pies if he or she only intends to make two.

Motion

Muda of motion has to do with how employees themselves move during a process. This type of waste is often relevant to people-powered processes in manufacturing, warehousing, shipping, delivery, or industrial fields, but waste of motion can even crop up in processes that are computerized.

For example, if a data-entry employee has to click back and forth between screens when entering information, this could be muda of motion. If the system is designed so that a number is to be entered in one window and a second number entered in a different window, the click between windows is wasting motion. Moving to another window involves a mouse or keyboard action that could be eliminated if the data were entered on the same window. It seems like an inconsequential detail, but imagine what happens when the data employee completes this process hundreds or thousands of times a day. The waste can absolutely add up:

- If each data-entry employee completes 600 entries an hour on average, and there are 10 employees on a team, the team is completing 48,000 entries each day.
- If it takes only half a second more to toggle between the two windows, the team is still spending a collective 400 minutes a day – just over 6.5 hours – toggling.
- If the average hourly wage for a data worker is $10, the team is spending an extra $325 each week – almost $17,000 each year – to cover the act of toggling between windows.

Given those numbers, a programing change that includes both data elements on the same window could save the company $17,000 in a single year. This same concept can be applied to any form of muda when you can apply a time and dollar figure to the waste.

Other examples of muda of motion include a task that requires an individual to physically move back and forth between work, extra motion that stems from a poor layout of work, or movement that occurs when an employee leaves an area and has to return one or more times because he or she forgot something. Public libraries have long employed a simple tool to avoid muda of motion in the reshelving process: books are first ordered on a cart. The cart allows an employee to carry many books without moving back and forth, and placing the books in order on the cart lets the individual move through the stacks once. If books are placed at random on the cart, the subsequent movement between shelves wastes motion and time.

Streamlining company processes eliminates muda of motion, and data must be collected and analyzed to identify unnecessary movement. A common tool used in manufacturing and similar environments to track movement is known as a spaghetti diagram. Begin with a basic, bird's eye drawing of the workspace. Include furniture, computer stations, machinery, doors, and walls. Observe an actual process, tracking any and all movements with a line on the diagram.

When drawn correctly, the diagram looks like a string of spaghetti fell onto your page. Once the process is complete, you can look at the diagram to see where the movements cross paths multiple times or go out of the way unnecessarily. This helps you find opportunities for streamlining the movement in a process—sometimes, it's as simple as moving furniture or resources around to reduce unnecessary movement. It's worth noting that a spaghetti diagram only reveals a snapshot of movement in time; sometimes, it is worthwhile to complete more than one such diagram at different times of day or with different employees to reveal an overall picture of a process and possible muda.

Conveyance

Muda of conveyance is similar to muda of movement except conveyance involves the movement of outputs, products, or resources. It is sometimes also referred to as muda of transportation. For example, in a doll-making facility, if the glue that binds doll eyes to doll faces is kept in an inventory room and carried, as needed, to the process, there might be muda of conveyance.

If an expense report is printed and then carried to a manager for approval who then routes it in an inner-office envelope to a director, who then carries it to the accounting department, the muda of conveyance is occurring. This is especially true because appropriate technology used correctly and efficiently lets organizations handle expensive reporting via computer with little conveyance at all.

If a plate is prepared by a chef and placed on a counter where a kitchen assistant moves the plate to a different table where wait staff know to pick it up, conveyance is occurring. The wait staff then carries the plate to the customer.

Conveyance can relate to physical movement of items or digital movement of data or workflow. Email strings, which are present in many work environments, often present muda of digital conveyance. A CEO might email a director with a request for data. The director emails a manager, who emails a supervisor, who emails a subject-matter-expert. The SME delivers the information to her supervisor, and the emails work their way back up the chain. The same request and information was conveyed multiple times when it only may have needed to be conveyed once. This allows for many opportunities for error.

Some might point to chain-of-command concerns, but for the purpose of this example, if the data request is a repeated process, then it makes sense for the chain of command to inform the CEO where this information comes from. To go even further, a truly Lean process would require all waste be removed from this process. If the data requirement comes on a weekly basis, then Lean ideals require that the SME automatically generate the data and send it to the CEO weekly.

Physical conveyance is often easier to locate and address than digital conveyance. A spaghetti diagram, process map, or value stream map can help you identify areas where muda of conveyance might exist. Spaghetti diagrams work well in physical conveyance situations, and process maps help you identify conveyance in digital settings.

Once you identify muda of conveyance, you can eliminate it by making changes in the process, layout, or inventory requirements for the work. If conveyance waste isn't due to poor process design or work-area layout, it might be related to another form of muda. Conveyance is often seen in processes that involve a lot of correction, because work is transferred back and forth between staff or areas. By addressing the muda of correction, you often also address the muda of conveyance.

Over-processing

Over-processing occurs when an employee or process inputs more resources into a product or service than is valued by the customer. This could occur because of ignorance, a desire for perfection, or even excitement. Sometimes over-processing occurs because an employee hasn't had training on the most efficient way to handle a task. Other times, it occurs because an employee or process is more thorough than is worthwhile. A goal of any process should be to do just enough useful and necessary work to ensure that customer or end-user expectations are met.

One example of over-processing often occurs in healthcare administrative offices during the insurance verification process. Insurance verification occurs when a healthcare provider's office attempts to verify that a person is covered by insurance for the services that are about to be rendered. Depending on the type of insurance coverage and the office's policies, a staff member either checks benefits via a computer program or calls the insurance company.

In most cases, the goal of insurance verification is simply to ensure that the insured is covered by the plan for the date the services are to be rendered. Sometimes, however, an office worker delves deeper into the verification, spending up to an hour on the phone with an insurance company to receive detailed benefits or calling back to check with another representative to ensure the original information provided was correct. While specific cases exist that require in-depth insurance verification, basic doctor's visits don't require this level of work. A staff member who is taking up to an hour to verify insurance coverage is overproducing, and it's probably causing productivity problems for the office as a whole.

In consumer-centric processes, over-processing occurs when you put more into a product than the value afforded by the customer. While product excellence is important, at some point the work you put into a product exceeds that which is deemed necessary or useful by the customer, and this is often tied to price point. A customer expects more out of a premium, more expensive model, for example.

An example of over-processing might be painting the bottom of an inside cabinet shelf when no one will ever see it. In a restaurant, ironing table linens to an exacting standard could be considered over-processing, especially if you remove the linens between meals for washing. In most restaurants, much of the table linen drapes over the table; owners might want linens that aren't full of wrinkles, but they don't need crisp and perfect seams. In the technical world, building an app with 100 features when 99 percent of people only want to use 10 main functions can be considered both over-processing and over-producing.

A value stream map, covered in Chapter 35, is a good tool for identifying any points of over-processing. Any part of the process that doesn't provide value could be considered over-processing; when the process features a series of linked events and none provide value, it's even more likely that over-processing is occurring.

In a true Lean process, every step of a process provides value, but it can be tricky to determine when value is not occurring. Quality is important to both the success of the process and the end customer, for example, but the customer doesn't care, or usually even realize, that your process is imbued with quality checks throughout. They care instead that a process takes 10 minutes longer because of those quality checks—teams have to dig deep into processes, metrics, and customer voice to determine if those 10 extra minutes are providing enough added value to cover the annoyance or loss of customer because of

the added time. This knowledge is all ascertained through data collection and statistical analysis discussed in detail throughout this book.

Waiting

Muda of waiting refers to any idle time in a process, whether that idle time is for machinery or people. In other words, an employee or machine is working below capacity or is not working at all due to waiting on inputs from another part of the process. Waiting occurs when steps in the process are not properly coordinated, when processes are unreliable, when work is batched too large, during rework, and during long changeovers between staff or machines.

In a retail or fast food environment, when one cashier's shift is over, another cashier takes over at the station. To maintain financial integrity, almost all companies switch out cash register drawers during the change between cashiers; if there is a mistake with the drawer, the company knows who was running the register at that point in time, making it easier to find trends or issues. However, when the drawer is being changed out, the register usually can't be used. The cashier is simply waiting, sometimes along with the customer.

To reduce the muda of waiting in this cash register example, most organizations use a process that includes a series of register drawers that are prepped at the beginning of the day or shift. The drawers are designed to be interchangeable in the registers, so the old drawer can be pulled and the new drawer put in in less than 30 seconds, solving the waste of waiting.

Waste of waiting is common in construction environments. Construction of roads, bridges, buildings and other structures requires close attention to order and detail: you can't build the roadway of a bridge until the pillars are in place and steady. This concept is seen even on a small scale in construction, causing paid employees to often stand around waiting for others to complete a piece of the job before they can finish the assigned task.

Because construction is a field of specialists and certifications, one employee often cannot do the work another can. In other words, employee tasks are not interchangeable. This causes additional muda of waiting; one group of construction workers might have to wait on the forklift operator to come and move some items. Meanwhile, the forklift operator is finishing up with a task on the other side of the construction lot. This isn't a problem limited to construction: some offices have policies requiring an official IT staff member to handle any computer issue. Whether it's a software glitch, a troubleshooting error, or simply the need to switch out an underperforming mouse, regular office staff must send a support ticket or make a phone call and wait for IT staff to solve the problem.

You can eliminate waste of waiting within many processes by balancing machinery, people, and production. The process will only perform as fast as the slowest link; beefing up the production of a single element does nothing for the whole, so teams must work to balance and improve the entire process.

Sometimes, scheduling is a key component in eliminating waiting. In the construction example, advanced planning and scheduling tactics could reduce the chance that one team would be waiting for a forklift operator while he or she is busy elsewhere. Understanding organizational, team, project, and process needs also helps leadership provide the right amount of resources to reduce waiting. The construction site might benefit from two forklift operators, for example. In the IT example, a company

can reduce wait times by maximizing IT staffing at high-volume times or implementing processes within the IT department to create more efficient responses to help tickets. An auxiliary IT staff member can be hired to handle less technical issues such as switching out an under-performing mouse.

Other Forms of Waste

While Toyota originally defined seven common muda, even Taiichi Ohno agreed that other types of waste exist. In some cases, what seems like other types of waste are just more defined or specific types of the seven muda discussed above. Some forms of waste don't seem to fit neatly into one of the seven muda categories.

Talent

Talent can be wasted when a process doesn't make the most use of the labor or staff available. If a process calls for data to be entered, and the staff member slowest on 10-key is assigned to the task, resources are being wasted. Hiring the wrong person, putting staff in the wrong position, or ignoring a staff member's growth potential could all be instances of muda of talent. Wasted talent is more a concern for leadership and human resources than for process improvement specialists, though Six Sigma experts should be aware that the way personnel resources are handled can drastically impact the efficiency of a process.

Ideas

Muda of ideas occurs when the thoughts and ideas of people are discounted, not sought out, or misappropriated in a way that doesn't make sense. Leadership and project teams can often overlook subject matter experts who have detailed insight into a process and, as such, could offer first-hand knowledge and ideas. The result could be the design of a process that works great in theory but falls flat on a granular level once it's instituted.

One reason waste of ideas is such a concern for organizations is that people themselves rarely come forward with thoughts. Staff members might think they don't have anything real to contribute, might feel like their ideas won't be heard, or could be anxious about looking silly or ignorant.

Six Sigma Green or Black Belts in charge of projects can facilitate less muda of ideas by encouraging subject matter experts to contribute and encouraging leaders to seek all ideas before moving forward with change. Brainstorming tools, which are covered in later chapters, are valuable for this purpose because they are designed to create a safe haven for all ideas. By fostering all ideas in a safe environment, teams can foster valuable ideas and avoid waste of ideas.

Capital/Cash

Saving for a rainy day is smart, but banking cash when there are profits to gain isn't always the right decision. Muda of capital or cash occurs when leadership decides not to invest in upgrades or improvements that would create additional cash flow. This type of waste is very similar to waiting, except the cash itself is waiting, often for a time when leadership feels safe enough to spend it.

Six Sigma helps reduce muda of cash because statistical analysis helps point leaders to decisions that involve the least risk or most gain. No business decision is 100 percent guaranteed, but Six Sigma helps leaders hedge bets by using statistical data in the decision-making process so they don't sit on cash or capital that could be used to drive gains in efficiency, production, and profit.

Two Types of Muda

All muda is waste that fails to add value to a product or process as defined by the customer or end-user. All muda can also be divided into two overall types, which can help organizations prioritize waste for project and improvement purposes. Muda can be referred to as type I or type II.

Type I Muda

Type I muda are non-value-added tasks that might actually be essential or required by circumstances. Inspection of products during a process might be required if the process is known to produce defects. Organizations don't want defects to reach customers, so they put quality controls in place. The act of the inspection, and the time and expense it adds to a process -- are all muda. However, an organization can't remove that waste until it addresses the cause of the defects within the process.

Sometimes, auxiliary processes within an organization are Type I muda. For example, the external end customer doesn't receive direct value from human resource processes within an organization. At the same time, if employees don't receive pay checks or support regarding benefits, they aren't likely to continue performing work. Those processes are then essential to the organization. Instead of removing the muda completely, teams might look for ways to make essential muda as efficient and cost-effective as possible.

Type II Muda

Type II muda are non-value-added tasks that are not essential and can be immediately removed from a process. For example, if a product is carried to and from several work stations while it is being completed, it's likely type II muda of conveyance exists. By rearranging the workflow, teams might be able to reduce the muda by a substantial amount without making any actual changes to how the product is put together.

5S

5S is a Japanese Lean approach to organizing a workspace, so that by making a process more effective and efficient, it will become easier to identify and expunge muda. 5S relies on visual cues and a clean work area to enhance efficiencies, reduce accidents, and standardize workflows to reduce defects. The method is based on five steps:

- Sort (Seiri)
- Straighten (Seiton)
- Shine (Seiso)
- Standardize (Seiketsu)
- Sustain (Shitsuke)

Phase I: Sort

During the sort phase, all items or materials in a workspace are reviewed, removing unneeded items and keeping necessary resources.

Consider the copy room in an office: over the years, supplies, tools, and machinery have piled up. When going through the room, teams might decide that the stapler and Scotch tape stay; people still need to staple pages or access tape. The old paper cutter isn't necessary for the team, since no one ever performs paper-cutting duties. However, someone notes that the team in shipping and warehousing has to manually cut pages down sometimes, so the paper cutter is relocated to that department. The team decides to toss a bin of miscellaneous loose paper and an old fax machine because a new copy machine includes fax capability. By eliminating obstacles and unnecessary items, costs, time, and employee frustration are also removed.

The sort step lets you take inventory of an area, discover unused or wasted resources, and make room for reorganization. Sort can also be applied with computerized processes.

Phase 2: Straighten

Once excess is removed from the work area, teams must provide a streamlined and easy-to-use location for everything necessary to the workspace. During the straighten phase, every item, tool, or material is given a home. To facilitate ongoing organization, the location of resources should be labeled clearly. The idea is to create a workspace that anyone could use: if someone from another area comes to your copy room, it should only take a few seconds to locate the right size paper. Employees in a factory should be able to move from station to station, finding equipment and tools with ease. The goal is to provide the visual controls that allow for common-sense operation. Labeling a shelf for letter-sized paper, arranging sockets in size order in a drawer labeled sockets, or parking the forklift in a marked area of factory floor when not in use are all good examples. Labeling the stapler with a label maker is an example of things going beyond common sense: you don't need to label items that most people in the workplace would recognize on site.

The straighten phase also works well in a digital environment, especially when computers or systems are used by a variety of people. In an office that has a shared workspace policy, computer desktops might be pushed out by technical resources so that the same programs are available to everyone. Not only are all programs the same, but the icons are in the same location on each desktop so users don't have to search for programs if they move to a new workstation.

Phase 3: Shine

The third phase in the 5S methodology is targeted to keeping the workplace clean and neat. Seiso can also be translated to "sweep, sanitize, or scrub." The goal is to shine the work space by cleaning it, maintaining equipment, and returning items to the proper place after use. In a computerized environment, the shine phase can be accomplished by naming files in a manner that makes them easy to locate, keeping folder structures intact, and deleting or archiving files that are no longer necessary.

Shine can be applied to any environment, physical or digital.

Phase 4: Standardize

The standardize phase is used to maintain the progress achieved in all previous phases. By keeping high standards of orderliness in place, the benefits of the 5S methodology can be long-term. The stress and speed of a daily workday can make it hard to keep up with the 5S standards. If everyone is committed to working together, the benefits can be ongoing.

5S only works if everyone on the team or within the organization commits to the process. Employees must follow the rules that are set up for standardizing and sustaining the organization. Otherwise, the team enters a cycle of cleaning up after a period of failing to keep up with the standards of 5S.

The overall benefits the 5S method includes:

- Reduced risks of accidents and safety issues
- Increased compliance with regulations from organizations such as OSHA
- A foundation that makes additional improvements easier to implement
- Waste is easier to identify and eliminate
- Production and quality are generally improved

All of these benefits translate to increased profits and customer satisfaction, which are the overall goals of the Six Sigma methodology.

Just-in-Time Manufacturing

Just-in-Time manufacturing, or JIT, is another Lean concept that originated with Toyota. Originally, JIT took a literal meaning. The goal of JIT manufacturing was to produce an output "just in time," or "as needed" by the customer. The customer was the person or process that required the output; sometimes, that meant the end customers, and, other times, the customer was a different employee or process within the organization.

In a JIT processing situation, one machine might produce a part required by another machine. JIT manufacturing means that the first machine supplies only the amount of parts that the second machine can process. If the second machine can process one part per minute, the first machine is set to produce one part per minute. You'll recognize this idea from the sections on muda of inventory and overproduction.

It's obviously not always possible to run a process just-in-time for the end customer, but most modern companies do try to come as close as possible. Using predictive analytics, companies attempt to estimate how many of each product will sell before they produce those products. In some cases, such as with book publishing, companies run a smaller number of items first. If those items sell well or sell out, the company orders bigger and bigger runs of the product.

Some entrepreneurs have applied JIT manufacturing to DVD sales. These individuals and companies buy the rights to films that have never been released on DVD or Blu-ray before. They usually go after low-cost films that are likely to have a small cult or niche following. Because the demand is small, it isn't feasible to print and market these DVDs in traditional fashion. However, the companies make a stable profit by selling the DVDs through online retailers such as Amazon.com and printing the DVDs to order. Modern technology lets this process occur with minimal expense and waiting.

Today, JIT mentalities are less about the literal idea of providing the product just in time; rather, it has become a more general concept of Lean manufacturing that helps organizations eliminate waste in the process.

Lean Concepts Crop Up in Many Improvement Methodologies

We've covered many of the high level Lean concepts, and you'll see some of these concepts repeat throughout the rest of this book. While Six Sigma is concerned with improving processes and reducing defects, eliminating waste and increasing efficiencies goes hand-in-hand with these goals.

Chapter 5: Basic Six Sigma Concepts

In the last chapter, we covered some of the major concepts associated with Lean. In this chapter, we'll look at some of the major concepts of the Six Sigma methodology. These, along with the concepts introduced in Chapter 1, are some of the building blocks used in improvement projects and statistical process control.

Standard Deviation

The driving goal of Six Sigma is to reduce defects. By reducing defects, teams can increase productivity, decrease overall costs, increase customer satisfaction, and create maximum profit. One idea inherent in the Six Sigma methodology is that variance is the root of many defects.

For example, if an oven heats to exactly 350 degrees in five minutes and stays at that temperature until it is turned off, it is less likely to burn cookies. If a cook measures each ingredient exactly, he or she is more likely to turn out cookies that consistently taste good. Add variation in the process, and consistency is lost. When consistency is lost, defects are introduced. If the oven doesn't maintain an exact temperature all the time, the cookies might burn. If the cook puts in a cup of sugar instead of a cup and a half, the cookies might not be sweet enough. Variation makes for inconsistent quality.

It's important to note that removing variation alone doesn't always improve quality. What if the cook set the oven to 400 degrees all the time and only used half a cup of sugar for each batch? The process has no variation, and neither do the results. The cookies will always be bland and burnt.

Six Sigma process improvement teams usually take a two-step approach to improvements. First, they have to determine if the process is functional. In the cookie example, does the recipe work at all? Is there even a recipe? Once the team determines there is a workable recipe, they make improvements to remove the variation that causes outputs to deviate from the result intended by the recipe.

The statistical measure used by teams to understand variation in a process is known as standard deviation. Standard deviation is represented in math by the lower case Greek letter Sigma – the σ you saw in Chapter 1.

Standard deviation measures the distance between data points and the mean of all data. A large standard deviation means an overall wide spread of points; a smaller standard deviation means a closely clustered set of points.

Less deviation   More deviation
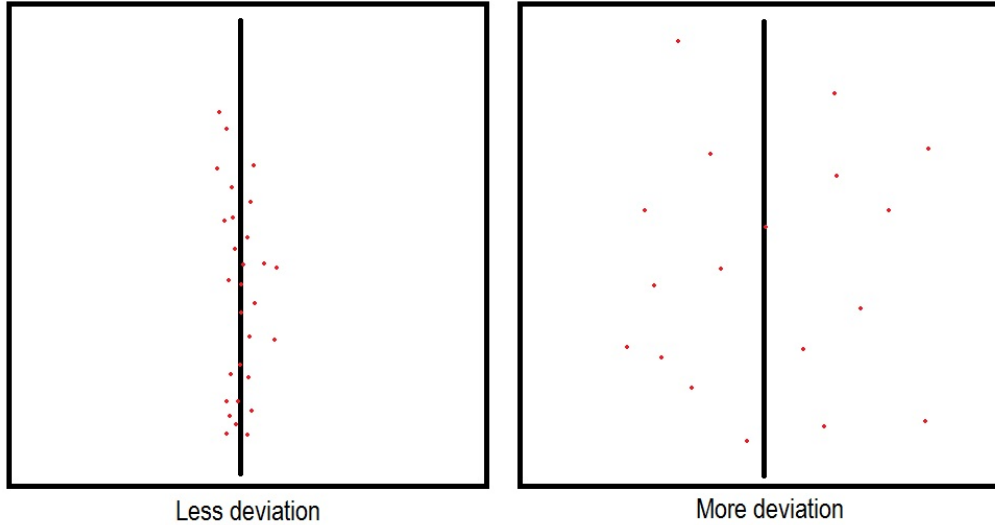
The image above provides a graphical representation of deviation. Imagine the vertical axis is a measure of time and the horizontal axis is a measure of temperature. The center line in each image represents the mean temperature. You can see that the temperature over time varies much more in the figure on the right.

