COUNCIL FOR

SIX SIGMA CERTIFICATION

Six Sigma Black Belt Certification

TRAINING MANUAL

JUNE 2018 EDITION

Unit 1: Introduction to Six Sigma

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

[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

[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:

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

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 5 of them have errors. Applying that to the total amount, they estimate that as many as 750 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 750 defects.

((150,000 – 750) / 150,000) * 100 = a yield of 99.5

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

Yield %	DPMO	Sigma Level
99.7450	2,550	4.3
99.6540	3,460	4.2
99.5340	4,550	4.1
99.3790	6,210	4.0
99.1810	8,190	3.9

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 customer in a timely manner	4.3

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

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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

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 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 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.

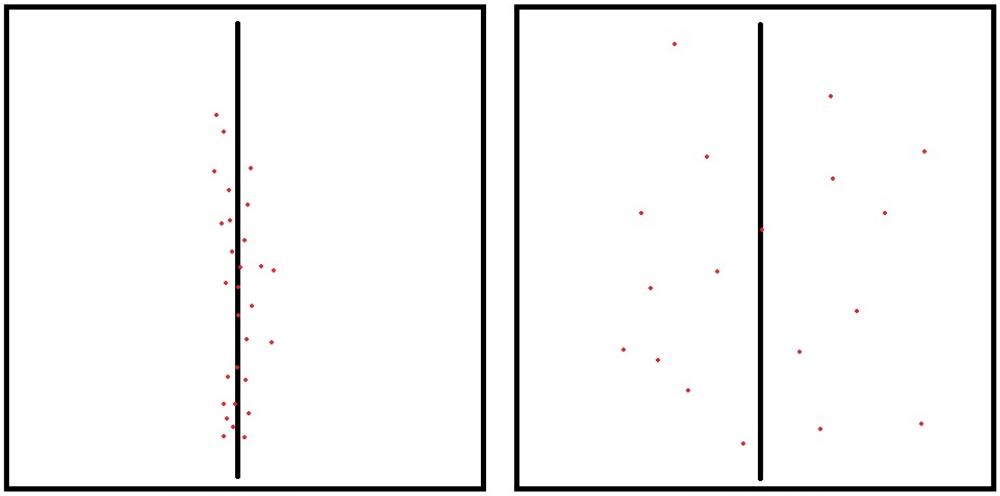
For example, if an oven heats to exactly 350 degrees in five minutes and stays at that temperature until it is turned off, it is less likely to burn cookies. If a cook measures each ingredient exactly, he or she is more likely to turn out cookies that consistently taste good. Add variation in the process, 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.



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.

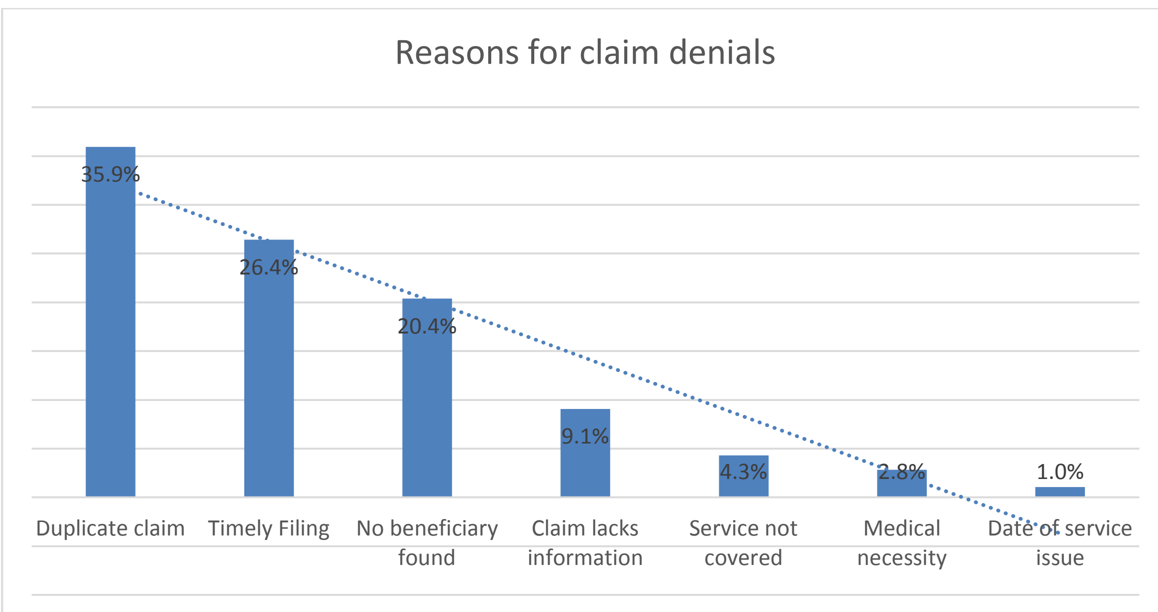
The Pareto principle is best displayed using a Pareto chart, which is a graphical representation of data elements – usually inputs or causes – in a ranked bar chart. Unlike a regular bar chart, the bars are arranged in order of height, with the highest on the left and the lowest on the right. Statistical 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.

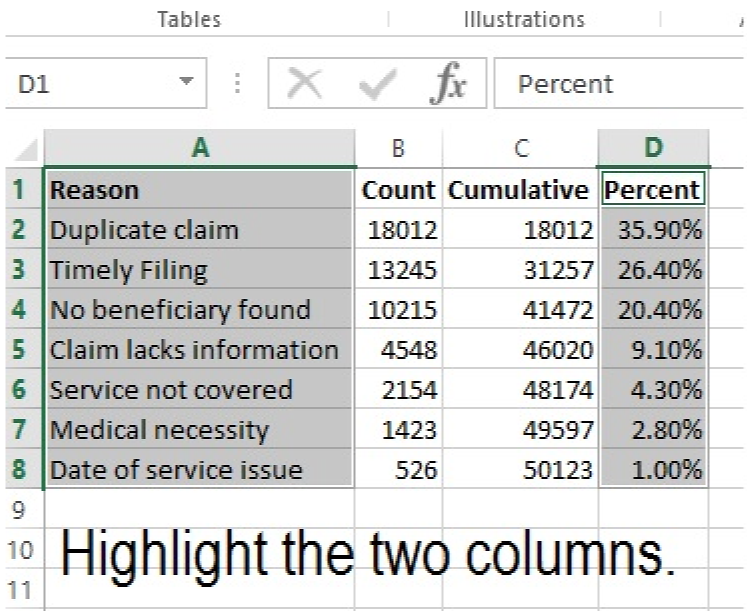
Creating a Basic Pareto Chart in Excel

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.

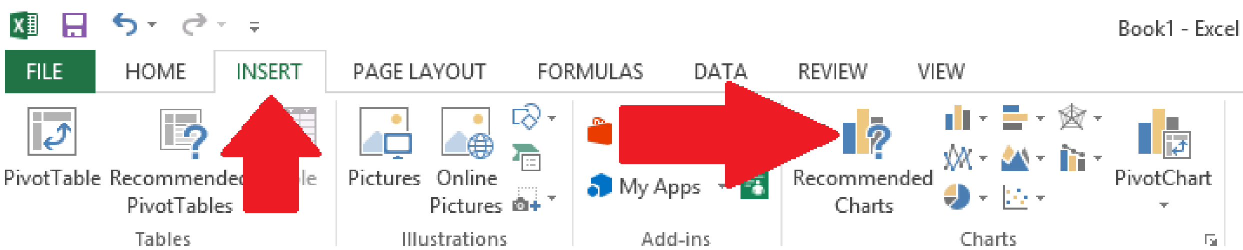


Tables | Illustrations

D1 | fx | Percent

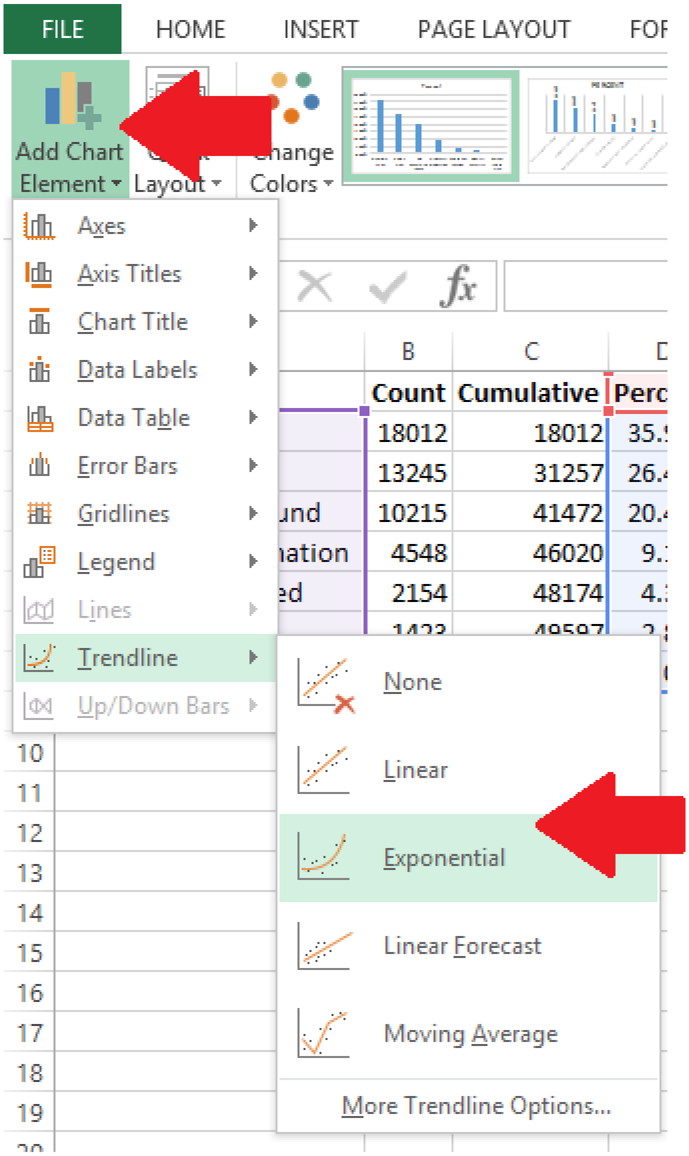
	A	B	C	D
1	Reason	Count	Cumulative	Percent
2	Duplicate claim	18012	18012	35.90%
3	Timely Filing	13245	31257	26.40%
4	No beneficiary found	10215	41472	20.40%
5	Claim lacks information	4548	46020	9.10%
6	Service not covered	2154	48174	4.30%
7	Medical necessity	1423	49597	2.80%
8	Date of service issue	526	50123	1.00%
9				
10				
11				

Highlight the two columns.

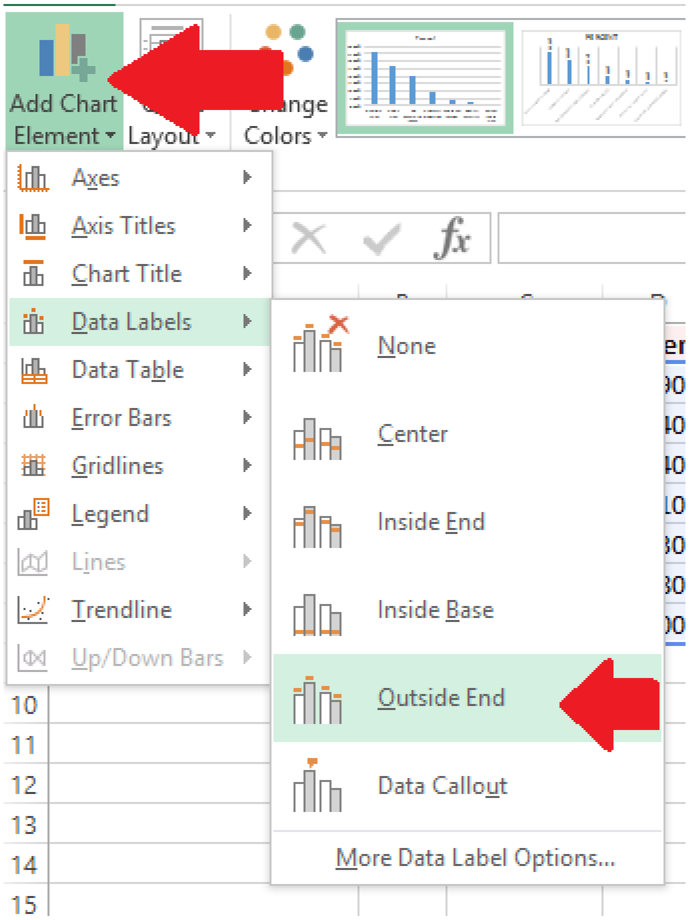


Click insert, then click on bar charts.

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

- 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

Tool	Cost	Benefits	
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 most expensive	-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:

مهم ← (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 scrapped, 5 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

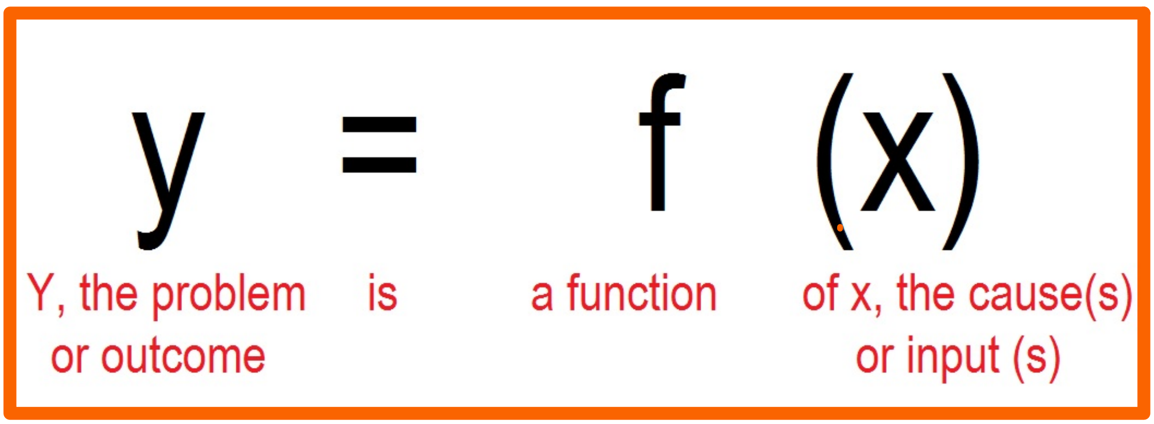
Calculate the FTY and the RTY for this process.

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:



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

Ex

- 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?

- What process did the problem involve?
- How is the problem measured?
- 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:

- Where did the problem occur? Jacksonville, Florida
- When did the problem occur? February 2015
- What process did the problem involve? Answering phone calls
- How is the problem measured? Average speed of answer
- 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:

- Where did the problem occur? Ohio
- When did the problem occur? Unknown
- What process did the problem involve? Unknown
- How is the problem measured? Unknown
- 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.

Ex: 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.

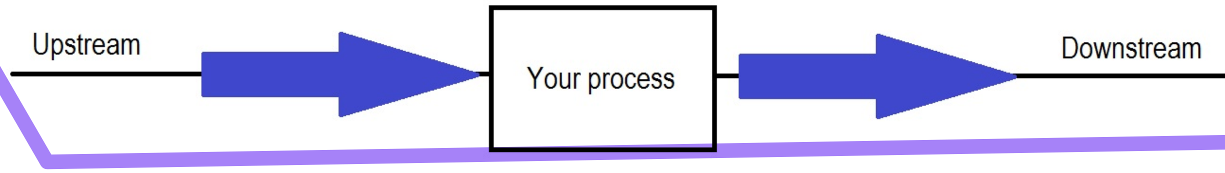
With just this information, you can probably see an easy way to reduce stocking time in this example: move stocking duties to non-peak times when possible. Simply understanding the steps to stock the area is not enough to understand the process; you also have to gather data about process times.

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.

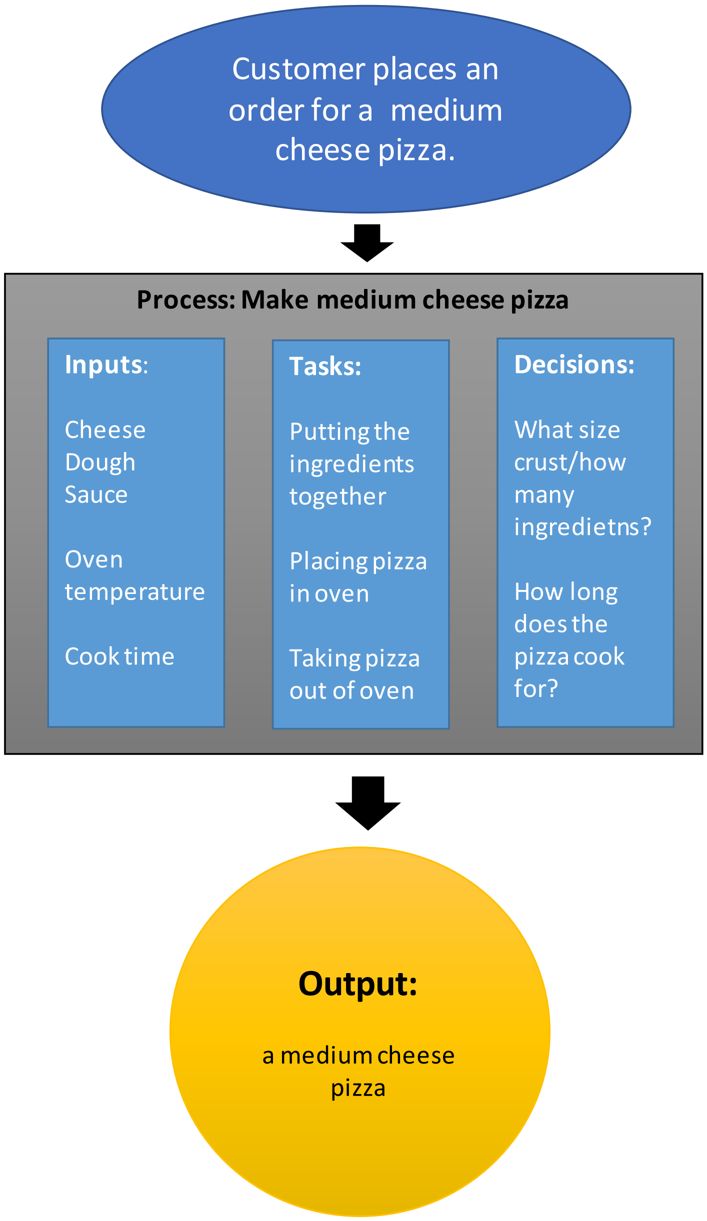


Figure 1 Medium Cheese Pizza Process

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

process owner

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

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 Label machine	Unlabeled bottles Data for labels	Choose bottle size Print label	Labeled bottle	Bottle-filling station

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

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) Warehouse (provides legs, screws, and protective cover)	Stool top Legs Screws Protective cover	Align legs Attach legs with screws Place protective cover	Barstool with legs attached	Packing station
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.

Process : coffee shop order (Iced spanish latte)

Suppliers	Inputs	Process	Outputs	Customers
supplier (market) backaging vendors equipment suppliers	coffee beans milk sugar condensed milk water cups, napkins, straws paper (reciepts)	1- recieve order, complete payment, give bill, place order. 2- grind coffee beans 3- brew coffee 4- add milk, sugar, ice, condensed milk 5- Pack & serve to customer	1- Iced Spanish Latte cup 2- reciept	1- walk-in customers 2- Delivery agent

Enablers:

Electricity

المكينة الي بتطلع قهوة؟

Barista

coffee machine

grinder

Ice maker

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.

critical to customer

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.

[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.

