Their first step was to present the plan to the executive group. Actually, they met prior to the presentation with their sponsor, Di Edsota, as well as with the head of sales, Phil Cooler, to review the plan. They felt Phil's support would be especially important because they were asking salespeople to put more detail into LOAs, which might add some time to the selling process. They also knew, though, that Phil was a strong proponent of continuous improvement and would see the strength of their reasoning.

The top managers had some concerns, especially about the notion of eliminating the legal review. It would also mean the likely layoff of about 20 attorneys, which was not the initial objective of the project. In the end the leaders agreed to let the team move forward with the work to refine the process plan and make sure it would operate as envisioned.

Before unveiling the process to any other groups in the organization, the team decided to do some of its own tough evaluation of the process, and gave Bob Tull the go-ahead to start working on the policy contract templates. The first analysis they did was a walk-through of each step in the new process design. By taking an entire day, they were able to flesh out some of the more important procedures for the process and identify where others would need to be developed.

The walk-through also caused one aspect of the new design to be placed on the questionable list: the database tracking of policies. "As busy as things are in the IS (information systems) group," said Toni, the team leader, "this may hold up the entire project—and I'm not sure if manual tracking won't work just as well for now."

Their next step was to divide the work into two main areas:

1. Analyze the process for potential problems.
2. Prepare an initial piloting plan.

Their potential problem analysis turned up a number of possible trouble spots that they were able to address. For example, one was described as follows:

Process Step: Customer Contract Review
Potential Problem: E-mailed review file is edited by the customer online, making it difficult to track revisions and ensure legal validity of the document.

Preventive Action: Send customers a markup file on which they can add comments and changes but not actually edit the document itself.
Contingent Action: None

Getting Focus Group Feedback on the Redesigned Process

The next refinement action was to review the still-evolving process design in a series of focus group–type meetings with COLA associates. A back-and-forth debate arose on whether to have cross-functional meetings or to focus on one department at a time. In the end they split the difference: Three sessions would be held, each with one or two representatives from policy administration, underwriting, sales, accounting, and claims. They decided to do a special session with a couple of folks from legal; in light of the potential layoffs, it was thought not to be a good idea to involve them in the cross-functional sessions.

A lot of preparation went into the sessions. First of all, the team wanted to present the process in a positive light and accurately. Second, they wanted to ensure that people would not clam up and not offer helpful criticism. Most of the reaction was positive, though, and it was clear that the communicating Rute Biere had done since the "mass layoff" rumors hit had helped to prepare people well for the coming changes. At the same time, some stern critiques were issued along with the helpful suggestions. A lot of unforeseen issues were raised, which gave the team more food for thought and led to more ideas on how to make things run smoother.

At the end of a series of revisions to the process, Toni, Bev Ehridge, and an accounting manager prepared a budget for the implementation. It included severance packages and outplacement services for attorneys, and costs for moving some staff locations, as well as salaries for an additional two underwriters. Toni met alone with Rute Biere and Di Edsota and presented the updated plan and budget. She sent an e-mail to the team as soon as the meeting was over: "It's a go!"

Implementing the New Process: Start with a Pilot

To repeat the point about implementing Six Sigma solutions from the last chapter: You should *always* start with a pilot rather than with a full-scale launch. Piloting gives you an opportunity to test the assumptions, procedures, and people-challenges of the new process, try out your measurement systems, and limit any damage that might occur if things go less than perfectly, which they *will*.

Various options are open to you when preparing a pilot. The most sophisticated pilots can be used as experiments to compare different approaches and identify the best combination of factors for effective, efficient performance. Some broad choices for pilot strategies that will also influence how you eventually implement the process permanently are described in the following paragraphs.

Off-Line Pilot. Like a laboratory test, in this approach the pilot is really a "dummy" operation that resembles/replicates the real world. The output of this approach may end up not being sold or delivered to customers, but its quality can still be evaluated to check the effectiveness of the process. In some companies a pilot plant is used to test new processes and equipment or to develop products for test (i.e., pilot) marketing.

Selected Times. A defined-length pilot offers a couple of advantages:

1. Participants know the test has a defined end point, so they may approach it with more of an open mind.
2. The postpilot period offers downtime for corrections or refinements that may be harder to accomplish if the pilot continues to operate.
3. Comparative measures can be even more revealing. For example, if improvements are seen during the pilot period, but then disappear afterwards, it adds validity to the conclusion that the solution (not some other unknown factor) created the gain.

Selected Items or Customers. In essence, this approach creates an alternate path in which a certain type or number of real items is sent through the new process. This piloting strategy can lend itself well to a parallel implementation in which more and more work is moved over to the new process.

Selected Locations. If you have different regions or locations, you can switch one site to the process as the pilot, gather data and refine the operation, and convert other sites as appropriate.

Selected Solution Components. Rather than testing the entire new process, different parts of the change can be tried independently. For more on this approach, which works best as an experimental method, see the information in "Design of Experiments" in Chapter 17.

Choosing a Pilot Strategy. These pilot strategies can all be mixed and matched. For example, you might conduct an off-line pilot of one component of the new process, or you could do a time-limited test at one location. Depending on the scope, complexity, and potential risk of your new process or solution, piloting in several dimensions and/or phases can be key to ensuring that the full implementation goes as smoothly as possible. Let's see what COLA decided to do with its pilot plan.

Case Study #12 Continued: COLA Develops Pilot Plan of the Old and New Processes Working in Parallel

The Limit Busters' piloting plan called for a selected group to try the new process in parallel with the existing one for a four-week period, taking all the new letters of agreement from two sales associates. The sales and underwriting members of the team had actually already begun preparing their prospective customers for the more detailed decisions that would need to be made before signing the LOAs. So far, clients were showing no resistance to defining their coverage requirements more explicitly in advance of the LOAs, and the extra detail was not adding much time to the sales cycle. "If you can get my policy ready faster," said one Internet services provider CEO, "a little upfront work is not a problem."

The team had agreed that each policy coordinator would keep track and measure the progress of his or her contracts manually (i.e., not on a central database). "This has been a lot of work," Tye Neebublscz of policy administration told the pilot group, "but it's really been fun, too. I'm getting more and more excited as we go."

After the first four-week pilot would be a two-week evaluation period. At that point the decision would be made as to whether a second pilot was needed. Assuming that it was not, the plan was to have the pilot group convert to the new process full time, then shift the rest of the group and make the conversion in two phases.

At the end of the meeting, consultant Art Glass made a brief (for Art . . .) speech about the excellent work the group had done. The design team later explained to the pilot participants that Art actually had been a huge help in their effort. "You just have to get used to him."

Look at This COLA Fizz!

Like almost any pilot, the four-week test of the new policy completion process experienced a few bumps. The predefined coverage categories and the new policy templates were not well matched, so it took the policy coordinators some extra work to clarify just what clauses and endorsements would be needed. Having a team approach made that adjustment go smoother, though, because the coordinators were in close touch with their sales/underwriting partners most of the time. They also found that it had not been routine in the past to get customers' e-mail addresses, so when the time came to send out policy documents for review, they had to call the customer's office first to get the address.