Calculating Standard Deviation for Population Data

Standard deviation is a statistical concept. The formula for standard deviation when dealing with data of the entire population is:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2}$$

Formula Key:

σ = Standard deviation

μ = mean

Σ tells you to add up the results of all the calculations done for the items listed in the parentheses

N = the number of data elements for which you calculated standard deviation

X = a place holder for each data element

You would use this formula if you have all the data elements of a population and not just a random sampling of data elements. For example, if you wanted to find out what the deviation was in the size of pizzas made, you could ask staff to measure each pizza before serving it. You would have the data for the entire population of pizzas for the day, so you could use the equation above. However, if you wanted to calculate standard deviation when you have sample data, you would use the equation from the next section.

If you're new to statistics, the equation for standard deviation looks complicated. We'll break it down and run through some exercises on calculating standard deviation manually, but in practice, you will usually use a statistical software tool to make this calculation automatically.

For our explanation, we'll use a data set from a teacher. She wants to find the standard deviation of scores on the latest test. The scores from her class of 15 students are:

67, 68, 73, 74, 81, 85, 88, 88, 90, 90, 90, 93, 94, 98, 99

1. Calculate the mean.

To begin the standard deviation calculation, you need to know the mean for the population. The mean is represented mathematically by the Greek letter mu, or μ. Mean is calculated by adding all of the numbers and dividing that sum by the number of items in a data set. In this case, there are 15 items.

67 + 68 + 73 + 74 + 81 + 85 + 88 + 88 + 90 + 90 + 90 + 93 + 94 + 98 + 99 = 1278

1193/15 = 85.2

2. Subtract the mean and square it.

The formula calls for you to take each number in the data set, subtract the mean from it, and square the result. The first number is 67, so:

67 – 85.2 = -18.2

-18.2 * -18.2 = 331.24

If you apply that concept to all 15 numbers, you end up with a list of results:

331.24
295.84
148.84
125.44
17.64
0.04
7.84
7.84
23.04
23.04
23.04

60.84
77.44
163.84
190.44

3. Find the mean of the results.

The rest of the formula under the square root sign simply tells you to add up all the numbers you just calculated and divide by N, where N is the number of items in your data set. Or, to put it another way, you need to find the mean of the new numbers you just calculated.

The sum of the numbers above is 1496.4.

1496.4 / 15 = 99.76

This new number, 99.76, is called the variance.

4. Find the square root of the variance.
The standard deviation is the square root of the variance. In this case, the square root of 99.76, which is 9.987.

The standard deviation for the test scores is **9.987.**

Calculating Standard Deviation with Sample Data

While statistics based on total population data are always more accurate than those based on sample data, you'll probably work from sample data more often. It just becomes too expensive or even impossible to get population data for many elements. Sometimes, the data is measuring events or states over time, which means population data doesn't exist. For example, if you wanted to understand temperature fluctuations in a warehouse, you might record the temperature at a certain location every ten minutes. After several days, you have sufficient sample data to analyze.

Other examples of sample data include:

- A random sample of reasons for denied medical claims
- Measurements for river height taken three times per day for a month

The formula for standard deviation based on sample data is:

$$S = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2}$$

Formula Key:

s = Standard deviation of a sample

x-bar = the mean of the sample

Σ tells you to add up the results of all the calculations done for the items listed in the parentheses

N = the number of data elements for which you calculated standard deviation

X = a place holder for each data element

Since mu is the mean of *population* data, it's been replaced in this formula with x-bar, which is the average of the data points in your sample. Sigma has been replaced with s, but the only mathematical difference is that you divide by N-1 instead of N to get the variance as a way to make up for some of the accuracy lost in using a sampling.

Using the same data from the population example above, let's assume that the 15 grades the teacher had were a random sampling from all of her classes. The only difference in the math would come in the second to last step, where we divide by 14 instead of 15, so:

1496.4 / 14 = 106.885

The square root of 106.885 is 10.338, which would be the standard deviation for the sample.

See for yourself:

Lab techs are measuring the response of bacteria to an ingredient in a potential treatment. They want to know how long it takes bacteria to show a response. Sample data for response times in minutes is:

2, 3.5, 2.3, 2, 2.5, 3.1, 2.2, 3.2, 4

Calculate the standard deviation.

Standard Deviation in Excel

Admittedly, if you're calculating standard deviation by hand, it's a lot of arithmetic. Luckily, once the statistical concepts behind the numbers are understood, statistical analysis software, such as Excel and Minitab, can be used to accurately crunch numbers. Standard deviation is automatically calculated in most statistical analysis software programs by clicking a button after you enter your data sets. The standard deviation is also calculated automatically by such software programs when you initiate other calculations that require standard deviation. We'll look at some of these functions more in-depth in the chapters on using Excel add-ons and Minitab for statistical analysis.

In the meantime, you can quickly calculate standard deviation in Excel using the standard deviation function. To do so:

1. Enter your data set in a column

	A
1	2
2	3.5
3	2.3
4	2
5	2.5
6	3.1
7	2.2
8	3.2
9	4

2. In a new cell, enter =STDEV()

3. Select the cells with data you want to calculate standard deviation for.

8	3.2
9	4
10	=stdev(A1:A9)
11	

4. Hit enter

7	2.2
8	3.2
9	4
10	0.719568
11	

Note: The formula in Excel calculates a sample standard deviation using the N-1 math, which means you can use this formula for samples and not for populations.

Why Calculate Standard Deviation?
Standard deviation gives you an idea of how much variation actually exists in a process while taking outliers somewhat into account. In the example of the grades from above, the sample standard deviation indicates that most of the grades are going to fall within 10.33 points on either side of the average.

That tells the teacher that students have a fairly wide performance on her test. If the results were an average score of 90 with a standard deviation of 3, he or she might assume that students in class were

learning and retaining the knowledge as expected. If the average score was 64 with a standard deviation of 2, then he or she might assume students in class were not retaining the knowledge as expected or there was some issue with the test structure. Both of these situations indicate a small variance in the way students are performing, which points to the success or problem being tied to the class, the teaching, or the test.

On the other hand, if the average score was 60 with a standard deviation of 30, then some students were performing very well while others were performing poorly. This might indicate to the teacher that some students are falling behind. If he or she took samples from several classes, he or she might investigate and realize that the lowest scores were mostly from one class, which could indicate that he or she forgot to adequately cover a certain concept in that class.

Standard deviation alone serves as a pointer for where to investigate within the process for problems or solutions. Another reason to calculate it is because it is involved in many of the other statistical processes we cover in later chapters. Standard deviation becomes an important concept in both analysis and statistical process control and often serves as the starting point for further Statistical Six Sigma analysis.

The Pareto Principle

The Pareto principle, also called the 80/20 rule, says that 20 percent of the causes lead to 80 percent of the effects. This there is also called the law of the vital few: the vital few inputs drive the majority of the outputs.

The Pareto principle was first suggested by a management consultant named Joseph Juran. Juran named the principle for Vilfredo Pareto, an economist in Italy who wrote that 20 percent of the nation's people owned 80 percent of its land. The principle has become common in various circles. Business professionals commonly state that 80 percent of sales come from 20 percent of customers, and volunteer organizations usually operate with 20 percent of the people doing 80 percent of the work.

The principle is critical to Six Sigma not because causes and effects line up nicely via an 80/20 breakdown, but because it almost universally applies that a few inputs create more impact than all of the other inputs. Individuals seeking to reduce defects can almost always identify three to four inputs that, if improved, will create dramatic impact on the outcome. While resources, costs, and difficulty of improvements also play a role in solution selections, understanding which inputs or root causes are high on a Pareto chart let project teams determine where improvements will make the biggest impact to the bottom line.

The Pareto principle is best displayed using a Pareto chart, which is a graphical representation of data elements – usually inputs or causes – in a ranked bar chart. Unlike a regular bar chart, the bars are arranged in order of height, with the highest on the left and the lowest on the right. Statistical software used to create such charts adds formatting and other elements automatically, but you can also create a basic Pareto chart in Excel.

To illustrate the Pareto principle, we'll look at a common situation involving defects in the medical field—specifically in the process for submitting medical claims. Payers often deny claims, and they do so for a variety of reasons. When claims are denied, provider offices have to rework, resubmit, or appeal the denials. Some denial reasons are not appealable, which means the provider's office loses the revenue associated with the claim.

We'll imagine a medical office that is experiencing a cash flow problem because of claim denials. The office gathers data about the denials and creates a Pareto chart so the team can see where the bulk of the denials are coming from. The data is listed below, followed by a basic Pareto chart created in Excel.

Reasons for Denying Medical Claims

Reason	Count
Duplicate claim	18012
Timely Filing	13245
No beneficiary found	10215
Claim lacks information	4548
Service not covered	2154
Medical necessity	1423
Date of service issue	526
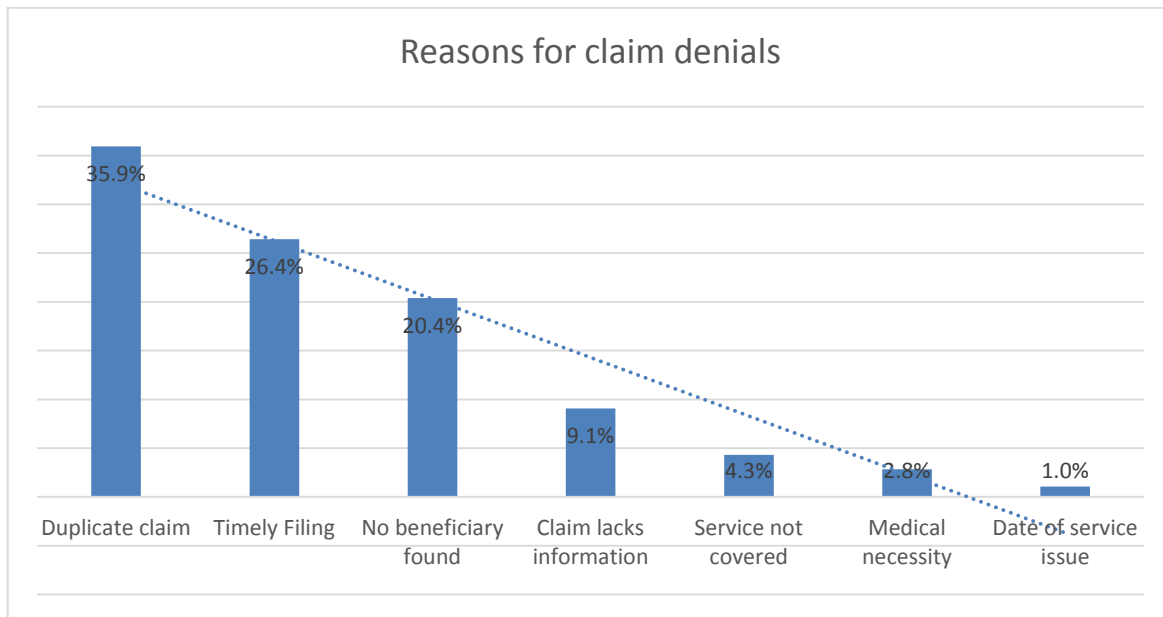
From the Pareto chart, you can see that the top three denial reasons account for 80 percent of the denied claims. An experienced billing team could tell you three things just from looking at this data:

1. The office has muda of rework. They are sending a large percentage of claims more than one time.
2. The office has an efficiency problem. Almost a fourth of their claims are not making it to the payer prior to timely filing deadlines.

3. The office has an insurance verification problem, because a fifth of their claims are being sent with information that doesn't match anything on the payer's end.

Addressing duplicate claims is important because it reduces rework and could enhance the office's relationship with insurance companies. However, the team might choose to work on the timely filing problem first because timely filing denials are final, which means the office is losing the revenue associated with all those claims. Filing claims on time is not difficult in many cases, given the fact that most payers allow months or even a year for claims to be filed, so this could be an "easy" win for the team. A Pareto chart often uncovers low-hanging fruit in this manner.

Creating a Basic Pareto Chart in Excel

If you don't have statistical software, you can create a basic Pareto chart like the one above in Excel. Use the claims denial data or data of your own to practice making a Pareto chart.

1. Create a column for the data labels. Pareto charts work well when you have quantifiable causes for a defect or other effect. In the example, the data labels are the reason for the denial. No matter what type of data you are using, enter it in order from largest to smallest for Pareto chart purposes.
2. Create a column for count. Enter the total for each cause in that column.
3. Create a column for cumulative count. This column provides a running total. You can calculate the numbers manually or using Excel. In the data table below, you would set C3 = B3. In C4, you would enter the formula =C3+B4. You can drag that formula down and Excel will change the references for each cell so you get =C4+B5, =C5+B6…and so forth.
4. Create a column for percent. In the data table below, the formula for D3 is =B3/C9. Cell C9 has the total of all denials, so we want to divide each individual denial total by C9. The dollar signs in the formula let you copy it into each lower cell. The first reference will change, moving to the next line, but the dollar signs tell Excel to keep the C9 reference for each calculation. The final result is a table that looks like this:

Reason	Count	Cumulative	Percent
Duplicate claim	18012	18012	35.9%
Timely Filing	13245	31257	26.4%
No beneficiary found	10215	41472	20.4%
Claim lacks information	4548	46020	9.1%
Service not covered	2154	48174	4.3%
Medical necessity	1423	49597	2.8%
Date of service issue	526	50123	1.0%

5. To create the Pareto chart, highlight the information in both the Reason and Percent column and select Insert → Chart → Bar chart.

	A	B	C	D
1	Reason	Count	Cumulative	Percent
2	Duplicate claim	18012	18012	35.90%
3	Timely Filing	13245	31257	26.40%
4	No beneficiary found	10215	41472	20.40%
5	Claim lacks information	4548	46020	9.10%
6	Service not covered	2154	48174	4.30%
7	Medical necessity	1423	49597	2.80%
8	Date of service issue	526	50123	1.00%

Highlight the two columns.
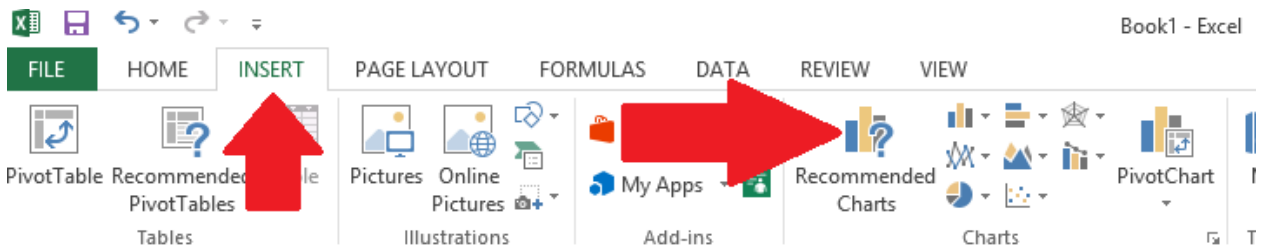
Click insert, then click on bar charts.

6. The bar chart will be created automatically. Select Add Chart Element → Trendline, and add either an exponential or linear trendline.
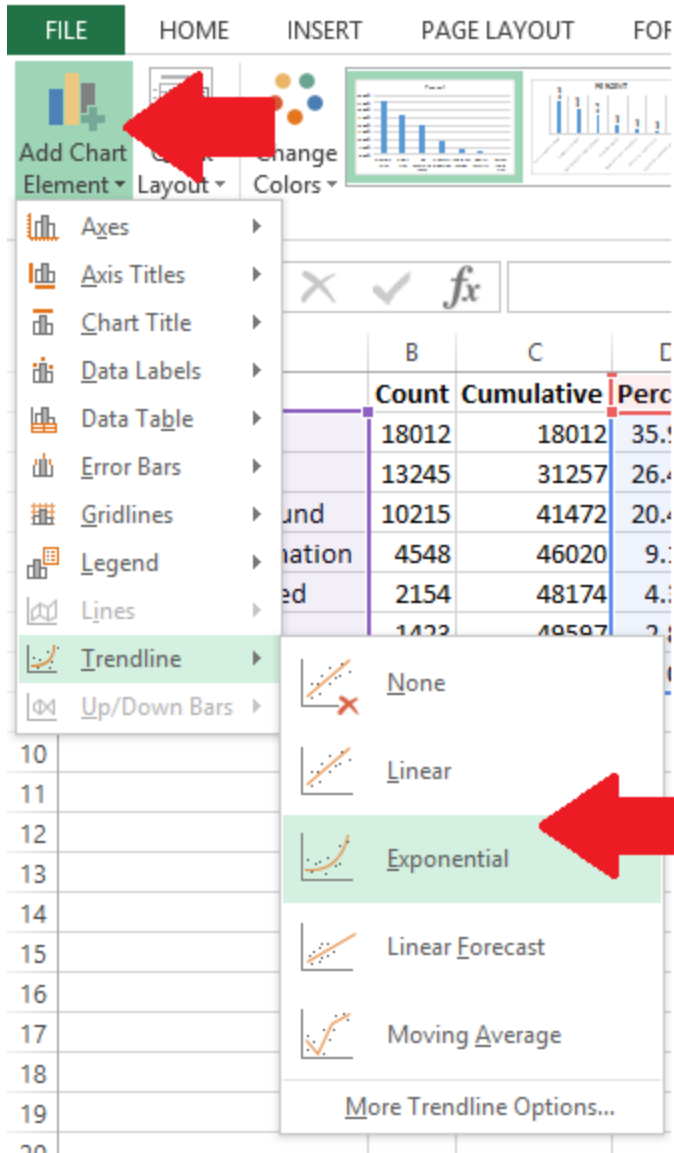
7. Select Add Chart Element → Data Labels, and select the format of data label you prefer for your chart.
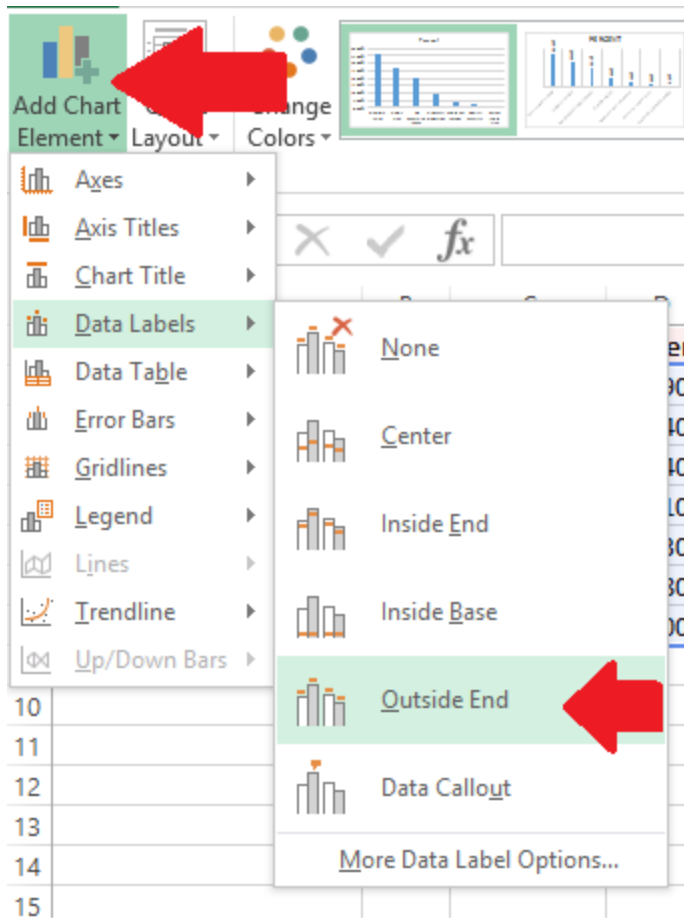
Use of Pareto Charts

Pareto charts are helpful analytical tools when you need to analyze frequencies or causes of problems. They also help narrow an approach for a problem that has many causes or is too broad to address in a single improvement project. Like the claims denials example above, you can find a single cause to work on that can yield large results across the entire process.

Pareto charts are also helpful when communicating information about causes to others, especially those outside of the Six Sigma process. Although Pareto charts are a powerful analytical tool, they also represent complex data in a visual format that is familiar to most anyone. Business professionals know how to read a bar chart, and putting the chart in order only makes it easier for individuals to see the true causes behind issues. For this reason, many Six Sigma experts regularly include Pareto charts when presenting to business leaders and others, especially if the data might be considered surprising or need visual reinforcement.

Voice of the Customer

Voice of the Customer, or VOC, is a foundational concept in many quality programs. The goal of quality is to make a better, more consistent product. One of the ways you know you've reached this goal is that your customers will be more consistently satisfied. The only way to reach this goal is to seek feedback from the customer, making VOC data critical to collect before, during, and after improvement projects.

Successful VOC programs are proactive and constant in their desire for feedback, and technology makes it possible to seek customer feedback in numerous ways. Some methods for capturing feedback include:

- Surveys via telephone, mail, email, or online
- Focus groups in person or online
- Interviews
- Beta or user testing
- Feedback forms
- Customer complaints
- Social media or site interaction
- Reviews
- Forums

The VOC can be sought as a means to clarify needs and desires, clarify specific problems with a process, or as a regular part of improvement, customer service, and marketing agendas.

Building a VOC Campaign

Asking the right questions, in the right way, helps you create powerful VOC campaigns that provide useable data for Six Sigma teams. We'll talk about two specific types of VOC campaigns in this section: general customer feedback and specific customer feedback.

General Feedback

General customer feedback is often obtained through feedback forms, customer complaint records, and passive information gathering via websites or social media. Through such methods, organizations are usually testing general waters to get a temperature reading: are customers happy overall, dissatisfied overall, and is there any direction as to the cause of customer feelings?

Pick up a feedback form in any fast food restaurant or access the online survey usually linked to on a receipt and you'll get a good idea of the type of information sought in general VOC campaigns.

Kroger, a grocery store chain in the United States, includes a link to a survey on most of its receipts. The survey first asks for the date, time, and an entry code from the receipt. This helps the company know where and when a person shopped so they can attribute feedback to the right location and staff.

Next, the Kroger survey asks in which areas of the store a person shopped. The rest of the survey asks specific questions about each area of the store a person visited, including:

- What was the overall satisfaction with the store?
- What was the customer's satisfaction with:
  - Employee friendliness
  - Prices
  - Service
  - Cleanliness
  - Items being available
  - Weekly specials
  - Ease of movement
  - Quality of brands

- o   Check out times
- Whether the shopper is likely to recommend the store to another person in the next 30 days.