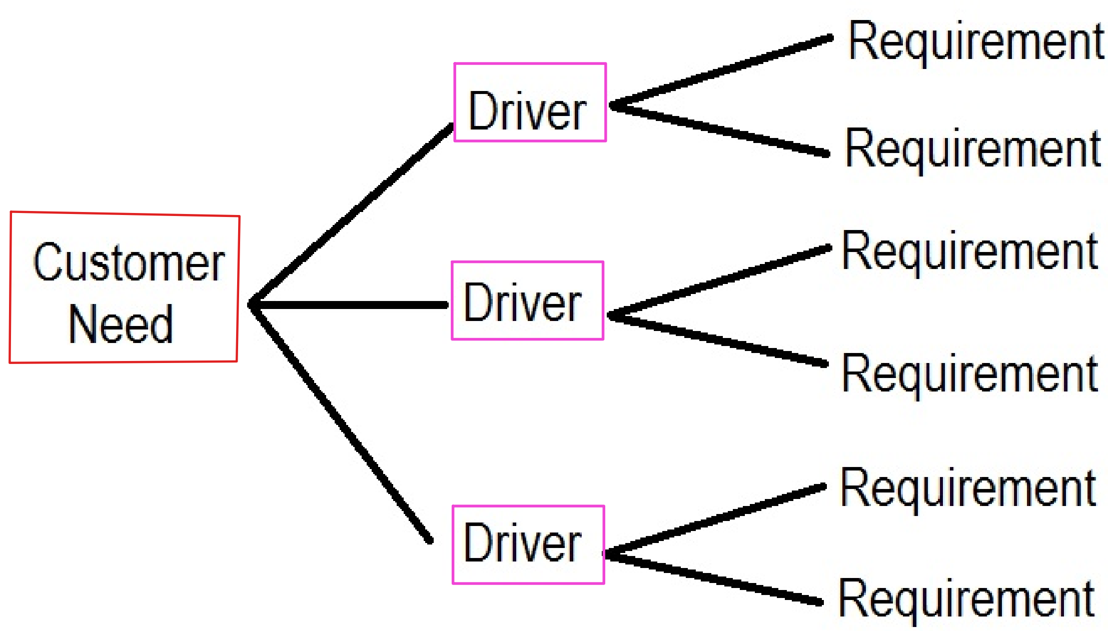
Outside of a project environment, understanding CTQs lets organizations stay on top of quality. By managing a few critical metrics, teams can ensure excellent output in a continuous fashion and identify potential areas for improvement before they become customer-facing problems.

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

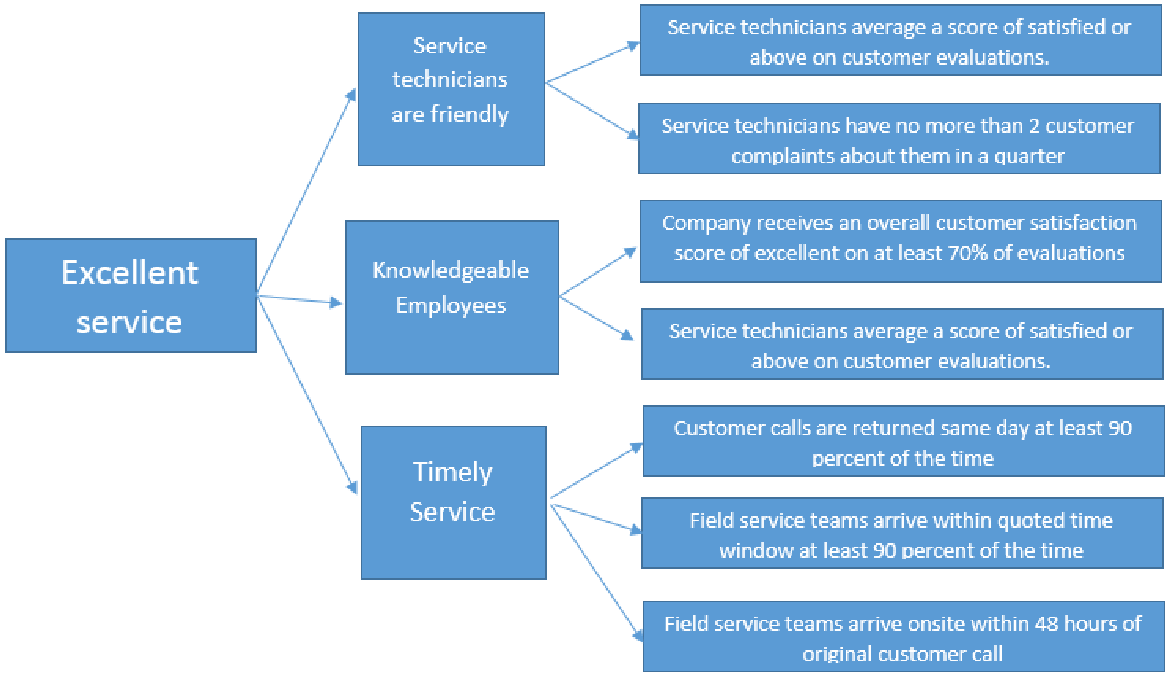
Once you have a list of critical needs, work with one need at a time to create a tree similar to the diagram above. Identify quality drivers that must be present or met for the customer need to be fulfilled. For example, customers of an HVAC service company might require excellent service. Drivers for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

Losing customer is cost

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:

$$\text{CoPQ} = \text{External Failure Costs} + \text{Internal Failure Costs}$$

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:

$$CoQ = CoPQ + \text{Prevention Costs} + \text{Appraisal Costs}$$

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%

first: reducing poor quality cost

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		

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?	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			

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

لـ معيدها أضيق ال project كل ما زاد الجدول مثلاً" طلع عشوائي كور معهم
فوق الـ ٣ شو بتحتاج منهم ؟ أكلو أصحابك scores

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

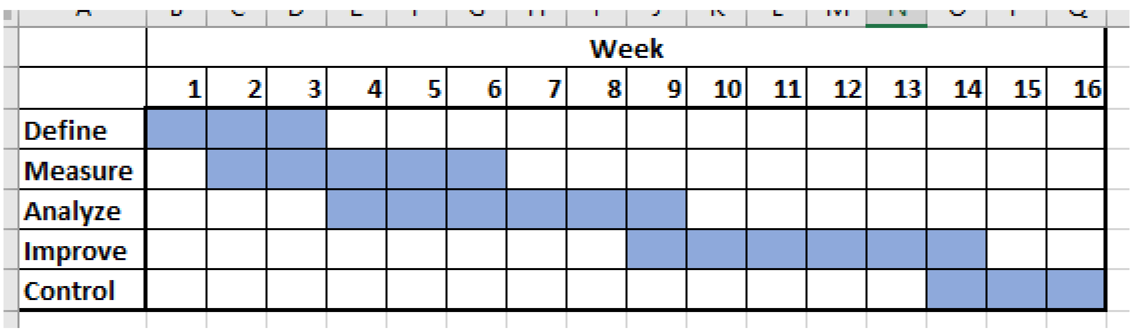
Scheduling and maintaining that schedule is an integral part of the Six Sigma project process. Organizational leaders need to understand how long a project will take, when results can be expected, and when team resources will be freed up for other endeavors. Without this information, leadership can't 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.



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:

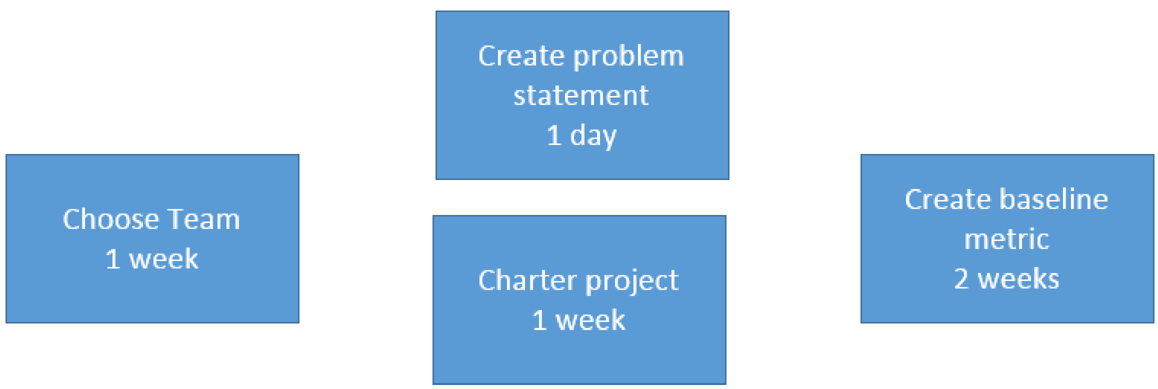
- Choose a team
- Charter the project and define the problem (these tasks can be done simultaneously)
- Create a baseline metric

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.

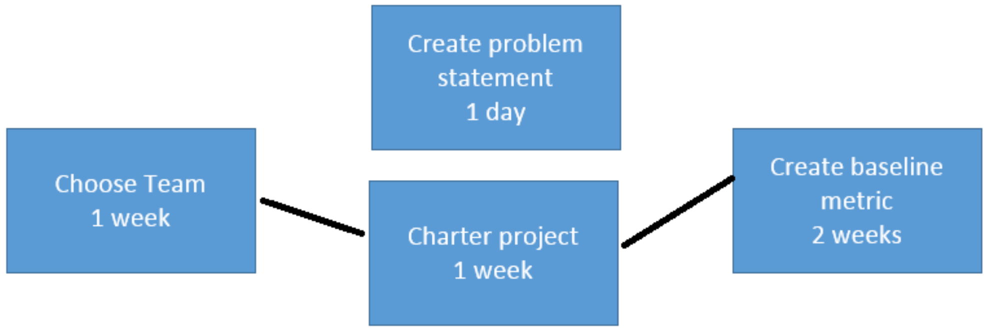
4. Create a diagram of the tasks, stacking simultaneous or parallel process and including time figures.

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.

(مطلوب من التابتر)

مادر الجدول

	DMAIC	DMADV
	Exiting Process	Future Process
Define:	Define existing prob. Define requirments Define customers Define measure performance (→ flexible process variety objective) Define stakeholders Target goal	Define future customer Define requirment Define goal Define KPIs performance Define stakeholders complex change managment (rigid) ← مضبوطة بقوانين الشركة
Measure	measure existing KPI Assess actual deviation between goal and target	Collecting data about: Measure how to assess performance ← الهدف نلاقي الmeasure إلي بدنا نقيسه
Analyze	Root-causes of the prob. Statistics - sigma level / Pareto	- find best practic in order to keep good performance - Value-added vs. non-value added - Bottlenecks - low performance
improve / **Design:**	find improvment solutions: - feasibility: • Economic • Environment • Technical to find best solution	- Design the process: workflow, HR, Instructional ↳ to find best design
Control: / **Verify**	transition → process owner Control chart Sop (standard operating procedures)	Transition → process owner Control chart Sop

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.

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.

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.

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.

Unit 3: Advanced DMAIC

Chapter 12: Define

Six Sigma teams enter the project process with various levels of information. Sometimes, a problem is fairly well defined before the team begins work, particularly in organizations that use a Six Sigma leadership council to choose projects and create teams. Other times, teams begin work with little information except that a problem – of some type – exists because the outcomes of a process are not as expected. Teams might not know where errors are occurring or even begin a project with a complete understanding of the inputs and outputs associated with the process.

Whatever knowledge teams begin with, the define phase is when teams move from very basic information about a process or problem to the knowledge and organization necessary to enter measure and subsequent other phases with a successful foundation. In the define phase, teams set rules, create a charter that will govern efforts moving forward, identify stakeholders and customers, define a process through process mapping, and prepare for a define tollgate before entering the measure phase.

Creating a Project Charter

A project charter, or team charter, is a short document that includes information about the team and what they plan to accomplish. The purpose of the charter is to set expectations that can be agreed upon by the team as well as the sponsor or executive leaders, keep the team focused on the goal, ensure the project remains aligned with the goals of the business, and documents the fact that control of a process is being moved from a business executive or manager to a Six Sigma project team.

Minimally, team charters should include:

- A complete and concise problem statement that follows the guidelines set out in Chapter 6.
- A list of critical to quality metrics, or those measurements that will ultimately determine project or process success. Critical to quality was introduced in chapter 8.
- The names and roles of each person on the team. Selecting team members and appropriate team member roles are covered in Chapter 10.
- A list of both internal and external process customers. Use a SIPOC, discussed in Chapter 7, to begin defining internal or external customers.
- The name of a sponsor and/or champion.
- A duration for the project.

Teams might also include information such as a list of non-customer stakeholders, an estimated schedule for each phase of the project, scope definitions for the process or project, and financial drivers for the project.

The information for the team charter usually can't be gathered in a single brainstorming session; the charter is an outcome of the entire define phase, not a quick notation at the beginning. By taking time to properly consider all elements of a team charter, Six Sigma teams create a stronger foundation for the rest of their work.

Benefits of an Organizational Team Charter Template

Businesses that are implementing Six Sigma organization-wide might consider creating or using a specific template for team charters. Templates streamline define phases and make it easy for leadership teams and other employees to understand critical process components at a glance. While final team documentation is likely to be extensive, and even in the define phase, teams themselves might work with lengthy requirements documents, charters themselves should be as concise as possible. Some organizations distill charters to a single page while others use multipage documents. A sample one-page charter template is attached at the end of this chapter.

Details for Charter Elements

We've covered some of the most important elements of the charter in detail in previous chapters, but here's a quick look at some of the items we didn't cover in as much detail and are worth mentioning again.

Business Case

The business case might also be referred to as the financial drivers behind a project. Related closely to the problem statement, the business case is a short statement that provides a reason the project should be undertaken. The problem statement tells someone where, when, and how; the business case says why it's important. If you think back to Chapter 6, we said dollar amounts or another financial metric were important to include in the problem statement. If you include a business case in your charter, you would build on that basic financial statement to explain why, specifically, the loss of money, efficiency, or quality is important to consumers, employees, or the organization. You might also make an argument for why the problem must be solved now; in essence, why is this project being run now in place of another project?

Project Scope

We introduced the concept of scope briefly in Chapter 6. For the purposes of the team charter, the scope should include a hard beginning and end of the process or problem being considered. You might also include a short list of items or activities that are in scope and out of scope for your project. A SIPOC diagram helps teams identify the parameters for a project, and you can also use the In and Out of the Box method described later in this chapter to understand the intended scope of a project.

The scope should be clear. Listing the scope for a project or process as "beginning at the order stage and ending with fulfillment" isn't clear, because different people might consider different points the beginning of the order stage or the end of fulfillment. A better scope statement might be "beginning when a customer places an order and ending when the order is boxed for shipment." Going even further, a team might deem return and replacement processes out of scope for a project so that they are only dealing with original orders. Successful projects have a well-defined scope that is approved and backed by a project sponsor or champion.

List the Stakeholders

Listing major stakeholders on the charter helps the team remember who and what they are likely to impact in addition to end customers. Having the list visible during meetings reduces the chance that the team will initiate changes that might have a negative or unwanted effect on other process owners or processes, and it helps direct the team to resources outside of the team that can provide help, access, or information to areas related to the project.

Team Member Roles

Team members and roles were covered in Chapter 10, and the team charter simply needs to list the names of all team members along with their role and expected time commitment. Adding time commitments to the charter helps sponsors and executive leadership understand the human resource requirements for the project; often a Six Sigma team leader has to seek approval for staff members from other areas to devote a specified amount of time to the project.

Time commitments can be listed in hours per week but are often listed as a percent of the employee's overall time. For example, a subject matter expert who is expected to attend all of the team meetings to provide input, but is not expected to complete data collection, analysis, or improvement work, might be listed as providing 10 percent of his or her time to the team. A list of team members in a charter might look something like the list below. You don't have to list all the staff members you might possibility consult during the course of the project.

- Mike Smith, Black Belt, 100%
- Chase Michaels, Green Belt, 100%
- Lisa Javes, Green Belt, 100%
- Rosalie Myers, Process Owner, 25%
- Brent Reed, subject matter expert, 10%
- Brenda Tran, subject matter expert, 10%

Milestones

In Chapter 10, we covered creating a draft schedule for a Six Sigma project. The diagram included in Chapter 10 that broke down the timeline for a project is called a Gantt chart. Adapted by Henry Gantt in the early 20th century, a Gantt chart is a bar chart that displays the phases of a project according to time. One of the benefits of using a Gantt chart to display a rough project schedule is that it can easily be included in a one-page project charter; anyone reviewing the charter can quickly visualize the time element required for the project.

Teams should ensure a date is provided for the end of each of the DMAIC phases and that all team members agree that the dates are plausible given what the group wants to do. In some cases, milestones might be set by the project sponsor or champion, but the team should agree that milestone dates are possible. If dates seem implausible, teams can present a counter schedule with logical arguments regarding why the original schedule wouldn't work.

In addition to milestones at the end of each project phase, Six Sigma teams might also want to set milestones for work within each phase – specifically for the more laborious measure, analyze, and improve phases. While the team should document all milestones it agrees on, detailed milestones don't necessarily belong in the one-page charter document.

Measurement of Success

Everyone needs to know how the team is going to measure success. If a sponsor is measuring success on customer satisfaction scores and the team is measuring success on internal quality scores, ideas about the outcome of the project are likely to differ. Usually, measures of success can be pulled from the critical to quality metrics discussed in Chapter 8. If teams can convert a CTQ to a measurement, they can understand what major metrics determine success of a project. While teams might begin to gather measurements or look at existing measurements while in the define phase, finalization of metrics can extend into the measure phase.

Expected Financial Benefits

Financial information is already likely included on the charter in both the business case and the problem statement. Teams might include expected financial benefits in the business case section of a charter, but it must be included somewhere. For some sponsors and executive leaders, the financial benefit is the most important piece of information included in a charter. An estimated savings or increase in revenue also provides a measuring stick by which leaders can consider requests for resources for a project.

A Six Sigma expert should *never* over extend estimates regarding financial benefits; it's almost always better to under-promise and over-perform. If you tell leaders a project will save $500,000 in the first year because a big number means you're more likely to get project approval and all the resources you ask for, you're the one that answers when the project saves only $80,000. As with any aspect of a Six Sigma project, be as accurate as possible, but be conservative with estimates when accuracy is in question.

Review the Charter with Success in Mind

Before a Six Sigma team presents a charter for approval, it should take time to review the document as a group to ensure the charter lays a foundation for success. Some questions a team might ask itself about a charter include:

- Is everything—especially the goals, financial expectations, and timeline—challenging but realistic?
- Can everyone on the team devote the committed amount of time to the project?
- Is the project backed by a sponsor or champion with enough influence to drive critical assistance and resources?
- Does the team expect to be supported by auxiliary departments such as information technology, human resources, compliance, accounting, or legal as necessary for project success?
- Does the team expect to have the necessary freedom to implement a solution it designs after the solution is approved by the sponsor, champion, or executive steering committee?
- Does the team have a leader who is well-versed in Six Sigma tools and project management?

If the answer to any of the questions above is no, then the team could be setting itself up for failure. Before moving forward, the team should address these concerns and, if possible, make changes that convert no answers to yes answers.

Project Ground Rules

Before moving forward with any work – even defining a team charter – it's a good idea for a Six Sigma team to establish some basic rules and requirements for the team. We touched briefly on this in Chapter 10 when discussing management of a team. The ground rules for a project should be maintained in writing and approved by all team members, but they don't have to be part of an official charter document. The reason for documenting the rules and having all team members approve them is because a single team member cannot later claim to be ignorant of the rules.

At the same time, rule generation on a Six Sigma team shouldn't be a completely democratic process. Some of the more common sense or critical rules can be provided by the Black Belt or team leader. For example, ground rules should cover topics such as who should attend each meeting and the fact that team members should hold certain information confidential. A Black Belt might simply state that team members should observe confidentiality and attendance rules, be on time to meetings, and respect each other. The team itself will likely vote on the frequency of meetings and when meetings should be scheduled. Seeking team member input ensures that all team members can actually commit to meeting time slots. For consistency, it's best to hold meetings on the same days and at the same time each week, but it's understandably difficult to keep such a schedule through the entire life of some projects.