With the COLA people really on their toes and concentrating on getting the policy papers finished in less than eight days, the cycle times were close to the target, especially as the pilot progressed. It was somewhat difficult to manage the client review time; sometimes it would take four or five days to get the papers back. But when the customers did turn their review around in a day, the total cycle times were less than one week.

At the end of the pilot, the full group held an assessment debriefing session. They identified the following refinements:

1. Include customer e-mail addresses on LOA data sheets.
2. Clarify a primary and an alternate person to review the documents on behalf of the client (for a backup if the primary person happened to be out of the office).
3. Adjust the coverage codes and policy templates so that the right items could be included in the policy documents.
4. Inform clients one day in advance of e-mailing policy documents for review, and send a client-reminder e-mail two days after transmission of the review documents.

The team realized that their measures were not as clear as they should be, and that the role of the customer needed to be taken into account. Therefore they resolved to change the cycle time goal to make it more specific, namely:

Maintain a 7-working-day average cycle time per month, with a maximum cycle time (in the event of client delays) of two weeks.

The operational definition for a cycle-time measure was updated to clarify that the clock would start on the day LOAs were signed by the customer, except for those signed after 3 p.m., which would be measured starting the following working day. Any policy contract would be considered a cycle-time defect:

1. Completed in more than 8 days if signed off on by the customer in three days or less; or
2. Completed in more than 10 days if signed-off on by the customer in more than three days.

The other primary output measure of the policy completion process, "contract accuracy," would continue on unchanged.

Over the four-week period the average cycle time was 8.5 days, with only 5 of the 150 policies processed taking more than 10 days. The team—both the design group and those in the pilot process—were confident that these refinements, with some learning curve time, would allow them to meet their goal.

The Final Process Rollout

It is a big mistake to get overconfident after a successful pilot. The pilot is usually a much more controlled situation than real life, with fewer variables to manage and fewer people involved. Other problems are almost sure to arise in the conversion from test to final rollout of a new process. Some of the critical ingredients of a successful launch of a redesigned process include the following:

- **Training.** New approaches need to be learned, old habits broken.
- **Documentation.** References on how to do things, answers to frequently asked question, process maps, and so on are all important.
- **Troubleshooting.** Responsibility needs to be clear with regard to who will deal with the issues that arise.
- **Performance management.** Keep your eyes open for needs/opportunities to revise job descriptions, incentives, and performance review criteria.
- **Measurement.** Results need to be documented.

Finally, let's look at the results of the COLA team's effort, and then at Exhibit 15.6, which lists the "dos and don'ts" to help you through your own improve phase of DMAIC.

Case Study #12 Conclusion: The COLA Team Declares Victory in the Redesign of Its Insurance Policy Completion Process—from 12 Weeks to 8 Days

Six months after the first pilot of the new policy completion process, the people at COLA were beginning to wonder how they ever could have lived with the old 12-week limit. The rollout of the new process throughout the rest of the company encountered a few glitches. Not all the salespeople were ready to do the extra work on the LOAs the new process required. A couple of them actually had to be let go.

Nor were customers always as quick to turn papers around as had been hoped. Over time, the organization learned ways to better prepare its customers to be ready for the reviews. And even though the shorter policy documents were a huge hit, eventually COLA added to the process a documents review appointment, during which policy coordinators would walk through policy with customers (usually by phone). That new "moment of truth" actually turned out to be a big customer satisfaction-booster.

The before and after report tells the story (see Figure 15.6). Even with a much tighter customer requirement, process performance and capability improved. Staff in policy administration, underwriting, sales, and claims discovered that their work is much more rewarding without the constant confusion over coverage terms that would come up during the 10 weeks it used to take.

In the annual report of International Insurance and Indemnity (COLA's parent), the subsidiary was singled out for its Six Sigma Design effort:

> In one of the fastest-growing markets in the insurance industry, Computer Outage Liability Assurance (COLA) has established itself as the leader in responsiveness, customer focus, and understanding of the needs of its high-tech customers. "Without COLA's work," said the top executive of NetSetGo, the fifth largest ISP in the finance sector, "many

COLA **Policy Completion Process: Comparative Performance Data**

Measure:	Before Redesign:	After Redesign:
Total Cycle Time	**10.4 weeks**	**8.2 days**
Average Pages/ Contract	**26.3 pages**	**9.2 pages**
In-Process Revisions/ Contract	**7.1 revisions**	**.4 revisions**
DPMO (rounded)	**321,000**	**75,000***

*** Based on new 8–10 day completion requirement**

FIGURE 15.6 COLA BEFORE AND AFTER RESULTS REPORT

companies might have had to close because of undue liability risk. Their work is literally keeping us in business." COLA CEO R. O. "Rute" Biere is projecting 35 percent annual growth over the next five years. This year, Biere was named to the III Board of Directors.

Exhibit 15.6

"DOS AND DON'TS" FOR THE PROCESS DESIGN/REDESIGN IMPROVE PHASE OF SIX SIGMA

- Do—*Concentrate on seeing the process in a new way.*
  - Try to identify what rules or assumptions govern today's process and ask: "Are these valid? Why? How can we make them invalid?"
- Do—*Set performance criteria to analyze the design.*
  - Give the team a framework to assess their creative ideas against the practical reality of the process.

- Do—*Refine and enhance the process iteratively.*
  - Get feedback, use simulations, walk through the process, and add detail as you go.
- Do—*Pilot the process, in multiple phases when warranted.*
  - It may take longer, but the chief benefit will be a smoother final implementation.

- Don't—*Run a downtime pilot.*
  - Test the process in a variety of conditions, including when things are really busy.
- Don't—*Assume everyone will love the new process.*
  - Even if it is only unconscious, resistance will come up. Respond to it, and learn from it, but also be ready to enforce new procedures when people are downright belligerent.
- Don't—*Take your eye off the process.*
  - Expect problems, and you will be ready for them. Stay alert throughout the duration of at least one process cycle. Prepare to transition to control.

CHAPTER 16

Expanding and Integrating the Six Sigma System (Roadmap Step 5)

Imagine you decide to lose some weight by using the new Six Sigma diet plan. With the help of a well-defined problem ("I'm 25 pounds over my optimal weight"), some carefully recorded valid measurements, a review of your eating and exercise processes, and the advice of a doctor and some fitness instructors, you implement a solution of changed diet and increased exercise. You are so successful that you go beyond the goal you set for yourself and lose 27 pounds. And just in time for summer holidays!

How might this success story end? As with Six Sigma, so with diets: It depends.

Old habits are hard to break. Maybe you pile on an extra helping of your favorite food, skip jogging on rainy days, order *whole*-milk lattes instead of nonfat. And before you know it the scale is back up where it started. The alternative takes more discipline: You decide to control your weight by keeping an eye on your eating and exercising processes and by keeping some charts on your weight and eating patterns. You even manage to get your cholesterol down, and people say you are looking great.

Six Sigma companies face much the same challenge as the dieter. When improvement or design projects achieve their goal of reducing defects or waste, discipline is essential to sustain the results. It is more complicated than losing weight, of course, because a process involves many people, not just the dieter. Do Six Sigma gains ever fade when solutions are turned over to full-time operations? Do dieters ever gain back lost pounds?