These questions are designed to gauge general customer feelings on critical quality elements for the store. Understanding your critical to quality factors, or CTQs, is important to designing a strong VOC campaign. We'll cover CTQs more in depth in Chapter 8.

General VOC feedback is often used as a smoke alarm. A smoke alarm is designed to alert individuals in a business, home, or other building that the possibility of a fire exists. Smoke alarms are set at a sensitive level, so they go off when smoke is present and people within the building can take action. Often, the alarm and early action saves lives and can even reduce damage associated with a potential fire.

VOC data can work the same way. If numbers change suddenly in a certain area, an organization knows to look deeper into the issue. It's an indicator that a problem could exist; early investigation and action can help prevent problems from becoming bigger or more costly. For example, if a certain Kroger store always scored high in cleanliness, and the numbers dropped consistently across a month, then store management might need to revisit maintenance and cleaning training.

Results from general VOC feedback are also used in some organizations as an indicator of quality for certain employees. Sales and services staff are often rewarded financially and in other ways for high customer satisfaction scores. This also increases employee drive and satisfaction.

Specific Feedback
Sometimes, organizations want feedback that is specific to a problem, product, or idea. The same tools used in general feedback campaigns can be used in specific campaigns, but you can also tailor the VOC tool to the need. If you want feedback about a new app, you could use a beta test. If you want to test a product, idea, or marketing campaign, an in-person or online focus group might be best.

For specific feedback, you have to ask specific questions. This is especially true if you are seeking additional information or clarification of general feedback. For example, if Kroger did see a problem with ratings on cleanliness, it might want more information about how and where customers note uncleanliness. Without additional feedback, managers might have staff mopping the floors more when customers really felt the store was dirty because of a lack of lighting or because shelves were stocked in a sloppy manner.

Selecting the Right VOC Tools
Getting the right type of feedback—and keeping costs and timelines within budget—requires selecting the right VOC tool for your project. The table below rates each tool on relative cost and provides some brief pros and cons.

Tool	Cost	Benefits	Disadvantages
Feedback form	Low	-Gathers a lot of data from many sources -Can be geared toward numeric data for easier analysis	-An individual must decide to leave feedback, skewing results to people who feel strongly one way or the other

Survey via phone	High	-Can randomly select, which allows you to draw conclusions for the entire population	-Requires a lot of labor hours -Customers may be annoyed by unwanted phone calls
Survey via mail	Medium	-Can randomly select, which allows you to draw conclusions for the entire population. -Lower cost alternative to phone or in-person surveys.	-The customer must send it back for it to count. Because many people won't do so, you have to send more surveys to get a statistical sampling.
Social media	Low	-Ongoing ability to seek feedback. -Ability to ask questions on the fly. -Possibly the least expensive option for VOC.	-Requires an established social media following. -Relies on followers and fans, which means you are asking for feedback from people who already favor your brand in some way.
Focus groups in person	High	-Lets moderators seek more in-depth answers or feedback immediately	-Limits data pool to local customers or those willing to travel. -Can't use data to make assumptions about the general population. -Customers may be less inclined to be honest when face-to-face with surveyors
Focus groups online	Low	-Lets moderators seek more in-depth answers or feedback immediately -Doesn't require travel	-Can't use data to make assumptions about general population.

		and you can access customers across the globe	
User or beta testing	High	-Provides feedback about a specific produce, service, or process.	-Takes time and requires experienced users or testers.

The Likert Scale

When designing your own VOC tool, keep in mind how you intend to use the information gained. If you want to input data into statistical analysis software to test hypothesis or create visual charts, then you need to ask questions that yield actual data points that can be analyzed using statistics. A popular way to do this is with a Likert Scale.

Using a Likert Scale, you would frame all questions so they are answered via a 5-point ranking. The ranking can be any number of things, but most commonly is some variation of:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

The answers are coded with numbers when data is entered into statistical software. For example, an answer of strongly agree might be coded as 10. Agree would be 7, neutral 5, disagree 3, and strongly disagree 1. By using numerical data, you can easily create charts and graphs and run more in-depth statistical analysis, which is covered in future chapters.

Basic Metrics

We introduced some ideas about Six Sigma metrics in Chapter 1 when we talked about sigma level and defects per million opportunities, or DPMO. Metrics are extremely utilized when applying Six Sigma to processes and improvements, requiring that anyone working in a Six Sigma environment be familiar with them.

Defects per Million Opportunities

Many Six Sigma metrics come with an equation, just like standard deviation. For example, the equation for DPMO is:

(number of defects in a sample/opportunities for a defect in the sample) * 1,000,000

For example, if a mail-order retailer examines quality of the order process, it might sample forms entered by customer service representatives. If each form has 10 fields, then there are 10 opportunities for an error on each form. If the retailer reviews 90 forms, then there are 10 * 90, or 900, total opportunities for errors.

During the review, the retailer finds 2 errors, or defects. To calculate DPMO, the math would be as follows:

(2/900) * 1,000,000 = 2,222 defects per million opportunities.

Defects per Unit

DPU is a measure of how many defects there are in relation to the number of units tested. DPU is concerned with total defects, and one unit could have more than one defect. The formula for DPU is:

Number of defects found / number of units in the sample

For example, if a publisher printed 1,000 books and pulled out 50 books for quality checks, it might be looking for the following defects:

- Incorrect printing
- Incorrect alignment
- Missing pages
- A loose spine
- Torn cover

Out of 50 books, the publisher discovers:

- 3 books are missing pages
- 1 book is missing pages and has a torn cover
- 2 books have loose spines
- 1 book has incorrect printing and incorrect alignment

There are 9 total errors, as two books had two defects each.

The DPU is calculated by dividing defects by number of units sampled. In this case, 9/50 = 0.18.

DPU provides an average level of quality—it tells you how many defects on average each unit can be expected to have. In this case, that is 0.18 defects on average.

First Time Yield (FTY)

First time yield is the ratio of units produced to units attempted to produce. For example, if you put 12 cookies in the oven, but only 10 come out edible, then you haven't produced 12 cookies.

The formula for FTY is:

Number of good units produced / number of units entering the process

In the cookie example, the FTY is 10/12, or .833.

Most products or services are created via multiple processes; you multiply the FTY for each process to calculate an overall FTY. For example, consider the following process chain:

- 100 units enter process A and 95 units exit.

- 95 units enter process B and 85 good units are achieved.
- 85 units enter process C and 80 good units exit.

The FTY would be calculated as follows:

- 95/100 = 0.95 = FTY of process A
- 85/95 = 0.89 = FTY of process B
- 80/85 = 0.94 = FTY of process C
- 0.95 * 0.89 * 0.94 = 0.79

The overall FTY of the process is 0.79.

Rolled Throughput Yield (RTY)

The rolled throughput yield, or RTY, provides a probability that a unit will be generated by a process with no defects. One of the main differences between RTY and basic yield or first time yield is that RTY considers whether rework was needed to generate the number of final units. This is a valuable concern, because organizations don't always think about the rework that is inherent in a process, which means they often measure a process and deem it successful even if muda is present.

RTY is calculated in a similar manner to FTY, but it takes rework into account. If process A from the FTY example only achieved a yield of 95 because someone reworked five items to make them good, then RTY calculations add five instances of rework into the ratio. The formula is:

(Number of units entering - (scrap + rework))/number of units entering process

In the case of process A: (100 - (5+5))/100 = 90/100 = 0.9

Consider the following process chain:

- 100 units enter process A. Five are scraped, 10 are reworked, and a total of 95 are produced.
- 95 units enter process B. Ten are scrapped, 5 are reworked, and a total of 85 are produced.
- 85 units enter process C. Five are scrapped, 15 are reworked, and a total of 80 are produced.

The RTY is calculated as follows:

- 100 – (5 + 5) = 90, 90/100 = 0.9 RTY for A
- 95 – (10 + 5) = 80, 80/95 = 0.84 RTY for B
- 85 – (5 + 15) = 65, 65/85 = 0.76 RTY for C
- 0.9 * 0.84 * 0.76 = 0.574

The overall RTY for the process is 0.574, which is a much lower rate than when you look at FTY alone. RTY doesn't provide an indication of final production or sales, but a low RTY indicates that there is waste in the process in the form of rework.

See for yourself

A government agency handles applications for assistance for local families. The process for each application includes:

- A representative enters the family's information into a computer system
- A separate staff member reviews the information and uses an income scale to determine if the family is eligible for any assistance
- The second staff member sends the family a letter stating their options for assistance

All of the applications and customer feedback for March were reviewed, and the team found the following information:

- 643 families sought assistance in March
- 3 families were not able to complete the application process because the representative took too long to see them
- 50 applications could not be passed to the second rep because of incomplete information
- 45 applications did not have complete information at first but that information was later received
- The second staff member was able to process all completed applications she received
- Of all letters that went out to families, 10 included incorrect information

Calculate the FTY and the RTY for this process.

Chapter 6: Approaching the Problem

Understanding how to approach the problem – beginning to identify the problem and defining it with a statement – is critical to creating a foundation for successful Six Sigma projects. In later chapters, we'll cover the importance of defining a variety of project, process, and problem aspects, but in this chapter, we're going to discuss the project in general, digging deeper via a series of why questions, and creating a general problem statement as a launching point for a project.

Problem Functions: y = f(x)

Because Six Sigma approaches things with a statistical mindset, it considers all problems as a function. Using mathematical symbols, this looks like:

$$y = f(x)$$

Y, the problem   is   a function   of x, the cause(s)
or outcome   or input (s)

The y=f(x) statement can be used in two ways. First, it is a general map for stating a problem. Y (the problem) occurs because some X (input or cause) is occurring. In reality, Y is usually occurring because of some group of causes or inputs, which means there are going to be more than one X inputs.

The idea can also be applied to specific processes and outcomes within the problem. As you get more and more granular, the y=f(x) concept becomes increasingly mathematical; in many cases, you can graph the relationship between the output (y) and the input (x).

To understand the concept of thinking of problems as a function, let's look at a problem that might occur for a large HVAC service provider. The manager of a service team has discovered that service calls are taking much longer than expected; in fact, his five team members take 1.75 times longer on average than other service reps in the company to handle all types of calls.

To find out what might be causing the situation, the manager researches the problem by talking to the reps, talking to the customers, and going out on random calls with all five representatives. He makes the following observations:

- One representative is a native to the area the team services, which means he or she knows many of the customers personally. This results in friendly chatter that lengthens the time on the job.
- One representative is providing homeowners with very in-depth explanations and education about HVAC issues, sometimes over and beyond what the homeowner would ever need to know regarding his or her HVAC unit.
- One representative is new to the job and takes longer to complete each task because he or she is unsure of the work, has to double-check the work, or calls another rep to ask questions about the work.
- The remaining two reps perform work in times that are on par with company averages.

The manager distills this data down to two overall causes for the problem:

- Too much talking (reps one and two)
- Inadequate training

The problem can now be stated as a function:

> The extra time is a function of too much talking and inappropriate training.

The manager also now has two root causes to address. The example is simple, but it illustrates the basic concept in defining a y=f(x) relationship for a problem and its causes. It's not always so easy to conduct the research and analysis to find the relationship, but the relationship is *always* present.

Some other examples of y=f(x) relationships include:

- Low customer satisfaction with hamburger taste is a function of an uncalibrated grill.
- Low employee morale is a function of a poor time-off approval system.
- Customer wait times are a function of technology distractions for employees.

The 5 Whys

Data analysis is one of the best ways to validate a y=f(x) assumption, but teams who are familiar with processes can often arrive at some basic relationships through a process known as the 5 Whys. This is a brainstorming tool that asks increasingly granular why questions about a problem or process, seeking to understand the root cause or actual problem. The 5 Whys can be used to define a problem or to begin seeking causes.

For example, consider the hamburger example above. Teams addressing a problem of customer satisfaction might begin doing so because feedback forms have shown a lower-than-normal satisfaction with food quality over the past week.

The team first asks: *Why are customers dissatisfied with the food?*

Looking at feedback tied to orders, the team notes that the customers who are rating the food poorly are mostly customers who ordered hamburgers of some type. The answer to the first question is that the customers are dissatisfied with the food because they are dissatisfied with the hamburgers.

Why are customers dissatisfied with hamburgers?

The team looks at written feedback on forms or speaks with customers directly and discovers that many customers feel that their hamburgers were undercooked. The new answer is that customers are dissatisfied with hamburgers because the meat is undercooked.

Why is the meat undercooked?

An investigation into the kitchen reveals that the grill is not properly calibrated and is providing inconsistent results. At this point, you have the y=f(x) relationship, but the team could keep asking questions.

Why is the grill not properly calibrated?

Further investigation shows that the morning shift, responsible for calibrating the grill, has a new grill cook. During training, education on performing this function was omitted. The grill is not properly calibrated because the employee responsible was not properly trained. Now the team has a specific cause and a solution: train the grill cook.

In a Six Sigma environment, the team might move on with one more question: Why was the grill cook not properly trained? This might lead to the development of a consistent training policy so the problem doesn't occur the next time a new grill cook is hired.

In the hamburger example, it only took four why questions to get to the root of the problem, and a fifth question started pointing to controls or long-term solutions. It isn't always this easy; the tool is called the 5 Whys because it often leads to answers within five questions. However, teams could ask a dozen questions if they begin at a very high level and work down through a complex process.

When to Use 5 Whys
One benefit of 5 Whys is that it only costs your team a small amount of time to use—a team familiar with a process can conduct a complete 5 Whys session in less than an hour if a moderator keeps things on task. Because of its simplicity, the 5 Whys tool can be used for almost any problem. Use it to address a problem team members bring up, to address a problem a supervisor noticed, or to address the vague feeling that there is a problem when no one has been able to define what is actually wrong. At the very least, a 5 Whys session facilitates communication and thought.

In a Six Sigma project environment, 5 Whys is usually deployed when processes involve human interactions or people-powered inputs, though it can be an effective start to brainstorming on any process.

Conducting a 5 Whys Session
Since a 5 Whys session is usually based on input from subject-matter-experts, gather people who are close to the process. On a white board or web conference screen, display a basic problem statement as you understand it. This problem statement is not going to be detailed like the statements we'll discuss in the next session—a 5 Whys session is often one of the tools you use to get to that detailed statement.

Examples of statements you might see in a 5 Whys station include:

- Customers are not happy with the selection of produce

- Customers are receiving orders late
- The printing process is resulting in too many defects
- Lead times on the bottling process are excessive
- Employees are not happy with vacation schedules

These are all fairly general statements that simply say something about defects or dissatisfaction. Begin by asking the highest-level "Why?" question possible about the statement. "Why are employees not happy with vacation schedules?" Write this question down.

The team works together to provide a high level answer to the question. Employees are not happy with vacation schedules because it's rare to get the exact time off requested. Write the answer down under the question, then create the highest-level "Why?" question you can about the new answer.

"Why are employees not getting their first choice time off for vacation?" Perhaps the answer is that supervisors take so long to approve vacation requests that other employees have also asked off for the same time, so it's hard for supervisors to accommodate everyone.

The next question is "Why are supervisors taking too long to approve requests?" The answer might be that the time-off system is too cumbersome, so supervisors put off approvals until they have a lot of time to manage them.

"Why do supervisors see the system as cumbersome?" Because there are wait times when moving from screen to screen and each approval requires a vast number of clicks and entries.

Now, the team has a root cause: the system itself is inefficient, which leads to problems down the line. If the team can correct the programing issues and encourage supervisors to approve vacation requests faster, employee morale can be improved.

Creating a Problem Statement

A Six Sigma improvement project usually starts with a formal project statement. This is different from the basic statements used to launch a 5 Whys session. A strong problem statement is similar to a 30-second elevator pitch, which executives and sales people across the globe use to hook clients or business investors on an idea. The problem statement, like that pitch, provides enough information that a busy executive can understand what the issue is and why there is a need for an improvement effort.

Project statements should include:

- Where and when the problem was recorded or was occurring
- A measurement of magnitude for the problem, preferably with some tie to cost
- A brief description of the problem that could be understood by professionals not closely aligned with the process (avoid too many niche words and acronyms if you will be presenting information to non-niche professionals)
- A brief notation about the metric used to measure or describe the problem

Example of a Strong Problem Statement

In the first quarter, the California distribution center sent 108,000 packages. Of those packages, 15,000 were returned, resulting in a 13.8 percent return rate. The rate of return is above the accepted 7 percent rate and cost the company an additional $372,000 for the quarter. Over the course of the year, the current process could result in additional costs of over $1.4 million.

This problem statement covers all the basic information:

- When? During the first quarter of this year.
- Where? The California distribution center
- What? Returns
- How many? 15,000, or 6.8 percent above expectations
- What is the magnitude? The cost could be $1.4 million a year

The problem statement doesn't talk about solutions or provide too many details. This is a strong problem statement because it answers all the basic questions *and* it provides a significant reason for leadership to invest interest: $1.4 million a year is a big loss.

Example of a Weak Problem Statement

The Canton, Ohio bakery is producing undercooked bread. Customer dissatisfaction with the bread is resulting in returns and bad word of mouth. The bread is supposed to be baked at 350 degrees for 40 minutes.

This statement introduces a problem, but it doesn't provide details about when the problem occurred, how it was measured, and what the true magnitude is. The problem statement also begins going into possible root causes when it includes how the bread should be baked; the problem statement isn't the place to begin this type of analysis.

This statement might be better framed as:

In November and December 2014, customer satisfaction complaints were traced back to bread baked in the Canton, Ohio facility. The facility produced 300,000 loaves during that time period and received 50,000 complaints of bread being undercooked. Bread returns and loss of sales related to quality are estimated to be $125,000 per month.

Writing Your Own Problem Statement

When you first start writing problem statements, it's sometimes harder than you might expect to get all the information into a couple of sentences. To avoid leaving out information, it helps to use a list and to consider yourself a problem-statement journalist.

When journalists write a report, they are looking to answer some specific questions: What happened? Who did it happen to? When did it happen? Why does the audience care?

The same is true when you are writing a problem statement. Follow the problem statement checklist:

- Where did the problem occur?
- When did the problem occur?

o   What process did the problem involve?
o   How is the problem measured?
o   How much is the problem costing (in money, time, customer satisfaction, or another critical metric)?

Use the checklist to construct the problem statement, and then ask yourself: Could someone else answer all the questions in the checklist from your problem statement alone? Before you present your statement to a boss or other decision-maker, test it out with a coworker or someone who is not as familiar with the issue as you are.

Here are two problem statements. See if you can answer all of the questions in the checklist just using the information provided.

Problem Statement 1
The call center in Jacksonville, Florida, handled 36,000 calls in February 2015. Of those calls, 8,000 had an average speed of answer (ASA) over the contract-required 15 seconds. Those 8,000 service-level-agreement violations resulted in costs of $200,000.

Problem Statement 2
The call center in Ohio has a service-level-agreement issue that is costing approximately $9,000 per day.

Problem statement 1 answers all of the questions on the checklist:

o   Where did the problem occur? Jacksonville, Florida
o   When did the problem occur? February 2015
o   What process did the problem involve? Answering phone calls
o   How is the problem measured? Average speed of answer
o   How much is the problem costing (in money, time, customer satisfaction, or another critical metric)? $200,000 per month

Problem statement 2 does not answer all of the questions:

o   Where did the problem occur? Ohio
o   When did the problem occur? Unknown
o   What process did the problem involve? Unknown
o   How is the problem measured? Unknown
o   How much is the problem costing (in money, time, customer satisfaction, or another critical metric)? $9,000 per month

Problem statement 2 would benefit from adding a place, a specific reference to a process, and a specific metric.

Problem Statements Lead to Objective Statements/Goals
Another way to tell you have a strong problem statement is that you can create an overall project objective statement or goal directly from the problem statement. Consider the two examples above.

The team working with problem statement 1 might create an objective that states:

The goal is to reduce answer speed SLA violations in the Jacksonville call center by 50 percent within three months. The potential savings to the company is $100,000 per month.

The team working with problem statement 2 would not be able to create a goal statement with this much detail. They would simply be able to say they hope to reduce the service-level-agreement violations in the facility.

Specific problem and objective statements are critical to Six Sigma project success for several reasons. First, being as specific as possible sets up appropriate expectations. In the first example, leadership has a specific expectation of the project: the team is going to work to reduce average speed of answer, and success is a reduction of 50 percent. No one is going to expect the team to solve another problem, such as customer satisfaction with phone operators. That is out of scope for this project.

In the second situation, the problem and goal statements are not specific enough. What SLA violations is the team addressing? What, exactly, does success look like? Is the team expected to reduce costs completely? Not being specific enough sets you up for failure. Leadership might expect you to address service level agreements that have to do with how reps route phone calls, but you are only intending to address service level agreements that relate to the speed with which calls are answered. Leadership might think success is a 75 percent reduction in costs when you intend to work toward a 25 percent reduction.

Creating strong problem statements lays a stable foundation for the rest of your project, gives the team a beacon when they get overwhelmed with information, and reduces the chance of scope creep and misunderstanding.

Scope and Scope Creep

Scope is the definition of what is included – and what is not included – in a process or improvement project. You begin defining scope with your problem statement. The information you include in the statement gives clues to what you will be working on, and the goal statement provides appropriate limits on the work to be done.

Six Sigma projects are not everlasting initiatives, though the culture of improvement that comes from Six Sigma is. This means your individual project needs a specific, challenging, but attainable goal. Once that goal is met, the project is concluded and you begin looking for a new problem to improve upon.

Scope creep occurs when teams look to make infinite perfections on a process, attempt to reach unrealistic goals, or begin to reach for processes or problems that are out of the original scope. For example, consider the problem statement from one of our examples in this chapter:

In the first quarter, the California distribution center sent 108,000 packages. Of those packages, 15,000 were returned, resulting in a 13.8 percent return rate. The rate of return is above the accepted 7 percent rate and cost the company an additional $372,000 for the quarter. Over the course of the year, the current process could result in additional costs of over $1.4 million.

A related goal statement might be:

The goal is to reduce the return rate to the accepted 7 percent and save the company $372,000 per quarter.

In scope for this project are processes related to shipping and returns only insomuch that they impact the return process. At some point, the team might stumble upon a packing process that is using too much material, thus costing the company an additional $50,000 per month. Unless the packing process is causing the returns—which is not likely in this situation—this issue is not in scope for the team and they should not seek to fix it. The team can, however, note the issue or report it so that a future project might be launched to address the problem.