Black Belts might also provide some tips and suggestions for how team members should participate during meetings, particularly during group brainstorming sessions. For more information on running a brainstorming session, see Chapter 35. Black Belts should also dictate the rules for creating an agenda and running a meeting according to the agenda, though they might delegate some of these functions such as time keeper and secretary.

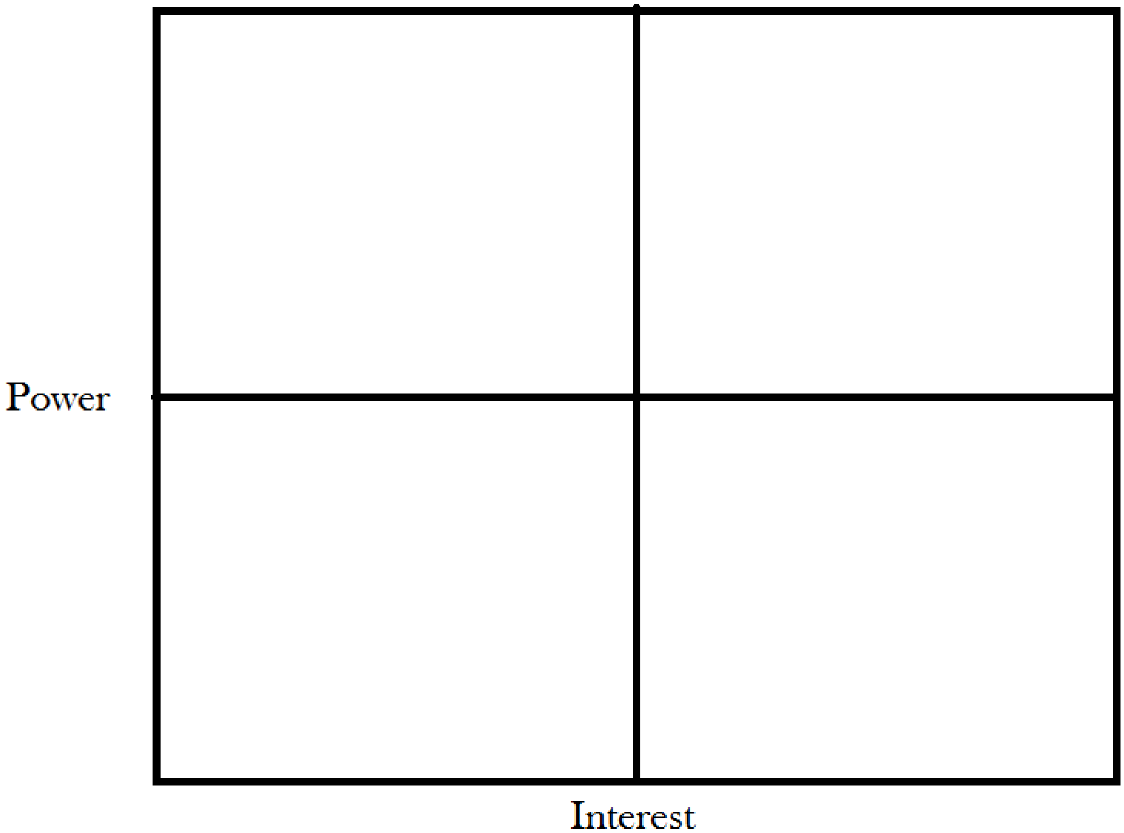
Define Toolset

We've covered a number of define tools in previous chapters, including the SIPOC diagram and the 5 Whys. Process maps and value stream mapping are two advanced Six Sigma tools that are often used in the define stage. Some Six Sigma teams begin using run charts to start defining a baseline in the define phase; run charts are covered in Chapter 13 on the measure phase.

In this section, we'll cover three additional tools that are common to the define phase: the Stakeholder Analysis, the In and Out of the Box Method, and the Is/Is Not Matrix.

Stakeholder Analysis

A stakeholder analysis is a quick way to identify how various people within an organization relate to a project and how the team should keep them informed. Begin the analysis with a grid drawn over an x and y axis. The vertical axis represents the amount of power a person has in the organization. The horizontal axis represents the amount of interest a person has in the team's project. The stakeholder analysis works best when teams conduct it on a whiteboard or large flipchart. Draw the basic diagram, as seen in the figure below, in large format.



Provide the team with sticky notes. Ask them to write down possible stakeholders for a project or process. Stakeholders are anyone who has an interest in the project, who might benefit from the outcome of the project, or who might be impacted by the work done via the project. Take a few minutes to discuss the names that were brainstormed and discard any the team feels are not actually stakeholders.

Once the team decides who the stakeholders are, begin placing the names on the chart according to power and interest. People with both low power and little interest will be placed in the lower left corner. People with higher power and low interest are placed in the upper left; people with less power but a lot of interest are placed in the lower right corner, and people with high levels of power and a lot of interest are placed in the upper right corner. A name might be placed high and to the right of the lower-left corner if the stakeholder has a moderate amount of interest and power, but the team doesn't feel like the person quite crosses the line. Likewise, a name placed at the lower bounds of any quadrant might show lower amounts of power than those placed nearer the top of the box; the stakeholder analysis lets teams prioritize stakeholders in this manner, even within the four quadrants.

Each of the quadrants of the diagram correlate loosely to the type of stakeholder, providing some guidance on how the team might interact with each person or department listed.

Top Left: Keep Satisfied

Stakeholders that fall into the top left quadrant of the diagram have enough power that they could interfere with a project, but they aren't extremely interested in the day-to-day outcomes. The team should ensure these individuals are satisfied in whatever way they do interact with the project. Teams might also consult with these individuals at various times during the project. For example, a team working to solve problems of shipping in a warehouse might need to consult with procurement managers at some point because the team identifies a need for a different type of packing tape. Procurement leaders have power over obtaining the resource, but they might not have a great deal of interest in the project overall.

Sometimes, teams might identify a stakeholder that falls into this section and realize that it would be valuable to the team for that particular stakeholder to be more invested in the project. Six Sigma leaders can work with stakeholders to try to move someone from low interest to high interest categories – this is a political tactic that some teams use to bolster support for a project.

Bottom Left: Minimal Effort

Stakeholders that fall into the bottom left quadrant have the least important connection to a project. Teams will mostly communicate general information about a project via newsletters or email to these stakeholders. While these stakeholders take minimal effort from teams, some situations might exist where teams want to move stakeholders from this box to the lower-right box.

Bottom Right: Keep Informed

Individuals in the lower-right box have a strong tie or interest in the project, but do not have access to power to support projects from a resource standpoint. These stakeholders might include employees in departments related to the process being improved or subject matter experts that will be consulted about individual aspects of a project.

While stakeholders in the lower-right quadrant can't usually bring resources to bear, they *can* act in support of a project, often in the form of a goodwill ambassador.

Top Right: Key Player

Individuals in the top-right quadrant are either key players regarding a process or executive leaders with the ability to assign resources to a project. These are the individuals teams will report to at various tollgates; often, the executives responsible for the ultimate success of a process or project appear in the top-right quadrant.

In and Out of the Box Method

The In and Out of the Box method is a quick and easy method that helps teams define project or process scope. Begin by drawing a large box on a whiteboard or flip chart. Provide markers and sticky notes for the team. Ask the team to write down elements of the process to be worked on, including resources, activities, and people. Each item should be written on a sticky note. Work together to create as complete a list as possible, placing the sticky notes on a wall or table as you go. Make sure everyone on the team understands that there are no wrong answers and the first phase of the exercise doesn't require discussion. By brainstorming items with little-to-no discussion, teams can capture more ideas, leading to a more accurate picture of what is in and out of scope.

Once a comprehensive list is made, begin working as a team to assign each item to a place inside, on the line, or outside of the box. Items outside of the box are those that will be considered out of scope for the project. Teams might place items outside of the box because they don't have access or control over the items, they don't have time to work on the items, or they have specifically been told not to include the item in the project.

Items that are within the box are considered in scope for the project. These should be elements of the process the team can reasonably be expected to influence. If the team isn't sure yet where an item might fall, they should place it on the line. Items that go on the line might be ones that the team hopes to be able to impact but for which the team leader needs to seek permission or assistance from someone outside the team.

Once all items are placed on, in, or outside of the box, review the placements as a team and make any changes. Document the exercise by photographing the diagram or recreating it on a computer. The team might reflect back on the diagram when attempting to control scope creep or considering who they should approach for help with a project.

Is/Is Not Matrix

The Is/Is Not Matrix is another quick brainstorming tool teams can use to define scope. It can also be used to help define some of the information necessary to a problem statement. The matrix works by considering specific things about the process or project and coming up with both is and is not answers.

For example, if a Six Sigma team is tasked with determining why the furnaces in a certain factory are not heating to proper temperatures, they might create an Is/Is Not Matrix like the one below.

	Is	**Is Not**
Where	South plant	North or East plan
What	Steam furnaces	Wood furnaces
When	January 2015	Prior to January 2015

The matrix clearly shows that the scope of the project only includes work at the south plant on the steam furnaces. The problem was noted in January 2015, which provides the team with a starting point for gathering data. This is a very simple matrix; teams can ask as many questions as they like to narrow down scope or better understand processes and projects through the Is/Is Not structure.

Define Tollgate Checklist

A successful define phase ends with all of the following deliverables:

- A comprehensive project statement
- A team charter
- An understanding of the process and a project diagram or map
- An understanding of the Voice of the Customer
- A definition of what success will look like that has been agreed on by the team members and any sponsors or executive leaders

Team Charter Template

<table>
<tr><td colspan="4">Project Name:</td></tr>
<tr><td colspan="3">Team Members</td><td rowspan="2">Sponsor:</td></tr>
<tr><td>Name</td><td>Role</td><td>Time Commit</td></tr>
<tr><td></td><td></td><td></td><td rowspan="4">CTQs:</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td rowspan="3">Financial drivers:</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td rowspan="3">Internal Customers:</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Non-Customer Stakeholders</td><td colspan="2">In Scope</td></tr>
<tr><td colspan="2">Out of Scope</td><td>External Customers:</td></tr>
<tr><td colspan="4">Problem Statement:</td></tr>
</table>

Objective/Goal
Project Schedule:

Chapter 13: Measure

Moving from the define phase to the measure phase of a project, Six Sigma teams continue to delve into the process, now coming to understand processes more fully through data. The measure phase is often the most laborious phase for the team, especially when data is not already available in digital formats. In this chapter, we'll review some of the metrics covered in previous chapters and introduce some concepts for data collection. We'll continue building on the concepts of measure introduced in later chapters on statistical analysis.

One of the first steps of the measure phase is determining the capability of a process. This step can be completed before a team formally leaves the define phase if the data needed to perform sigma level calculations is available. Calculating sigma levels for a process was covered in Chapter 1. In addition to sigma levels, teams might also calculate various metrics for a process, including defects per million opportunities, FTY, or RTY, which were all covered in Chapter 5.

Failure Modes and Effect Analysis

The Failure Modes and Effect Analysis is a tool that can be applied by a Six Sigma team in any phase from define to analyze. Often, teams begin working with FMEAs in measure because it helps them identify risk priorities for various inputs and errors within a process. Used properly, the FMEA uses systemic data and team input to set the stage for root cause analysis in the next DMAIC phase. Remember, while tollgates do occur and teams move through five phases during a DMAIC project, hard borders don't always exist between the phases. Teams might begin working on measure phase tasks before leaving the define phase, and it's almost certain that teams will begin some analysis while still collecting data.

Ultimately, an FMEA tool should be used when teams need more detailed information about inputs and possible associated fail-points than the tools discussed in the define chapter allow. The FMEA offers some of the information that is offered by SIPOC, but it also provides evaluations of the inputs. Teams typically create FMEAs in a spreadsheet program, as some calculations are required during the process.

To create an FMEA, create a spreadsheet with the following column headers:

1. Process step
2. Potential failure
3. Potential failure effect
4. SEV
5. Potential cause of failure
6. OCC
7. Current monitor/control
8. DET
9. RPN
10. Recommended changes/actions
11. Who and When?
12. Action completed

To create an FMEA, create a spreadsheet with the following column headers:

1. **Process step:** "main steps"
   - identifying all possible process steps, activities, or inputs
2. **Potential failure:**
   - indicate what might go wrong for each process step
   - you can list process steps more than once if there are multiple opportunities for error within each step
3. **Potential failure effect:**
   - enter a short description of the impact of the failure on the customer

FMEA

7. **Current monitor/control:**
   - create a short description of the current controls that are in place to monitor the process or prevent the failures
8. **DET:**
   - rate the ability of the process or staff to detect failure if it does occur
   - rate detection between 1 and 10, with 1 being a process that includes automated detection that rarely fails and 10 being no detection at all
9. **RPN:**
   - calculate the risk priority number by multiplying the severity, occurrence, and detection ratings

13. SEV
14. DET
15. RPN

Columns 1 through 9 of the FMEA might be completed during the measure phase while columns 10 through 15 are more appropriate for the improve phase.

Begin by identifying all possible process steps, activities, or inputs in column one. In column two, indicate what might go wrong for each process step. Note that you can list process steps more than once if there are multiple opportunities for error within each step. If the team has created a detailed enough list of steps, however, this won't likely be the case for a majority of the steps.

In column three, enter a short description of the impact of the failure on the customer. Incorrect measurement can result in increased variance in a product, for example. In the SEV column, rate the severity of the possible failure you described in the previous columns. Rate the severity from 1 to 10, with 1 being no effect, 5 being minor disruption to production, and 10 being severe enough to endanger a process or person.

In column five, enter the potential reasons the specific failure might occur, and in the OCC column, enter a numeric rating for how often the failure might be expected, with 1 being a very unlikely failure and 10 being an almost inevitable failure.

In column seven, create a short description of the current controls that are in place to monitor the process or prevent the failures the team has described. In the DET column, rate the ability of the process or staff to detect failure if it does occur. Rate detection between 1 and 10, with 1 being a process that includes automated detection that rarely fails and 10 being no detection at all.

Finally, calculate the risk priority number by multiplying the severity, occurrence, and detection ratings, as in the example below.

A Six Sigma team working on a project to improve the speed with which refunds are processed to customers is creating an FMEA. One row of the FMEA includes the following information:

- Process step: Refund request is entered in system.
- Potential failure: Incorrect amount is entered.
- Potential failure effect: The customer receives more or less refund than anticipated.
- SEV: 8
- Potential cause of failure: Data-entry employee transposes numbers or makes a similar typing mistake.
- OCC: 10
- Current monitor/control: A supervisor randomly reviews a sample of refund requests to ensure accuracy.
- DET: 7
- RPN: (SEV * OCC * DET) = (8*10*7) = 560

The team completes a second row as follows:

- Process step: Refund check is printed.

- Potential failure: The printed check has defects that make it difficult to cash.
- Potential failure effect: The customer can't cash the check and has to call for a new one.
- SEV: 9
- Potential cause of failure: Printer is misaligned or out of ink.
- OCC: 1
- Current monitor/control: The person who signs the checks reviews the checks as they sign them.
- DET: 2
- RPN: (SEV * OCC * DET) = (9*1*2) = 18

The potential failure in the first example has a much higher risk priority number, which means, as the team moves forward, they are more likely to work on solving that potential failure. During analyze and improve phases, the team would recommend changes, implement the recommended actions, and rescore the process to determine if the RPN of the changed process is lower. If it is higher or the same, then the change was not a good one and the team might need to try again.

Collecting Data

Creating a baseline metric for a process begins in the define phase, but teams cannot leave the measure phase without a strong understanding of current process performance. That understanding begins with figures such as sigma level, but teams should also define a process-specific metric where possible and gather historical data regarding that metric so they have something to compare future data against to prove that improvements were made.

Ideally, the team would have access to historical metrics for the process. In some cases, the team has to collect data from scratch. We'll introduce data collection later in this chapter and cover it in depth in the units on sampling.

Continuous versus discrete data

Before creating and displaying a baseline metric via graphical representation, you have to understand the type of data you are dealing with. Data is either discrete or continuous, and teams collect data either as a population sample or a process sample. How teams collect data and the type of data collected determine how the data can be viewed graphically and analyzed.

Discrete Data

has a natural order but the difference between them are not necessary

Discrete data is categorical in nature; it is also referred to as qualitative data or attribute data. Discrete data falls into three categories: ordinal, nominal, and binary, or attribute, data; some data collected can be expressed in one or more of the discrete categories. For example, student test scores can be conveyed in an ordinal fashion via the grades A, B, C, D, and F or in a binary fashion via the Pass/Fail distinction.

Discrete data can be displayed via Pareto charts, pie charts, and bar charts. In some instances, the data can be converted to run and control charts using variation within the data or ratios as the item being charted. In the chapter on the control phase, you'll begin understanding why a team might want to convert discrete data to be used in a control chart.

Within discrete data, binary or attribute data is usually the easiest data to collect. Attribute data records one of the other answers. Does the person choose paper or plastic? Is the room hot or cold? Is the glass empty or full? Is the light on or off? Depending on the scenario, attribute data can be very accurate. The light is either on or off; the switch position tells you that. Attribute data in this case can be automated with the right technology, which means it would be highly accurate. Whether the cup is empty or full is another story, because there are so many variations between completely empty and completely full. If the data is being collected by people, personal biases might enter the equation. Teams can remove some of those biases and better ensure accurate measurements, which will be covered in the sections on measurement systems.

Continuous Data

Continuous data is quantitative data and is measured in units. For example, the time of day is measured in hours. Temperature is measured in degrees, and almost anything can be converted to continuous data by making it a percentage.

+ run charts, control charts

Continuous data is visualized in graphs such as histograms and box plots. Box plots are discussed in chapter 14, and histograms are covered in depth in the chapters on statistics. Continuous data can also be viewed in the form of run and control charts.

better than Discrete

Choosing Between Discrete and Continuous Data

Sometimes, a process or activity can be measured in both discrete or continuous data. Depending on the purpose of the measurements, teams might need to pick between the two data types. For example, if a Six Sigma team has identified room temperature as an input into the quality of product, they will want to monitor the temperature of the room. They can do so by recording the temperature in degrees every ten minutes; that data would be continuous. Alternatively, the team might create a tick sheet, having someone make a mark every hour to note whether the temperature was in the 40s, 50s, 60s, 70s, or 80s with regard to the Fahrenheit scale. That data would be discrete.

ex:

In this particular example, most teams would choose to record the continuous data. Exact temperature measurements every 10 minutes provides a lot more information than whether the temperature of the room was in the 70s at the turn of the hour. The continuous data could be converted to provide teams with the discrete data easily; the discrete data in this case – and in most cases – could not be converted to continuous data.

What is true in the example is true for most scenarios. When possible, teams should convert measurements to continuous data. Continuous data:

- Provides more information than discrete data does.
- Is typically more time-consuming to collect than discrete data unless teams have access to automated or computerized data collection.
- Is more precise than discrete data.
- Lets teams remove variation and errors inherent in estimation and rounding.

Levels of Data

types of analysis

Data can be classified at four basic levels: nominal, ordinal, interval, and ratio. Attribute, or binary, data is actually a limited form of nominal data.

Nominal Data

Nominal is considered to be the lowest data classification level and simply involves applying number labels to a qualitative description so statistical analysis programs and tests can be applied to the data. The numbers assigned to each category don't provide any information about whether the data is better or worse than other data in the listing – in nominal data, numbers don't reflect a scale.