Even when improvement sticks, a Six Sigma company faces another challenge similar to the dieter's: Those first few pounds tend to come off easily, but they get harder to shed as you go. Without a sustained, focused effort, the beginning drive for improvement will lose energy and your company will become a *former* Six Sigma organization.

In this chapter, we explore both the short- and long-term challenges of sustaining Six Sigma improvement and building all the concepts and methods of Steps 1–4 into an ongoing, cross-functional management approach. The key actions to be taken in managing processes for Six Sigma performance are these three:

1. Implement ongoing measures and actions to sustain improvement (the control phase of DMAIC).
2. Define responsibility for process ownership and management.
3. Execute closed-loop monitoring and drive on toward Six Sigma performance.

Step 5A: Implement Ongoing Measures and Actions to Sustain Improvement (Control)

Our first consideration is how to solidify the immediate gains made through Six Sigma efforts. It is at the end of a process improvement or design/redesign effort that the results achieved are most vulnerable. A team alone cannot keep its efforts from fading away. The ensuing subsections give you the essentials of sustained improvement.

Build Solid Support for the Solution

Being smart about getting others to understand and buy in to your solutions is a recurring theme in Six Sigma, and the need to "sell" the solution doesn't stop. Some of the most important considerations here are described in the following paragraphs.

- **Work with those who manage the process.** It helps if those who must manage new and improved processes also participated in their creation. When this is not the case, teams and project sponsors have to carefully explain the benefits of the improvement. Having a process or solution owner to take over responsibility for your change can make the task simpler.
- **Use a storyboard with facts and data.** The project storyboard tells the background, plot, and outcome of your Improvement in words and pictures. Being able to show why and how the change you developed makes sense for your organization's customers will go a long way to convince people that the new approach is the right one.
- **Treat the people using the new process as your customers.** Tailor your pitch and product to the internal groups who need to embrace the change. Results need to be expressed in terms each group understands. For example, people in customer support will be happy to hear "reduced customer complaints," but may not care much about "additional referral business." When people are being asked to do new or extra work as part of the solutions, explain clearly how other aspects of their job will get easier.
- **Create a sense of purpose and enthusiasm.** Sharing credit for the solution and building a sense of participation is not just a good selling tool, it is also realistic. As we noted previously, no Black Belt or team can even hope to make a meaningful improvement happen alone.

Document the Changes and New Methods

In the minds of many people, the thought of documenting a procedure or process—even one they created themselves—falls somewhere between the thrill of dental work and the ecstasy of filing income taxes. But documentation is a necessary evil and can even be a creative undertaking in itself. A successful Six Sigma organization needs to look for new and better ways to make documentation usable and accessible, to get away from the horrors of all those huge procedures manuals and process descriptions guaranteed to cure insomnia.

The following paragraphs provide some general guidelines that will help people to actually follow your directions and/or documentation; then we look at a case study of a home furnishings company that used Six Sigma to transform the way it did business to keep up with changing consumer tastes.

- **Keep the documentation simple.** Write in direct, jargon-free sentences. If you must use specific terms that someone new may not understand, include a definition or glossary. Explaining the meaning of TLAs and FLAs (three-letter and four-letter acronyms) is important, too. If a lot of detail is needed, consider including it in the support or reference materials, so that people can get the *basics* easily and more background as needed.
- **Keep the documentation clear and inviting.** Using pictures and flowcharts whenever possible can make your message clearer and more accessible. Use of white space, bullets, various fonts, and highlights will make the documents both easier to navigate and more appealing to the eye, which is an important criterion in today's visually oriented world.
- **Include options and instructions for emergencies.** One of the ways to ensure that your new processes and procedures are not abandoned is to plan and document ways to adjust them under various conditions. Include information on how to identify problems or issues, too.
- **Keep the documentation brief.** Yep! (Actually, there's more. . . .) If you want a good guide to brief instructions, read cake recipes. Usually they are models of clarity and brevity. By contrast, check the operating instructions for a TV. The longer instructions are, the less likely it is that people will have time to read or understand them.
- **Keep the documentation handy.** One sign that an organization really is not taking the Control phase seriously is when documents are hard to find, either physically or on-line. Hard-to-locate documentation sends the implicit message that—despite all of someone's hard work and analysis—you can feel free to do any old thing you care to while working on this process. But guess what? That old devil, variation, will be sneaking in whenever this happens, and it won't be for your company's good.

Have a process for updates and revisions. It is not enough to say "have to keep this up-to-date." Documentation, like measurement, is a process that needs to be *designed* and managed, with document tracking and revision as key parts of it. The need for revision should be one of the most important considerations in designing the documents to start with: The more complicated they are, the harder it will be to update. But the less often they are revised, the more likely it is that people will ignore the documentation.

Of course, you face the risk of creating a documentation bureaucracy. Having a "document control" department has worked fine for some companies. Our recommendation, though, is to try to keep ownership of documents close to the work and in the hands of those people who are best able to judge *what* needs to be documented, to what level, and when it should be revised. Guidelines to maintain consistency across the organization are important as well.

Case Study #13: A Home Furnishings Company Uses Six Sigma to Transform Its Business

UpHome is a small but successful chain of retail stores that sells "contemporary country" home furnishings in 17 locations in the Mid-Atlantic states. UpHome carved its niche by being the first store of its kind to sell products that had a country look but had been updated to contemporary tastes. People wanting their décor to be cozy but not old-fashioned have been terrific customers for UpHome.

As the market for home furnishings diversified, however, UpHome began to see some decline in its sales. Looking at their prospects, company leaders and store managers concluded that their *products* could still outshine their competition, but that the real edge would come from the service provided to their customers. UpHome subsequently launched a transformation effort based on the Six Sigma system with the theme "Making People Feel UpHome."

One of the first projects completed was the development of a new furnishings loan-out process. UpHome salespeople (called "neighbors") and folks in advertising began to actively promote the option of trying out items in people's homes to make sure they actually worked well. The "Take It Home" process was piloted at two stores before being implemented chainwide; the tests showed it to be a huge success.

Take It Home was not a simple process, however, because it involved issues such as inventory, delivery, potential damage, and the risk of theft. The team that developed the process worked out as many issues as possible in the design phase, and then fine-tuned the various procedures during the pilot with the active participation of the management and staff of the two pilot locations.

The result was a kickoff campaign for the full rollout of Take It Home that created a lot of excitement throughout UpHome. Salespeople from the pilot stores gave testimonials about the stronger relationships they were able to develop with customers. Sales figures showed an almost immediate 25 percent jump after the launch of the program.

In addition to a series of training programs held at each location to explain the new process and tasks, each store associate was given a personalized "How to Help 'Take It Home'" guidebook. The most useful was an extensive intranet site that provided complete instructions on how to handle questions and issues as they arise, which was linked to an online sharing site where issues and questions were posted. A section with maps of the key process elements was one of the most popular features. A committee made up of representatives from each store was responsible for reviewing and updating the site as adjustments were made to the process.

To make sure no store associate created a problem for customers due to uncertainty about the Take It Home policy and procedures, each staff member was given three "your call" opportunities per month, in which whatever they decided to do was okay. The only requirement was that they be posted on the sharing platform.