It takes discipline and organization to address only that which is in scope for a project. Understanding the relationship between problems and inputs and knowing how to create a strong problem statement are the first steps to controlling an improvement process.

Unit 2: Projects and Processes
Chapter 7: What is a Process?

In Unit 1, we introduced Six Sigma as a concept and covered a lot of principles that are foundational to creating and maintaining improvement in a business. In Unit 2, we'll begin looking at what a process is, why quality is important in a process, and how Six Sigma projects can improve processes. The concepts you learn in Units 1 and 2 become the bricks used to build project work that we discuss throughout the rest of the book.

What is a Process?

A process is a collection of tasks, steps, or activities that are performed, usually in a specific order, and result in an end product such as a tangible good or the provision of a service. In a business, multiple processes work together to achieve organizational goals. Technically, the business or organization itself can be seen as one enormous process. For example, a law firm that handles criminal defense cases operates via a huge, complex process. Defendants and their cases enter the process. The output of the process is the result of the case: a bargain with prosecutors, a win or loss in court, or dismissal of charges prior to court.

Within the huge process that sees the defendant through to his or her outcome, there are hundreds, possibly thousands, of smaller processes. There are processes within processes. A lawyer and team of paralegals might move through the process of negotiation; a legal secretary might go through the process of setting appointments. Holding depositions, making copies, sending letters, and filing legal documents are all examples of processes. At the most detailed level, even answering the phone or typing a letter can be considered processes.

In Chapter 6, we briefly introduced the idea of scope and scope creep. To define and maintain proper scope, we said that a Six Sigma team had to identify the processes that were related to a process improvement or project. In the legal firm example, a project to reduce the time it takes to set appointments would likely not include a process for filing a legal brief. To know that, however, you have to know that the legal brief process doesn't share components with the appointment setting process. In this chapter, we'll cover the components of processes and a format for mapping those components known as a SIPOC.

Four Layers of the Process Definition
As you continue with this chapter, you'll see that processes can be very complex. Our basic definition above is just that: Basic. Before we begin defining the components of a process, let's peel back the layers of this concept known as "a process."

The Steps
Whether physical, digital, or ideological, every process is a series of some number of steps. You can put those steps on paper in the form of instructions—often called a standard operating procedure in a formal business training or policy document -- or a visual diagram known as a process map. A process

map uses standard shapes and connections to create a map of a process that can be understood by most employees and any Six Sigma team member.

Processing Time

Processes all take a certain amount of time, and processing time can change with a variety of factors. Process maps and documents can only record information such as the average time a process takes or measures of variation in the processing time. This information is often noted in such documents because it provides valuable information to teams, but real-time observation of a process almost always provides better information about processing time.

A retail chain might create a process map for restocking a certain area. The process documentation notes an average time of two hours to fully restock the shelves in the defined area. In an effort to obtain more data about the process, a Six Sigma team observes employees actually performing job functions in real time at various times of day for two weeks. Some notes that come from those observations include:

- Stocking in the evening takes only minutes.
- Stocking during the day is hampered by the movements of customers.
- Stocking work performed during peak shopping hours usually takes the longest.

With just this information, you can probably see an easy way to reduce stocking time in this example: move stocking duties to non-peak times when possible. Simply understanding the steps to stock the area is not enough to understand the process; you also have to gather data about process times.

Interdependencies

Almost any process in a business will be dependent upon one or more other processes. Remember, the business itself is a series of linked processes all working toward the same goal or goals. Sometimes, interdependencies are noted on processes maps. Other times, interdependencies are resource-related.

For example, consider a very simple passenger train scenario. The train leaves station A with passengers, carrying them to station B. Before the train can leave, the engineer must be on board and prepared to operate the machine. Safety checks, clearance from the rail yard, the closing of all the doors: these are all processes that must be completed before the train leaves the station. The process of the train transporting passengers is dependent upon the completion of other processes.

When working with processes during a Six Sigma improvement project, teams must be aware of interdependencies. What does any process you are working on rely? What relies on your process? The first is important because you might need help from processes or people upstream from your process when making improvements. The second is important because you have to know how your improvements will impact downstream processes and people – and improvement in the performance of your process doesn't do any good for the company or organization as a whole if it hinders the

performance of a downstream process.
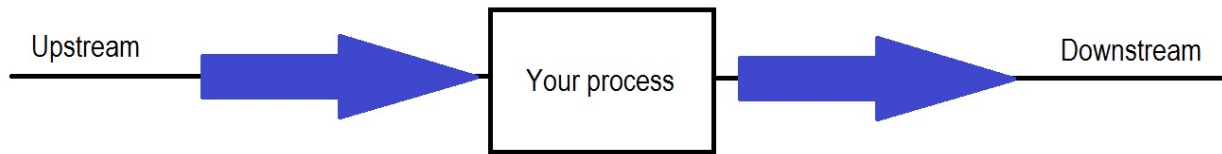
Resources and Assignment

Processes require resources. Like a motor vehicle requires fuel or electricity to run, a process requires resources such as power, people, cash, digital bandwidth, computer equipment, machinery, supplies, parts, and even skill. Since someone in an organization has to approve and pay for resources, project teams must understand the resources involved, the cost of those resources, and the owners of the processes and resources in question so they can make appropriate requests about needing additional resources.

Major Process Components

Processes are made up of components that include inputs, outputs, events, tasks (activities), and decisions. Inputs enter the process when a specific event occurs; tasks and decisions are performed upon or with the inputs. At the end of the process, an output is generated. Most of the time, the idea of process components is introduced with a simple factory-based illustration: raw goods of some type enter the factory, work is performed, and finished goods leave the factory. For example, if a factory makes hard candy, things such as sugar, water, plastic, and electrical power enter the factory. Equipment and employees take the inputs and work with them. The end result is a wrapped piece of candy ready for the store.

The figure below illustrates the idea of process components using a pizza shop example. An event – the ordering of a certain pizza – begins the process. You can see all of the components in the diagram, and we'll talk about each component in detail in the section that follows.
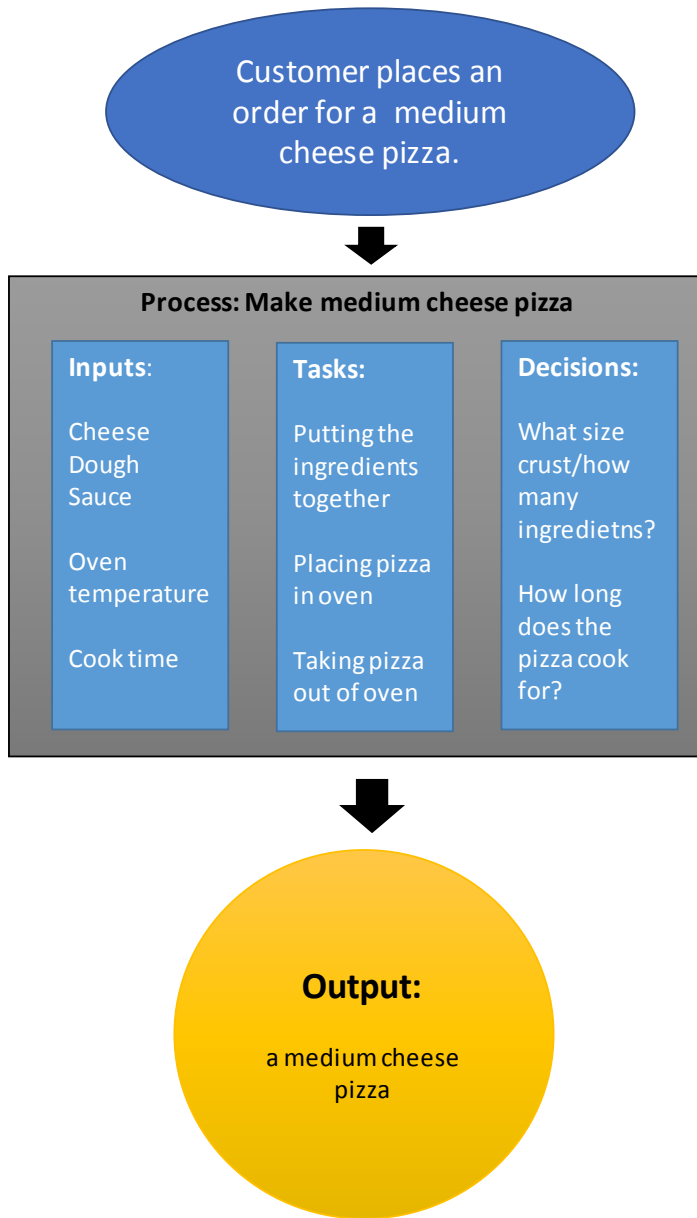
Figure 1 Medium Cheese Pizza Process

Inputs

Input refers to anything that enters a process or is required to enter a process to drive the creation of an output. In the pizza example above, the inputs are all the ingredients needed to make the pizza. You might also consider factors such as oven temperature, type of oven, and the cook's skill level to be inputs in the process.

Understanding all inputs to a process is important in Six Sigma because inputs are often causal – or related to causal – factors regarding a process. Inputs or the results of those inputs can cause errors or

defects in the process. The cookies burn when the oven is too hot. The computers made in a factory don't function when the circuit boards are bad. A lawyer doesn't win his case if his or her information is wrong. The oven temperature, the circuit boards, and the lawyer's information: these are all inputs into processes that are also causing problems within the processes.

Other reasons for defining inputs when working with a process include:

- Understanding the resources required for a process to run
- Identifying extraneous inputs that aren't required
- Understanding costs for the process
- Understanding how the process relates to processes that come before it

Remember, in a business, processes are linked together to accomplish a final goal or goals. The inputs entering process B might be the outputs leaving process A.

Outputs

The output of a process is the service or product that is used by the customer of the process. In the pizza example, the output is the cheese pizza the customer is going to eat. In the candy factory example, the output is the hard candy that will be sold by the retail store.

The process customer is not always the traditional end customer who purchases a product or service. Customers can be internal or external. An example of a process serving an internal customer might be seen in a business office that employees a receptionist to answer phone calls. If the receptionist takes messages or transfers phone calls, he or she is serving both the person on the phone *and* the person who is receiving the call or message.

In some cases, the customer of a process is not even a person. Many processes feed other processes. In a pharmacy, the process of entering data about a prescription feeds the process that bills an insurance company for the medication.

From a Six Sigma perspective, an output is almost always of more value to the ultimate process than the input is. The process itself involves adding value of some kind to the inputs. A bakery puts raw bread dough through the oven to add value to it: the result is an edible and tasty product that a consumer is more likely to purchase or to pay more for.

Events

Events are specific, predefined criteria or actions that cause a process to begin working. A process that performs well responds to an event just like a light bulb responds to the action of a switch being pulled. Six Sigma teams must determine what events trigger a process because it helps them understand why a process is being performed and whether the process is being run when it isn't needed.

Consider an example about compliance audits in a financial sector company. Perhaps a company created a specific audit process that initiates when red flags on accounts are raised; the audit process is comprehensive and usually takes an average of 80 labor hours. You can imagine that it is an expensive process to run. In investigating, a Six Sigma team identifies the event associated with the process: anytime a discrepancy in an account is noted by a clerk, the compliance process is triggered.

The team investigates and realizes that this is true even when the discrepancy was minor – a few dollars or less – or the clerk was able to reconcile the discrepancy later in the day. The team might suggest that the relationship between the process and the event is a problem. The process is running at times when it might not be valuable for it to do so.

Tasks

Tasks, or activities, are the heart of a process. Just as the heart pumps blood through your body, the tasks within a process pump the inputs through, turning them into the outputs. Tasks are the physical, automated, or computerized actions within a process. Examples of tasks include:

- A machine joining two metal parts with a weld
- A person entering data into a software program
- A computer processing data to create a report
- An email being written
- A piece of computerized work being routed within a workflow system
- A chef chopping ingredients for a recipe

Decisions

Decisions are closely related to tasks and can be tasks themselves. A chef preparing ingredients for a soup dish has to chop those ingredients, but he also has to decide how much of each ingredient he needs. His decision will likely be guided by the recipe and the number of people he has to feed.

Decisions within a process are typically governed by a set of rules. Sometimes those rules are formally documented; other times, decisions are made via informal rules along with staff knowledge and experience. Processes that are governed by informal rules can have problems of consistency; even when all staff are experienced, they could have individual variations on performing a task. And, as we discussed in Unit 1, variation can lead to more opportunities for defects and a reduction in quality.

Using the task examples above, here are examples of decisions in a process:

- A person entering data into a software program makes a decision to select a certain drop down category because of training or rules provided by the software
- A computer processes a report; the result of that report is a number above a set threshold, so the computer sends the report to a person
- When writing an email, a person chooses to include certain specific information, such as an order number or customer number, because it is protocol to do so when sending this type of email

All Components Are Related

You're probably noticing that processes can be extremely complex, and the relationships between all the components are equally complex. Inputs can be outputs from previous processes; outputs can be inputs in the next process. A decision might result in an event that starts a new process, but it can also be the factor that decides which task begins. As Six Sigma teams work with processes – observing them, diagramming them, and measuring them – the teams begin to understand the relationships of the components, and that helps them make decisions about possible improvements and changes.

Process Owners

As teams work to improve processes, they need to understand who the process owners are. Depending on the business organization, process owners can be the people with the power to approve changes. In some organizations, the lowest-level owner might not have veto or decision power about all changes, but he or she is held responsible for the performance of the process.

A process owner can be:

- A person in charge of a very specific process or function
- A team supervisor or department manager
- An executive-level individual who is probably responsible for a number of processes in his or her division

What does a process owner do?

The responsibilities of a process owner are often defined by the infrastructure of a specific business, but commonly, a process owner will:

- Monitor how the process performs, usually using one or more metrics or regularly reported data elements.
- Understand how the process fits into the overall business, why the output of the process is critical to business goals, and what inputs feed the process.
- Ensures the process is documented via standard operating procedures (SOPs) and that process documentation is kept current and accurate.
- Ensures operators within the process have the resources and training they need to complete their jobs.

In a Six Sigma environment, process owners might also ensure a control plan is in place and regularly review the process for possible improvement opportunities.

Data

Finally, all processes generate some form of data. Even if data isn't yet being captured, information is inherent in any process. A computer program that automatically routes work in a workflow might generate data such as the number of items in work queues, how many items were worked that day, the time items have been waiting in queues, how many items were transferred, and where those items were transferred to. A process for filling bottles with liquid might generate data such as how much liquid is placed in each bottle, how many bottles per hour are filled, and perhaps variation between bottles.

Data is extremely valuable to Six Sigma teams because it's often how they define whether a process is in control and successful.

Defining Process Components: The SIPOC

The SIPOC diagram is often an important part of the define stage of a Six Sigma project. But you can use the SIPOC diagram anytime you want to learn more about a process or understand how a process in a business environment is linked to other processes.

SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customer. For the purposes of a SIPOC, inputs and outputs follow the same guidelines described previously in this chapter. Suppliers are the people, processes, and organizations that supply inputs to your process. Customers are the people, processes, and organizations that make use of the outputs of your process. The process itself is the series of steps that take the inputs and make them outputs.

Benefits of a SIPOC Diagram

The SIPOC diagram is one of the most often used tools for understanding process components and process relevance because it is so effective and simple. Teams can create SIPOC diagrams in a single brainstorming session, though effective diagramming usually requires the presence of a process owner and one or more SMEs who are familiar with the process on a daily level.

SIPOC diagrams are also infinitely scalable. Teams can diagram processes at a very minute level, but they can also use SIPOC to diagram an entire business. We'll walk through creating a SIPOC diagram and then provide some examples of SIPOCs at various levels to illustrate scalability.

> **SME: Subject Matter Expert**
>
> An SME is someone who is closely associated with or familiar with a process or work function. Six Sigma teams invite SMEs to participate in discussion, process mapping sessions, or problem and solution brainstorming, because SMEs have valuable insight that might not be provided by high-level process owners or a review of the data.

Creating a SIPOC Diagram

You can create a SIPOC diagram as an individual exercise or within a team environment. SIPOCs can be created using a computer and software tool such as Word or Excel, but you can also draw them freehand on a whiteboard or piece of paper. Freehand diagramming is a valuable brainstorming tool because teams can quickly edit the rough draft of the diagram as they discuss a process. Keep this in mind :many of the diagrams presented in this book look clean because they have already been typed and edited. As you diagram your own processes, they can tend to look messy at first with edits, arrows, scratch outs, and inserts. "Editing" or putting rules on the brainstorming process can limit the ideas and information that flow during the process. You can always create a clean copy of the diagram for presentation purposes when you are finished brainstorming.

Step 1: Create Swim Lanes

A SIPOC diagram is based on swim lanes. Swim lanes let you show how cross-functional activities and resources relate to your process. A SIPOC diagram gets five lanes: one each for Suppliers, Inputs, Process, Outputs, and Customers. You'll end up with something that looks like the figure below.

Suppliers	Inputs	Process	Outputs	Customers

Step 2: Set Boundaries and Name Your Process

Before beginning a SIPOC session, set a definition for where your process or responsibility begins and ends. If you don't understand the scope of your process, then your SIPOC session can get out of hand or produce a diagram that isn't useful for your project.

Naming your process helps the team identify more readily with a specific aspect of the business. For example, a team working to improve processes within a medical office might look at a process named "Gathering New Patient Information." By naming the process, the team has put some scope limitations in place: the team will talk about things related to gathering information from patients. The scope is further limited to the process by which staff gathers information from *new* patients.

As you work through the SIPOC diagramming exercise, you can point back to the name and the scope you've defined to keep the team on task with the discussion.

Step 3: Complete Swim Lanes

You can complete SIPOC swim lanes in any order, but best practices usually have teams enter data in the following order:

- Process
- Outputs
- Customer
- Inputs
- Suppliers

Realistically, teams will think of things as they work through the process, so you'll be returning to swim lanes repeatedly to move information around and add new information.

A SIPOC isn't usually a low-level or detailed map of the actual process, so keep teams high-level when completing the process swim lane. You can simply enter the name of the process in that section, or you can list some of the high level steps required for the process. Listing steps is a good exercise if teams aren't sure about outputs and inputs – beginning to visualize the process usually helps ideas flow about how the process is connected to other processes and resources in the company.

To keep the session from turning into a detailed process mapping activity, ask the team to describe the process in less than five to seven steps. Keep things simple by limiting process steps to short verb-noun combos such as "Enter information," "Collect money," or "Place labels."

Name Outputs and Customers

Once you have a rudimentary process definition, begin with either inputs or outputs. Ask the team "What does this process make? What comes out of this process?" Those answers go into the outputs swim lane.

Next, ask the team "Who or what uses the things that come from this process?" Place those answers in the customer swim lane. Remember that customers can be external or internal, and another process can be the customer in cases of automation.

Name Inputs and Suppliers

Ask the team "What does the process need to perform? What raw goods or materials feed the process?" Record those answers in the inputs section.

You can divide the idea of inputs into two types, if you like. First, you have the actual inputs – the goods and services that are transformed by the process to create the outputs. Second, you have *enablers* of the process. These aren't technically inputs because they don't enter the process and aren't changed by the process; instead, they are required for the process to function. Machinery is an enabler. In a process that cuts metal parts from a steel sheet, the machine that does the cutting is an enabler. While it's not required, separating enablers on your SIPOC helps you define the process and provides additional information for later in the project.

Once you have a list of inputs, ask the team, "Where do the inputs come from? Who or what supplies the process with these things?" As with customers, suppliers can be external or internal. A vendor might provide the raw sugar that goes into the candy in a factory; the marketing department might provide the leads that the sales department uses to create orders.

Suppliers can also be other processes, particularly in an automated environment, and you can have a list of several suppliers for one input in a raw SIPOC diagram. For example, support tickets come into the Information Technology (IT) department. The supplier of the ticket could be both the end-user submitting the ticket and the automated process that routes the ticket to the appropriate work queue. If you are documenting enablers, you might record the end-user as the supplier and the automated process as the enabler.

Step 4: Validate the Information

Ensure that your understanding of the process at this high level is accurate by validating your diagram. If you've put together a comprehensive team that includes SMEs, the team can validate most of the information on its own. It's always a good idea to get a second opinion on anything the team isn't sure about, though. Invite other SMEs or the process owner to review the diagram briefly with the team and provide feedback.

Tips for a SIPOC Brainstorming Session

One of the best ways to create an initial SIPOC diagram during a team session is on large pieces of paper or a whiteboard. Create swim lanes by drawing them on the whiteboard or hanging a piece of paper for each swim lane on the wall. Provide the team with sticky notes and markers; write on sticky notes instead of writing directly on the board or paper. This lets you move components around quickly as you work through the diagram.

Sample SIPOC Diagrams

Here are some sample SIPOC diagrams. The first diagram is at the highest level: the process is the business itself. The second diagram features an automated process. The third diagram illustrates a people-powered factory process and includes enablers.

Business-Level SIPOC Diagram

This diagram shows the SIPOC for a mid-sized printing company. It's a very high-level, simplified SIPOC that shows how customers and vendors provide information and items; the printing company then turns those inputs into products such as printed business cards. The final product goes to individuals, businesses, and marketing professionals who placed the order.

Suppliers	Inputs	Process	Outputs	Customers
Paper vendor	Orders/customer specifications	Receive order	Business cards	Individuals
Ink vendor	Paper	Layout designs	Brochures	Business owners
Copy and print machine provider	Ink	Print designs	Banners and signs	Marketing departments
Customer	Designs	Deliver printed product	Mailers	
			Letterhead	

Most of the time, a Six Sigma team won't deal with a business-level SIPOC diagram. However, if the team includes members from outside the division or company, such as vendors or consultants assisting with an improvement, then starting with a high-level diagram can help those outside of the business understand the overall goals of the company.

SIPOC of an Automated Process

The diagram below represents an automated process in a mail-order pharmacy. The process in question puts labels on bottles that are to be filled with corresponding medications. The scope of the process is only the labeling of the bottles.

Suppliers	Inputs	Process	Outputs	Customers
Bottle sorting machine	Unlabeled bottles	Choose bottle size	Labeled bottle	Bottle-filling station
Label machine	Data for labels	Print label		

Prescription software	Labels	Affix label		
	Ink for printing			
Ink and label vendors				

Because this is a process within a chain of automated processes, almost all of the components are machines, processes, and things. Prior to labeling, a machine sorts bottles by size. That machine feeds the labeling station as needed. After the labeling is done, another station fills the bottles.