An example of nominal data might be applied in a list of birth states for a classroom. In a class of 30, the number of students born in various states breaks down as follows:

- Texas: 6
- Louisiana: 4
- Arkansas: 10
- Mississippi: 1
- Oklahoma: 9

In nominal data, each state would be provided a numeric label:

1. Texas
2. Louisiana
3. Arkansas
4. Mississippi
5. Oklahoma

That doesn't mean 5 students are from Oklahoma; it means 9 students fall into category 5 for the question "What state were you born in?"

For nominal data, central tendencies are calculated not with means or medians, but with mode. For example, a list of the nominal data in our example would be as follows:

1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 5, 5, 5, 5, 5, 5, 5, 5, 5

The mode is the number that appears most in the set; in this case, 3.

Statistically, analysis is limited with regard to nominal data, but some tests can be performed with statistical analysis software.

Ordinal Data

Ordinal data is considered to be a higher form of data than nominal, though it still uses numbers and categories to identify data elements. With ordinal data, though, the numbers themselves actually provide some meaning. The numbers used in the FMEA scales at the beginning of this chapter were ordinal data. The numbers are qualitative in nature, but they are also ranked. Central tendencies with ordinal data are measured by either the mode or the median, and common uses for this type of data include ranking various things against each other or rating a specific thing, such as a movie or pain level.

Ordinal data can be arranged in an order that makes sense: on a 1 to 10 scale, Suzy rated the movies as 2, 5, 6, and 9. If one is the worst and 10 is the best, then we can assume Suzy liked the last movie best.

While ordinal data comes with a logical order, the intervals between the numbers don't mean anything. If Suzy rated movie A as a 10 and movie B as a 9, the conclusion is that she liked movie A better. Exactly how much more she liked the movie is not discernible using ordinal data.

Interval Data

Interval data is an even higher form of data classification. Interval data provides numeric values that can be arranged in a logical order with meaning; the big difference between ordinal and interval data is that the difference between each interval value provides meaning. If Frank is keeping track of the temperature in his house and he sees that at 8:00 a.m. it was 76 degrees and at 9:00 a.m. it was 80 degrees, he not only knows that 9:00 a.m. was hotter; he knows that it was 4 degrees hotter at 9:00 a.m. than at 8:00 a.m. Interval data is continuous, or quantitative, and offers more flexibility when it comes to statistical analysis.

Ratio Data

Ratio data is considered to be the highest of the data classifications. Ratio data has an absolute zero point, can be both discrete or continuous in nature, and provides the highest capabilities for statistical analysis in many cases. Some examples of information that can be recorded using ratio data include force, defects per million opportunities, voltage, height, units per hour, and volume.

Choosing the Best Measurement Systems

Measurement systems analysis applies scientific principles to help teams analyze how much variation a system of measurement brings to a process. The purpose of the MSA is to identify errors of accuracy within data collection tools. Teams can then redress measurement systems to create more accurate data captures or, if that isn't possible, take the possibility of errors into account when performing analysis on data.

During measurement systems analysis, teams should review multiple components of possible measurement error. Six Sigma teams analyze:

- Whether bias occurs in the accuracy of measurements
- Whether the measurement has the proper resolution
- What measurement scale linearity exists
- Whether measurement activities are stable over time
- Whether measurements are repeatable and reproducible

Depending on the measurements the team is dealing with, the MSA can be time consuming and is often why the measure phase of a DMAIC project is one of the longest.

Creating Accuracy

In this stage of MSA, teams define the difference between the most accurate measurement possible and the data being collected by the current measurement system. The goal of a measurement system is accuracy: coming as close as possible to a defined target, if not the exact measurement. For example, in a computer manufacturing plant, one employee might solder a chip to the motherboard. For the rest of the chips and wires to be added to the motherboard, the chip must be placed within a 2 mm area. In this case, a measurement tool might be implemented with a required accuracy of plus or minus 0.5 mm to ensure the chip is placed within the area targeted.

Teams can ensure accuracy of data by verifying that the gauge used to collect data is performing accurately. If a digital scale is being used to weigh ingredients, teams should calibrate the scale using calibrated weights. If templates are used on a factory floor to make measurements more efficient, teams should ensure those templates are accurate by comparing them against known measurement tools such as verified rulers and scales. Note that, for the purpose of the MSA, accuracy reflects the performance of the measurement tool, not the operator. Whether the employee uses the measurement tool correctly or records the amount correctly is considered a concern of precision, which is covered later in this chapter under R&R Gages.

Guidelines:

Once a Six Sigma team is confident that a measurement tool is properly calibrated, they can 1. instruct employees or others who are responsible for recording data. 2. Data should be accepted as it is collected for most efficient access and because early review can turn up specific problems with data collection. When possible, 3. teams should not round data but collect it as it is recorded.

4. If data is being collected manually, employees should have a data collection template that prompts them to collect data at appropriate times and record information about the data collection event, including the person collecting the data, the machine or process involved, conditions of the environment – especially those that are different from normal conditions or might have a direct impact on measurements – and the measurement tool being used if multiple tools are an option. These details help Six Sigma teams rule out outliers, which are discussed in the next chapter.

Before measurements are passed to the analyze phase, Six Sigma experts should 5. review data to ensure there are no misplaced or missing decimal points, that duplicate entries haven't been recorded, that frequency-based measurements aren't missing points, or that any other obvious issues haven't occurred with the data. Addressing obvious data problems before beginning analyze phases reduces the chance that teams will come to false conclusions about root causes or viable solutions for a process.

Addressing Resolution

Measuring at the correct resolution ensures that a measurement system can detect change in the data or process appropriately. For example, if a Six Sigma team is working to improve a process that cuts pipe for bathroom fixture installations, it might be concerned with the length of the pipe. In reviewing the measurement system for the cut pipe, the team finds that the process includes measuring the pipe to the nearest centimeter. If, however, pipes that are off by several millimeters cause issues in the installation, then the nearest centimeter measurement is not a small enough resolution.

A good rule of thumb to follow for resolution is called the 10-bucket rule. Break your measurement resolution into a tenth of what is required. If the pipe must measure within a range of 5 mm to perform, the measuring tool should measure to the ½ mm. In another example, a food service department might be tasked with maintaining the correct temperature in a freezer. To monitor the temperature, an employee records the temperature once per hour. If temperatures fluctuate quickly in the freezer, a change in temperature that would impact quality of food or ingredients might come and go between recordings. In this case, the proper resolution might be gained by recording measurements every 10 minutes or every six minutes for 10 readings per hour. Even better, in a freezer with a digital thermostat connected to a network, teams might be able to access readings recorded every minute.

Resolution is usually one of the easiest things to correct within a measuring system, but it isn't always cost-effective or plausible to measure at the most detailed resolutions. Teams should consider resource requirements when developing a measurement system. If, however, the most detailed resolution is possible, measurements obtained will provide more information about the process and a larger sample size from which to work.

Adjusting for Errors of Linearity

Linearity describes how a measurement system performs across a range. A standard metric ruler in the hands of most people is fairly accurate at measuring centimeters, but is less accurate at measuring millimeters or kilometers. A scale with a range between 0 and 10 kilograms might measure less accurately at either end of the range.

Taking measurements at various ranges with an existing measurement system and comparing those measurements to data gathered with tools known to be accurate across all ranges can help teams find errors of linearity. In some cases, teams can develop mathematical equations to account for the discrepancies. For example, if the scale is accurate at 5 kilograms, but is off by an extra quarter of a kilogram for each kilogram thereafter, a measurement of 8.5 kilograms would actually be:

8.5 – ((8.5-5)*.25) = 7.625

If mathematical adjustments are not possible, then teams should not use measurement systems to measure ranges where linearity errors regularly occur.

Stability

Stability describes the consistency of measurements over time. If operators are measuring in the same way and using the same tools – and those tools don't have any of the other problems described above – then measurements should reflect stability on a control chart. Control charts are introduced in Chapter 16 and covered in depth in later chapters on statistical process control.

If the variation of measurements, as reflected on a control chart, do not indicate stability, then teams might want to first rule out a problem with the measurement system before determining that the process is out of control.

Gage R&R

Gage R&R tools are used to ensure repeatability and reproducibility with regard to measurement systems. In most cases, Gage R&R tools apply to measurement systems that involve human operators and appraisers. Six Sigma teams apply Gage R&R tests to find weaknesses within such measurement systems.

In Gage R&R testing, repeatability means that a single employee, using the same measurement system and appraising the same things, can repeat his or her measurements. Reproducibility means that multiple employees using the same measurement system and appraising the same things come up with measurements that match or are very close to matching.

Most Gage R&R tests fall into two types: attribute and variable. The premise for testing each type of measurement is the same, though the criteria and statistical analysis following the test differ slightly.

Attribute Gage R&R

An attribute Gage R&R is used when Six Sigma teams are analyzing measurement systems for go/no go data. For example, if operators review an item in the product line and decide simply to pass or fail it, this would be an attribute measurement. In the example of the freezer measurements above, an employee might simply be tasked with recording whether the temperature was in an appropriate range: a yes/no measurement. As previously stated, attribute measurements provide the least information about a process, so in the case of the freezer temperature, it's better to record the actual temperature. Whether that recording was within appropriate range can be determined systemically from the temperature data.

When attribute data is used, an attribute Gage R&R is used to test the measurement system following the steps below.

1. Select at least two appraisers.
2. Provide a number of samples. Label the samples in a way that you know which one is which but that wouldn't identify the sample for the appraiser.
3. Record the actual attribute measurement for each sample according to the best possible (most accurate) measurement you have.
4. Have each appraiser record the attribute measurement for each sample provided (go/no go; yes/no; hot/cold; pass/fail; etc.).
5. Repeat the process with the same samples and appraiser, randomizing the order in which you present the samples. Randomizing sample order the second time appraisers are presented with them reduces the chance that appraisers remember what measurement they recorded the first time and record the same measurement by default.
6. Enter all data into a spreadsheet or Gage R&R file similar to the one below that shows a test of a pass/fail measurement.

Sample Label	Actual Attribute	Appraiser 1		Appraiser 2		Agreement
		Trial 1	Trial 2	Trial 1	Trial 2	Yes/No?
1	P	P	P	F	P	No
2	P	P	P	P	P	Yes
3	P	P	P	P	P	Yes
4	F	P	F	F	F	No
5	P	P	P	P	P	Yes
6	F	F	F	F	P	No
7	F	P	P	F	F	No
8	P	P	P	F	F	No
9	F	F	F	F	F	Yes
10	P	P	P	P	P	Yes

From the Gage R&R above, you can see that the measurement system is reproducible only 50 percent of the time, making it a poor measurement system. It is repeatable 90 percent of the time for Appraiser 1 and 80 percent of the time for Appraiser 2, and the appraisers are accurate 80 percent and 70 percent of the time respectively. Given these results, a Six Sigma team might determine that there is some problem of clarity with instructions for how to determine whether a sample is a pass or a fail. The chart above only provides data for a set of 10 samples; more accurate attribute Gage R&R testing usually requires at least 20 data points.

Variable Gage R&R

Not all data is attribute data, which is why teams can also perform variable Gage R&R tests. While the raw data from a variable Gage R&R test can provide a Six Sigma team with a picture of whether a measurement system is obviously failing or not, statistical analysis is usually required to make a true determination about the performance of a measurement system. This is because, with variable measurements, some differences between measurements and operators is likely, particularly when measuring to very small or large figures or capturing data in a moving measurement.

Set up a variable Gage R&R test in much the same way you set up an attribute test, using two to three appraisers and at least five to ten outputs to be measured. Have each appraiser measure each sample two or three times, randomizing the order in which samples are presented to avoid appraisers remembering the measurements initially entered. Record all data on a variable Gage R&R template, such as the example below.

Sample	Actual Measurement	Appraiser 1			Appraiser 2			Appraiser 3			Variation
1											
2											
3											
4											
5											
6											
7											

The statistical analysis performed in Excel SPC or Minitab by a Black Belt or Green Belt typically returns four figures:

- % Study Variation
- % Tolerance
- % Contribution
- Number of distinct categories

Teams should look to ensure all four elements of a variable Gage R&R test calculation are in what are considered “safe” ranges. Commonly, each element comes with a scale for safe, or green, zones along with caution zones and failure zones. If one of the elements falls into a caution zone and all others into the green, then a team will likely conclude that the measurement system is sufficient. In some cases, all or a majority of caution zone scores might be deemed acceptable, particularly if making the measurement system any more accurate would be costly or cause application issues for other processes. Measurement systems that score in the failure zone for any element should probably be repaired or replaced.

Common criteria used to judge each element of the variable Gage R&R calculations are as follows:

Element	Pass	Caution	Fail
% Study Variation	0 to 10	10 to 30	30 and above
% Tolerance	0 to 10	10 to 30	30 and above
% Contribution	0 to 1	1 to 9	10 and above
# of Distinct Categories	10 or more	6 to 10	1 to 5

Note: Another tool that is effective in identifying variation in a measurement system is called the ANOVA, or Analysis of Variance. ANOVA is also useful for analyzing variation of any type, and will be covered in Unit 5 on intermediate statistics.

Collecting Data Samples

Once teams are sure the best possible measurement tools are in place, they can begin collecting data to be used in the analyze phase of the DMAIC project. The most accurate conclusions come when a team can analyze data for the entire population, but that is rarely possible due to time and cost constraints. If you can gain access to automated data or data warehouses, you might be able to collect population data or extremely large sample sizes that better approximate population data. Otherwise, Six Sigma teams must randomly sample the population that is available and use those samples to draw conclusions about the population as a whole.

To ensure samples can be used to draw statistical conclusions, they must be handled correctly and be the appropriate size. In this section, we'll simply cover the types of sampling strategies that Six Sigma teams might use and why.

Simple Random Sampling

Simple random sampling works when there is an equal chance that any item within the population will be chosen. For example, if you put 20 marbles of the exact size, weight, and texture in a bag and blindly select one, each marble in the bag has a 1 in 20 chance at being selected. If the marbles are different sizes or weights, those differing attributes can impact the chance that each marble will be selected. Heavier marbles might sort to the bottom of the bag; bigger marbles might be more likely to be picked up.

Random sampling for statistical analysis requires that the sample will represent similar attributes and percentages as the entire population. The population is "N" items large. The sample size is "n" items large. How big the sample needs to be to statistically represent the population is decided by a number of factors.

Metric	Appraiser-Related Insight
% Study Variation	Measures total variation, including appraiser inconsistency (within and between)
% Tolerance	High values may indicate appraisers consume too much of product tolerance via variation
% Contribution	High values indicate large variation between appraisers' measurements
Number of Categories	Low values mean appraisers can't distinguish enough differences between parts

Stratified Sampling

Stratified sampling occurs when the population as a whole is divided or can be divided into subgroups with differing attributes. For example, if a shipping company wants to test the accuracy of its estimated shipping times against actual shipping times, it might assume that the results will vary according to the distance a package has to travel. By randomly selecting samples from the entire package population, there's a chance the company might only end up with samples for packages delivered within a 200-mile radius.

Ex

To prevent bias in the data, the shipping company might divide the population into four subgroups:

- Deliveries within 200-mile radius
- Deliveries within 201 to 400-mile radius
- Deliveries within 401 to 600-mile radius
- Deliveries over 600 miles

By sampling randomly from the stratified subgroups, the team ensures a sample size with less bias.

Sequential Sampling

Sequential sampling involves selecting every X item for inclusion in the sampling. Sequential sampling can be used when teams are collecting data at intervals such as time. The team might collect data every 10 minutes. Sequential sampling can also be used to sample physical items; every 5th item on a product line might be reviewed. Given the right parameters and enough time, sequential sampling can provide valid statistical results. Teams must be cognizant, however, that the sequence of the sampling could, in rare cases, skew results. It is possible, for example, that something occurs during every 5th iteration of a process that causes a difference to occur.

Samples that Aren't Random

Non-random sampling should not be used when dealing with statistical analysis because it is more likely to introduce user or sampling error. While all sampling comes with some form of error, random sampling errors can be calculated and accounted for in analysis. The same cannot be said of non-random samples.

Non-random sampling includes convenience or judgment sampling. Convenience sampling occurs when a team takes the most convenient measurements. "We want to know about the process right now, so let's review the next dozen items that come off the line." That type of analysis only truly tells the team how the process performed at that exact moment in time.

Judgment sampling occurs when an expert or knowledgeable person is tasked with "selecting" appropriate samples. A supervisor might say to his or her team members, "Select some of your work that represents the normal way you function in a given day." In most cases, the team members select what they believe is better quality work, skewing any results from the sample.

Delivering a Baseline Metric

X

One of the major deliverables coming out of define and measure phases is the baseline metric. How is the process performing now, and what measurement will the team use to compare current performance to post-improvement performance?

Baseline metrics are numbers, but most teams find that presenting the metric graphically resonates best with business resources and executives. Visual representations also provide teams with a quick way to determine if progress is occurring.

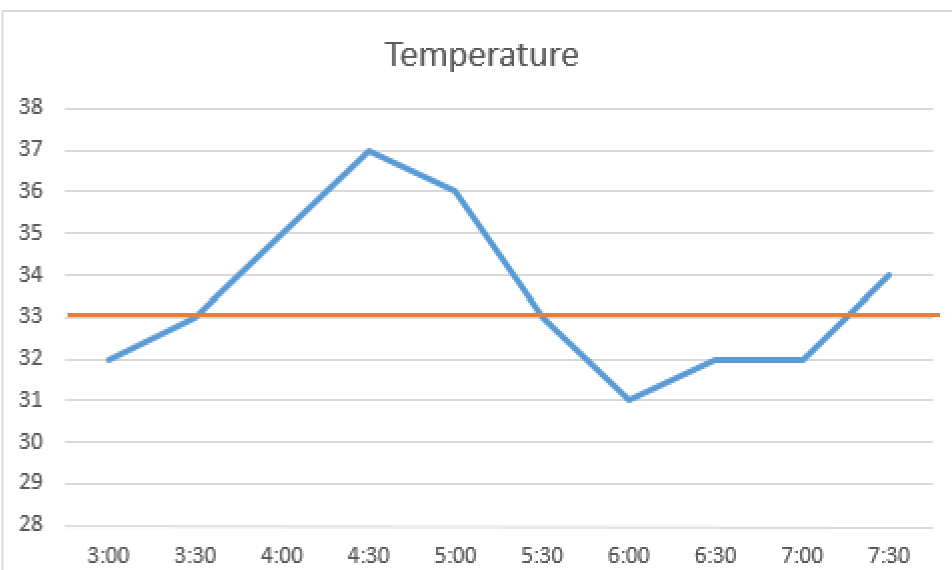
The type of visual representation you use depends on whether your major metric is discrete or continuous. Discrete data can be displayed on Pareto charts (see Chapter 5) and continuous data can be displayed via run charts. You can also use variation or other calculations to convert discrete data to continuous data for display in run charts and control charts (see Chapter 16 for information about control charts).

Run Charts

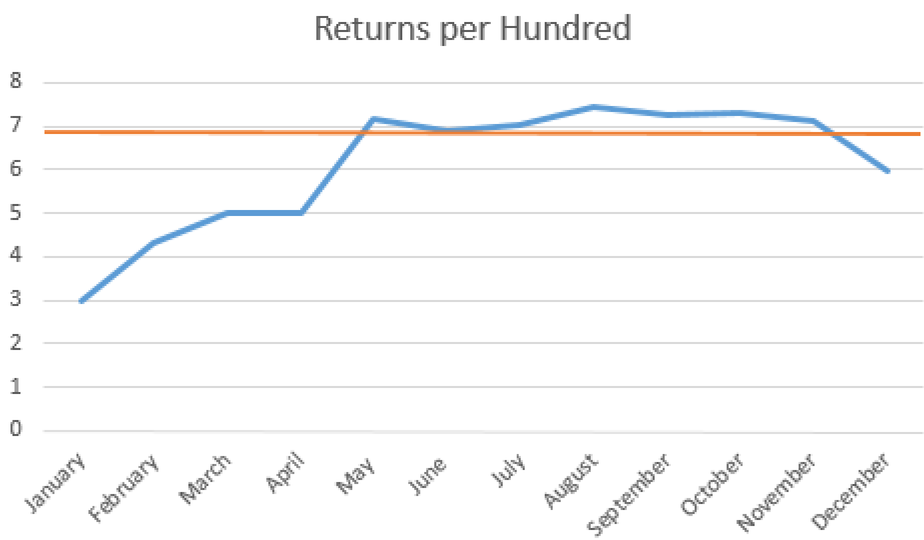
A run chart can be used to monitor the performance of any variable or process over time. With a single, intuitive chart, Six Sigma teams can display trends, shifts, and cycles within a process; they can also monitor a process for concerns, though run charts are not as effective at this as the very similar control chart is.