Establish Meaningful Measures and Charts

Imagine you are the coach in a football game in which you are not quite sure of the score or how much time is left in the game. How do you know what plays to call? How do you handle that fourth-and-one situation, whether to let the clock run or call time-out? Well, your experience may lead you to some pretty good guesses, which is what many managers rely on much of the time.

Now that you are successfully invested in Six Sigma projects, however, you put your victory in jeopardy if you revert to the management guessing game. You avoid guessing, on the other hand, by employing well-chosen and well-implemented measures to track your process and solution. By now, we expect that you understand some of the basics and tools of measurement covered in previous chapters. Thus the two questions in Step 5 become: "What measures do we continue to use?" and "How do we make them useful?"

Selecting Ongoing Measures. We already looked at several ways in which you can categorize measures: input, process, and output; efficiency and effectiveness; predictors (Xs) and results (Ys). One of the first rules with ongoing measures is to include a balance among these categories so as to give a full picture of the organizational system. For example, measures of defect levels will tell you how well you are meeting customer requirements, but in-process measures are better at giving you early warning of pending problems. Financial measures are useful, but other data can be more indicative of what is happening to drive costs.

Another consideration is rate of change. Things that change more frequently—especially factors that can impact customers, product, or service quality, and costs/profits—should go higher on the measurement priority list. You cannot ignore the more slowly changing factors, but it may be possible to keep an eye on them through different mechanisms than an ongoing measure.

What you measure should also be influenced by what is important at a particular point in time. Some will be long-term maintenance measures of things such as defects, cycle time, and cost per unit. Other measures will be situational. For example, in the first few months after a new process has been introduced you may measure several aspects to make sure it is working well, then phase them out once the success of the improvement seems certain. Still other measures may be improvement-focused. Obvious examples would be those initiated during a DMAIC project to gather data on a problem or causes, or those tied to a business imperative such as a new-product launch.

Finally, you can test each possible measure with our favorite two criteria: *meaningful* and *manageable.* Will the data from the measure really help track the business and lead you to make better decisions, and will the resources and logistical issues behind getting the data be affordable?

Using Your Ongoing Measures. As with any product, the more you can tailor how measures are designed and reported, the better. Some people love the details and are not happy without a full spreadsheet of numbers. Others want the barest synopsis.

As a general rule, however, simpler, graphical measurement reports work best. They are quicker to read, make for easier comparisons, and can be colorful. The kinds of charts we already mentioned, such as run or trend charts, Pareto charts, and histograms, along with many other familiar "data pictures," can be the workhorses of measurement reporting. Another technique, profiled in Chapter 17, is the control chart. This chart helps you to see at a glance how much variation is occurring in a process and whether the process is "in control."

As data are collected at various points throughout the organization, the need to summarize *many* measures becomes critical so that top leaders can effectively get an idea of what is happening in the trenches. One of the most popular and useful tools you can use to reach that high-level view is the *balanced scorecard*, popularized by Robert Kaplan and David Norton.[1] A balanced scorecard (BSC) is a flexible tool for selecting and displaying key indicator measures about the business in an easy-to-read format. Many organizations *not* involved in Six Sigma, including many government agencies, use the BSC to establish common performance measures and keep a closer eye on the business.

One of the strengths of the balanced scorecard concept is the emphasis it places on four categories of measures: innovation, process, customer, and financial. So it can offer some help in choosing what to measure. But whether you use a by-the-book balanced scorecard or develop your own approach, just taking the action of creating an easily digestible array of measurement data can help to ensure that *using* measures becomes a part of the new habits of your Six Sigma organization.

Building Process Response Plans

Given the power of Finnegan's law ("Murphy was an optimist"), we can rest assured that sooner or later something will go wrong in any process, even one that has been improved by a crack Six Sigma team. Having advance guidelines on when to take action and what to do is part of the proactive management practice of any Six Sigma company.

A process response plan includes three major elements:

1. **Action alarms.** With clear standards in place at key points in the input, process, and output phases of a process, and measures tracking performance, *trigger points* can be set at which some action needs to be taken to correct a problem or concern. For example, if test data show circuit boards approaching the edge of their rated

energy consumption, an engineer may want to begin investigating to see what is wrong. Or if no-shows at a hotel get 5 percent above the seasonal normal, some special contingency plans could be implemented.

2. **Short-term or emergency fixes.** By no means can every problem wait for a chartered team or Black Belt assignment. Having some guidelines on quick fixes mean they can be more effective and less likely to cause the collateral damage that often results from haphazard short-term solutions.
3. **Continuous improvement plans.** A process for identifying and prioritizing ongoing or serious problems so they can be acted on feeds into the DMAIC process and other higher-level activities such as strategic planning and budgeting. Guidelines can also be established on how significant a problem or opportunity must be before it qualifies for a continuous improvement action. Continuous improvement plans are a key link in the closed-loop business management system of Six Sigma.

Anticipating possible problems is clearly an important part of an effective response plan. Techniques like potential problem analysis and FMEA (covered in Chapter 17) can support that effort. Let's take a look at how our home furnishing company monitored its new process.

Case Study #13 Continued: UpHome Keeps Its Eyes Open to See How Its New Process Works

Despite the early success of furniture and decorating retailer UpHome's new Take It Home service and process, the company was not ready to declare victory. Each store was asked to keep track of such key variables in the new process as

- Percent of Take It Home customers who make purchases
- Dollar volume of Take It Home–related sales, overall and by neighbor (sales associate)
- Defect data (e.g., missed or wrong deliveries; erroneous billing; etc.), including a Sigma score

- Damaged/lost merchandise
- Customer satisfaction index data

The data were reported by each location and then summarized for the UpHome chain as a whole.

To help you with your control phase of DMAIC, Exhibit 16.1 provides a list of "dos and don'ts" for ongoing measures and control, and Exhibit 16.2 provides a checklist of the steps you should follow.

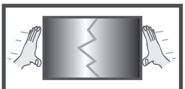
Exhibit 16.1

"DOS AND DON'TS" FOR ONGOING MEASURES AND CONTROLS

- Do—*Develop good documentation to support the new process.*
  - Keep it simple, clear, and easy to use, and have a plan for updating the document.
- Do—*Select a balanced mix of measures to monitor process performance.*
  - Look at results, process variables, customer requirements, and costs. Avoid strictly financial measures.
- Do—*Create measurement reports that convey information quickly and simply.*
  - Charts and graphs usually are preferable to raw texts and tables of figures.
- Do—*Develop a plan to take action in case problems arise in the process.*
  - Responding in a preplanned, effective manner is much better than reacting in an ignorant panic.

- Don't—*Leave documents to gather dust.*
  - Designing and finding ways to use documentation helps ensure they are kept up-to-date, and will help keep the process from reverting to bad habits.
- Don't—*Forget the process maps.*
  - They are the best tools for quick reference and review of workflows, customer/supplier relationships, and key points for measurement. Process maps make changing the process much easier, too.

Control Checklist



5. Control

Instructions:

If you can respond "yes" to each statement, you have completed all key steps in your DMAIC project and are ready to *celebrate* and maintain your improvement.

For our project we have ...