SIPOC with Enablers Noted

The SIPOC diagram below illustrates how enablers might be recorded for your process. The process in question takes place in a factory that makes furniture; in this process, a person attaches legs to a barstool on an assembly line. For the purposes of this illustration, leg attachment is the last step in the completion of the product, which means the product moves from the leg attachment station to packing and shipping.

Suppliers	Inputs	Process	Outputs	Customers
Upholstery station (provides final top of stool)	Stool top	Align legs	Barstool with legs attached	Packing station
	Legs	Attach legs with screws		
Warehouse (provides legs, screws, and protective cover)	Screws	Place protective cover		
	Protective cover			
Enablers:				
Conveyor machine that moves products				
Drill for application of screws				

Without the conveyor machine, the people in involved in this process would have to move items manually. The conveyor isn't 100 percent required for legs to be added to the stool, but it enables the process to move at a more efficient pace. A case could be made that the drill isn't required either – screws can be installed manually – but it's certainly what enables the process to move at a speed required for mass production.

With just this simple SIPOC diagram of a process, a Six Sigma team would already have some idea about where variation could be hiding, what drives efficiencies in the process, and how the process relates to the overall business.

Create Your Own SIPOC Diagram
Whether working in a team or on your own, choose a process you know about and practice creating your own diagram. Pick a process associated with your business or a business example you have experience with. Use the templates on the next page to get you started.

Suppliers	Inputs	Process	Outputs	Customers

Enablers:

Suppliers	Inputs	Process	Outputs	Customers

Chapter 8: Quality

One of the most concise definitions of quality comes from the International Organization for Standardization, or ISO. ISO 9000 defines quality as the "degree to which a set of inherent characteristics fulfills requirements."[7]

The same document defines requirements as expectations or needs that are implied, obligatory, or stated, and the ISO notes that requirements can be generated by different interest points. A Six Sigma team should be interested in requirements generated by all interest points, but often focuses most on those generated by the customer. Various types of requirements might include:

- Customer expectations, which are typically stated or implied values. It's implied that a customer wants the product he or she ordered. Expectations of delivery speed might be stated in the form of feedback in customer surveys.
- Compliance or regulatory rules, which are *obligatory*. For example, banks must protect credit card information—they are obligated by rules from government and the industry's Payment Card Information Data Security Standards (PCI-DSS). Similarly, healthcare organizations must protect the confidentiality and security of patient data; they are obligated to do so under the Health Insurance Portability and Accountability Act (HIPAA).
- Brand expectations, which come from in-house leadership. Brand expectations are typically stated; while not obligatory in the sense of being backed by regulation, companies for which high-quality, a specific voice, or other unique factor is a component of branding might treat brand expectations as obligatory. Coca-Cola, for example, has a brand that is recognizable around the globe. While components of that brand, such as the design of logos or soda cans, aren't mandated by regulations and might not be required by customers, Coca-Cola itself holds these components as important and puts resources and effort into them because it values its brand.

In this chapter, we'll take a look specifically at quality factors critical to processes and process improvement as well as costs associated with quality in general.

Critical to Quality Characteristics

Critical to quality characteristics, or CTQs, are the factors or parameters that are the major drivers of quality within an organization or process. Usually, CTQs are key characteristics that can be measured; where the performance of said metric provides information about whether or not the customer is going to be satisfied.

CTQs are closely related to CTCs, or critical to customer characteristics, but they are not the same thing. Something can be critical to quality – even critical to how a customer ultimately feels about a service or product – without being critical to the customer directly. CTQs are internal concerns, but they drive CTCs.

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[7] https://www.iso.org/obp/ui/#iso:std:iso:9000:ed-3:v1:en:term:3.9.11

Let's look at some examples of CTQs and CTCs to understand the difference and the relationship between these two factors.

A Pair of Pants

When a customer purchases a pair of pants, he or she is usually concerned with how the pants fit and look. Are they comfortable, is the size correct, and does the clothing match the customer's personal style?

It's hard to create a measurement for whether pants are comfortable, but a manufacturer can take customer feedback on various types of pants and learn that a certain fabric with a certain cut is most comfortable for the target audience. The manufacturer can also determine appropriate measurements for each size. During the manufacturing process, these critical-to-quality factors are applied: only fabric that meets the specifications identified is used. The fabric is then cut to specific measurements and sewn together in a specific manner – measurements and sewing methods are critical to quality.

The average customer, however, doesn't want to hear about the exact measurements of each fabric piece or the way the seams were sewn. They want to put on a pair of pants and experience a comfortable fit.

Chocolate Bars

A chocolate company conducts a survey to find out why sales of its newest product haven't performed as expected. The feedback suggests that the chocolate is too sweet – the taste and the sweetness of the chocolate is a critical to customer characteristic.

The company might tweak its formula, reducing the amount of sugar that goes into the chocolate. The recipe – and the amount of sugar -- is a critical to quality factor in this case. But what if the customer feedback indicated that health-conscious consumers simply didn't want to buy a chocolate bar with so much sugar in it? Then the amount of sugar in the recipe becomes both a CTQ and a CTC. It is critical to the quality of the taste of the bar, but customers might also look at the nutritional information on the bar and make purchasing decisions based on the amount of sugar in the chocolate.

Mobile App Development

If a business wants to launch a mobile app for its customers, then an obvious customer-centric need is that the app works on the customer's phone. The customer doesn't care about the process the business needs to go through to launch the app on the platform in question, but the business must meet the criteria for Apple, Android, Windows, or other mobile operating systems. Those requirements become some of the CTQs for the mobile app development, even though certain requirements from the platforms might not appear to be at all related to statements from customers about desires or needs.

Why Identify CTQs?

In a process improvement environment, CTQs are critical to narrowing work scope and understanding how to enact change. Consider the 80/20 rule discussed in Chapter 5. Often, CTQs are the factors, characteristics, or outputs that drive 80 percent of customer satisfaction. By improving these few critical factors, teams can substantially impact customer satisfaction and the performance of the overall process. Identifying CTQs lets teams create the most improvement possible with the time, money, and people resources available.

Outside of a project environment, understanding CTQs lets organizations stay on top of quality. By managing a few critical metrics, teams can ensure excellent output in a continuous fashion and identify potential areas for improvement before they become customer-facing problems.

Using a CTQ Tree to Convert Customer Needs to Quality Metrics

In Chapter 5, we introduced the concept of the Voice of the Customer, or VoC. Six Sigma teams usually start with some type of VoC data when they are defining a problem and working on goals for a project. Either the team conducts surveys to hear from a statistically relevant group of customers during the first few phases of a project, or the team receives feedback from internal customers about a process. Sometimes, the VoC information a team begins with is something as simple as a champion or executive-level individual making a statement about expectations for an internal process or project. When VoC data is limited in such a fashion, teams might have to work harder to validate assumptions with data before moving on to CTQ analysis.

To gain a better understanding of how to measure the quality of a process, teams must convert VoC statements to CTQs. One of the best ways to do this is through a diagramming process known as a CTQ tree.

A CTQ tree begins with specific and critical customer needs, breaks that need down into drivers, and uses the drivers to create requirements. Specific requirements are easier to convert to measurable quality components. While each CTQ tree is unique, they begin with a common form. The common structure of a CTQ tree is shown below.
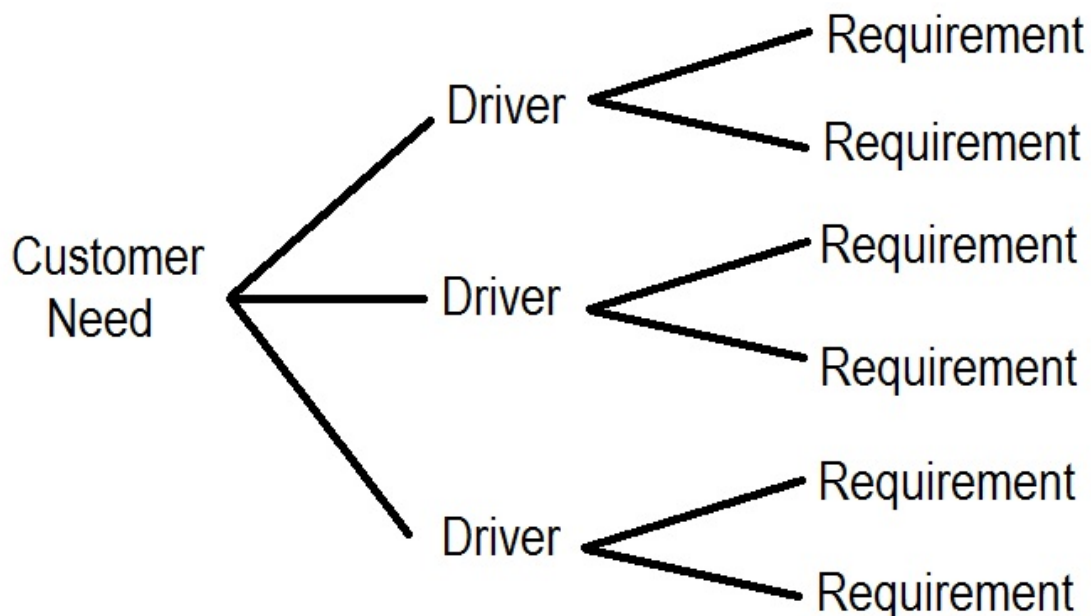
When creating a CTQ tree, you don't have to follow an equal pattern for drivers and requirements. Some customer needs will have more drivers than others; some drivers will have more requirements. You might also have multiple CTQ trees – you'll want to create one for every need you identify that is critical to a customer.

Identify Critical-to-Customer Needs

Begin the CTQ tree process by creating a list of needs that are critical to the customer. A bank working on processes dealing with online checking access might identify accessibility, user-friendly interfaces, and security of information as the major critical-to-customer needs, for example. Define needs in broad terms to help catch all drivers and requirements later in the diagramming process.

The best way to define needs is to directly ask customers for feedback, but time and resources don't always allow for surveys. Six Sigma teams might be able to take advantage of data collected via recent surveys or feedback forms, which is the next-best thing. In the absence of customer feedback, brainstorm critical needs with a group of employees who has knowledge of and experience with the customer. Subject matter experts from sales, customer service, and complaint departments can often provide viable information when the customer is the end-user. You can also begin a CTQ tree with the outputs of your SIPOC diagram; depending on how you structured the outputs on a SIPOC, you might need to define critical quality factors for the output as a starting point for your CTQ tree diagram.

Identify Drivers of Quality

Once you have a list of critical needs, work with one need at a time to create a tree similar to the diagram above. Identify quality drivers that must be present or met for the customer need to be fulfilled. For example, customers of an HVAC service company might require excellent service. Drivers for that need might include friendly service technicians, helpful and knowledgeable employees, and a timely response to service calls.

Drivers are the transition point between customer needs and requirements; you don't necessarily have to be able to measure drivers, but you want them to be a bit more detailed than the broad customer needs you already identified and you want to be flowing in the direction of measureable factors when possible.

List Requirements for Each Driver

Requirements are the most detailed breakdown regarding critical to quality characteristics. These are the things that you *can* measure that lead you to understand whether drivers are performing appropriately so customer needs are met.

For example, let's look at our HVAC example in a CTQ tree format.
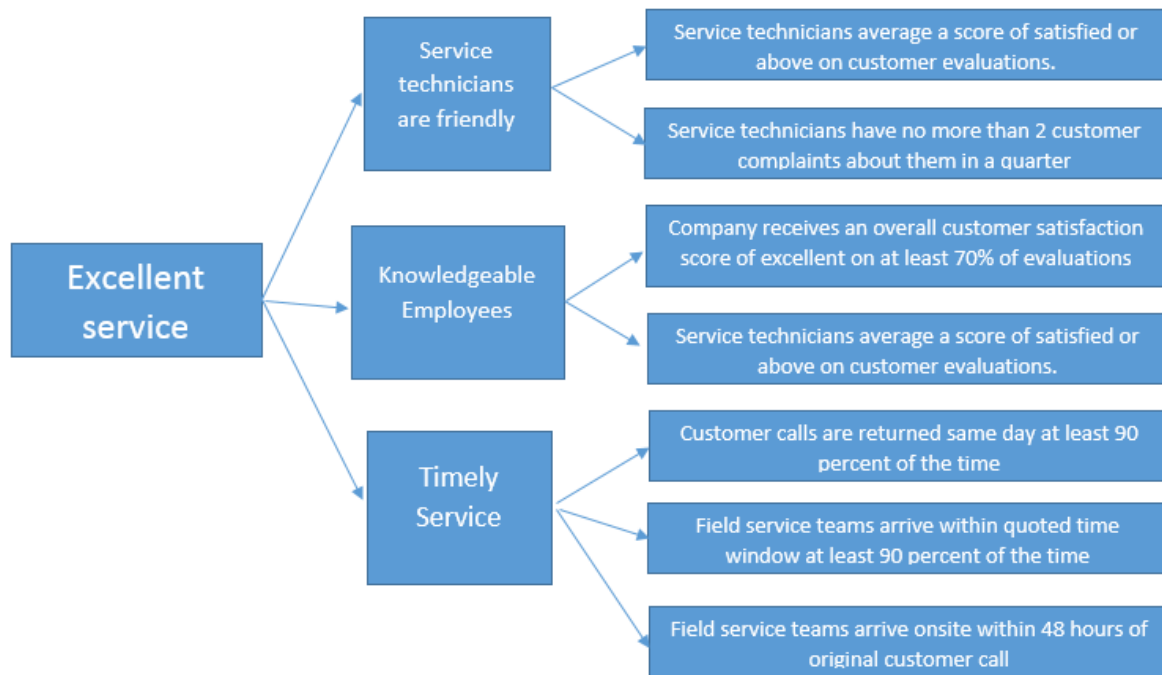
You can see in the above CTQ tree that drivers have been converted to requirements – and each of those requirements can be measured with numbers. In some cases, driver-to-requirement conversions equate to a hard number. The chocolate bar example at the beginning of this chapter features such a scenario: if the company deems that the recipe with a quarter cup of sugar is the correct recipe, then the process metric for quality is exactly a quarter cup of sugar.

In other examples, companies might provide leeway for exceptions or the understanding that a process is not going to hit an exact number every single time. For example, an HVAC team cannot possibly arrive at a customer's home exactly 24 hours after a phone call is made – and if the service technicians can arrive earlier than 24 hours, most people would want them to. That means the company has to create a definition for the requirement: how many hours is it before a customer considers a technician untimely? In the case of our example company, it's 48 hours. The requirement in another situation might be 24 hours.

Because teams will use the requirements from the CTQ trees to develop process measurements and metrics for success, it is extremely important that each requirement is vetted before teams incorporate it into the project or process. Requirements should be compared to VoC data, to existing measurements, and to experience and knowledge from subject matter experts and leaders. The team should ask themselves and others "If these requirements are met, will the customer be satisfied?" If the answer is ever no, then the requirements need work. The team might also consider asking "Are these requirements possible in the real world." If the answer is no, then either the process or the requirements needs work.

The CoQ and the CoPQ

Six Sigma teams must always be aware that quality comes at a cost. When talking about quality costs, many organizations consider what is known as the cost of poor quality, or CoPQ. The cost of poor quality is defined as the costs or expenses associated with defects created by a process. Quality actually has a broader cost – avoiding poor quality comes at an expense as well. The cost of quality, or CoQ, covers the expenses associated with maintaining good quality throughout an organization or process. Sometimes, this is referred to as the cost of good quality. In this section, we'll talk about both types of cost measurements, how they relate to Six Sigma in general, and how they relate to Six Sigma teams and projects.

The Cost of Poor Quality
In some ways, the cost of poor quality is easier to measure than the cost associated with overall quality. CoPQ is usually broken into two major categories: costs associated with external failures and costs associated with internal failures. External and internal failures are often referred to as the costs of nonconformity – they are the expenses that occur when outputs do not conform to critical to quality requirements.

External Failures
External failures usually occur after products or services have been delivered, which means they are directly associated with customer dissatisfaction. External failures might include revenue losses associated with a reduction in sales because of the quality of products, services, systems, or information. Other types of external losses include expenses associated with repairs, returns, or rework associated with a customer complaint; expenses associated with warranties; or loss of revenue or sales because of customer ill will or bad word-of-mouth.

Internal Failures
Internal failures occur when products, services, or processes don't conform to the requirements set by the company, and the product or service is provided to the customer in an unsatisfactory fashion. Internal failures are usually handled by scrapping the work, redoing the work, or repairing the work. Obviously, such rework results in added material and labor costs, but it also results in losses associated with delays, shortages of parts or inventory, and lack of flexibility or the ability to adapt. For example, if a process has such poor quality that 50 percent of the items produced by it require rework, then the process might be producing 40 percent less on a daily basis than it could be. That means the process can serve fewer customers, generate less output, and contribute less overall to the company's profit.

Calculating the Cost of Poor Quality
Understanding the cost of poor quality is critical to Six Sigma organizations because it lets leaders understand how financial needs are related to the need for quality improvements. The higher the cost of poor quality, the more likely an organization will work toward improvement.

At a project or process level, the cost of poor quality might help determine budgets for improvement. If poor quality within the process is costing an organization $5,000 a month, a project that costs $20,000 but saves $3,000 a month in quality would pay for itself in just seven months. On the other end, a

project that costs $100,000 when the costs of poor quality are only $1,000 a month is less likely to make sense.

The equation for CoPQ is:

CoPQ = External Failure Costs + Internal Failure Costs

While the equation seems simple, identifying all of the costs associated with poor quality can be difficult. Most experts use the metaphor of an iceberg to explain the hidden costs of poor quality. On the surface, you see the very small tip of the iceberg—the obvious costs of poor quality. These might be things such as scrap, reprocessing, warranty claims, customer returns, and extra shipping.

Beneath the surface, however, an iceberg is always much bigger. The same is usually true of the cost of poor quality, and hidden costs might include:

- Loss of customer loyalty
- Loss of morale
- Loss of employees if morale remains low for extended periods
- Conflicts associated with scheduling or rescheduling
- Higher risks of compliance issues, including fines
- Higher administrative costs
- Unpredictable revenue, sales, or production

Calculating the cost of poor quality is extremely difficult on an enterprise-wide level and still moderately difficult on a process level. A method for listing all possible costs and formulizing them to dollar amounts doesn't exist. It's a good idea for organizations to develop a streamlined method that is used throughout the enterprise when calculating CoPQ. At the very least, Six Sigma experts in the organization might consider defining a specific way of listing costs of poor quality company-wide so that various process teams are using similar measures when they report to leadership.

The Cost of Quality
The cost of quality, or CoQ, includes the cost of poor quality *and* the cost of good quality. In addition to internal and external failure costs, CoQ includes prevention and appraisal costs. Prevention and appraisal costs are often referred to as the costs of conformity – they are the expenses related to ensuring outputs conform to critical to quality requirements.

Prevention Costs
The costs of prevention are the expenses that are related to any activity meant to stop an error or defect from occurring. Error-proofing, which is covered in detail in later chapters on controlling processes, results in prevention costs. For example, if a company produces baked goods, at some point in the process people or machines must measure ingredients to add to dough batches. One way to error-proof such a process is to provide specialized machinery that will only allow a specific amount of each ingredient to be introduced to a batch. Such a machine would likely be quite expensive; it would also have to be managed by a qualified operator and maintained by appropriate repair and cleaning staff. All of that activity would generate costs which might be considered preventative in nature.

Other types of prevention costs include expenses related to quality planning, reviews, or education and training focused on quality. Quality review and evaluation processes also create prevention costs, whether those reviews are related to suppliers, products, processes, or people. Customer surveys, the creation of technical manuals, work to create and manage requirements and specifications, and the management of job descriptions can all lead to prevention costs. Even housekeeping costs might be considered preventative costs, especially if a clean work environment is required to reduce flaws or errors in product manufacturing.

Appraisal Costs

Appraisal costs are those associated with any activity meant to ensure high levels of quality across a process or organization. If a manufacturing plant hires a quality control specialist, and that person's job is to review parts that come down the manufacturing line and either return the work for correction or report the level of quality as a metric, then the salary of that person and any expenses related to his or her employment are appraisal costs. In some cases, those expenses might also be considered prevention costs, *but they would not be counted twice when calculating CoQ.*

Other types of appraisal costs might include expenses related to quality audits on products, services, or processes, the cost of calibration and measurement equipment or software, and the costs of field tests. Prototype inspections, consulting expenses, financial reporting and auditing, security checks, safety checks, supplier certifications, employee surveys, and customer feedback are all further examples of areas where appraisal costs might exist.

Calculating the Cost of Quality
The equation for CoQ is:

CoQ = CoPQ + Prevention Costs + Appraisal Costs

The same challenges inherent in calculating CoPQ also exist when calculating CoQ. The same iceberg analogy is relevant, and prevention and appraisal activities often have hidden costs such as unnecessary overtime, paperwork, or system expenses.

The Cost of Quality and Six Sigma
Traditional wisdom might say that if the cost of poor quality goes down, the cost of good quality is likely to go up. You have to spend money on quality to have good quality, in other words. While historically that might be true for many organizations, it is not the case in a Six Sigma company. Because Six Sigma works to create quality that is inherent in the process – meaning things are done right the first time and defects are reduced – the costs of quality often go down while quality itself goes up.

In Chapter 1, we showed that a process with a higher sigma level (and thus, higher quality) has fewer defects. Defects decrease in an exponential manner as sigma level rises. Because there are fewer defects, the costs of poor quality are exponentially reduced as well. But time and again, Six Sigma has also reduced the cost of overall quality. As the sigma level of processes is increased via the application of Six Sigma tools and methodology, the cost of both prevention and appraisal goes down as well.

One way of relating the cost of quality – and perhaps the most common way of doing so among corporations – is as a percent of sales. The cost of quality as a percent of sales typically aligns so closely with sigma values that you can predict the cost of quality based on a company's or process's sigma value. The average ranges for CoQ in relation to sigma values are shown in the table below. As you can see, as companies improve their sigma levels, they experience a substantial savings in the cost of quality.

Sigma level	Cost of Quality as a Percent of Sales
2	Above 40%
3	25 to 40 %
4	15 to 25%
5	5 to 15%
6	Less than 1%

Managing Cost of Quality

Six Sigma is one of the best methodologies for managing the cost of quality because it works to build quality into every process. When approaching an organization or process that has a high cost of quality, teams and leadership can apply a triage-based method to reduce those costs. While no organization can remove quality costs 100 percent, the goal should be zero costs of failure, either internal or external, and minimal preventative and appraisal costs.