A basic run chart is simply a line plot of the data over time, which means anyone can create the chart. Most Six Sigma run charts also feature a line representing the median of all data points for visual reference. Depending on the type of information being charted, you may need to convert data to a ratio for a more accurate run chart. For example, if you are plotting the temperature of a surface over time, there is no need to convert data. If you are plotting the number of patients readmitted to a hospital within 30 days of being discharged, then it helps to convert the data to a percentage of the number of patients discharged within the same time period. In a 30-day period where 10,000 patients were discharged, you can expect a higher number of returns than a period during which only 5,000 patients are discharged.

The figure below illustrates a run chart of temperature over time. You can see how temperature changes through time and begin to see some possible trends. A Six Sigma team would be able to zoom out, viewing the run chart over more time to validate trend assumptions. You can also see that the median temperature for the process is 33.



The run chart below indicates the number of returns per hundred sales for each month of the year. You can see that returns as a rate of sales increases steadily during the first part of the year before holding steady from May through November. The orange line indicates the median returns per hundreds sales, which is just under 7.



Create Basic Run Charts in Excel

Statistical analysis software, including Minitab and Excel SPC, creates all elements of a run chart automatically from entered data, but anyone can use basic Excel functions to create a run chart if needed.

First, create a data table.

Creating a data table for a single attribute, such as temperature, just requires entering the time labels in one column and the attribute measurements in another. For the example, we'll walk through creating a rate data table, since it involves additional steps.

1. Enter the data labels (month, week, hour, etc.) in the first column of Excel.
2. In the next column, enter the corresponding measurements for the attribute you are interested in: in this case, the total number of returns per month.
3. In the third column, enter the total number of items you are comparing the attribute to: in this case, the total number of sales per month.

	A	B	C
1	Month	Number of Returns	Number of Sales
2	January	105	3500
3	February	95	2200
4	March	125	2500
5	April	140	2800
6	May	215	3000
7	June	200	2900
8	July	190	2700
9	August	245	3300
10	September	225	3100
11	October	270	3700
12	November	285	4000
13	December	250	4200
14			

4. In the fourth column, calculate the percentage the first column of data is of the second. In this case, the percentage of returns per sales for each month. The calculation is achieved in this case by the formula =B2/C2 for January, =B3/C3 for February, and so forth.

	A	B	C	D
1	Month	Number of Returns	Number of Sales	Rate of Returns per Sales
2	January	105	3500	0.03
3	February	95	2200	0.043181818
4	March	125	2500	0.05
5	April	140	2800	0.05
6	May	215	3000	0.071666667
7	June	200	2900	0.068965517
8	July	190	2700	0.07037037
9	August	245	3300	0.074242424
10	September	225	3100	0.072580645
11	October	270	3700	0.072972973
12	November	285	4000	0.07125
13	December	250	4200	0.05952381

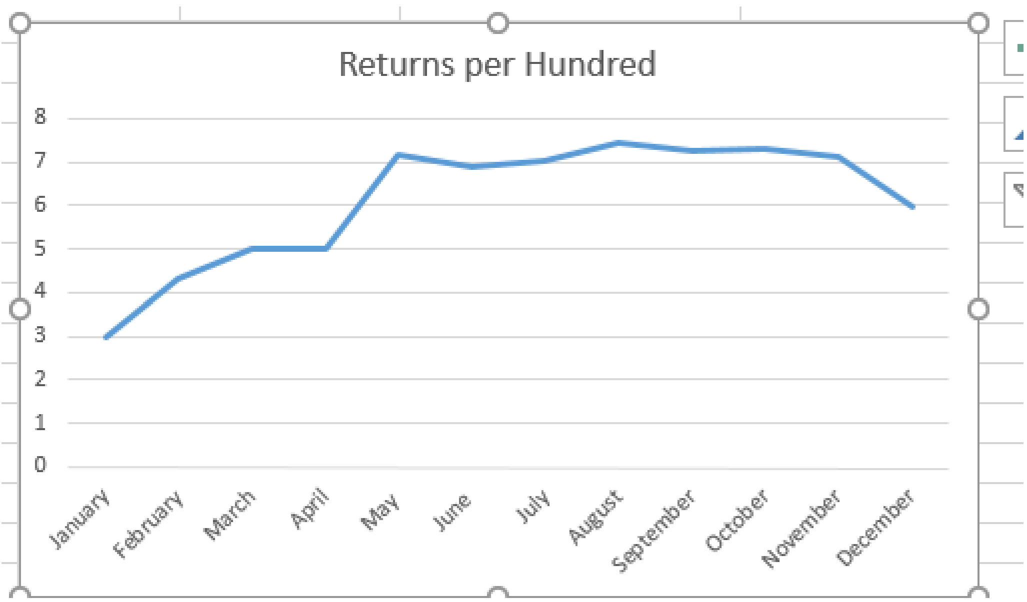
5. Decide whether you want to create a run chart showing percentages, or if you would like to create the chart illustrating rate per 100, per 1,000, etc.
6. If you want to illustrate a rate per (x), multiply the percentage calculation in the fourth column by (x). In this case, the figures in column D are multiplied by 100.

Month	Number of Returns	Number of Sales	Rate of Returns per Sales	Returns per Hundred
January	105	3500	0.03	3
February	95	2200	0.043181818	4.318181818
March	125	2500	0.05	5
April	140	2800	0.05	5
May	215	3000	0.071666667	7.166666667
June	200	2900	0.068965517	6.896551724
July	190	2700	0.07037037	7.037037037
August	245	3300	0.074242424	7.424242424
September	225	3100	0.072580645	7.258064516
October	270	3700	0.072972973	7.297297297
November	285	4000	0.07125	7.125
December	250	4200	0.05952381	5.952380952

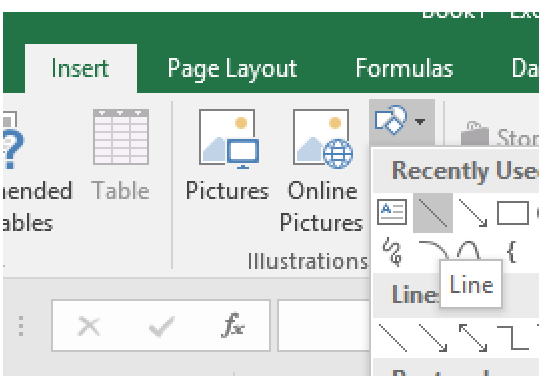
7. Use Excel to calculate the median of the number you plan to chart. The median is calculated with the formula =Median(Number 1, Number 2,…), where the numbers in the formula correlate with the range of all the charted data points. In this case, the median is 6.96679
8. Highlight the data labels (in this case, column A) and the figures to be charted (column E)

Month	Number of Returns	Number of Sales	Rate of Returns per Sales	Returns per Hundred
January	105	3500	0.03	3
February	95	2200	0.043181818	4.318181818
March	125	2500	0.05	5
April	140	2800	0.05	5
May	215	3000	0.071666667	7.166666667
June	200	2900	0.068965517	6.896551724
July	190	2700	0.07037037	7.037037037
August	245	3300	0.074242424	7.424242424
September	225	3100	0.072580645	7.258064516
October	270	3700	0.072972973	7.297297297
November	285	4000	0.07125	7.125
December	250	4200	0.05952381	5.952380952

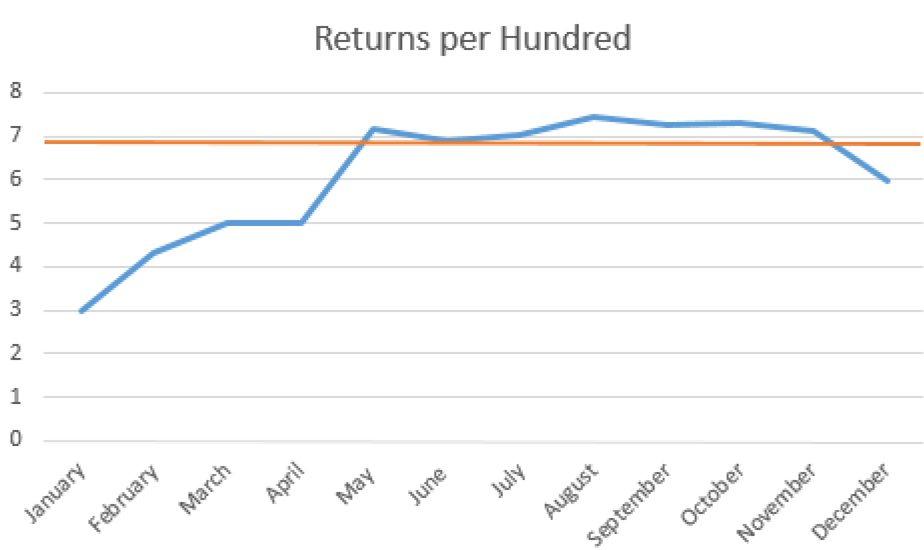
9. Select Insert > Charts > Line Chart to insert a line chart of the attribute or attribute calculation.



10. Select Insert > Shape > Draw Line.



11. Draw a line on your run chart approximately where the median would be. Use Excel tools to select a color and thickness for the line that you desire.



The completed run chart can be used to present information to the Six Sigma team or include a graphical representation of baseline process performance in a measure phase tollgate presentation. Again, it should be noted that manual creation of a run chart is not required for most Black Belts and Green Belts, who will have access to statistical analysis software.

Measure Tollgate Checklist

Use the checklist below to determine whether a team is ready to move from the measure phase to the analyze phase of a DMAIC project.

- The team has agreed upon the key measurements and come up with a baseline measurement of process performance.
- The team has analyzed measurement systems and identified any issues that might contribute to analysis errors.
- Where possible, the team has corrected measurement systems to remove error risks.
- The team has calculated process variation and sigma level.
- The team has conducted appropriate sampling to allow for statistically valid conclusions in the next phase.
- The sponsor or champion has reviewed and signed off on all elements of the measure phase.

Chapter 14: Analyze

If the chapter on the measure phase seemed especially long, it's because the phase itself is long and requires a great deal of work. Without a strong measure phase, the team cannot move on to analyze data and make data-based decisions that drive improve and control phases. Analyze phases also require a lot of work, but that work is usually performed by Black Belts and Green Belts, who report findings to the Six Sigma team and ask for feedback about analysis and verification of analysis.

In this chapter, we'll discuss a number of tools that might be used by Six Sigma teams during the analyze phase, but we'll also reference other chapters and units. Units 4, 5, 7 and 8 provide in-depth information about the statistical tools referenced throughout this chapter.

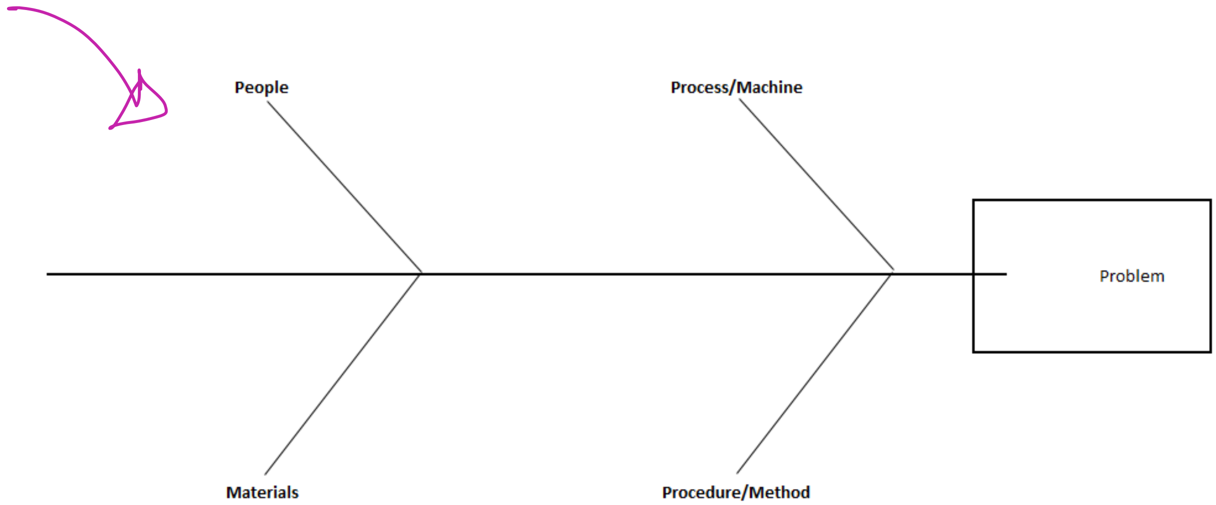
Root Cause Analysis

One of the fundamental activities of the analyze phase performed by the entire team with help from identified subject matter experts is the root cause analysis. Root cause analysis is used to identify root causes for problems or defects when a team has reached the analyze phase without a clear idea of primary causation. Some of the tools described for identifying root causes in this chapter could be used in either define or measure phases at the discretion of the Black Belt leading the team; the FEMA described in Chapter 13 on measure could likewise be used in the analyze phase as part of root cause analysis.

The Cause and Effect, or Fishbone, Diagram

A popular method for brainstorming and analyzing causation in a process is the fishbone diagram. The fishbone diagram can be completed by a single Six Sigma expert, but it typically has more value when it is completed by the entire Six Sigma team. The diagram lets teams concentrate on a brainstorming process that generates ideas about possible problem causes, organizes those possibilities in a logical way, and lets teams visualize the information to identify priorities, trends, and relationships between ideas. When used as a team activity, the fishbone diagram encourages participation and input from all team members, which increases the chance of laying the foundational work for a viable and original solution.

The cause and effect diagram is called the fishbone diagram because you begin with what looks like a simple drawing of a fish skeleton. Reference the diagram below and follow the instructions to create a fishbone diagram as part of a team brainstorming exercise. You can also use these instructions now to practice a fishbone diagram based on a process or problem you have experience with.

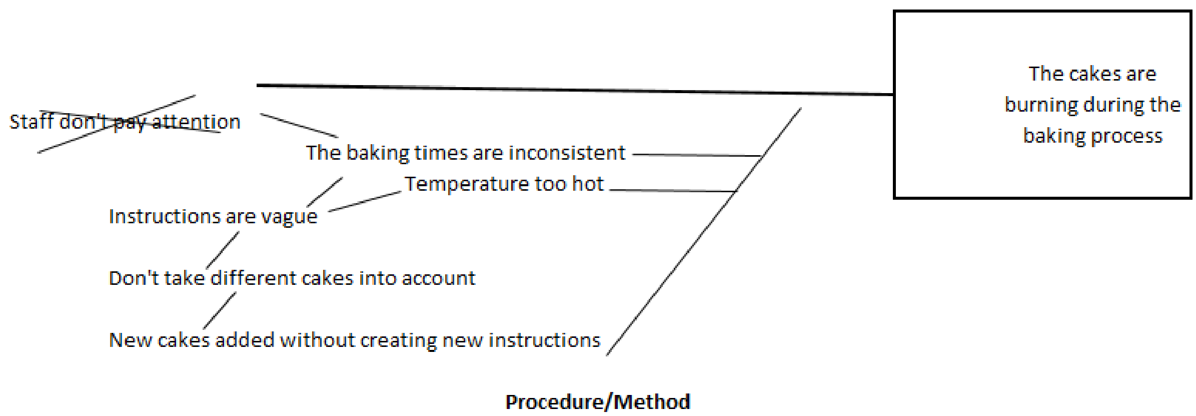


1. Sketch a basic fishbone shape on a whiteboard or large flipchart. Write a summarized version of the problem where the fish head should be. Note: You don't have to conduct a fishbone diagram only on the problem statement from the define phase. Teams might also conduct the diagram on a specific defect or issue found during the define or measure phase. For example, if the problem statement discusses the amount of waste in a restaurant, the team might have discovered during the measure phase that bread is being thrown away at a rate higher than all other food items. One of the activities handled in the analyze phase might be a fishbone diagram specifically about the reason for so much bread waste.
2. Draw a fish spine and four major connectors. Label each connector as People, Process, Materials, and Procedure. Some Black Belts also include two other major connectors: Equipment and Environment.
3. Explain the categories of the fishbone diagram to the team. Note that there are some places, especially with particular processes, where the various categories will overlap. Some ideas generated by the team as they complete the fishbone diagram might fit in more than one category, and that's okay.
    a. People references anyone who carries out or interacts with a process.
    b. Process or machine refers to the process by which inputs become outputs.
    c. Procedure or method refers to the way things are done, whether by written documents or unwritten rules.
    d. Materials are the inputs, such as raw goods, into the process.
    e. Equipment includes the technology or machines required to handle the work.
    f. Environment is the immediate area surrounding the process.
4. Begin with each category on the fishbone diagram, asking the team how something in that category might be responsible for a problem or defect.
5. Use sticky notes to write down ideas and place them on the fishbone diagram so you can move ideas around later. You can also write directly on the diagram.
6. Couple cause-and-effect brainstorming with the 5 Whys exercise described in Chapter 6. For each branch of the fishbone diagram, ask "Why?" at least five times to ensure the most granular detail possible.
7. Once the team has run out of ideas for the first category, repeat steps 4 through 6 for all other categories.

8. Take some time as a team to review the diagram, discussing the placement of potential causes, and moving them to appropriate categories and subsections to create an organized visual representation.
9. Remove or cross-out causes that don't prove to be valid after initial discussion.
10. As a team, decide which root causes seem most likely or highest priority. Circle those causes as high-priority possibilities for further investigation.

Cause and Effect Brainstorm Example

To provide a better idea of how a fishbone diagram works, consider the example image below and we'll walk through how the team came up with the information recorded on the procedure/method line of this diagram.

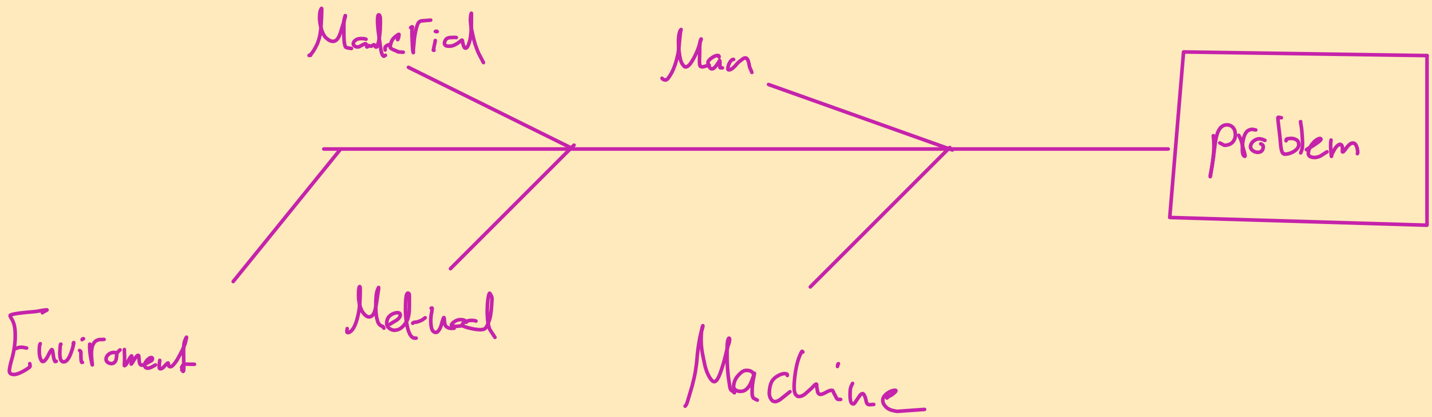


The team above was working to solve a problem of burnt cakes in a food-service bakery. When discussing the method by which the cakes are being baked, the team first came up the with the reason that the cakes were being baked at inconsistent times. Perhaps, suggested one team member, staff weren't paying attention and were leaving cakes in the oven too long. The idea was written down.