1. Compiled results data confirming that our improvement has achieved the goal defined in our DMAIC team charter. YES NO
2. Selected ongoing measures to monitor performance of the process and continued effectiveness of our solution. YES NO
3. Determined key charts/graphs for a process scorecard on this process. YES NO
4. Prepared all essential documentation of the revised process, including key procedures and process maps. YES NO
5. Identified an owner of the process who will take over responsibility for our solution and for managing continuing operations. YES NO
6. Developed (with the process owner) process management charts detailing requirements, measures, and responses to problems in the process. YES NO
7. Prepared a storyboard documenting the team's work and data collected during our project. YES NO
8. Forwarded other issues/opportunities we were *not* able to address to senior management. YES NO
9. Celebrated the hard work and successful efforts of our team. YES NO

Exhibit 16.2 **CONTROL CHECKLIST**

Step 5B: Define Responsibility for Process Ownership and Management

As your company adopts and implements the steps on the Six Sigma roadmap, you will be positioning your organization to adopt the most promising solution to cross-functional barriers and organizational silos: a *process* management approach. What might this adoption and implementation mean in terms of how your company operates? Well, here are some elements of the process management vision:

- Business leaders will concentrate on getting work to move effectively and efficiently *across* functions to the benefit of customers and, ultimately, of shareholders.
- Employees will identify as much with the process as with their individual functions/departments.
- People at all levels will understand how their work fits into the process and adds value to the customer.
- Customer requirements will be known throughout the process.
- Processes will undergo continuous measurement, improvement, and redesign.
- More energy and resources will be focused on delivering value to customers and shareholders, rather than be wasted on bureaucracy or infighting.

The Process Owner

Perhaps the most essential step in the transformation to process management is designation of process owners.

The Process Owner's Responsibilities

Although there is no official job description for a process owner, the responsibilities described in the following paragraphs are key to the role in a continuous improvement-focused organization.

Maintaining Process Documentation. The process owner is the person who creates and becomes keeper of process design data (i.e., maps, flows, and procedures), background data on customer requirements, and other defining documents of the process. Part of that responsibility includes keeping data and documents up-to-date.

Measuring/Monitoring Process Performance. You may already have wondered: "Who is going to *do* all this measurement and tracking of the process?" Process owners see that the right measures are executed in the right way.

Identifying Problems and Opportunities. As the primary observer of performance data, a process owner is the person who should first see problems as they arise, or to whom other people report the problems or issues they observe. Process ownership ideally involves the authority to take action to address quick fixes and longer-term solutions.

Launching and Sponsoring Improvement Efforts. When projects to improve, design, or redesign a process are identified, the process owner will take up the key role of supporting, if not *leading*, the effort. Just as importantly, the process owner takes the handoff from an improvement team, assuming the responsibility for maintaining the gain.

Coordinating and Communicating with Other Processes and with Functional Managers. One of the most important principles behind the process owner role is that the work coming *into* and especially *out of* the process is just as important as the work *within* the process. Some of the biggest obstacles to serving *external* customers come from poor coordination between *internal* suppliers and customers. It is only through upstream and downstream coordination that the process owner can remove the barriers or us-against-them attitudes that arise in the functional world. A process owner has to work with suppliers and customers to meet the goal of top-level performance. In addition, a process owner needs to align the various groups in the process to make sure the work flows smoothly and is done well.

Maximizing Process Performance. All the responsibilities noted thus far lead to this most-important objective. The process owner becomes the key driver to achieve Six Sigma levels of quality, efficiency, and flexibility.

Process Owners in the Organization

Decades of functional management is not likely to give way to a process management orientation overnight, nor is it clear that it *should*. To maintain the command-and-control advantages of the functional system, a hybrid of process and hierarchical structures may be more effective.

For example, some businesses use levels of process ownership, with a core process owner having two or more subprocess owners engaged in a process management team. Each of these individuals wears a functional hat as well, but the process owner role concentrates on the overall cross-functional operation and on improvement of the process. If these process management layers were to turn into a new reporting structure, it is not clear how much better it might be than existing organizational hierarchies. This issue poses one of those evolutionary questions about process management that will have to be answered over time and by each organization based on its own needs and experiences.

What *is* clear about process ownership is that the emphasis on measuring, improving, and coordinating flows of work calls for a somewhat different, if not broader, set of skills than does functional management. A profile seeking to identify potential process owners might include these traits:

- Results-oriented, with an emphasis on "win-win" gains and a focus on the customer
- Respected by senior leaders, middle management, and staff
- Strong business knowledge, with ability to think and work as a generalist
- Excellent people skills, especially in the areas of team development, consensus building, and negotiation
- Skilled in Six Sigma concepts, measurement, and process improvement and design methods
- Ability to share credit for success and to take the responsibility for setbacks

Strong technical knowledge or statistical expertise also can be helpful, but not if it takes away from that more important generalist perspective.

Exactly where process owner candidates will be found in an organization is anyone's guess. It will likely take some creative talent-scouting to find the right mix of skills and potential to fill the ownership role in your organization. It is safe to say, though, that old-style authoritative managers are not right for the role unless they can change their approach. In fact, one of the reasons that process management will require a long-term evolution is the fact that many of today's managers will have trouble adapting to the new "horizontal" approach. It may take a whole new generation to really develop the talent needed for the new role.

Where to Put Process Owners?

We laid the groundwork for an answer to this question back in Chapter 11, where we explored core and support processes. As your organization prepares its inventory of critical or strategic processes, you are also setting the stage for designating *owners* of those processes. In larger organizations, as in the organization noted previously, having layers of ownership is the best option. No one person can oversee a single large, diverse process. Where responsibility for a larger process is divided, those owners would form what some companies call a process management team (PMT).

It is also important that process owners be deployed at an operating level of a business. We have seen situations in which a company with several divisions created a macro process management system at the corporate level. Unfortunately, even though the different divisions included common processes, each was unique and required focused ownership at the division level. The firm struggled for a while before realizing and correcting its mistake.

Can process ownership reach all the way down to the departmental or functional level? The answer is a qualified "Yes." Clearly, some processes *within* a function can be managed with many of the same methods and measures as cross-functional processes. Nonetheless, we say the shift to process management at the department level is best driven by a change in focus, rather than by creating a new process owner assignment within functions. Individuals are already in place to manage functions: vice presidents, directors, managers, and so on.

Let's take a look at how the company in our case study selected its new process owners.

Case Study #14: UpHome Selects Process Owners to Manage Its New Process

Top management at UpHome was pleased with the results of the design and management of the Take It Home process. They were early in their Six Sigma effort, though, and still unsure whether or how the concept of process management would fit in with a dispersed retail operation.

The launch of the new process seemed to provide a good opportunity to test how the process owner role would work, and to see whether it would add value to the organization and its customers. After a discussion of the idea of creating a Take It Home process owner, top management agreed that it did meet several important criteria:

- It was a cross-functional process, involving many of UpHome's departments.
- It was a continuing effort, not just a marketing campaign, and hence an appropriate choice for establishment as a key business process.
- The ability to measure, assess, and improve the Take It Home process would be key to its continued success. As customer needs, product mixes, competition, and so on changed, it was likely the process would need to adapt.