First, teams should concentrate on costs associated with failures. It's often easier and less expensive to detect costs associated with nonconformance, and improvements that seek to correct causes for a few critical failures can have a big impact on overall quality and total cost. Instead of adding layers of quality programs over processes to ensure quality – which only adds prevention or appraisal activities and increases the cost of quality – Six Sigma improvement projects build preventative measures into processes themselves. In other words, efficient Six Sigma processes are self-regulating. They have built in checks and balances that work to constantly reduce defects and rework.

The benefit of building failure stop-points into a process include:

- Earlier detection when errors do occur, which keeps hidden costs down. When the error can't make it to the next process or to the customer, you avoid many issues and costs associated with low morale, reduced customer loyalty, or product returns.
- Employees are able to support and manage higher quality. When quality is something employees have ownership of, they are more likely to work hard to create the best possible output. In contrast, appraisal-style quality programs can spark feelings of paranoia at being closely watched or create a relationship in employee minds between the idea of quality and the idea of reprisal or correction. Poor performance on a continuous basis does need to be addressed, but employees should not default to a negative mindset when they hear the word quality.
- In-process quality assurance is actually more effective than post-process or over-process prevention and appraisal methods. Statistical process control and Six Sigma improvements *can* push a process to six sigma level. To ensure the same level of performance – 3.4 defects per million opportunities – quality assurance employees would need to review millions of parts and ensure only a very tiny few had defects. It's simply not an economical option for most, if any, organization.

After teams use the Six Sigma and Lean process management methods discussed throughout this book to reduce failure costs, teams can turn to prevention and appraisal costs. Often, in a process that is functioning at a high sigma level, prevention and appraisal activities are a form of muda. They can be expunged from the process without impacting the end product, quality, customer satisfaction, or employee morale. In some cases, removing prevention or appraisal from processes actually creates a positive impact on quality, production, and customer and employee satisfaction.

Identifying Prevention and Appraisal Activities

The first step to removing quality-related muda is identifying it. Process maps, spaghetti diagrams, and value stream maps are valuable tools for uncovering activities that don't need to be included in a process. All of these tools are covered in depth in Unit 9.

Whether you're mapping a process or simply discussing various components with process owners or a Six Sigma team, asking questions about value and necessity can also help identify muda of prevention and appraisal. If you think an activity related to a process might be an unnecessary form of prevention or appraisal, ask:

- Does the activity itself add any value to the output?
- Does the activity substantially reduce the time it takes for the process to produce an output?
- Does the activity substantially increase the cost of the process?
- If the activity is designed to prevent defects within the process, can the activity be made more efficient?
- If the activity is designed to prevent defects, can the activity be made less expensive?
- If an activity is designed to capture quality data about the process for reporting purposes, are those reports necessary?
- If quality reports are necessary– either because of obligatory requirements such as compliance or because the reports provide value in another process – can the reports be automated to reduce associated expense?

The answers to these questions help teams identify areas where muda can be removed or where quality-related processes can be improved.

Quality is Critical to Success

When Six Sigma teams are expunging quality-related costs and unnecessary activities from processes, it is critical that they don't actually remove quality. While it's true that traditional quality programs and costs don't have to be present to ensure a reduction in defects and an improvement in customer satisfaction, it's equally true that you have to replace those programs with some other form of control. By the end of this book, you will have learned about a number of tools, from statistical process control to poka yokes, which you can use to create quality within a process.

It's also worth noting that a single Six Sigma team – or even an entire department devoted to Six Sigma – can't reduce the costs of quality in an organization on their own. Corporate leadership must buy into the belief that quality is better when controls are incorporated within the process, and they have to be willing to communicate this fact via training and example. Some companies choose instead to use Six Sigma to improve processes while maintaining the expense of traditional quality, compliance, and audit departments. For some industries, such as healthcare or finance, audits and other appraisal and prevention costs might be mandated by laws and regulations. Outside of that mandate, it's almost always best to remove any quality activity that doesn't provide additional value.

Chapter 9: Selecting the Right Projects

Teams can bring abundant knowledge of Six Sigma to the table, but if organizations don't choose the right projects, improvements won't drive effective changes for the benefit of the bottom line and/or customer satisfaction. Since Six Sigma works best when it is implemented as a company-wide culture, project selection should work as an enterprise-wide function. This chapter covers a number of tools and methods for brainstorming and selecting projects that are most likely to bring significant improvement to processes and serve overall business goals.

Juggling the Right Amount of Projects

A critical part of Six Sigma success for organizations is knowing when teams reach maximum project load. Even when organizations hire employees dedicated to process improvement, they can only sustain a certain number of improvement projects without substantially reducing the positive outcomes of those projects. While project work, including data gathering and analysis, might be handled by employees committed 100 percent to improvement projects, teams usually have to engage with and pull resources from regular staff members. An organization that juggles too many projects puts daily output at risk. *In seeking to improve processes, a company that selects too many projects at one time could actually negatively impact quality.*

No formula exists for how many Six Sigma projects a company should run at a given time, but a few well-designed projects are more likely to make greater impact than many poorly designed, overlapping, or unfunded projects. Organizations should only launch projects they can:

- **Fund.** Six Sigma projects take monetary resources, which means organizations must prioritize based on financial criteria.
- **Support with people resources.** Six Sigma projects require work from employees at all levels. Companies shouldn't launch three projects at one time that draw heavily on IT resources or attempt multiple, simultaneous projects that need input from the Director of Compliance on a regular basis. Relying too heavily on resources for multiple projects can burn out employees, decrease morale, impact quality, and impede work that is necessary to keep the business running from day to day.
- **Manage.** Project teams require leadership; Six Sigma teams are usually run by Black Belts, sometimes along with certified Project Managers. Since Black Belts are supported by Green Belts who handle much of the data collection and analysis work, a single Black Belt can usually manage more than one project at a time if needed. This is especially true for experienced Black Belts who are not responsible for any type of daily operation. Even so, organizations with limited Six Sigma experts on staff can't launch dozens of projects without putting a strain on those resources.

Enterprise-Level Selection Process

When companies are working to apply Six Sigma culture to the entire enterprise, executive leaders and other decision makers should work directly with Six Sigma experts to identify improvement opportunities and launch projects. Doing so lets leadership align project selection with organizational

goals, ensure projects are organized in a way that matches resources, and keep a bird's eye view of improvement endeavors. Organizations can apply a five-step procedure for identifying viable Six Sigma improvement projects.

1. Data-Based Review of Current State of the Organization

Organizations can begin with a high-level look at internal and external sources of information about performance. Internal information might include complaints or issues raised by employees, existing performance metrics or reports, financial reports, and quality reports. External sources include all of the Voice of the Customer tools we covered in Chapter 5. In reviewing internal and external information, organizations should ask:

- What types of things are customers or employees complaining about?
- Where is the organization falling short of benchmarks or competitor performance?
- What needs do customers have that the organization is not meeting?
- What needs might customers have in the near future that the organization is not yet able to meet?
- What processes are outputting the most defects?
- What processes are known for the most rework?
- What are the slowest or most expensive processes in the organization?
- What are some obstacles keeping the organization from reaching its goals?

2. Brainstorm and Describe Potential Projects

Answers to the questions in step one become a brainstorming list for potential projects. What types of things are customers complaining about? Perhaps surveys and feedback forms show customers complaining about long shipment times, poor quality of products, or rude customer service. With just a single question, an organization has a list of possible projects:

- A project to reduce the time it takes for customers to receive orders
- A project to increase the quality of products
- A project to create better customer service

Admittedly, the scope is enormous with these examples, so organizations would need to look for a bit more detail. Why do customers think the quality of products is low? In Chapter 6, we covered the 5 Whys brainstorming method, and that method is relevant here. During the brainstorming process, organizations and teams should repeatedly ask "Why?" questions to get a more granular look at project possibilities.

For example, if a feedback form for a carpet installation company indicates that customers aren't satisfied with the service they receive, the team might ask "Why are customers dissatisfied?" Further investigation into customer feedback might indicate that the customers are unhappy because carpet edges are coming up shortly after the carpet is installed. Why is this happening? The short answer is that something is wrong in the installation process. The organization might add "Improve carpet installation process" to a list of possible projects.

Creating a list of possible projects in this manner isn't always a matter of a single brainstorming session. As issues are raised, more information might be required to list possible projects, but if you gather the right group of people for a few braining storming sessions, it's likely someone already has that information or knows some basic answers. Remember, the point of this exercise is to call out possible areas for improvement, not validate assumptions or come up with solutions.

Once teams have a large list of possible projects, they should begin creating short descriptions that will become the basis of step three. The descriptions also let teams quickly identify things that are not actually problems or would not apply within an improvement project environment. Descriptions should include answers to three questions:

- How is the issue painful to the customer, the employees, or the organization? In short, how does the issue impede someone from getting what they want or need?
- What is the goal that would be accomplished with an improvement?
- Why should an organization address this issue now?

If this is starting to sound familiar, it's because the answers to these questions create something similar to, though slightly less formal than, the problem statements discussed in Chapter 6. Using the carpet installation example, for example, the description might be:

Customers are not satisfied with carpet installation because edges are coming up within a few weeks of installation. The poor edges are creating safety and aesthetic issues and increasing expense and rework for teams who have to return to sites to address defects. The goal is to reduce the number of times carpet edges come up by 80 percent. The organization should address the issue because it is costing $20,000 per month in errors.

Some basic idea of what the team wants to do is provided, and leadership has a very real measurement of why the improvement is important. Even better, the measurement -- $20,000 in additional costs each month – can be compared to other project opportunities.

3. Apply Some Basic Criteria to Shorten the List

Once a list of possible projects is created, teams can apply some very basic criteria to remove projects that are inappropriate, would not work with Six Sigma methodology, are not property scoped, or have little likely return on investment. This step usually begins during the second part of step two, when teams are creating short descriptions of possible projects.

First, teams can remove items from the list where there is no real pain point. If a significant difference between desired state and current state doesn't exist, then there's nothing to improve. For example, if a single employee complaint about the efficiency of a piece of software made it onto the initial list, a company wouldn't pursue improvements further if it turned out no one else was having the issue.

Second, teams can remove issues that have very obvious problems and/or solutions. Consider the carpet installation problem: if the issue of edges cropped up in the last month and someone on the team reviewing potential problems recently received an email about defects in edging materials from a carpet vendor, the solution might be obvious. Perhaps the vendor sent notification that the materials in a certain batch of carpet were faulty and provided instructions for a solution. In this case, action is required on the part of the organization, but that action isn't a Six Sigma project. We'll talk more in

Chapter 11 about the DMAIC process, but if a problem is already defined and a solution provided, you don't need to spend time going through the DMAIC phases.

4. Create Unique Business Criteria

After removing project ideas that don't fit Six Sigma methodology, teams should create and apply business criteria to further filter the list. Business criteria usually come in the form of expenses, monetary gains, impact on customer satisfaction, and urgency. Some questions teams might ask include:

- How will the improvement impact revenue-facing measurements such as profit, orders, or income?
- What savings will the improvement create?
- How is the problem trending? Is it becoming a bigger and more urgent issue quickly, or can the organization operate with minimal impact without making an immediate or near-future change?
- How much will the improvement cost?
- How many employees/employee hours will be required for the improvement?
- What resources are required for the improvement?

5. Use Business Criteria to Prioritize Project Lists

Using the business criteria, teams should prioritize projects and select projects from the top of the prioritized list for immediate work. One of the best ways to prioritize projects is to create a selection matrix with defined criteria and a numerical ranking system.

For example, using the example questions in step four, we might create the following list of criteria:

- Potential savings
- Potential cost
- Potential increase to revenue
- Ability to access resources needed

A matrix can be created using the criteria and a list of projects. Teams can then rate each project against each criteria using a numeric scale. In the example below, we applied a scale from 1 to 10, with 1 being the most negative and 10 being the most positive.

It's important to note that in this example, the numbers aren't associated with real-world numbers. For example, when rating savings, a higher number just means a more positive expectation. In this case, the positive expectation would be a high amount of savings. When rating costs, however, the higher number (and more positive expectation) would relate to a project with a lower overall cost.

	Savings	Costs	Revenue increase	Access to resources	Total
Project 1	1	8	9	10	28
Project	5	5	4	6	20

2					
Project 3	10	2	2	2	16

In the table above, you can see that Project 1 has low expected savings, but the team also estimates it will have a low overall cost, drive a high increase in revenue, and has easy access to resources. Project 3, on the other hand, has a high expected savings, but negative ratings in all other categories.

To rank projects, add up the scores for all categories and order the projects from highest to lowest by total score.

The Project Viability Model

Teams can choose to create their own criteria for a project selection matrix, or they can use a 15-point viability model as defined below. One benefit of the project viability model is that it provides some weighting, letting teams make some criteria more important than others. It also removes some of the objective nature of the selection matrix defined in the previous section.

This model is based on 15 criteria, which are defined in the table below.

Criteria	Definition
1. Sponsorship	The project is likely to be sponsored at a high level. (For more information on project sponsorship, see the team building information in Chapter 10). Sponsorship increases the chance that teams will have access to the funds and resources required for a successful potential project.
2. Corporate alignment	The goals of the project are aligned with the goals of the business. Working on potential projects that aren't aligned with business goals can reduce business effectiveness.
3. Data	Data is available or can be accessed so the team can design project metrics. Without access to data, a Six Sigma methodology can't be applied. If data is excessively time-consuming or expensive to collect, then the potential project is usually not the best choice.
4. Definition of defect	There is a specific, well-defined defect or problem. Without a well-defined defect, potential projects run the risk of scope creep.
5. Stability	The potential process is stable and there are no expectations that the process is going to be overhauled, redesigned, or changed in the near future. There is usually no reason to spend time and money improving a process that will drastically change soon anyway.
6. Customer	The planned goal of the potential project would create a substantial and positive impact on customer satisfaction or perception of quality.
7. Benefits	The potential project has a strong cost-benefit ratio.
8. Timeline	The timeline for a potential project is relatively short. Timelines for

	most Six Sigma improvement projects are around 6 months, though some do run longer. Longer timelines decrease the chance that an improvement fits within the DMAIC methodology.	
9. Solution	The potential project purpose is to find a solution that is not already known or defined. As we previously stated, if a solution is obvious, you don't need to run a project to find it.	
10. Implementation is likely	A solution identified and verified by the potential project is likely to be implemented. If, for any reason, change is very unlikely within a process, then going through Six Sigma improvement work is a waste of resources.	
11. Required investment	The potential project requires a large investment of cash. Generally, the greater the cash or capital investment required, the less likely a project will be selected or a solution will be implemented due to cost-benefit analysis.	
12. Available Six Sigma Resources	The Black and Green Belts required for the project are available.	
13. Inputs can be controlled	For a Six Sigma process improvement project to be successful, at least some of the inputs must be within control of the team or organization. For example, a team can't work to improve the quality of a part that is provided wholly by a vendor.	
14. Redesign	The process can be improved as is and doesn't need a complete redesign.	
15. Process quality is improved/maintained	The improvement doesn't negatively impact the quality of service or products along the value chain.	

Based on the above criteria, teams create a matrix.

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Is there a sponsor or champion?						
Do project goals align with corporate goals?						
Is data available or accessible?						
Are defects well defined?						
Is the process stable?						
Are there customer benefits to the project?						
Are there company benefits to the project?						
Can the project be completed within 6 months?						

Is the solution unknown?						
Is it likely a discovered solution will be implemented?						
Would a new solution cost little to no cash?						
Are Six Sigma team members available for the project?						
Can inputs in the process be controlled?						
Can the process be improved without a full redesign?						
Will the improvements maintain or improve quality across the value chain?						

Teams then apply a numerical weight to each criterion. Weight each criterion on a scale of 1 to 5, with 1 being least important and 5 being most important. For example, our team with the carpet installation issue might create weights as follows:

	Weight
Is there a sponsor or champion?	3
Do project goals align with corporate goals?	4
Is data available or accessible?	3
Are defects well defined?	3
Is the process stable?	1
Are there customer benefits to the project?	5
Are there company benefits to the project?	5
Can the project be completed within 6 months?	3
Is the solution unknown?	4
Is it likely a discovered solution will be implemented?	3
Would a new solution cost little to no cash?	5
Are Six Sigma team members available for the project?	3
Can inputs in the process be controlled?	5
Can the process be improved without a full redesign?	2
Will the improvements maintain or improve quality across the value chain?	5

Next, teams should answer each question by marking a 1 in the relevant box on the grid; the answers correspond with no, mostly no, possibly, mostly yes, and yes. The complete grid for our carpet installation problem is featured below.

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Is there a sponsor or champion?	3		1			
Do project goals align with corporate goals?	4					1
Is data available or accessible?	3			1		

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Are defects well defined?	3					1
Is the process stable?	1				1	
Are there customer benefits to the project?	5					1
Are there company benefits to the project?	5				1	
Can the project be completed within 6 months?	3			1		
Is the solution unknown?	4				1	
Is it likely a discovered solution will be implemented?	3			1		
Would a new solution cost little to no cash?	5			1		
Are Six Sigma team members available for the project?	3	1				
Can inputs in the process be controlled?	5		1			
Can the process be improved without a full redesign?	2					1
Will the improvements maintain or improve quality across the value chain?	5		1			

Once a matrix is completed for each project, teams must calculate and compare the score for potential projects. These calculations are completed via the following steps.

1. Divide each weight by 3; a weight of 3 equals 1, but a weight of 5 equals 5/3, or 1.7

2. Convert each of the 1s listed on your grid to a weighted value by multiplying it by the converted weight from step one. For example, the weight for the first question on the grid above is 3. We divided 3/3 to get 1. We would multiple 1 * 1 for the first row. The next row is weighted 4; 4/3 is 1.3. The numbers have all been converted in the grid below.

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Is there a sponsor or champion?	3		1			
Do project goals align with corporate goals?	4					1.3
Is data available or accessible?	3			1		
Are defects well defined?	3					1
Is the process stable?	1				0.3	
Are there customer benefits to the project?	5					1.7
Are there company benefits to the project?	5				1.7	
Can the project be completed within 6 months?	3			1		
Is the solution unknown?	4				1.3	
Is it likely a discovered solution will be implemented?	3			1		
Would a new solution cost little to no cash?	5			1.7		
Are Six Sigma team members available for the project?	3	1.3				
Can inputs in the process be controlled? Can the process be improved without a full redesign?	5		1.7			
	2					0.4

		No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Will the improvements maintain or improve quality across the value chain?	5		1.7			

3. Sum the numbers in each of the five columns.

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Is there a sponsor or champion?	3		1			
Do project goals align with corporate goals?	4					1.3
Is data available or accessible?	3			1		
Are defects well defined?	3					1
Is the process stable?	1				0.3	
Are there customer benefits to the project?	5					1.7
Are there company benefits to the project?	5				1.7	
Can the project be completed within 6 months?	3			1		
Is the solution unknown?	4				1.3	
Is it likely a discovered solution will be implemented?	3			1		
Would a new solution cost little to no cash?	5			1.7		
Are Six Sigma team members available for the project?	3	1.3				
Can inputs in the process be controlled?	5		1.7			
Can the process be improved without a full redesign?	2					0.4
Will the improvements maintain or improve quality across the value chain?	5		1.7			
		1.3	4.4	4.7	3.3	4.4

4. Multiply each of the summed weighted scores by the number at the top of the column. For example, the sum of the column for the "No" answers is 1.3. Multiplying that by 1 equals 1.3. The other columns are calculated as:

- 4.4 * 2 = 8.8
- 4.7 * 3 = 14.1
- 3.3 * 4 = 13.2
- 4.4 * 5 = 22

5. Add up the answers from the previous step. In this case, the total is 59.4.

6. Divide the sum from step five by the sum of the weighted totals from step three. In this case, 59.4 / 18.1 = 3.28

7. The answer from step 6 is the score for your project.

Once you score each potential project, you can determine if it is a viable project within a DMAIC methodology with the following key:

Score	DMAIC Viability
< 2.0	Not viable for DMAIC
2.0 to 3.0	Possibility viable, but organizations should validate further
Above 3.0	A viable DMAIC project

It should be noted that the 15-point matrix described above can only be used to determine if a project is viable within a DMAIC structure. A process might still need to be improved even though it doesn't fit DMAIC methodology; in the case of a redesign, the DMADV structure might let Six Sigma teams approach the improvement. The differences between DMAIC and DMADV methodologies, and how to determine which method is best for a project, are covered more in-depth in Chapter 11.

Project Selection at a Process Level
The goal of a Six Sigma team is not to define appropriate projects at an enterprise level. A department or team responsible for only a few processes might be seeking to make an improvement. In an organization where Six Sigma is important to business culture, departmental leaders are likely familiar with some Six Sigma tools and might even be Green Belts or Black Belts themselves. While these leaders have daily responsibilities that are not Six Sigma related, they can bring Six Sigma thought processes to their department.

Departmental leaders might want to identify potential opportunities to present to leadership. They might also want to identify areas where they and their teams can work toward improvement themselves. In some organizations, department leaders can run smaller versions of projects with the guidance of on-staff Six Sigma experts – especially when such projects would require little in the way of capital or resources.

Departmental staff can use all of the tools in this chapter to identify possible projects. Often, though, they are close enough to the situation that they can identify possibilities for improvement without going through brainstorming stages. If data is already present, departmental staff might use Pareto charts to identify some areas where improvement would create results; they can then use the selections matrix to validate those assumptions and prioritize efforts.

See for Yourself
Consider a problem or need for improvement in your own company or one you faced in a past work experience. Practice completing the project viability matrix using the template below.

	Weight	No (1)	Mostly No (2)	Possibly (3)	Mostly Yes (4)	Yes (5)
Is there a sponsor or champion?						
Do project goals align with corporate goals?						
Is data available or accessible?						
Are defects well defined?						
Is the process stable?						
Are there customer benefits to the project?						
Are there company benefits to the project?						
Can the project be completed within 6 months?						
Is the solution unknown?						
Is it likely a discovered solution will be implemented?						
Would a new solution cost little to no cash?						
Are Six Sigma team members available for the project?						
Can inputs in the process be controlled?						
Can the process be improved without a full redesign?						
Will the improvements maintain or improve quality across the value chain?						
	TOTALS:					
					Score:	

Chapter 10: Basic Six Sigma Team Management

Six Sigma is typically managed on two levels within an organization. First, the culture of Six Sigma must be managed at an enterprise-wide level, usually by a group or council of senior managers, such as executives, with the guidance of a Master Black Belt or Black Belt. Ultimately, this group sets the tone for Six Sigma within an organization, provides final approval on projects, and holds others accountable for metrics, performance, and success. While many of these individuals might also work as sponsors or champions on projects, as a group they don't tend to get involved in the day-to-day project details.