The instructions for baking cakes are vague, said another team member – this time, a subject matter expert from the bakery. "Why?" asked the team. The subject matter expert responded that the instructions in the bakery don't take various types of cakes into account, leaving staff guessing about bake times for some cakes. Further "Why?" questions helped the team determine that new cakes were added to the menu without the overall instructions for bakery staff being updated.

After digging deeper into the inconsistent baking times, the team again asked themselves how methods could be responsible for burnt cakes. Someone suggested that the temperature in the oven was too hot, and the team tied that suggestion to the same root cause as the inconsistent bake times. Upon final review, someone noted that the suggestion that staff not paying attention was a cause wasn't valid, because the bakery was equipped with alarms that sounded when baking time was done. The team crossed that idea off the diagram.

In this case, the Six Sigma team might prioritize the fact that instructions are not available for all types of items being prepared in the bakery. Because this would likely be a simple and common-sense improvement to make, the Black Belt might even assign someone to begin working on the improve



Created by Notein

phase as soon as the cause was verified. Many times, the root cause is not as obvious and the solution for the cause even less obvious, requiring additional analysis and validation before moving forward.

Root Cause Verification Matrix

Once teams identify possible root causes, they must verify that the causes are valid. Root cause verification can be completed via a variety of methods, including statistical analysis, design of experiments, logical questioning, observing a process, gathering additional data, analyzing data via graphical representation, and mapping processes at a more granular level than accomplished in the define phase. While this chapter touches briefly on statistical analysis and graphical representation, those topics, as well as experiments and process mapping, are covered in later units.

Whatever method is used to validate root cause assumptions, the Six Sigma team should document it. Documentation regarding root cause verification is usually completed on a matrix that includes the problem, possible root causes, the verification method, why the verification method was chosen, results of the verification, and, in some cases, whether a senior Six Sigma leader, such as a Master Black Belt, agrees. A template for such a matrix is included below, but teams can also create similar documents in Excel or Word.

Problem	Possible Root Causes	Method of Verification	Reason for Verification Method	Verified?	Notes

The root cause verification matrix for the burnt cake example might be completed as follows:

Problem	Possible Root Causes	Method of Verification	Reason for Verification Method	Verified?	Notes
Cakes in the Delaware bakery are coming	Temperature too hot	Run chart of temperature against required temperature	Allows team to visually determine whether temperatures exceed requirements at any point during bake process	Yes	

out burnt 10 percent of the time.	Bake times inconsistent	Box plot of bake times per type of cake	Provides visual representation of the variation per cake type; bake times should not vary widely by cake, so the boxes should be flat; lets teams determine if certain cake types are more of a problem.	Yes	
	Instructions not provided to staff	Process observation	Easy way to determine if bakery staff have the instructions necessary to complete work without defects	Yes	

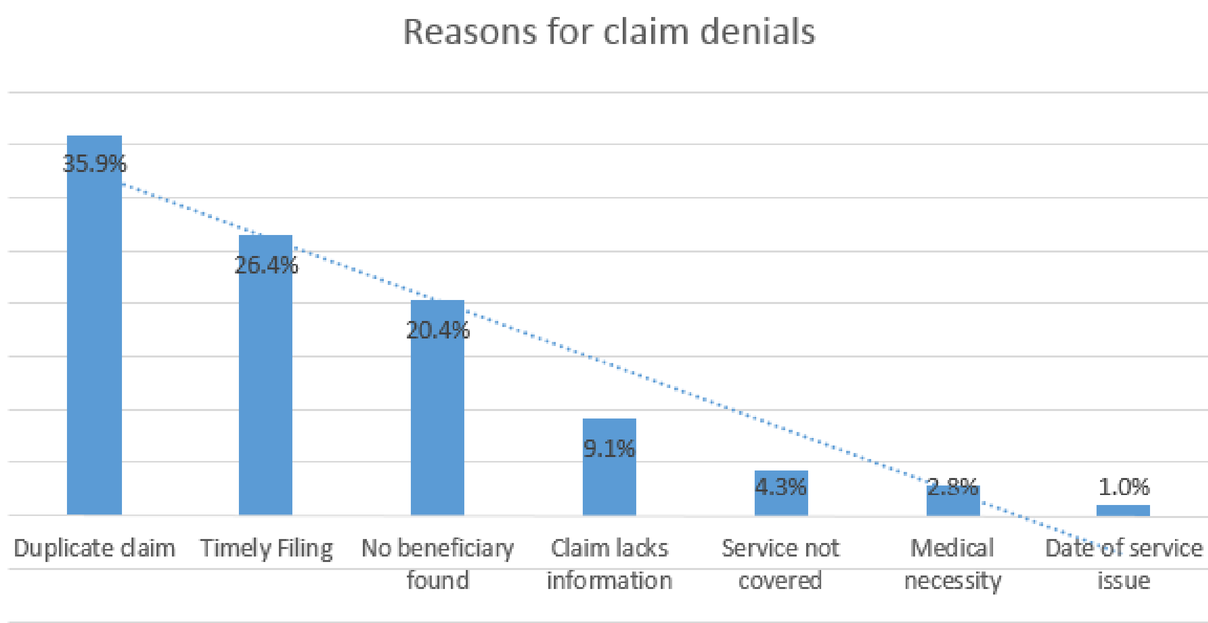
Graphical Analysis

Six Sigma experts and teams can use a variety of graphical analysis tools to help generate ideas about root causes or understand how inputs and outputs really impact each other. Some of those graphical analysis tools require statistical analysis software, and those will be covered in later chapters. In this section, we'll look at a few graphical representations you can create easily with Excel.

Pareto Chart

The first graphical tool for validating root causes is the Pareto chart, which was covered in chapter 5. Chapter 5 discussed the Pareto Principle, or 80/20 rule, which says that 20 percent of the causes lead to 80 percent of the results. Because of this, a Pareto chart is a good starting point for root cause brainstorming – teams can start with the few inputs or attributes accounting for the bulk of the Pareto chart. Just as you can "drill down" using the fishbone diagram, asking deeper and deeper "Why?" questions, you can drill down using a Pareto chart.

Consider the Pareto chart illustrating reasons for medical claims denials from Chapter 5.

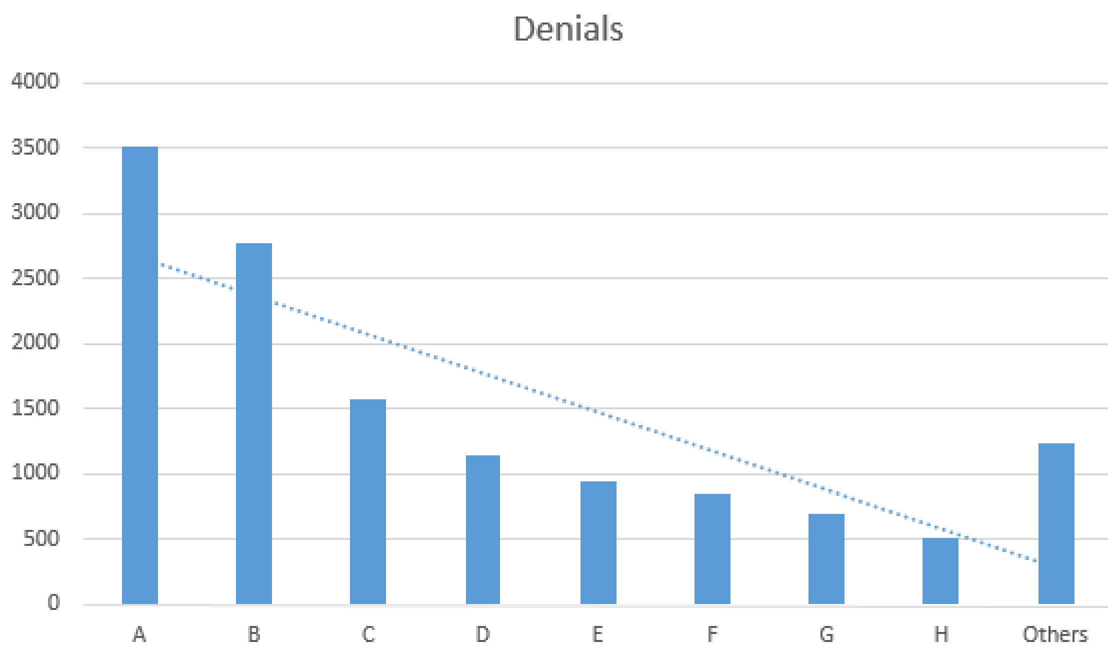


In this case, the team might decide to concentrate on the top two claims denial reasons: duplicate claim and timely filing. The team could use various methods for digging deeper into root causes for these two claims denial reasons. They might perform a fishbone diagram to discover why duplicate claims are being generated. To understand the timely filing problem, teams might gather additional data for graphical analysis.

Timely filing means that the claim was not originally filed with an insurance company prior to the deadline for claims submission. Different insurance companies have various timely filing requirements, and the countdown usually starts at the time of service to the patient or the time of discharge from a facility. The team might want to understand which payers are denying claims for timely filing, so they collect data as follows on how many timely filing denials are associated with each payer. Because Pareto analysis is concerned with the top few, you can lump the many others together in a single entry and, for the purposes of the Pareto analysis, ignore them. A medical provider might bill claims to dozens of providers; including every provider on the data table and Pareto chart would be a waste of both time and space for this particular exercise.

Payer	Denials
A	3512
B	2779
C	1575
D	1142
E	945
F	847
G	702
H	502
Others	1241

Converted to a basic Pareto chart, the data is illustrated in the graph below.



It's easy to see from the graph that the bulk of the problem is with payers A and B; perhaps these companies have shorter timely filing guidelines than the other companies or billing staff is unaware of the proper timely filing requirements for those payers. Six Sigma teams can begin asking questions specific to these payers as they continue analyzing data and discovering root causes.

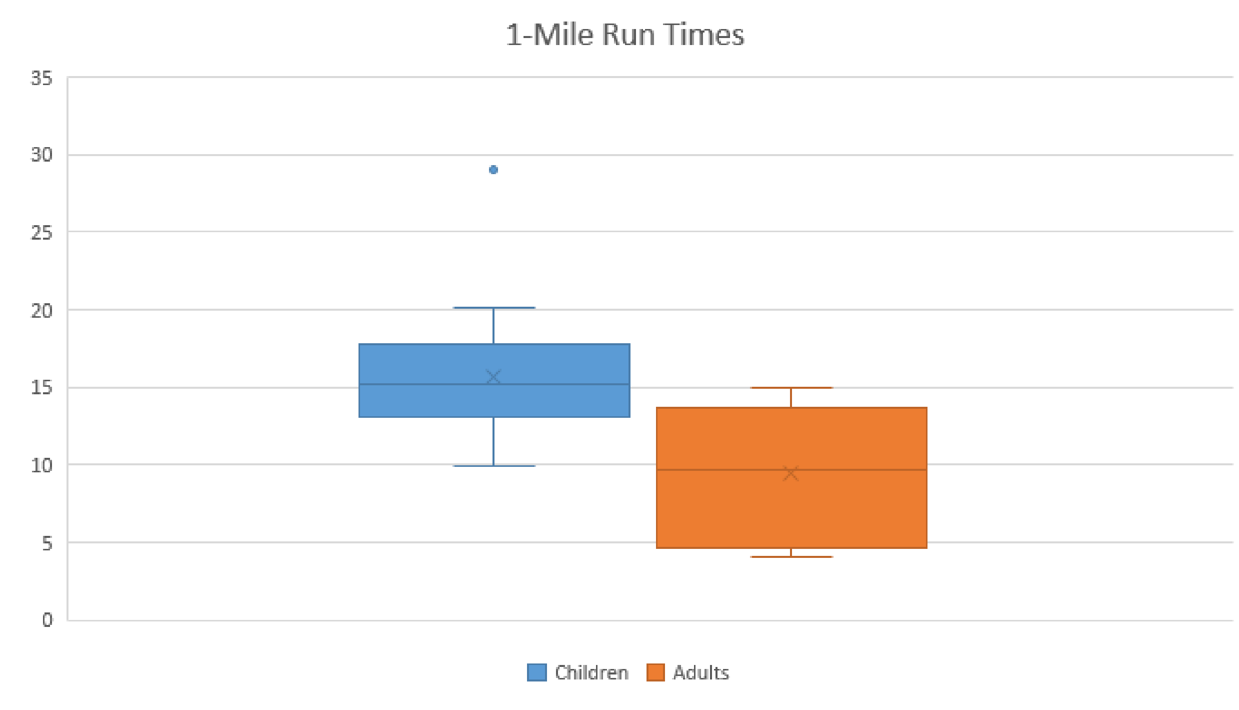
Box Plots

Box plots are another graphical representation that can be handled with Excel. In later chapters on statistical analysis, we'll cover how box plots can be related to hypothesis testing and other analysis. When differences between distributions are marked, however, or when outliers are fairly obvious within data, the image of a box plot tells its own story without requiring advanced statistical knowledge.

Box plots are often called Box-and-Whisker graphs. To understand how to read a box plot, consider the data table and graph below. The data table shows the time in minutes in which various runners completed a one-mile race. The results are divided into the categories Children and Adults.

Children	Adults
9.9	4.1
10.2	4.1
11.6	4.5
12.7	4.6
13.8	4.7
13.4	7.5
13.4	8.3
13.9	8.9

15.2	9.7
15.8	9.8
15.7	10.1
16.2	11.6
16.7	13.5
18.9	13.7
19.4	14.8
20.1	14.9
29	15



The above image shows a box plot of the data table, generated in Excel. Even without further explanation, you can likely tell that the children completed the race on average slower than the adults. The blue box, which represents the children, is shorter than the orange box, indicating that the middle 50 percent of children completed the mile-long run in times that had less variation than that of the middle 50 percent of adults. To understand how this conclusion was arrived at, we'll take a look at all the elements of a box plot.

A box plot begins with the upper and lower hinge – the top and bottom of the box. The top represents the 75th percentile; the bottom represents the 25th percentile of the data. The line within the box represents the 50th percentile. Within the box are the 50 percent of data points between the 25th and 75th percentiles.

Each box plot receives upper and lower whiskers indicating the range of most of the other data within a set. In this case, Excel creates whiskers that extend to the top and bottom of a range barring any statistical outliers. Some statistical analysis software or methodologies use other methods to create the whiskers with very similar results.

Finally, since all plot points must be represented on a box plot graph, outliers are indicated with dots. You'll see a blue dot above the children's box, representing the data point of 29 minutes. That particular point is a statistical outlier; Six Sigma teams who note outliers on box plots should consider the data that is shown as an outlier. If an explanation can be found for the outlier, it can be ignored. For example, if the child who took 29 minutes to complete the mile was much younger than the other children or was walking with an injury, the data point is explained and can be excluded from further analysis.

In addition to calling out outliers, box plots let you compare two distributions graphically to see if, as in the above example, there are obvious differences between the data sets. Box plots are useful in comparing how various attributes impact a process. Six Sigma teams might compare process results for different operators, different times of day, different teams, or using different inputs. It's important when comparing data in this fashion to only alter one attribute or input; otherwise, you won't be able to tell what the cause of any difference between data sets was if a statistical difference does seem likely on a box plot.

Use some information for a work process you are familiar with, or use the sample data provided, to create box plots in Excel following the steps provided below.

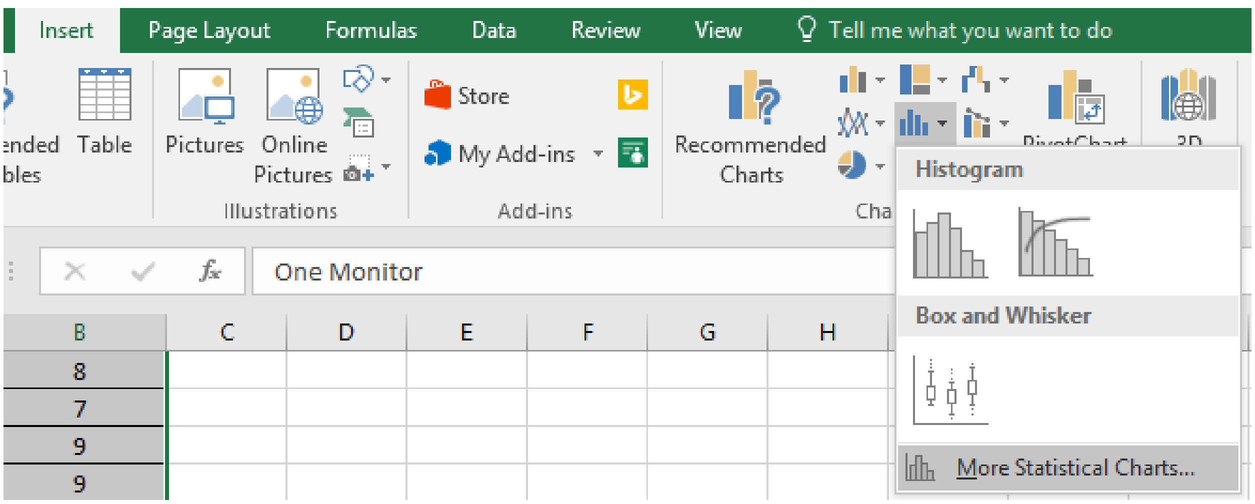
A department manager believes that the staff on her teams would be more productive if they were able to work with two computer monitors. Because outfitting an entire department with dual monitors would be costly, the manager's boss requires some proof that her assumption is correct. The manager equips a few stations with dual monitors and lets different team members work at the stations. She records the amount of work done within hourly increments at stations that have dual monitors as well as stations that have single monitors. Her data is featured in the table below.