One question provoked some debate: Could a process owner really oversee an activity being carried out at 17 different locations? The decision was to designate a companywide owner of the process, and to assign a process coordinator at the store level. (Some of the coordinators would cover two or three locations.)

Selecting the process owner was, fortunately, easy. One of the members of the team that had designed the new process, Margy McMahon, had already exhibited the kind of leadership and process perspective that seemed ideal for such an important cross-functional activity.

Margy's first task was to pull together many of the documents and notes prepared by the design team, which no one had touched since the pilot, and create an overall process guidebook. When that was ready, she set out on a tour of UpHome stores to begin selecting process coordinators.

Step 5C: Execute Closed-Loop Management and Drive to Six Sigma

Establishing process management is both the end of our Six Sigma roadmap and the *beginning* of becoming a real Six Sigma organization. Any business or process that has followed the roadmap through at least Steps 1, 2, and 3, will be forming the key elements of the process management approach. Let's briefly review these steps and their contributions:

1. **Identify core processes and key customers.** Defining the process, its key steps, customers, and outputs creates the blueprint for process management.

2. **Define customer requirements.** Process goals and performance standards, determined by market and customer needs, are the *raison d'être* of any process. Understanding those requirements in concrete terms helps you to answer that basic question: "Manage the process to do *what*?"
3. **Measure current performance.** Measurement in the process management system will provide ongoing, essential feedback on results (Ys) and key process factors (Xs).

As your efforts at Six Sigma mature, process improvement and design/redesign (DMAIC) become the strategies that drive work processes to ever-higher Sigma levels and respond to customer demands for new products, services, or capabilities.

Tools for Process Management

Every tool we described or mentioned, as well as those we will review in the next chapter, may play a role in helping to manage processes. A couple of other methods, however, can be of particular value to the process owner who strives to keep a process running smoothly and improving continuously. Let's take a look at two of these process-management methods, and then we check in with our case study company to see how it is managing its new process.

- **Process scorecards or dashboards.** The Process scorecard, like the balanced scorecard mentioned earlier, provides a summary update on key indicators of process performance. While the balanced scorecard typically provides organization-wide data, the process scorecard would be designed for a specific process. It can include alarms to show if and when a key indicator is nearing a problem level. For example, by noting the specified delivery time on a cycle-time chart, a process owner could see whether times are close to exceeding the requirements. Some companies, including a number of GE businesses, actually provide tailored process scorecard data to customers, telling them "here's how our process is performing for you."
- **Customer report cards.** Timely customer feedback is a key ingredient in optimized process performance. One of the focused tools that can support that need (i.e., an element of the overall voice of

the customer system) is a customer report card. Ideally, it provides representative data (i.e., an accurate, unbiased sample) of how well the process is meeting customer needs. The best customer report cards are more than surveys or complaint data; they provide input that is meaningful both to the customer and to the company on performance and concerns. In business-to-business relationships these report cards can be tailored specifically to the client, so that the "grades" or other feedback provided has been selected on the basis of each customer's unique needs and priorities.

Case Study #14 Continued: Process Management Finds UpHome

Six months after Margy McMahon was named the first process owner at UpHome and began overseeing the new Take It Home product trial process, company leaders were becoming convinced that the process management approach could be a big benefit to the organization as a whole.

For one thing, Margy and the network of process coordinators in the stores had made some significant contributions to the Take It Home process's continued success. For example:

- Three months after the process was launched, lost items began to climb. Margy and the process coordinators were able to determine that some of the UpHome sales associates were failing to record complete address data and were unable to recontact customers to get the items back. A simple fix solved the problem.
- By tracking the types of products where Take It Home led to the highest sales increases, they were able to anticipate additional inventory needs and gear up for higher demand. This change not only allowed for additional sales, but also gave UpHome an opportunity to get discounts from vendors.
- In a number of instances where squabbles arose between the sales and product delivery departments, Margy and the process coordinators were able to keep things from getting out of hand. By maintaining the focus on the customer, the issues were resolved to everyone's satisfaction.

The process scorecard Margy created for Take It Home helped everyone keep up-to-date on the performance of the process (see a sample of it in Figure 16.1).

As a first step in expanding the process management approach, UpHome's leaders scheduled a half-day meeting, to begin mapping out all their core business processes.

Conclusion: *Moving Toward Six Sigma*

We began this chapter with an analogy of regaining lost weight after a bout of successful dieting. We suggested that some companies, like complacent and undisciplined dieters, are doomed to backslide when they shift their attention to seemingly more urgent issues. We also noted that the gains of Six Sigma will come somewhat easily at first, like those first few pounds in a diet, but that the last few Sigma points will be harder to rack up in the drive for *Six* Sigma.

The process management discipline is where the momentum to "keep losing weight (or defects)" will come from. It is the mechanism

Take-it-Home PROCESS SCORECARD (Quarterly Summary)

	Target	Performance JLY	AUG	SEP	Notes
New Products Added	6 per Month	●	●	○	Quarterly target exceeded
Defects per TIH Item Loaned (DPU)	.01 (99% Yield)	○	○	◒	Total DPU of .031
TIH Volume Growth	6% Month-to-Month	◒	○	◒	Quarterly target met
% TIHs Purchased	75%	◒	○	○	Average 68% for quarter
% Customers Rating TIH "Excellent"	95%	◒	●	●	Strong positive comments
Sales Increase Due to TIH (estimate)	20%	●	●	●	25% increase approx. $8 mil.

● - Above Target ◒ - At Target ○ - Below Target UpHOME

FIGURE 16.1 UPHOME TAKE IT HOME PROCESS SCORECARD

that ensures your firm will make measures and improvement a daily responsibility, not just an occasional task. Moreover, as your business progresses down the Six Sigma Way, you will find more opportunities to use sophisticated tools to move past Four and Five Sigma. We look at the advanced Six Sigma tools in Chapter 17, but first, let's wrap up with Exhibit 16.3, which lists the "dos and don'ts" to help you manage Six Sigma performance in *your* organization.

Exhibit 16.3

"DOS AND DON'TS" FOR MANAGING FOR SIX SIGMA PERFORMANCE

- Do—*Document the steps and lessons in process improvement and design/redesign projects.*
  - A project storyboard will be helpful to "sell" the solutions and as an aid to future improvement teams.
- Do—*Develop a complete plan to control the process and maintain the gains.*
  - Selling, documenting, measuring, and responding are essential to solidify success, and they become key inputs to the process management system.
- Do—*Carefully define the role and responsibilities of a process owner for your organization.*
  - As a new player on the business landscape, a process owner and those who work with that person need a clear idea of the owner's function and objectives.
- Don't—*Take on process management without careful upfront consideration.*
  - As useful as this discipline and resource can be, an all-out process management implementation may not make sense. If necessary, try it out and learn (i.e., pilot the concept) before you create unnecessary business upheaval.
- Don't—*Create process reports and documentation that end up being just as underused as your current ones.*
  - Focus first on information you know you or others will need, and add to it as need be.