Some roles of a high-level Six Sigma leadership group include:

- Creating a rationale for the use of Six Sigma in the organization and supporting process improvement as a cultural goal.
- Setting clear objectives for Six Sigma initiatives to ensure that project goals align with business goals.
- Holding Six Sigma teams and the organization accountable for improvements and performance.
- Demanding and reviewing measurements of results
- Communicating wins and losses to the team in an honest manner.
- Rewarding teams and individuals for Six Sigma successes.
- Advocating for resources and funding for necessary improvement projects.

Six Sigma must also be managed at the team level, which is the primary focus of this chapter. We'll cover building a team, detail the various common roles within a Six Sigma team, and talk about managing a team with timelines and schedules, milestones, budgets, and a defined measure of success.

Building a Six Sigma Team

You can't simply have a pre-made team ready to begin work on every project that comes up. Six Sigma teams must be uniquely tailored to the goals and processes at hand. The same Six Sigma experts – Black Belt leaders, data analysts, or project managers – might work across multiple projects, but individual subject matter experts and team members only bring high value to the team if they are familiar with the process or have some related education, knowledge, or skill to offer. Not all team members will serve consistently throughout the entire life of a project, either. This is often why companies send existing employees for Six Sigma training rather than hire Six Sigma experts.

Executive leadership groups working with Six Sigma leaders and experts usually put teams together. Any process improvement team should have, at minimum:

- A Six Sigma leader
- A process owner
- An expert on the process
- Someone to manage budgeting and accounting

Some of those roles might be handled by the same person; the process owner might also be the process expert. Depending on expectations of needs, the team might also need to include technical resources, such as a programmer or IT leader, as well as individuals from human resources, compliance, legal, or other ancillary departments.

Three Types of Team Members

When putting teams together, organizations should remember that three basic team member types exist with relation to a Six Sigma project. First, there are the regular team members. These individuals participate in all activities of the team and attend all or almost all of the team's meetings. Regular team members include project leaders, process owners and experts, and identified subject matter experts who the team or executives feel would be critical components of their group.

Second, ad hoc team members provide expertise on an as-needed basis. Usually, these are subject matter experts or employees who work directly with the process. You don't want to take these employees from their job functions for every single team event, as that would negatively impact the state of current production. Instead, these employees are included in team meetings as needed when additional information or assistance is required.

Finally, resource team members are only included when the project team leader feels they are needed in a meeting or team event to provide expert information, counsel, or help in accessing resources. Resource team members are usually members of ancillary departments such as accounting, human resources, or compliance. Resource team members might also be managers or leaders in departments that are related to the process being improved. For example, if a team is seeking to improve a customer service department, they might need help with inputs from the marketing department; someone from the marketing department could be added as a resource team member.

Tips for Selecting Team Members

Most Six Sigma process improvement teams are relatively small: five regular team members is considered a good number on average. Adding too many regular team members can create communication problems, make it difficult to manage brainstorming sessions, and cause burnout. When all of a company's Six Sigma teams are large, there's a good chance that team members are serving on multiple projects. While ad hoc or resource team members can serve several projects and handle their own work on a daily basis, regular team members should not be asked to serve on more than one team *and* handle daily workloads. In fact, organizational leaders might want to consider reducing work requirements for team members who are serving as full-time members on a project.

Other tips for selecting team members include:

- Choosing employees who are knowledgeable about the customer, product, or process related to the project.
- Choosing employees who have shown a willingness and ability to work toward improvement in a team environment.
- Selecting employees who have access to and an understanding of the data required to learn about and measure the process or problem.
- Picking employees who can provide at least five hours of work per week to the team.

- Matching the skills of employees to the projects at hand; if a project is likely to include all technical improvements, you would be less likely to add a team member who is skilled in marketing.
- Removing political obstacles through team selection; if a specific person in an organization is likely to be an obstacle to a team, sometimes putting that person on the team can increase the chance that they will buy into the process.

Team Member Roles

The team member roles described in this section are based on Six Sigma process improvement best practices, but best practices also say that teams and team leaders should not be overly rigid. Experienced Six Sigma leaders and experts understand how to work within best practices while also creating unique team structures that are tailored to the project or process at hand.

Sponsors and Champions

We've briefly touched on sponsors and champions in previous chapters. In most Six Sigma environments, these are the senior-level leaders who oversee projects at the highest level. Even the Black Belt must report to the project sponsor or champion. The senior leader is usually responsible for the final result of a project, which means he or she usually wants regular reports about progress; sometimes, the sponsor or champion is the liaison between the team and the leadership council. As the senior leader, the champion or sponsor is also responsible for assisting the team with obtaining funds and resources to ensure project success. Some additional duties within this role include:

- Coaching the team, particularly at the project charter stage. The sponsor often provides input into what is in scope on a project and who might be included on a team.
- Locating resources for the team, including support from other departments, money, equipment, time, and labor hours.
- Handling matters of politics within a corporate structure so the team doesn't have to.
- Working with other managers within the organization to help the team succeed in improving a process and transitioning improvements to a daily work environment.

Business or Process Owners

The business or process owner is usually someone who is directly responsible for the process in a leadership capacity. Usually, the process owner is the person who is going to "receive" a solution implemented by a Six Sigma team once that solution is ready to be rolled out to all team members or used on a daily basis. Because of this, the process owner is usually included in the team because he or she must understand how and why any change is made. The process owner must also be familiar with methods of control that are created by the Six Sigma team as he or she will become responsible for maintaining and monitoring those controls once the process is transitioned from a team environment to day-to-day production.

A process owner usually also acts as a process expert on a Six Sigma team. The process owner has insight into the existing process, understands the needs of the customers and employees related to the process, and might already have access to data regarding the process. The process owner isn't always

the only process expert on a team, however; in some cases, the person who owns the process doesn't have enough day-to-day interaction with the process to be an expert.

When leading or managing a Six Sigma team, Black Belts and others do have to be wary of process owners who are resistant to change or who believe they have all the answers. Someone who is set in his or her ways might not want to involve other team members or might believe certain changes are "impossible" because they are new. Some leaders who are also process owners might be afraid that a team member will outshine them or threaten their position, which could lead them to block team members from participating on a team. These are some of the political and human resource problems Six Sigma leaders run into, and Black Belts and project leaders must work tactfully with champions, sponsors, and process managers to resolve such issues.

Six Sigma Leaders

Six Sigma projects are usually led by certified Black Belts, although some organizations do allow Green Belts to act as leaders on small initiatives with occasional feedback and guidance from Black Belts. In most organizations, the Black Belt holds primary responsibility for the regular work performed by a team and usually only works with one team or project at a time.

Best case scenarios let organizations align Black Belts with projects in areas they are already familiar with. For example, a bank might have several Black Belts on staff. Each Black Belt might specialize in working with certain processes or departments; one might usually work with compliance and audit processes, another with accounting, a third with customer-facing processes, and a fourth with online processes. Since Black Belt resources might be limited, this isn't always possible. Most certified Black Belts can bring Six Sigma methods to process improvements even in areas they aren't closely familiar with. In some cases, various managers or other individuals are certified as Black Belts and can lead processes in addition to their regular responsibilities, although this can put an undue burden on employees and isn't always the best solution.

Black Belt project leaders often work to:

- Help create a rationale for a project.
- Provide input for the selection of project team members.
- Lead teams throughout all the phases of DMAIC, which are covered in depth in Unit 3.
- Educate and support team members as they learn about and use Six Sigma tools.
- Provide oversight through time management, decision making, and planning.
- Maintain schedules and timelines, sometimes in conjunction with a certified Project Manager.
- Provide expertise in the form of statistical analysis or guidance with analysis.
- Assist with project transition.
- Report to sponsor or champion on a regular basis.
- Provide documentation at the end of the project.

In some organizations, Master Black Belts play an overall role in leading multiple Six Sigma projects. Master Black Belts act as coaches to multiple teams; Black Belts leading Six Sigma teams can work with Master Black Belts to solve especially difficult problems or seek help for complex statistical analysis. Master Black Belts provide continuing education to both Black and Green Belts, helping team members to constantly improve their grasp of Six Sigma methodologies.

Project Managers

Some organizations use traditional project management techniques alongside Six Sigma improvement methodologies. In these organizations, a project manager is usually assigned to a Six Sigma project. While structures vary by organization, the project manager does not usually lead the team. Instead, the PM offers leader support to the Black Belt by keeping up with documentation and timelines, helping keep meetings on track, and ensuring items are followed up on after meetings. At first, you might think that adding a PM to a team would cause problems for a Black Belt, but when the two roles work together, the Black Belt benefits. With a PM worrying about timelines or whether the meeting is getting too far off track, a Six Sigma exert is free to concentrate on the brainstorming session or statistical analysis at hand.

Timekeeper

Not all Six Sigma teams use timekeepers, but they can help keep meetings on track, reduce the chance of scope creep, and increase overall productivity. The timekeeper can be any person on the team who is not regularly engaged in leading meetings, brainstorming activities or recording team activities and notes. The timekeeper shouldn't police time in a such a rigid fashion that the benefits of fluid discussion and brainstorming are lost, but he or she should gently steer teams toward following agenda schedules or provide the project leader with an indication that time is up for the topic at hand.

To function properly, a timekeeper needs an agenda to follow. It is usually the responsibility of the Black Belt or project manager to provide a detailed agenda for each meeting. The agenda should include clear indications regarding how long each item is expected to take, though teams should always be aware that agendas might be changed during the meeting at the discretion of the project manager or project leader.

Team leaders should pick a timekeeper who is organized and level-headed. In the heat of discussions and arguments, it's easy for any member of the team to lose track of time – and the timekeeper *is* a member of the team. In addition to regular duties as a team member, the timekeeper is expected to:

- Keep an eye on the agenda and the time
- Let team members know when the time for a certain agenda is almost up; teams might want to set up a five-minute warning rule so they have a few minutes to wrap up a discussion
- Signal that the time is up for a certain discussion or item

While project leaders can choose to ignore agendas, they should also back up the timekeeper's ability to interrupt politely. Timekeepers can't perform if they are being heckled by other team members for noting the time.

Scribes or Minute-Takers

A lot of discussion occurs in the midst of Six Sigma brainstorming and team sessions, and someone needs to record that information. Notes are important because they help team members review what was discussed, create lists of follow-ups and actions from a discussion, and record charts, graphs, and diagrams that were created during brainstorming processes. While everyone can take notes, the team leader should appoint one person as the official scribe for the team. Sometimes, that person is a certified project manager working in conjunction with a Six Sigma team leader. Other times, it is a member of the team who is seen as detailed and organized.

The Black Belt or other project leader should never be the scribe; it is too difficult to take notes while leading a discussion or exercise. The Black Belt might make some notes during the discussion, but he or she is likely to miss important details while working directly with other team members.

The scribe should create notes or minutes of the meeting in typed format and disseminate those notes to all team members as soon as possible following a meeting. Team members can review the notes and add any missing information if desired; often, organizations create portals or shared file systems so teams can keep notes and all other documents in an easy-to-access location.

One challenge in recording the discussions of a Six Sigma project meeting is in recording the diagrams and brainstorming that occurred. This is especially true if teams use whiteboards, paper, or sticky notes to create diagrams; the scribe is not always equipped with the skills or the software to recreate a computerized version of such documents. One tip for recording such information that is used by many modern Six Sigma teams is to take a picture of the diagrams with a smartphone or digital camera. The images can then be uploaded into the team's shared workspace; if necessary, a Black Belt or Green Belt can convert the raw diagrams to a computerized version for the purpose of presenting information to leadership or other departments if desired.

Team Members

In the beginning of this chapter, we covered the three major types of team members: regular, ad hoc, and resource. Selecting members for each of these roles is up to the project leader, the sponsor or champion, and the overall organizational leadership team. In addition to the project leader, process owner, and process expert, Six Sigma teams are usually comprised of one to three other regular team members. In addition to acting as timekeeper or scribe as directed by the team leader, team members also:

- Participate in brainstorming sessions, discussions, and other team activities.
- Collect data and perform analysis under the direction of the Black Belt. Often, team members performing these functions are Green Belts.
- Perform work between meetings as required by the project leader.
- Report the results of and progress on individual assignments to the team.
- Review work performed by other team members and the team as a whole, offering suggestions and feedback.

Timelines, Scheduling, and Milestones

Scheduling and maintaining that schedule is an integral part of the Six Sigma project process. Organizational leaders need to understand how long a project will take, when results can be expected, and when team resources will be freed up for other endeavors. Without this information, leadership can't plan for ongoing improvement and employees can feel trapped in a project that seems to stretch on forever. In this section, we'll cover two methods for creating a project timeline or schedule and touch on the importance of milestones.

Phase-Based Timeline

Six Sigma projects usually follow a specific series of phases; we've briefly introduced the concept of the DMAIC method. DMAIC breaks a project up into five phases: Define, Measure, Analyze, Improve, and Control. Experienced Six Sigma experts with some data and information about a project and process can usually provide a very basic and raw estimate of time by assigning a certain number of weeks to each phase. It's also worth noting that most of the phases are likely to overlap.

To create a raw timeline for a project, a Black Belt or other Six Sigma leader usually starts with an overall time requirement. He or she either estimates the total time required for an improvement or works with a deadline imposed by the leadership group. For example, the leadership group might say that an improvement needs to be completed within four months.

Using a four month timeline and what information is already available about the process, problem, and resources, the Black Belt might create an estimated timeline for the DMAIC process that looks something like the figure below.

	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Define	█	█	█													
Measure		█	█	█	█	█										
Analyze				█	█	█	█	█	█							
Improve									█	█	█	█	█	█		
Control														█	█	█

The estimated timeline is for 16 weeks; the expert believes the Define phase will take 3 weeks and the Measure phase will take 5. The Measure phase overlaps with both the Define and Analyze phases, which is normal with Six Sigma projects.

The benefit of this approach is that you can generate a timeline quickly. The disadvantages are that someone without experience of Six Sigma and a fair amount of knowledge of the process being improved can easily misjudge the time required for each phase and leadership might consider this a hard timeline, which can create unrealistic expectations. When presenting such a timeline, make sure everyone knows that it is a rough estimate and the time for each phase can change as you go through the process.

Critical Path Method

The critical path method is a more detailed way of defining timelines for various elements of a project, but it does require more information and input from a project team. This means you probably won't be able to provide a detailed timeline until the project is underway; a critical path diagram could be one of the activities the team undertakes as part of the Define phase.

Creating a Critical Path Diagram

A critical path diagram can be created for the entire project or for each phase of a project. As we go through the steps of creating a critical path diagram, we'll use the Define phase of a project to reduce bad debt (uncollected invoices) in a medical billing environment as an example.

1. Identify the critical needs or activities to complete the project or phase of a project.

To complete the define phase of our project to improve bad debt in a medical billing setting, the team needs to choose a team, charter the project, define the problem, and create a baseline metric.

2. Put critical activities in order.

The order with which the team should accomplish the tasks defined in step one is:

- Choose a team
- Charter the project and define the problem (these tasks can be done simultaneously)
- Create a baseline metric

3. Assign a time to each task.

A Six Sigma expert estimates it will take one week to choose a team, one week to create a charter, one day to create a problem statement, and two weeks to create a baseline metric.

4. Create a diagram of the tasks, stacking simultaneous or parallel process and including time figures.

The diagram is created from left to right. The items on the left must be done before the items to the right can be completed. When items can be done at the same time, they are stacked.
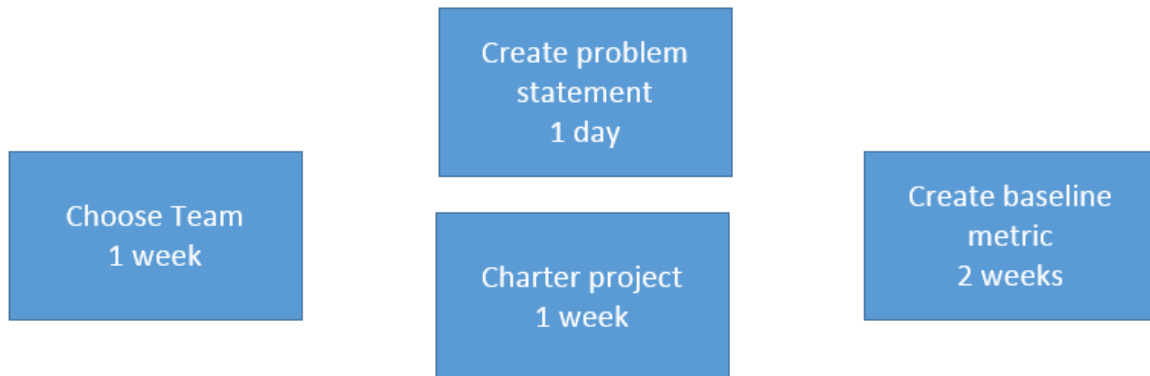
5. Draw a critical path through the diagram.

When steps are stacked, the critical path goes through the step with the longest time estimate. For example, the team might create a problem statement while they are working on a project charter; the project charter takes from Monday through Friday to complete. The problem statement is complete on Tuesday. However, the team is not done with all of the steps in that series until they are done with the project charter.
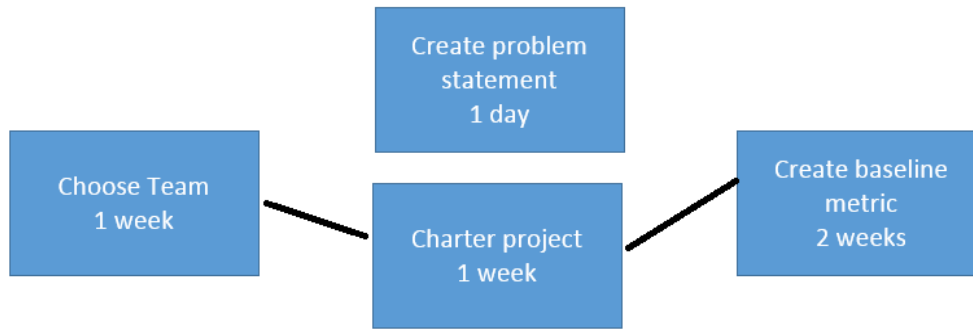
6. Add up the longest times from each section.

In this case, the team adds 1 week, 1 week, and 2 weeks to get to 4 weeks total for the Define phase.

We've used a very simple example, but you can use the critical path method to estimate timelines for extremely complex projects or processes.

Milestone Meetings

Once a timeline is established, set up milestone meetings and dates to help keep the team on track and notify the sponsor or champion of progress. In a DMAIC project, milestones are usually set at the end of each phase (Define, Measure, Analyze, Improve, and Control). However, teams can set custom milestones, and sponsors might require specific milestones if they are approving large resourcing or funding requests for a project.

You can also set up milestones within a team environment to manage goals and tasks; these milestones can be kept within the team. For example, a team working for a chain of sandwich shops is hoping to improve the process by which sandwiches are put together. They have set up the following milestones:

Define: January 21

Measure: February 12

Analyze: February 22

Improve: March 15

Control: April 10

The milestone dates are when the team or the Black Belt will meet with the sponsor to present the findings or results of each phase of the project. Each date gives the team something to work toward. However, the team has determined that certain tasks must be accomplished during the Measure phase. First, they have to create some definitions of terms so everyone is on the same page when discussing measurements. Second, the team has to gather data about the temperature at which ingredients are stored and cooked. Finally, the team wants to actively observe sandwich shop employees in order to measure the time it takes to make various sandwiches.

The team might set up internal milestones for the Measure phase, stating that definitions will be created by January 25, temperature data collected by February 5, and time data collected by February 10.

By breaking each phase, and each larger task, into smaller parts, it is easier for the team to stay on track and complete work. Smaller tasks seem more manageable, so they are more likely to be accomplished.

Budgets

Teams, and especially team leaders, must always be concerned with project budgets. While success is rated by end customers in terms of performance, quality, and satisfaction, Six Sigma teams also answer to corporate leadership. For leaders, success is also measured in terms of time and budget. A strong timeline and good milestones help you meet time requirements, and an understanding of financial drivers, strong communication, and financial oversight help you keep a project within budget.

One of the challenges when dealing with budgets in a Six Sigma project is that all team members are not always completely aware of financial drivers. In some cases, financial information might even be restricted; employers don't generally want specific data about employee pay made public to various team members, for example. Some information and analysis might need to be performed solely by a project-leading Black Belt in such cases, especially if data is critical or sensitive.

Outside of concerns with sensitive data, process improvement projects work best when all team members are made aware of as many of the drivers and data as possible. When teams know how much funding a champion is willing to seek on their behalf, they can make realistic decisions about how to improve a process. Sometimes, the solution that is most likely to generate the most improvement isn't viable because of budget. If an improvement project has a budget of $50,000, the team can't implement a solution that requires an $80,000 capital investment in machinery, for example.

Budget concerns vary by organization. In some organizations, leaders are most concerned with specific expenditures by a team, including expenses on new equipment, hiring new personnel, or purchasing new products or software. Some organizations take a more granular approach to project budgets, considering the expense of hours spent by the team on the project as well as the expenses associated with training and implementing a solution outside of the team environment.

Six Sigma team leaders must ensure they understand how leaders and organizations manage project budgets. Working for the first time with an organization or sponsor means having honest and thorough conversations about how budgets are calculated, how much sponsors are willing to work for increases in a budget, and what the Six Sigma leader's expected role in maintaining budgets is.

Defined Measures of Success
Finally, Six Sigma teams must create a well-defined measure of success. To best manage a Six Sigma project and team, leaders have to ensure all team members, leaders, and sponsors agree on what success means. If success isn't defined at all, the team risks scope creep and getting lost in a project that never seems to end. If success isn't well-defined, teams risk concluding a project without satisfying the customer, sponsor, or all members of the team. If a sponsor and the team don't agree on what success looks like, the team could think they've concluded a successful project while leadership believes the project was a failure.