One Monitor	Two Monitors
9	10
8	4
4	9
7	7
2	8
6	7
1	9
8	9
5	14
4	10
3	12
7	7
9	9
5	4
1	9

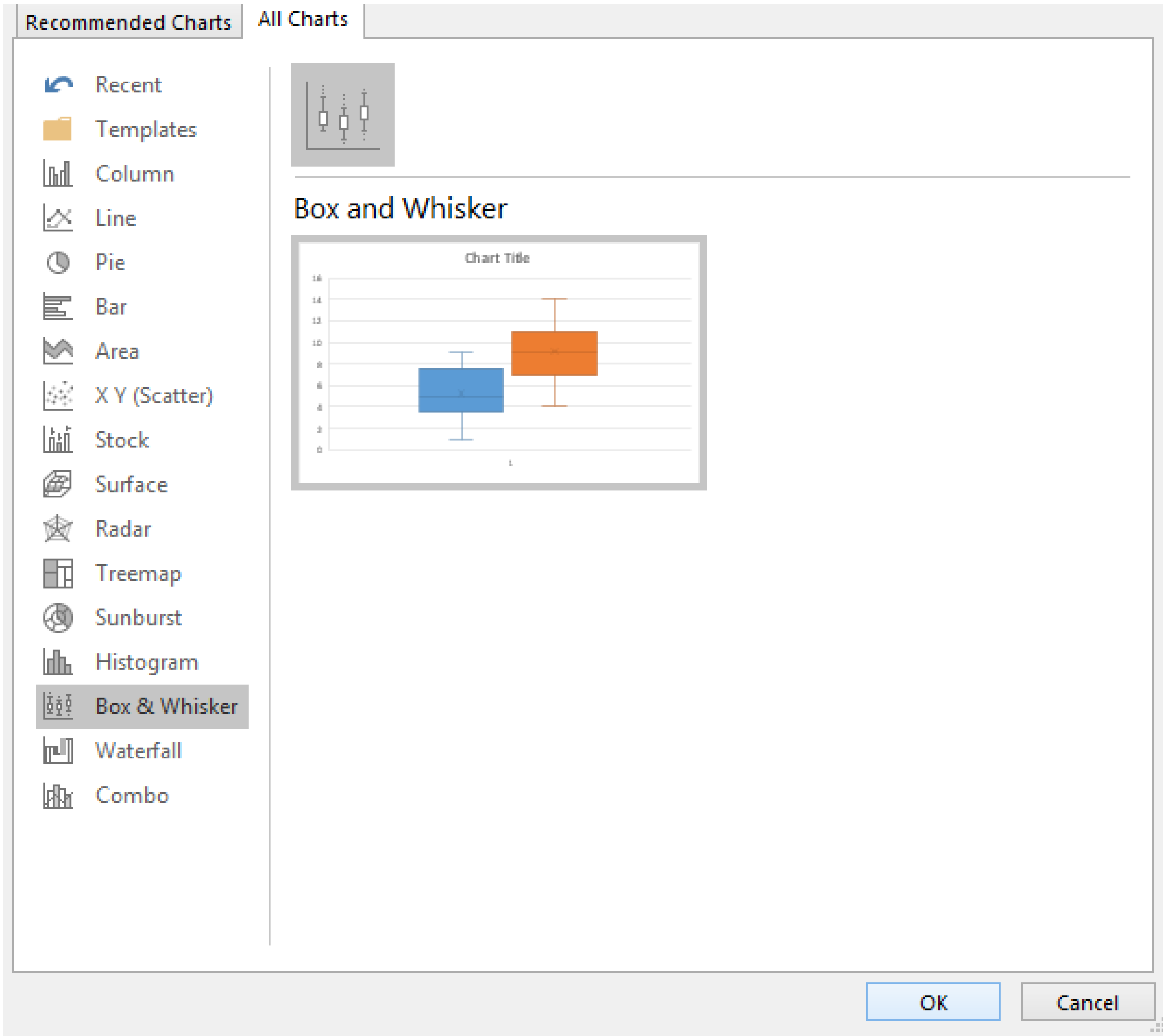
5	7
6	8
7	14
4	13
2	10
9	12
5	12
4	8
8	6
2	10

Create a box plot of the information in the manager's data table.

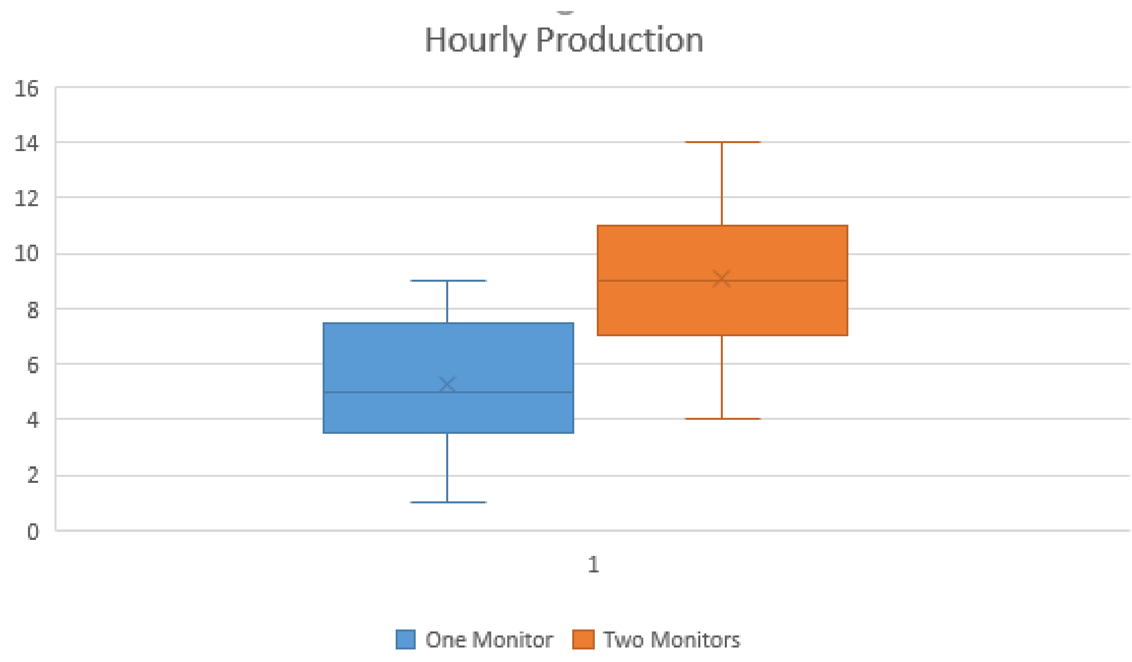
1. Copy the data from the table above into Excel.
2. Highlight all of the data cells, including the header row.
3. Click Insert > Statistic Chart > More Statistical Charts



4. Select Box and Whisker and click OK.



5. Using normal Excel chart editing functions, edit the title and data labels of your chart as desired.



While a Six Sigma Black Belt would be able to back up the conclusion with hypothesis testing or other analytics, the manager might get her request for monitors approved with nothing more than this box plot. It's easy to see that the second monitor *did* increase production capability for staff. Another thing worth noting is that the distributions for each of the boxes and whiskers is similar, which is somewhat expected. High producers are still going to produce the most, and low producers are still going to produce less than high produces, even if everyone is producing slightly more with the new set-up.

Note that the two examples used in this chapter used data sets that were different enough to be visually noticeable on a box plot. This isn't always the case, which is why box plots and other graphical representations are often only the starting point for analysis.

Statistical Analysis

Because statistical analysis is covered in several future units, this section lists some common statistical analysis tools with definitions.

Hypothesis Testing

Hypothesis testing lets Six Sigma experts draw conclusions about the population based on statistical analysis performed on a sample. Because the conclusions are based on samples and not the entire population, there is always some risk of error. You might have seen or heard poll results given with a plus/minus in the result: "60 percent, plus or minus 2 percentage points, would vote for the candidate today." That plus/minus is the value for the error risk.

In statistical analysis, the risk that a sample doesn't offer a good representation of the population is known as the alpha-risk and the beta-risk. Using information about the sample and alpha and beta risks, statisticians calculate what is called the p-value. The p-value is a probability estimate that tells statisticians how likely an assumption or conclusion drawn on sample data will be incorrect.

Statistical software removes a lot of the manual calculations from the process of setting up and running hypothesis tests. With Minitab, for example, Six Sigma experts can conduct hypothesis tests on prepared data with a few mouse clicks. They do have to know which types of hypothesis tests to use in which situations.

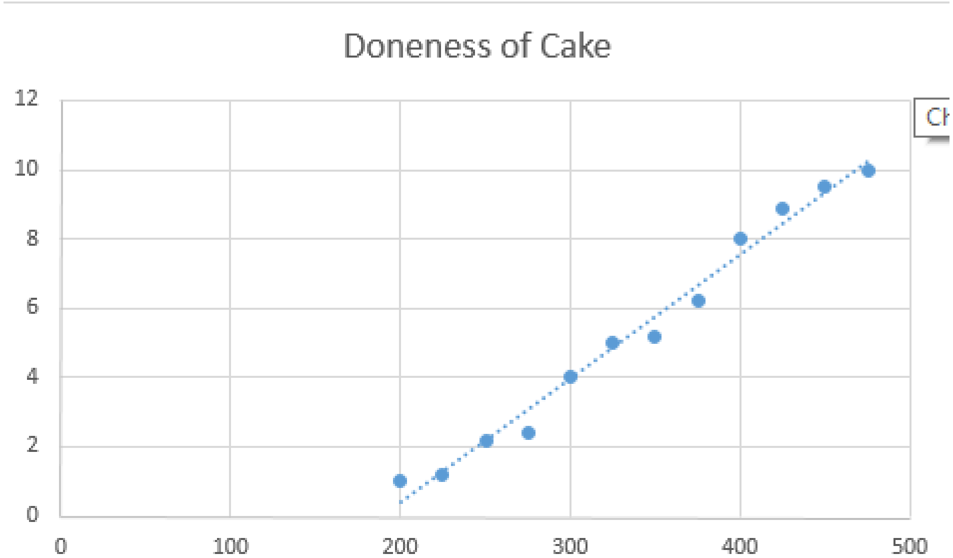
Correlation and Regression Analysis

Regression and correlation analysis helps Six Sigma experts understand how variables within a process might be related. Regression analysis helps teams define the relationship between one independent variable – possibly an input – and one dependent variable – possibly an output. Does the temperature in the oven have a relationship to whether the cake is baked correctly, and how close are the two things related? Does the number of hours a person works have an impact on his or her productivity – can the team show a correlation between lower production as employees approach the end of a shift? These are the types of questions that regression analysis can answer.

To work with regression analysis, both of the variables being studied have to be in numerical format. To conduct a regression analysis regarding the relationship between oven temperature and whether a cake is baked correctly, a Six Sigma team baked cakes at varying temperatures and rated them numerically on "doneness." A rating of 1 indicated the cake hardly cooked at all; a rating of 5 indicated a perfectly baked cake. At 10, the cake was completely burned. The temperatures and corresponding ratings are seen in the data table below.

Oven Temperature	Doneness of Cake
200	1
225	1.2
250	2.2
275	2.4
300	4
325	5
350	5.2
375	6.2
400	8
425	8.9
450	9.5
475	10

Using this data, the team creates a scatter diagram with a trend line, as seen below.



Just looking at this graph, you can tell that a relationship does exist. The data plots are gathered tightly around the trend line, which indicates that as temperature rises so does the doneness of the cake.

Design of Experiments

Correlation and regression analysis doesn't always provide the information a team needs to determine relationships between variables, especially when those relationships are complex, or multiple variables are present. Because the analyze phase sets the stage for the improve phase, teams have to be as certain as possible in their analytical conclusions before they decide on solutions for implementation. A design of experiments can provide the more granular details and analysis required for that level of certainty.

Design of experiments, or DoE, is performed via statistical analysis software such as Minitab. Teams can set up experiments for one factor or multiple factors.

Analyze Tollgate Checklist

- Primary root causes have been identified.
- Team has prioritized root causes.
- Champion or sponsor agrees with team priorities moving into the improve phase.
- Where possible, root cause assumptions are backed by statistical data.
- Relationships between variables within a process are understood.
- Where possible, variable relationships have been confirmed with statistical analysis.

Chapter 15: Improve

During the improve phase of a DMAIC project, Six Sigma teams brainstorm possible solutions for the root causes identified in the analyze phase and rank those solutions according to costs, how effective the solution would be, and how likely the solution could be implemented. Analytical rankings are used to prioritize and select solutions for implementation. Teams pilot solutions through beta tests or small roll outs, collect data on the solution, and verify that the solution is working as expected via statistical analysis. Once the team is confident that the solution works to address the problem, it plans and implements a full rollout of the solution.

Solutions Selection Matrix

A solutions selection matrix is an analytical tool that lets teams propose and rank solutions for any of the root causes identified in the analyze phase. While teams can work simultaneously on multiple solutions if multiple prioritized root causes were found, Black Belt and other team leaders must remain cognizant of timelines, resources, scope, and the purpose of the project. If a single solution provides enough positive impact to reach project goals, then other solutions might be saved for future improvement projects. If one solution would reach results, but another solution would be especially easy to implement and provide additional positive results, the team is likely to decide to implement both.

A solutions selection matrix can be created in Excel, and teams should work on the document together in a brainstorming capacity. It's a good idea to include the entire team as well as relevant subject matter experts and stakeholders during solutions brainstorming. This ensures the solutions the team comes up with are more likely to be a realistic fit for the process and business; once solutions are selected using the matrix, teams will also likely have to get sponsor, champion, or leadership council support before a partial or full implementation is possible. This is especially true where solutions require expenditure or will impact processes and people outside of the project's scope.

An example solutions selection matrix is pictured below.

Problem Statement	Validated Root Cause	Potential Solutions	Practical Method	Effectiveness	Feasibility	Cost-Benefit	Overall	Take action?

The matrix is completed by:

1. Entering the problem statement in the first column. This should be the final problem statement that was arrived at during the measure phase if the team decided that the statement should be

altered after gathering data. Otherwise, this can be the problem statement from the define phase.

2. Entering a priority validated root cause from the analyze phase. If the team is going to attempt to solve more than one root cause during the improve phase, it should create a solutions selection matrix for each root cause.
3. Brainstorming potential solutions in column three. During the brainstorming process, teams should not question or attempt to analyze solutions, but should record any solution suggested that seems at all viable. The only solutions that might be ignored are those that are clearly out of scope or impossible, but the Black Belt leading the brainstorming exercise will have to use his or her own discernment about such suggestions.
4. Noting, at a very high level, the practical methods by which a solution could be implemented. In one example used in the analyze chapter, a commercial bakery had a problem that was caused by lack of baking instructions. In this case, the Six Sigma team might propose that staff be provided with proper instructions. The method by which that solution occurs is written documentation and training.
5. Rating solutions. After a list of possible solutions and practical methods is created, the team rates each possibility on effectiveness, feasibility, and cost-benefit. Each category is given a rating between 1 and 10.
   a. Effectiveness is the measure of how well a solution will eliminate a root cause for a problem, with 1 being not effective and 10 being highly effective.
   b. Feasibility is the measure of effort required to implement the improvement, with 1 being not feasible because of the effort or resources required and 10 being highly feasible.
   c. Cost-benefit is an estimated measure of how the costs of a project compare to the savings expected. This rating is not a formal cost benefit analysis, but is a high-level estimation. If savings are expected to outweigh the costs associated with a project, the team ranks the solution as high. Otherwise, the team ranks the solution low.
6. The scores for effectiveness, feasibility, and cost-benefit are multiplied to calculate an overall score. The overall score can be used to prioritize solutions and select the solution that features the best overall effectiveness, feasibility, and cost-benefit rating.

Consider a possible solutions selection matrix created regarding the medical claims denial example used in the analyze chapter.

Ex.:

Problem Statement	Validated Root Cause	Potential Solutions	Practical Method	Effectiveness	Feasibility	Cost-Benefit	Overall	Take action?
The Florida medical facility is experiencing a high rate of claims denials.	Claims are not being filed in a timely manner due to a need to chase documentation for the claim.	Require reception staff to collect all necessary patient demographics during the office visit.	Program system to require entry of certain data elements during patient check in	5	7	7	245	Yes
		Require patient to sign up for email and portal access to communicate about need for additional information	Require email address as part of the admission procedure	3	1	5	15	No
		Require clinical staff to input all information, including codes, during clinical visit.	Program system to mandate entry of claims components during clinical notes process	7	3	3	63	No
		Create follow-up claims billing team who prioritizes claims that are missing information.	Assign specific follow-up duties to on or more team members and create workflow to manage claims	10	7	7	490	Yes

cost ↑ high ratio: low rate
low ratio: high rate

During the analyze chapter, a Pareto analysis indicated that timely filing issues were a root cause for high claims denials. In the solutions selection matrix above, a team has identified and prioritized four possible solutions after discovering that claims were not filed on time because claims billing staff didn't have all the proper information in time.

The first solution is to require the front desk to collect as much information as possible. The team gave this solution a mid-range rating for effectiveness because it doesn't address the fact that clinical information can still be missing from the claim. But, the process would be effective at gathering demographic information and would not require large expense or effort to implement, so the team rated it high for the other categories.

Next, the team considered creating and requiring a patient email or portal system so billing staff could communicate quickly with patients when information was missing. Because not all patients have email and many would be unlikely to use such a system, the team ranked this solution as low for feasibility and effectiveness.

The third solution considered by the team was requiring clinicians to include all information necessary for billing as they charted during the visit with the patient. The team thought this solution would be fairly effective, but that clinicians would be unlikely to take the time to be so thorough when dealing with patient issues. The solution might also slow physician visits, resulting in a negative impact to revenue.

Finally, the team considered a solution that put certain staff members in charge of claims with missing information. Because those staff members could concentrate on missing claims and would work through a new workflow built by the team, they would be more likely to file claims on time. Overall, the team ranked this solution highest, but they decided to implement both solutions one and four because solution one required so little effort and would actually help drive the success of solution four.

Cost Benefit Analysis

When teams include the appropriate individuals in the process, a solutions selection matrix is very adept at identifying the best possible solutions for implementation. Leadership councils and executive sponsors often want more information about the costs and benefits expected for a solution, though, so teams should be prepared to create a cost benefit analysis. Black Belts often have many of the elements required for such an analysis after the measure and analyze phases, but teams might also need to work with accounting, finance, or business planning departments to gain accurate financial details required.

The goal of a cost benefits analysis is to compare the costs of implementing a solution with the monetary benefits expected from the solution. Costs include expenses such as software development or purchase, equipment purchase, building development or renovation, additional labor or hiring, training expenses, additional supplies, and any losses associated with disruption as the solution is implemented. Benefits might include an increase in product margin, increase in revenue, cost savings or avoidance, and intangible benefits such as increase to staff morale or customer retention.

Six Sigma teams usually aren't in a position to handle detailed cost benefit analysis such as might be completed by a certified accountant, but they can create an idea of cost benefit relationships via the payback method of analysis. This is the simplest way to approach such an analysis and provides leadership with an estimated time before a project "pays off."

Payback, or Pay Off, Analysis

To conduct a payback analysis, Six Sigma teams must have an estimated cost for the project as well as the estimated financial benefit per year. Remember, financial benefits don't just include increases in revenue. Cost savings, new customers, or mitigation of customer loss can all be considered as contributing to benefits each year. The team also needs to understand the estimated operating costs of an improvement for each year.

The formula for this analysis is:

(Cost of implementing solution) / (Annual financial benefits – annual costs)

If a project costs $50,000 to implement and $2,000 per year in extra labor, and the team expects the project to generate $15,000 in financial benefits each year, then the calculation is:

$50,000 / ($15,000 - $2,000)

$50,000/$13,000

Or, approximately 3.84 years until the project pays for itself.

Obviously, organizational leaders are looking for payback calculations that are as short as possible, but if the solution will solve a major problem or set a foundation for extraordinary success in the future, a longer payback time doesn't necessarily keep a solution off the table.

Net Present Value

A more concise way of calculating cost benefits is known as the Net Present Value, or NPV. NPV adjusts benefits and costs as time passes because cash flow in the future is not as valuable as current cash flow due to inflation and other economic factors. The discount rate for various endeavors can be calculated using expected return, interest rates, or inflation rates. Often, corporate finance departments can provide Six Sigma teams with a discount rate used for NPV in the company. A very basic NPV model is shown below.

	This year	First Year	Second Year	Third Year Total
Benefits				
Increased revenue		$10,000	$20,000	$30,000
Cost Savings		$5,000	$10,000	$15,000
Costs				
Capital	-$20,000			-$20,000
Equipment	-$15,000			-$15,000
Training	-$5,000			-$5,000
Labor		-$2,000	-$2,000	-$2,000
Total Benefits – Cost Annual	-$50,000	$13,000	$27,000	$3,000
NPV (Discounted 5 percent)		$12,350	$25,650	**$2,850**

13.000 - (13.000 * 5%)

In this model, the team spent $50,000 implementing a solution and expects a $2,000 labor expense associated with the solution each year. The estimated benefits from the solution are recorded for the first two years, and all of the benefits and costs are added up for a third-year view. The NPV is discounted by 5 percent, and the final number is seen in the bottom right cell: $2,850. The goal is a positive NPV, so this project fits that goal.