CHAPTER 17

Advanced Six Sigma Tools: An Overview

In our journey along the Six Sigma Way so far, we have concentrated on the fairly simple methods and tools that drive much of the improvement in most organizations and processes. As we've noted, the publicity connecting Six Sigma exclusively with heavy-duty analytical methods has been very much exaggerated. Those who stick with the continuous improvement journey learn that the majority of problems and opportunities can be addressed with techniques nearly anyone can use. At the same time, one of the clear advantages of the Six Sigma system has been the application of more sophisticated tools that bring more power to the learning and improvement efforts.

Our objective in this chapter is not to make you an expert in any of these advanced methods. We will try, though, to make you familiar with *what* some of the most common Six Sigma techniques are, *why* they can be helpful, and *how* they can be applied to process design, management, and improvement. Each of the power tools we cover has one or more specific applications, and like any tool, it can be misused or unproductive if not chosen and applied with care.

These are the methods we'll review, with their most common purpose noted in italics:

- Statistical process control and control charts—*problem identification*
- Tests of statistical significance (chi-square, *t*-tests, and ANOVA)—*problem definition and root cause analysis*
- Correlation and regression—*root cause analysis and prediction of results*
- Design of experiments—*optimal solution analysis and results validation*
- Failure modes and effects analysis—*problem prioritization and prevention*
- Mistake-proofing—*defect prevention and process improvement*
- Quality function deployment—*product, service, and process design*

Statistical Process Control, and Control Charts

Statistical process control (SPC) involves the measurement and evaluation of variation in a process and the efforts made to limit or control such variation. In its most common application, SPC helps an organization or process owner to identify possible problems or unusual incidents so that action can be taken promptly to resolve them—in other words, to *control* the performance of a process.

When and Why to Use SPC/Control Charts

Use of SPC and control charts constitutes the ideal way of monitoring current process performance, predicting future performance, and suggesting the need for corrective action. Control charts, which are easily understood after just a bit of instruction, can be an effective communication tool. Numerous companies post control charts for key processes in readily accessible areas, giving visibility to daily activities, trends, and patterns, and warnings of possible problems. This practice can get everyone involved in the company's management and problem solving.

Control charts have three significant uses in the Six Sigma system:

1. In the early measure activities of a DMAIC project, they help teams identify the type and frequency of problems or out-of-control conditions. They can even suggest what type of investigation or corrective action might prove most effective.

2. In piloting or implementing a process solution or change (in the improve or control phases), they help track results, showing how variation and performance have been affected and perhaps even suggesting further areas of work or investigation.
3. Third, control charts act as an ongoing alarm system, alerting the observer to unusual activities in the process and triggering the process response plan discussed in Chapter 16.

You can think of SPC/control charts in that third application as being a smoke detector in your house: When it has batteries, is properly placed, and someone is around to hear it, it can sound the alarm in ample time to keep the place from going up in flames.

What Does the *Control* in SPC/Control Charts Mean?

"Control" means keeping a process operating within a predictable range of variation. The objective is to maintain the stable, consistently good performance of a process. In SPC, we add the notion of *statistical* control to the discussion. Thus to figure out whether a process is statistically in control or out of control, you begin by actually measuring a process over time and then examine the variation in the data you gather. With enough data you can calculate what are called "control limits," thereby taking a first step in checking to see how well the process is working.

Let's take an example. Imagine you are managing your company's e-mail system, and you want to know how much variation exists in the number of e-mail messages sent per hour. To get an answer, of course, you have to gather some data. So, after compiling hourly volume levels over a month (using excellent data-collection methods, no doubt), you plot e-mail traffic volumes on a run or trend chart (i.e., in time order—and described in Chapter 14). Next, you use those data to calculate the control limits (UCL for upper control limit, and LCL for lower control limit), and you add those to your chart along with a line indicating the average or mean. You now have a control chart (see Figure 17.1).

If you continue to gather data on e-mail traffic, the control chart will give you the ability not only to track changes in e-mail volume, but also to be able to see if and when the process is out of control or operating in a way that is no longer predictable.

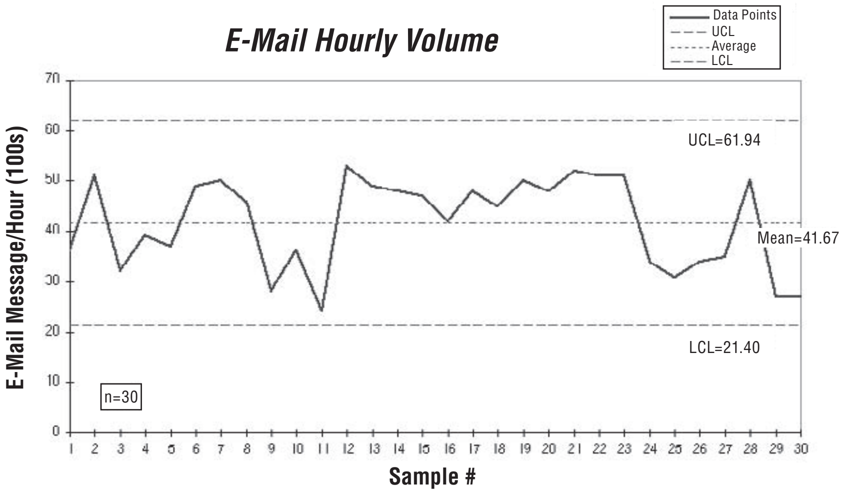


FIGURE 17.1 EXAMPLE: CONTROL CHART OF E-MAIL VOLUME

Control Chart Alarms

Because we expect that variation in a process under normal conditions will be random, several indicators can be used to signal an out-of-control situation:

- **Outliers**—any point outside the control limits
- **Trends**—a series of points continually rising or falling
- **Shifts**, or **runs**—a continuous sequence of points above or below the average
- **Cycles**, or **periodicity**—a series of points alternating up and down or trending up and down in waves
- **Tendencies**—situations in which the points continually fall close to the center line or to either of the control limits

Control Charts and Customer Requirements

One of the misunderstandings about control charts is that being "in control" means the same thing as being "good." If a computer repair shop decides to measure its turnaround time on routine repairs, it might create a chart showing a process under perfect control. The problem however is that while their average turnaround is five days, customers want these jobs done in *two*!

Remember that these two types of limits introduced in this book (control and specification, not outer and city) are developed differently:

Control limits are calculated from actual process data; they can change as the process performance changes over time. Specification limits come from the *customer*; they change only as the customer's requirements change.

Using Control Charts

The basic steps for implementing SPC should be familiar by now: Decide on the critical measures, implement a data-collection plan, plot the data, view the results, and take appropriate action. It is much in line with the closed-loop system that is the foundation of the Six Sigma organization. Plotting and testing the data can be easily accomplished using statistics software. Simply enter the data or copy it from a spreadsheet, select the chart type and the tests from menus, and there you have it—a control chart.

Choosing the right type of control chart to use is important. Several factors determine which chart format fits your situation. For example if you have a continuous data measure (weight, time, temperature, etc.) you use one of two types. SPC books usually feature handy guides to selecting the appropriate chart.

No business should be creating new control charts all the time, because they are of real value only in monitoring changes in process performance. Therefore you should only occasionally have to confront the question: "What type of control chart should we use?"

Finally, remember that SPC and control charts are methods for *monitoring* and *understanding* your process. They do nothing to *solve* problems or improve your performance, unless you take corrective actions or apply Six Sigma improvement methods.