In the end, successful Six Sigma team management hinges on many of the same concepts as successful leadership in other endeavors does. Choosing the right people, being clear about expectations, approaching work in an organized manner, and being honest and open about progress helps every member of the team succeed and provide value.

Chapter 11: Introduction to DMAIC and DMADV

One of the things that sets Six Sigma apart from some other quality improvement and management methodologies is a structured approach to every project. Projects that are meant to improve an existing process follow a road-map for success known as the DMAIC process; DMAIC is broken into five phases: Define, Measure, Analyze, Improve, and Control. The main activities of a DMAIC project include identifying the critical inputs or causes (the Xs) that are creating the problem (the Y), verifying those causes, brainstorming and selecting solutions, implementing solutions, and creating a control plan to ensure the improved state is maintained.

The DMAIC methodology is designed to be fairly inclusive – the vast majority of teams who are seeking to improve a project will be able to fit their activities in to the DMAIC steps because those steps are designed to allow some flexibility. Sometimes, though, teams realize that fixing or improving a process isn't the right way to achieve sustained improvement for the organization. Instead, a process might need to be completely replaced or redesigned to meet goals for customer satisfaction or organizational improvement. In such cases, teams can employ the DMADV method.

DMADV stands for Define, Measure, Analyze, Design, and Verify. The principles governing the method are very similar to those governing DMAIC, but the last two phases are geared toward rolling out and testing a completely new process. Six Sigma teams might approach improvements through DMADV if:

- The business wants to launch a new service or product.
- Business leaders decide to replace a process because of upgrade needs or to align business processes, machinery, or employees with future goals.
- A Six Sigma team discovers that improving a process is not likely to provide the success desired from a project.

Most teams go into the project knowing whether they are employing DMAIC or DMADV approaches, but some DMAIC projects can become DMADV projects – usually during the Define, Measure, or Analyze stages – when the team realizes the need for a complete process replacement. Switching to the new methodology during the middle of the project might require some shuffling of resources and could impact project schedules, which means keeping champions and sponsors informed of team progress and decisions is imperative.

It's worth noting that some organizations don't formally use the DMADV approach for any project, in part because they find it easier to stick with the nomenclature of a single methodology. These organizations might still complete process redesign projects by altering some of the activities handled in the Improve and Control stages of DMAIC. In short, the teams *do* use the DMADV approach, but they use the verbiage associated with DMAIC to streamline Six Sigma education across all levels of the organization.

DMAIC versus DMADV

The major differences between DMAIC and DMADV are the goals the team sets and the outcome of the completed project. In some ways, a DMADV project might feel like it has a more tangible outcome, but in reality, both methods are seeking to deliver better quality, better efficiency, more production, more profits, higher customer satisfaction, or some combination of these things. We'll introduce each of the phases of both methods in this chapter. But first, let's look at some quick definitions of each phase as they relate to DMAIC versus DMADV.

Phase 1: Define

During a DMAIC project, the Define phase is concerned with identifying the problem, defining requirements for the project, and setting goals for success. Requirements and goal setting might relate to a variety of factors and are dependent somewhat on guidance from the leadership team and expected budgets, and Six Sigma leaders can use various tools within the phase to create flexibility that allows for a variety of project types.

In a DMADV project, the Define stage is slightly more rigid. Teams also have to identify a problem and begin defining requirements, but requirements must be made within a change-management environment. Sometimes, organizations have a change management program in place, which means Six Sigma teams must incorporate all requirements of that program into the DMADV phases. The team also works to define customer requirements to create a measuring stick to which the process development can be compared.

Phase 2: Measure

The DMAIC Measure phase is when teams use data to validate their assumptions about the process and the problem. Validation of assumptions also merges into the analyze phase. The bulk of the measure phase is occupied with actually gathering data and formatting it in a way that can be analyzed. Measuring can be one of the most difficult tasks in a Six Sigma project if data isn't already being captured. Teams might have to build tools to capture data, create queries for digital data, sift through enormous amounts of data to find relevant information, or capture data by hand in some manual process.

> **What is Change Management?**
>
> Change management refers to a closely-managed process of making changes in an organization. Often, companies use change management policies and rules to govern how changes are made to software, infrastructure, or processes that have compliance or audit elements.
>
> During change management, teams must document all activity in keeping with corporate policies and report changes and results to an oversight committee. Sometimes, Six Sigma projects involve changes that are also governed by these policies, which means Six Sigma leaders must be prepared to report to change management committees.

After validating assumptions from the Define stage with actual data, the team might revisit problem statements, goals, and other process-related definitions. If the team leaves Define with a "rough draft" of these things, they should leave Measure with a final draft. Teams also work during Measure phases to measure key inputs and steps in the process in preparation for Define.

Teams working through a DMADV approach might do some of the same things during the Measure phase, but activities are typically more targeted. Teams will likely collect data and measurements that help them define performance requirements for the new process.

Phase 3: Analyze

During the Analyze phase of a DMAIC project, teams develop hypotheses about causal relationships between inputs and outputs and between Xs and Ys, they narrow causation down to the vital few (using methods such as the Pareto principle), and they use statistical analysis and data to validate the hypotheses and assumptions they've made so far. The Analyze phase tends to flow into the Improve phase in a DMAIC project; hypothesis testing to validate assumptions and possible solutions might begin in Analyze and continue into the Improve phase.

A team using DMADV might also identify cause and effect relationships, but they are usually more concerned with identifying best practices and benchmarks by which to measure and design the new process. Teams might also begin process design work by identifying value- and non value-added activities, locating areas where bottlenecks or errors are likely, and refining requirements to better meet the needs and goals of the project.

Phase 4: Improve or Design

Six Sigma teams start developing the ideas that began in the Analyze phase during the Improve phase of a project. They use statistics and real-world observation to test hypotheses and solutions. Hypothesis testing actually begins in the analyze phase, but is continued during the improve phase as teams select solutions and begin to implement them. Teams also work to standardize solutions in preparation for rolling improved processes to daily production and non-team employees. Teams also start measuring results and lay the foundation for controls that will be built in the last phase.

The fourth phase is where DMADV projects begin to diverge substantially from DMAIC projects. The team actually works to design a new process, which does involve some of the solutions testing mentioned above, but also involves mapping, workflow principles, and actively building new infrastructures. That might mean putting new equipment in place, hiring and training new employees, or developing new software tools. Teams also start to implement the new systems and processes during the fourth phase.

Phase 5: Control or Verify

For DMAIC and DMADV teams, the control or verify phase is where loose ends are tied and the project is transitioned to a daily work environment. Controls and standards are established so that improvements can be maintained, but the responsibility for those improvements is transitioned to the process owner. During the transition, the Six Sigma team might work with the process owner and his or her department to troubleshoot any problems with the improvement.

Which Methodology Would You Use?

Consider the following improvement projects. Which methodology do you think a Six Sigma team might use to approach each project?

1. A business wants to create a smartphone app to help customers make and manage appointments.
2. A doctor's office has had numerous complaints from patients because it is too hard to get appointments, appointment communications are confusing, or patients show up for appointments and are told they don't have an appointment.
3. A company that manufactures pizza boxes isn't happy with the profit margins in the small size boxes.

The team handling an improvement for the business in example 1 would choose a DMADV approach. They are creating a product that doesn't yet exist; while the team is meeting a need that already exists and is improving an overall process – the setting of appointments – the app itself is a new process and a new product. The app will need to be designed, integrated into existing systems, and the final product tested before full implementation.

Example 2 is for an existing process, so the team would begin with a DMAIC approach. It's possible that the team might determine during the process that one solution might be to develop a new appointment-setting software or replace existing software with something from a different vendor. In some cases, that might warrant a switch to DMADV, but, as previously stated, not all organizations would do so. Some organizations would continue with the DMAIC process and modify the activities in each phase to fit the needs of the project at hand.

Example 3 is a classic example of what brings many teams to the DMAIC method. The problem hasn't yet been defined, but the organization knows that goals and expectations are not being met. A leadership team might work with subject matter experts and one or more Six Sigma experts to discover more about the processes involved before settling on one or more improvement projects.

Define

During the Define phase of a Six Sigma process improvement project, teams create what is known as a project charter and a basic plan for work. A charter is a synopsis of the project. It provides some common information and a summary of what the team hopes to accomplish. The charter usually features a list of team members, names of those responsible for outcomes, a problem statement, a goal, and some basic definitions of scope and metrics for success. Some charters also include a rough timeline estimate for the project.

Also during the Define phase, teams create or list measurable customer requirements and create high-level documents about the process (including process maps). Often, teams will start with a SIPOC diagram to help them begin to understand a process. Teams should also identify stakeholders during the Define phase. Stakeholders are individuals, both within and without an organization, who have some level of influence on the success of an improvement project. By understanding who stakeholders are, teams can remain in contact with various persons throughout the project, communicating with those stakeholders as needed to ensure future viability of any improvement that is created. One way to identify stakeholders is through a Stakeholder Analysis.

Tips for Positive Movement in the Define Stage
One of the biggest challenges Six Sigma teams face when in the Define phase of a project is generating positive, targeted momentum that sets the foundation for the rest of the project. As a Six Sigma team

leader, you can increase chances of success by keeping the team as focused as possible during the Define stage. Begin by explaining the Six Sigma process and the purpose of the project for any ancillary team members who may not be familiar with Six Sigma and DMAIC. Next, work as a team to create ground rules for how the project will run – including how meetings are organized and managed, how information will be communicated, and what each team member might be responsible for during the project.

Create a charter and project plan so the team has something to focus on. If possible, have the Champion of the project spend time with the team. Hearing directly from an executive leader about expectations and the support of leadership for the project helps motivate a team. At the same time, ensure the Champion doesn't step in to take over the project, as this isn't his or her role.

Define is also a good time to explain the roles of scribe and time keeper and talk about the purpose of brainstorming. Some Six Sigma leaders like to let team members take turns facilitating various exercises for the group, as this integrates each person more tightly within the process and helps team members at all levels learn more about Six Sigma.

Measure

Once a team has a good grasp of what the process does and how it works, what the problem is, and what the goal for the project is, the team moves from Define to Measure. Usually, the transition between phases is marked by a tollgate review wherein the team presents its Define work to a champion or a Six Sigma leadership board. The champion or board provides feedback and makes the decision about whether the team is ready to move on to Measure.

During the Measure phase, the team is concerned with creating a baseline metric for the process and refining problem statements and other outputs of the Define stage. Creating a baseline metric lets teams understand how a process should be measured and how the process is really performing before improvements begin. It also provides a comparison point so teams can show how much improvement they've brought to a project at the end of the DMAIC method.

One of the biggest challenges, especially for teams and team members who are new to the Six Sigma method, can be deciding what to measure. Many times, inexperienced teams end up spending time collecting data that doesn't provide answers or can't be used for the process. Because the Measure phase starts with some educated guesswork and trial-and-error, teams and Six Sigma leaders have to keep a close eye on progress and redirect work when measurements are not creating the answers or production required.

A successful Measure phase requires strong observation skills, an understanding of the reasons behind measure, knowledge of data types such as discrete and continuous, tools for measurement assessment, and a strong background in statistical analysis. Some of the tools often deployed in the Measure phase, such as the CTQ tree and sigma level calculation, were covered in previous chapters.

Tips for an Effective Measure Phase
The Measure phase is often the most challenging phase for a Six Sigma team leader, especially when working with teams that are inexperienced in the methodology. When teams start to really dig deep

into a process and begin to measure things, they often get a true idea about how challenging the problem really is. They might also have a difficult time understanding how and when to measure things, and collecting data that hasn't been collected before can be time consuming and tedious. Because of all these challenges, teams might enter what is called a storming stage—team members question the viability of the project, rail against the Champion or the team leader, complain how much time the project is taking from other duties, or stop showing up to meetings altogether.

Six Sigma leaders can reduce the impact of storming on a team by demonstrating a calm approach to each aspect of the project and redirecting the strong emotion of storming to more productive work. If you can identify an easy task or problem, letting the team work on that and accomplish something immediately can reduce the excitement of storming; Six Sigma leaders should also ensure work is fairly distributed and that each team member knows exactly what his or her responsibilities are.

Analyze

Once measurements are collected – or are in the process of being collected – Six Sigma teams usually move on to the Analyze phase. Again, a tollgate review is often conducted between phases, but the lines between Measure and Analyze are often blurrier than the lines between Define and Measure. In some cases, a team has to measure, analyze, and then measure some more – particularly if metrics aren't already in place for a process.

Analyze phases are when teams perform detective work on the process. Using the clues gathered during the Define and Measure phases, along with information provided by the sponsor, process owner, and subject matter experts, teams attempt to identify root causes for a problem; they also use statistical analysis and other tools to verify causes before turning to the work of identifying possible solutions. During the Analyze phase, teams use a variety of tools – some of which were introduced in earlier chapters. Tools common in the Analyze phase include Pareto charts, run charts, histograms, cause-and-effect diagrams, scatter diagrams, process maps, and value analysis.

As teams work through the Analyze phase, they also start preparing for the Improve phase. During Analyze, teams might begin working on possible solutions and selecting solutions, developing improvement plans, and preparing some basic documentation about improvement work. Whether a team begins this work during Analyze often depends on the individual project and the manner in which the Six Sigma team leader would like to proceed. The Six Sigma team leader should ensure that teams aren't taking on too much of the project at one time and that working on early Improve work doesn't reduce the efficacy of the work done for the Analyze phase.

Tips for a Strong Analyze Phase

Teams in the Analyze phase might continue to suffer from storming; if teams didn't storm during Define or Measure phases, they might begin to do so in Analyze. Six Sigma leaders can use the same tips for controlling storming in the Measure phase in the Analyze phase.

Another common challenge for Six Sigma team leaders is introducing and explaining statistical concepts during the Analyze phase. When other team members or even the champion of the process are not familiar with statistical analysis, presenting advanced analysis in terms of statistical verbiage only can be

a mistake. Team members won't understand how you came to the conclusions you are presenting, which makes it less likely they will get behind the solution or improvement in a positive way.

Six Sigma experts should be aware of the knowledge limitations of various team members and work to both present information in a way that is understood by everyone *and* continue to add to team member knowledge by explaining concepts when possible.

Improve

During the Improve phase of a project, a Six Sigma team selects a final solution and begins to put it in place. Sometimes, teams will select more than one solution, especially if a few smaller solutions are highly related and work together for an overall solution. It can be hard to determine which solution actually improves a process, however, so it's usually a best practice to implement one change at a time and verify that change before moving on to something else.

Teams might also come up with many possible solutions, all of which would provide some improvement for the process. They should use a solutions selection matrix or other Six Sigma tool to evaluate solutions, choosing only the few best solutions. It's worth noting again that the best solution is not always the solution that provides the most improvement. Solutions that are so expensive or disruptive that they cause disadvantages that outweigh any benefits should never be selected by project teams.

During Improve, Six Sigma teams must continue to keep the project definitions in mind. The solution must address a root cause verified in the Analyze phase; the root cause must be directly related to the problem stated during the Define phase. After selecting solutions, teams must test them using statistical tools and real-world sampling to ensure effectiveness before deploying solutions to a live work environment.

Tips for Staying Strong Nearing the End of a DMAIC Project

Possibly the most common problem that plagues Six Sigma teams during the Improve phase is project fatigue. By the time teams come to Improve, they have been working on a project for weeks or even months; for many team members, the project work is on top of regular work. Fatigue or frustration might push team members to select and implement solutions just to have the project completed. Six Sigma leaders have to work to keep teams motivated on quality and improvement.

The best way for a Six Sigma team leader to create strength as the team nears project completion is to build a good foundation for Six Sigma in the earlier phases. Teams that understand the DMAIC process and have at least basic understanding of Six Sigma and statistical analysis by the Improve phase are more likely to stick with planning, analysis, and the DMAIC method.

Six Sigma team leaders should also continue to foster a team approach to all aspects of the project. One challenge for some leaders is the temptation to take measurements and analysis and begin performing much of the work themselves. Sometimes, it's faster and easier to handle decision-making and analysis on your own, especially when you are dealing with team members who aren't fluent in DMAIC or Six Sigma methods. Doing so alienates team members, though, and can result in a Six Sigma leader without direct process knowledge making the wrong decision. Keeping the team involved – and making exercises and meetings fun and productive – helps you make it through the Improve phase.

Control

Control is the final phase for Six Sigma teams employing the DMAIC process. During the Control phase, teams usually handle four tasks: creating the foundation for process discipline, finalizing documents regarding the improvement, establishing ongoing metrics to evaluate the process, and building a process management plan that lets the team transition the improvement to the process owner.

Tools used by a team during the Control phase include documentation checklists, control charts, response plans, process maps, and process dashboards.

The Control Phase is often easy for a team because the work of the team has already reached a crescendo. In a well-run DMAIC process, the Control phase is a time of wrapping up loose ends and arriving at the end of a project. At the same time, teams might find it challenging to let go of a process they have put so much time into. By the time teams reach the Control phase, they might have been working with a process for months. If a Six Sigma leader has done his or her job, the team has taken ownership of the process and feels personally tied to the quality and output, making it hard to turn the work over to other teams or employees.

Ending on a Positive Note

Six Sigma leaders can help team members transition a project by preparing them in advance for this phase. You might also find ways to incorporate team members into meetings or presentations where project results are being shared. Six Sigma leaders should always host a meeting to wrap up the project. The meeting should be somewhat celebratory in nature – if budget, time, and policy allows, Six Sigma leaders might consider having lunch or snacks at the meeting. Take time to recognize each team member's contribution, and ask team members to identify something they learned that can be applied to their own work. This helps team members see that Six Sigma is an ongoing culture within an organization, and the end of a particular project doesn't equate to the end of each person's involvement in continuous improvement.

Recognition is extremely important when ending a Six Sigma project. Team members might have put in extra hours to provide excellent work on a project while maintaining their own responsibilities. Often, work on a Six Sigma project is not part of a team member's regular duties, so they are going above and beyond what might normally be expected of them. Six Sigma leaders should make it a point to recognize the work of team members in front of a project sponsor or champion, and, when possible, in front of the department for which the improvement is being made.

Design

Design is the fourth phase of DMADV; it replaces the Improve phase of DMAIC. DMADV is one approach for what is called Design for Six Sigma, or DFSS. Another approach is called DMADOV, which stands for Define, Measure, Analyze, Design, Optimize, and Validate. Teams using the DMADV approach usually combine the activities from Design and Optimize, and we'll briefly introduce those activities in this section.

The Design phase of DMADV is when teams create a new process or develop a new product. A Six Sigma team would have previously done all the work to lay the foundation for development during the Define, Measure, and Analyze stages, which means most of the Design phase is taken up with the actual work involved in creating the process or project.

Using the plans, instructions, or maps created in earlier phases, the team either creates a product themselves or works with vendors, manufacturers, or other employees to create the product. For example, if the DMADV project involved the creation of a new app for customers or employees, the team might work with staff in the programming and technical departments. They might also work with a vendor who will be supplying the app or software in question; in such a case, a representative from the vendor should have been part of the team throughout all phases.

During Design, a team will also test the product, process, or service. Testing can be done in testing environments, in limited production environments, or via Beta testing. Usually, the team rolls out the new process or product to a limited number of internal or external customers; those customers provide feedback and the team uses the feedback to troubleshoot the new process or product as needed. Seeking feedback and troubleshooting the new process to create the best possible solution is where the Optimize in DMADOV comes in.

Tips for a Successful Design Phase
In a process redesign project, all phases are essential, but Design is often seen as the most critical. Teams that falter in the design phase can waste the work that was put into other phases, and it's easy for teams to fall prey to project fatigue just as work requirements pick up for everyone involved. Six Sigma team leaders can help improve the chances of a successful Design phase by following the tips for managing Improve phases. Teams should also be realistic about target dates for design work. Promising a complete solution in a short time period pleases leadership at first, but if teams are rushed, they tend to deliver low-quality processes. If you promise a too-good-to-be true timeline, you also run the risk of running far behind schedule, which can impede the work of other projects and process improvements.

Verify

The Verify phase of a DMADV or DMADOV project is very similar to the Control phase of a DMAIC project. The new process, product, or service is transitioned out of project mode and handed off to a process owner or employees who work daily with the process or product in question. Control plans, including control charts, might be put in place by the team to track ongoing results, and almost all of the tools used in a DMAIC Control phase are relevant to Verify.

One of the differences between Verify and Control is that DMADV teams might take time to complete further CTQ analysis at the end of a project so they can identify new critical-to-quality factors. This is done because the process or product is different than it was when the team first started working. While the team should have made educated guesses about CTQs for the new product – and used those CTQs in planning and designing – they could not predict 100 percent how the customer might react to the new product or process. A new process might have a capability the old one did not; having that capability, the customer might decide it is the most important factor in quality about the process or product.

At the end of the Verify phase, a team delivers a final product or process that meets the needs first identified in the Define stage. The process or product should be free of known problems and defects wherever possible, and teams should have provided a way to manage and control the process through statistical control charts, Lean templates, and policies.

Closing a DMADV Project

One of the major differences between DMAIC and DMADV is the possible timeline. We previously stated that a problem fits the DMAIC model if it can be solved in less than six months. While some DMADV projects might only take a few months, many process or product designs can take years. Because of this, the concluding challenges for a DMADV team are similar to those in a DMAIC environment, but they might be heightened by the length of time a team has spent on a project.

Team members who have spent a year or more working to develop a new process or product might feel like the end of the project threatens their job. This is especially true when team members have not been handling regular work duties in addition to product duties. Six Sigma leaders and champions can reduce these worries by communicating next steps and expectations clearly with staff.

Team members who have been working on regular job duties alongside project work for years might find it hard to return to regular duties without something else to work on. One of the benefits of Six Sigma is that team members learn to expect more of themselves, their coworkers, and an organization's processes. Six Sigma team leaders can work with employees returning to daily work and help them apply what they learned in a positive fashion within their respective departments.

Finally, Six Sigma team leaders should ensure that a DMADV project closes on a positive note by validating all team members and ensuring process owners have all the tools they need to accept the new process without disrupting work.

Breaking up the Elephant

You should now have a basic understanding of how a Six Sigma team approaches a problem or process improvement. Whether improving an existing process or creating a new process or product, teams work through phased approaches. The phases of DMAIC and DMADV provide control and organization for a project, help keep everyone on task, and let teams break up what can seem like enormous tasks into chunks that are tolerable. As the old adage says: How do you eat an elephant? One bite at a time. Similarly, the phased approach of Six Sigma breaks up the elephant so teams can work on it one bite at a time.