Piloting a Solution

Once a solution is selected and work done to bring it into production at a minimal level, the Six Sigma team is ready for a pilot. A pilot is a limited trial of a solution in a live environment. No matter how much analysis was completed or how well test cases were run, teams can't know for certain how a solution will behave in the "wild." The live production environment will always have variables that teams can't account for, particularly when people are involved in the process.

Benefits of a limited pilot include:

- Use of resources are limited, which reduces waste if the solution turns out to be incorrect or not effective in resolving the problem
- Confirmation that expected results occur
- Allows troubleshooting of a new solution on a smaller scale to minimize disruption during full transition
- Lets employees outside of the Six Sigma team provide feedback on the solution and implementation to make the final rollout more successful

Teams don't have to pilot every change they make. Simple or small changes can be made without piloting as long as teams document the changes well and measure results for verification. When changes are large in scope, could cause expensive or expansive consequences, or would be difficult to reverse, teams should begin with a pilot. The same is true for any solution that might be expensive to implement at a full scale.

Pilots can occur on a limited scale or for a limited time. Limited scale pilots incorporate a specific region, team, group of people, or machinery. Limited time pilots implement a temporary change; at the end of a scheduled time, the team makes a decision about whether the change should be made permanent.

Pilots can occur with either processes or products. Process pilots might feature testing specific locations, testing results with some customers, working with some employees to test new processes, or conducting dry runs of a process without impact to the end-user. Product pilots are conducted using test markets, product models, or alpha and beta testing of the product with certain end-users.

To create a pilot, a Six Sigma team must first select the audience for the pilot. Internal process pilots can be performed by a select team or a select few employees. External product pilots can be performed using a subset of customers. For the best pilot results, avoid biasing results by selecting the best possible performers or customers who are most likely to work hard to ensure a product succeeds. When the solution is implemented on a full scale, it will be used by everyone, so you want to ensure it works for everyone.

When possible, pilot at a very small level and then expand the pilot to a larger audience. This is the premise behind alpha and beta testing. A very small set of loyal customers tests the product first, because you know they will provide feedback. Next, an expanded set of customers tests the product after teams have made changes associated with feedback from the first group of users. Finally, if the limited tests are successful, teams choose to roll out the product to the entire audience.

Analyze Pilot and Test Results

Six Sigma experts can use all the tools associated with the analyze phase to test whether solutions have a positive impact during testing or pilot programs. Hypothesis testing can be used to compare data from before the solution to data after the solution, determining if there is a statistically significant and positive change. Graphical analysis can be very helpful in demonstrating for executive leaders how a solution has positively impacted a problem by reducing defects, improving production or efficiency, or reducing costs.

Planning Implementation

Once solutions have been verified through tests and analysis, teams can begin the work of implementing changes on a large scale. Teams should create and work from an action plan during this vital and active stage of the DMAIC process to ensure that no plans or requirements fall through the cracks. During the active part of the improve phase, the project leader will likely delegate numerous activities to members of the team, and the team will also rely on input and assistance from those outside of the Six Sigma team. Keeping an action plan document helps everyone on the team see where they are in the process, what they are responsible for, and what date work must be completed by.

If the Six Sigma team is working with a project manager, he or she is likely responsible for action plan documentation and follow-up. Teams can also use a basic spreadsheet or Word document, which should be saved in a common location, to keep track of what work is to be done and who will do it.

Because every project is unique, improve action plans are also unique. Most action plans will contain common tasks such as documentation, training, and transition.

Documentation

First, the Six Sigma team should have documented all of its work so far during the DMAIC process. If asked, the Black Belt or designated team member should be able to present analysis in the form of data tables, statistical calculations and explanations, and graphical analysis. All brainstorming activities and diagrams should be saved in a central file location where all team members can view them and appropriate team members can edit them as needed. Access to these documents helps team members work efficiently on additional documentation required for implementation.

Almost any organization will require new processes or changes to processes to be recorded in standard operating procedures. Depending on the organizational structure of a business, Six Sigma teams might be responsible for drafting such documents or they might need to work with knowledge management resources to create SOPs in keeping with corporate branding and templates. Teams might also create general communications letting other staff members know about the upcoming changes and the reasons for those changes as well as general reference documents such as cheat sheets and Frequently Asked Questions.

Training

Strong documentation is key to the next part of implementing improvements, which is staff training. Six Sigma teams usually aren't in charge of complete staff training on any improvement they make. Instead, teams begin the training process by working with training subject matter experts or delegates in the department impacted by the upcoming changes. The Six Sigma team trains these individuals, who then go on to train other individuals who will be impacted by the process. At some point, the process training should be integrated into regular organizational training by trainers or knowledge management departments.

Transition

During the improve phase of a DMAIC project, teams should begin to consider the need to transition a process back to the business and traditional process owner. Transition is part of the control phase, but teams should move from improve to control with a good understanding of how the process should be measured and monitored. Strong documentation and training during the improve phase helps cement the success of the control phase.

Improve Tollgate Checklist

- Solutions were reviewed and prioritized.
- One or two top solutions were selected for action.
- Solutions were implemented on a limited basis.
- Data from limited trials was analyzed and solutions appear to work as expected.
- Cost-benefits analysis was performed.
- Sponsor, champion, or executive steering committee signed off on implementing the solution completely.
- All team members agree the solution should be implemented.
- The solution is fully documented through SOPs and training materials.
- Critical staff received training on the solution and are prepared to pass that training on to others.

Self - Reading

Chapter 16: Control

The last stage of a DMAIC project is control. During the control phase, teams build monitors that let them ensure the process continues to work successfully after changes are implemented across the regular business process. At the same time, Six Sigma teams work to transition the process back to the process owner.

Up until this point in the DMAIC process, Six Sigma teams have worked with statistical analysis tools, and a Black Belt or other Six Sigma expert has been present to walk team members through analysis and interpretation. While many organizations train process owners and other employees in Six Sigma fundamentals, it isn't always true that a process owner and his or her team will be familiar with the statistical controls that Six Sigma experts have been using. Because of that, appropriate documentation via a control plan and education regarding tools such as control charts might be necessary to ensure business teams can maintain a process and identify when it is out of control and needs remediation.

Revise FMEA

At this time, Six Sigma teams might want to revisit the FMEA tool originally introduced in chapter 13. Six Sigma teams initially use the Failure Modes and Effect Analysis to identify potential failures in a process and causes of those failures. In chapter 13, we discussed how the FMEA listed potential failure points and ranked them according to severity, occurrence, and detection, calculating a total risk priority number.

At the end of the improve phase or beginning of the control phase, Six Sigma teams should revisit the FMEA, noting what recommended actions were completed and recalculating risk priority numbers for the improved process. There are two reasons for revisiting the FMEA. First, the team is able to see that positive and significant changes have occurred because of the solutions adapted during the improve phase. For any root cause that matched a solution implemented, the team would hope to see a smaller risk priority number.

Second, an updated FMEA helps the team identify the next problem or root cause that might be addressed. Remember, Six Sigma is a continuous improvement initiative. The team might have implemented a solution and met an improvement goal, but further improvements can always be made. Control is a time to review the process and suggest possible improvements for future projects.

Create a Control Plan

To facilitate continued success, Six Sigma teams should create a written control plan for the process owner. The purpose of a control plan is to help the process owner and business team track and respond to key performance indicators so that the process remains improved. The control plan should be a concise, easy-to-reference document that tells the business team when to monitor, how to monitor, what range of data is acceptable to the monitor, and how to respond with corrective action if the range measured is not acceptable.

Control plans can be spreadsheets, specialized digital documents, or hard-copy documents posted at a work station. Common elements of a control plan include:

- Company, division, or department name
- Name of person who created the plan
- Date the plan was created
- Name of the person who last edited the plan
- Date the plan was last edited
- Project and/or process name or identifier
- Process owner
- List of process steps where control action is required
- CTQ or metric associated with each action required
- Limit specifications, or the acceptable range of measurements
- The unit of measurement
- The method of measurement
- The necessary sample size
- The frequency of measurement
- The person responsible for measurement
- Where the information is recorded
- Correction actions
- Associated policy and procedure documents

In discussing quality in chapter 8, we introduced the example of a company that makes chocolate bars and noted that the amount of sugar in the chocolate bar recipe was critical to the customer's experience with the end product. If a Six Sigma team were tasked with improving customer satisfaction with a new chocolate bar product, they might have implemented a solution that ensures the proper amount of sugar is added to the mixture at the right temperature to incorporate the ingredient appropriately.

A control plan for the new chocolate bar solution might look something like the document below.

Company: XYZ Sweets	**Control Plan Created by:** Joe Black Belt
Process: Sugar addition, raw goods mixture	**Control Plan Created on:** Jan. 4, 2012
Process Owner: Sue Processor	

Process Step	Addition of sugar to batch	Heating of batch
CTQ/Metric	Total amount added to batch	Mean temperature during mixing
Limit specification	LSL: 4.90 cups USL: 5.10 cups	LSL: 105 F USL: 110 F
Unit of measurement	Cups	Degrees F

Method of measurement	6-cup sugar test bowl	Read integrated digital thermometer on mixing machine
Sample Size	One batch	3 reading, 2 minutes apart, during mixing
Frequency	Every 2 hours	Every 2 hours
Employee	Mixer operator	Mixer Operator
Record data in	Mix operation log spreadsheet	Mix operation log spreadsheet
Corrective action	Manually measure correct amount for current batch to allow for processing, calibrate sugar disbursement machine following SOP 100.54, test sugar disbursement for first batch after calibration to ensure problem is resolved. Report issue to supervisor.	Turn off machine, waste inappropriately heated batch, and report temperature calibration issue to maintenance.

The above example control plan provides instructions for two specific steps in the process with easy-to-understand measurement and monitor requirements. To reduce the chance of errors, the Six Sigma team has even specified a special measuring tool for measuring the sugar in the test batch so that every operator performing the monitor measures using the same tool.

At the end of the control document, the team provides steps for corrective action. The first step can be corrected by the operator, who has the ability to calibrate the machine him or herself. The temperature calibration in this case can't be performed by the operator, which means the process has to be stopped so that someone can attend to the issue. Note that it is always preferable, when possible, to build corrective action at the process level, such as was done with the sugar measurement. This minimizes downtime, puts employees more in control of the processes they own, and helps employees stay involved with the quality process.

The control plan above assumes that manual measurements must be taken or recorded. Optimally, Six Sigma teams should look for ways to automate measurements, which means data can be continuously gathered and converted into statistical process controls such as control charts. Automated data gathering doesn't mean a control plan isn't necessary, it just means that a control plan won't include instructions for gathering the data. Instead, employees and process owners can be instructed to review automated data or control charts and take action if necessary.

You'll also note that the specification requirements given above are provided with LSL and USL. LSL is the lower specification limit and the USL is the upper specification limit. These are the upper and lower limits of the acceptable range.

Visual Management

In addition to providing a control plan, Six Sigma teams can implement specific visual controls in a workplace to help business teams maintain a controlled process. Some of these tools were covered in chapter 4 on Lean process management, including 5S. Other visual controls teams might implement include signs, posted matrixes and instructions, auditing boards that let teams keep track of individual or group performance over time, color coding, and safety signals.

Standard operating procedures can often be distilled to visual representations on posters. A coffee shop, for example, might provide employees with a visual representation of what ingredients are used to create various complex drink flavors. Such a poster ensures that employees can prepare drinks quickly while reducing errors in ingredient inclusion.

Other SOP visualizations might include safety procedures in a medical environment, such as visual reminders for hand washing and short pictorial representations for how to operate equipment such as hospital beds. In an office environment, pictorial instructions are found on copy machines, where pictures indicate how paper should be loaded and visual gifs are often displayed on LED screens to help employees remove jammed paper. These are some examples that Six Sigma teams can follow when creating documents that will help business staff accept ownership of an improved process and maintain the improvements made.

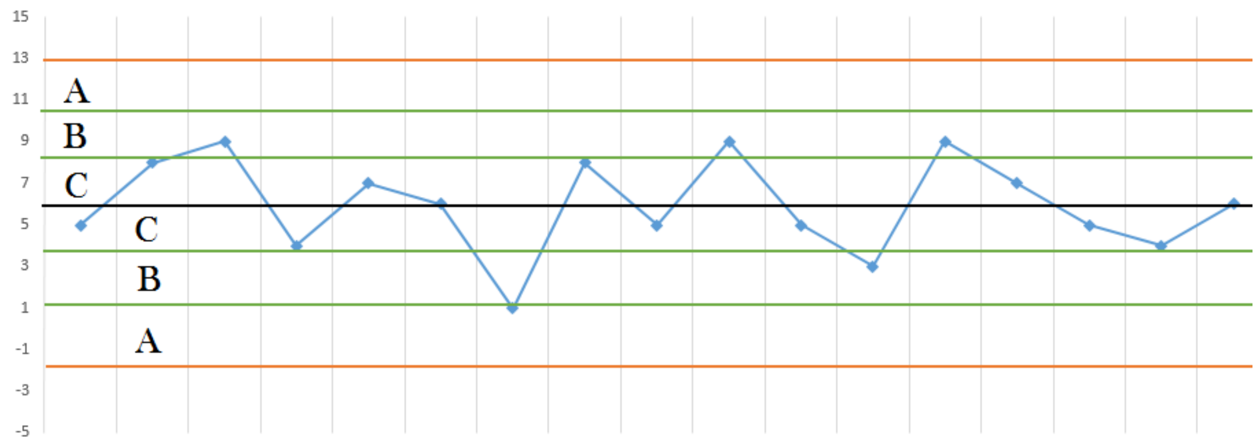
SPC Charts

One of the most common methods Six Sigma teams use to monitor a process is the control chart. A number of types of control charts exist, and Six Sigma experts must choose the right control chart for the type of data and analytical purpose.

Now, we'll cover the visual tests that let a Six Sigma team or process owner know that a process is out of control.

A basic control chart has the following elements:

- A line chart of data with plot points for specific data points
- An x-bar line representing the average of the data points
- Lines above and below the x-bar line representing 1, 2, and 3 standard deviations from the median in either direction
- An upper control limit (UCL) line at 3 standard deviations above the median
- A lower control limit (LCL) line at 3 standard deviations below the median



Above is an example of a control chart. The middle line, which is black, is the x-bar line. The x-bar line is bounded by green lines on both sides, indicating 1 and 2 standard deviations away from the mid-line. Those lines are bounded by orange lines on either side: at the top, the upper control limit, and on bottom, the lower control limit. Between the various lines are areas of the control chart, designated as C, B, and A going in either direction. These distinct areas are important for understanding if a process might be out of control. They are also called Zones 1, 2, and 3.

A control chart is best displayed using an automated reporting system or dashboard, where process owners or responsible employees can view it as needed. If automated data collection and control charting is not possible, then a business analyst can be tasked with collecting data and presenting it in this format periodically, though periodic graphical analysis is less likely to catch a problem of control within a process.

Statistical Process Control Tests: Control Charts

Eight tests exist that can quickly tell someone viewing a control chart if a process is out of control.

- **Test one:** A single point on the control chart appears outside of the upper or lower control limits. If this occurs, process owners should take immediate action, because it is evidence of a major problem within a process. While there is a very remote possibility that shifts outside of three standard deviations can occur randomly, the likelihood is only 3 in 1,000.
- **Test two:** Nine points in a row appear on one side of the center line. This indicates that a change occurred in the process; if the process owner knows what change caused the shift and it was intentional change, nothing needs to be done and the control chart will right itself over time with the new data. Otherwise, the process owner should investigate the process.
- **Test three:** Six points on the control chart increase or decrease in a row, indicating the process is becoming less or more efficient or is generating fewer or more errors. Process owners should investigate unless there is a known reason for the trend.
- **Test four:** Fourteen points on the control chart in a row alternate moving up and down. This could indicate variation in machines, employees, shifts, or over correction.
- **Test five:** Two out of three points in a row on the control chart are in the upper A section or in the lower A section. This might indicate some type of special cause creating sudden high variation.

- **Test six:** Four out of five points in a row on the control chart are located in the upper B section (or beyond) or the lower B section (or beyond). This can indicate a problem of major causation or a shift problem similar to that of test four.
- **Test seven:** Fifteen points in a row are located within the C section above or below the centerline. This can indicate that control limits are no longer relevant to the process; if a team has improved variation of a process, they should recalculate control limits to new parameters. Alternatively, this might occur temporarily when short-term variation is high or low relative to the rest of the points on a control chart.
- **Test eight:** Eight points in a row on the control chart are located on either side of the center line, but none are located in the C section above or below the line. This could indicate an issue of mixed resources or processes; a team might think they are measuring a single process when they are actually measuring two process, for example. Alternatively, it could indicate a major difference in processing for two employees or teams.

When it's possible to create control charts and display current data on a regular basis, these charts make a good addition to a control plan. Individuals don't have to be well-versed in statistical process control to learn about the eight tests, and business teams with the benefit of control charts can spend more time working on production or correcting issues and less time collecting and documenting measurements.

Control Versus Capability

It's important to note the distinction between a controlled process and one that is capable of meeting customer requirements. We touched on this concept in unit 1: controlled processes don't have a lot of variation. Capable processes don't have a lot of variation *and* the outputs center around a customer requirement. This is why both control limits and specification limits are important.

Consider the example used earlier in this chapter about sugar in the chocolate mix. The specification limits ranged from 4.9 to 5.1 cups of sugar in each batch. It's possible for a control chart to show that the process is in control if the measurements range from 3.5 to 3.6 cups of sugar per batch, but the process owner should know that those measurements aren't going to contribute to a product that meets critical to customer quality requirements.

To understand how a process is performing against specification limits, Six Sigma teams can calculate sigma level and process capability.

Sigma Level

Sigma level is the number of standard deviations between the current process center, as measured by the median, and the nearest specification limit (not control limit.) The equation for sigma level is the smaller of the following calculations:

$$\frac{USL - \bar{x}}{\sigma} \quad or \quad \frac{LSL - \bar{x}}{\sigma}$$

For example, if a process has an USL of 5 and a LSL of 3, a standard deviation of .25 and a median of 4.2, then you would calculate from the USL, since the median is closer to the USL.

$$\frac{5-4.2}{.25} = 3.2 = \text{sigma level}$$

Process Capability

Process capability is calculated by dividing the sigma level by 3. In the case of the example, the capability is 1.06.

Process capability is denoted as $C_{pk.}$ A process capability of 1.33 is equal to a sigma level of 4, which is what most experts agree is the minimal level at which most customers will be satisfied. Under statistical process control, many organizations aim for a process capability of 2.0 with minimal acceptable process capability at 1.5.

Team Celebration and Reflection

When Six Sigma teams deem improvements and the related process to be capable and in control, and they've passed those processes back to business and process owner control, they should take time to celebrate and reflect on the outcome of the project. This is usually done following the final tollgate review with a sponsor or champion, and can be a quick meeting to close loose ends, recognize the work done by the team, and discuss lessons learned within the process.

The celebration and reflection meeting is also a great time for team members to bring up ideas for possible improvement projects. While improvements – and the related problems and causes – are still fresh on the team's minds, they can effectively brainstorm ideas for next steps. As with any brainstorming session, no idea should be automatically held off the table because it seems silly, would be too hard to implement, is too costly, or seems too big. Not all of the ideas will become future projects, but the team's input provides valuable information that the Black Belt can later share with Six Sigma leadership panels.

Control Tollgate Checklist

- The team has calculated the performance and capability of the new process
- The team has written a control plan and communicated it to the process owner
- The team has created a monitor for the process, either through procedures for manual data collection or automated generation of control charts
- The team has provided the process owner and business team with all tools and information required to maintain improvements
- The sponsor, champion, or executive leadership has been informed about the state of the improvements
- The team met to reflect on the project and generate a list of ideas for future improvements