Exhibit 17.1 lists some "dos and don'ts" to keep in mind when using SPC and control charts.

Exhibit 17.1

"DOS AND DON'TS" FOR USING SPC AND CONTROL CHARTS

- Do—*Gather, plot, and review data promptly.*
    - A key to the value of SPC is to get early warnings of problems or opportunities. If your data-collection systems and reporting take days or weeks, or if no one looks at them, why waste the resources?

- Do—*Choose and prioritize measures carefully.*
  - One or two really meaningful control charts can be a big help. Having 10 or 15 mildly interesting ones only mean you will quit looking at them soon.
- Do—*Set and fine-tune your alarms.*
  - Use what you learn about the process to improve your response plans. The more promptly and effectively you can take action on key events, the more likely you are to keep customers and shareholders smiling!

- Don't—*Recalculate control limits too often.*
  - Because the control limits are a function of the data, they *could* be adjusted almost continuously, but that would make it much harder to detect alarm conditions. It is best to recalculate the limits only following a known process change. (When using software to present and test the control charts, set your preferences so as to prevent the recalculation of the control limits!)
- Don't—*Assume perfect data.*
  - Regular checks on the quality of your data collection, using methods such as Gage R&R, are important to ensure that alarms are not based on problems with the data itself.

Tests of Statistical Significance (Chi-Square, *t*-test, ANOVA)

When you measure and analyze a process or product, it is often possible to draw valid conclusions simply by *looking* at the data.

Sometimes, however, the lessons of the data are not obvious or certain. You may look at your data and say, "I don't see anything to help me here!" Or you may have a good hunch about what is going on, but want to be *extra* sure your conclusions are supported by the data. In these instances we can apply more rigorous *statistical* analysis methods to find or confirm trends or patterns in your data.

Tests of statistical significance are some of the most important techniques used by statisticians to look for patterns or to test their suspicions about data. In Six Sigma these tools have various possible applications, including:

- Confirming a problem or meaningful change in performance
- Checking the validity of data

- Determining the type of pattern or distribution in a group of continuous data
- Developing a root-cause hypothesis based on patterns and differences
- Validating or disproving root-cause hypotheses

Basics of Statistical Analysis: The Null Hypothesis

A 10-day heat wave hits your town and people say: "It's global warming!" You hit two holes-in-one in golf in two weeks, and exult "My game's really coming around!" The phone in the office seems to be ringing constantly and everyone says "It's going to be a busy quarter." You see a group of school kids making a lot of noise in the grocery store and say to yourself: "Kids these days just aren't brought up right!"

How valid are these conclusions? It is easy for us to extrapolate broad explanations from simple observations, and in some cases it is not a problem. The fact is, however, that in many instances, the so-called patterns we think we see are simply random variations. Wait long enough, and we will see just as much evidence for a completely *opposite* conclusion. When the cold spell hits its fourth week, someone is sure to speculate on the coming Ice Age. As you hit your fourth bad round of golf in a month, you figure you are "past your peak." And so on.

In statistics, we guard against the possibility of false patterns tricking us into faulty conclusions by adopting what is called "the null hypothesis." The null hypothesis states that any variation, change, or difference observed in a population or a process is due purely to *chance.* It is much like the attitude of that ultimate skeptic who won't believe anything unless you "prove it." And often the way we convince a skeptic is not to prove *our* theory but rather to *disprove* any other explanation. That is the approach we take in tests of statistical significance.

Testing for Statistical Significance: Methods and Examples

As with control charts, you can choose from several methods as you proceed to statistically test a hypothesis, described in the following paragraphs.

Chi-Square (χ^2) Test. This technique is used with discrete data, and in some cases with continuous data ("chi" is pronounced *kye*). As examples, you could apply a chi-square test so as to

- Compare defect rates in two locations to see whether they are significantly different
- Check to see if week-to-week changes in customer product choices indicate a meaningful level of variation
- Test the impact of various staffing levels on customer satisfaction

The *t*-Test. You use this method to test for significance when you have two groups or samples of *continuous* data. (As we noted in Chapter 13, continuous data measures have more power than discrete ones, but you need to be careful because these tests work only if certain conditions are met in the data.) Assuming that your data qualify, you might apply a *t*-test to:

- Compare the cycle time for a key step in your process at two weeks during the quarter, to check for any meaningful change
- Examine customer income levels in two regions, to see whether one serves significantly higher- or lower-income customers
- Test to see if the seek-time speed in two lots of disk drives is different

Analysis of Variance (ANOVA). ANOVA is another test of significance for continuous data; unlike the *t*-test, however, it can be used to compare *more* than two groups or samples. (If you find a significant difference among three or more groups of data, you have to do more analysis to find out *which* groups are different.) The following examples are the same as those for the *t*-test, but with the number differences shown in italic type:

- Compare the cycle time for a key step in your process for *each week* during the quarter to check for any meaningful change.
- Examine customer income levels in *four* regions to see whether one *or more* serves significantly higher- or lower-income customers
- Test to see if the seek-time speed in *five* lots of disk drives is different

Multivariate Analysis. In the first three methods described, the comparisons are based on a single factor or variable (time, income, speed, etc.). Of course *other* factors may be changing between one group or sample. Multivariate analysis (sometimes called MANOVA) is used to determine the significance of several factors. (It is usually best to do an ANOVA test before doing a multivariate.)

Basic Steps Taken in Statistical Tests

The good news about applying statistics to business problems these days is that a lot of the grunt-work has been eliminated, thanks to statistical software. The major steps in applying them remain relevant, however, regardless of how quickly the calculations are done. These steps are described here, followed by Exhibit 17.2, which lists the "dos and don'ts" for performing tests of statistical significance.

1. **Identify the issue being analyzed.** What is the key question or concern to which you want to apply a statistical test? Check to make sure statistical validation is really needed; is the answer already fairly obvious?
2. **Formulate your hypothesis and the null hypothesis.** Describe in your hypothesis (known technically as the "alternative hypothesis") what you think is happening, and then negate it by concluding: "It is actually just random probability that this is what we see" (the null hypothesis).
3. **Select the proper statistical test.** Before you make a final choice of a continuous-data technique, you will need to review the data to see whether it will work.
4. **Conduct the calculation and review the results.** Basically, the three possible answers here are: (a) the null hypothesis is proven, meaning these data provide no evidence supportive of your hypothesis; (b) the null hypothesis is *not* true, based on these data, indicating that some significant factor is affecting the data and hence your hypothesis may be correct; or (c) an *error* indicates that something in your data or in the tool you selected is not right.

Exhibit 17.2

"DOS AND DON'TS" FOR PERFORMING TESTS OF STATISTICAL SIGNIFICANCE

- Do—*Make sure the data being used is valid.*
  - A test done using faulty data is meaningless or even dangerous. If for example your sample size is too small, you find "significant" differences when they don't really exist.

- Do—*Select the right kind of test.*
  - For example, if it is discrete data, chi-square is the test to use.
- Don't—*Use your own expertise as a gut check of the statistical analysis.*
  - Statistics and experience are meant to work together.
- Don't—*Consider yourself an expert too soon.*
  - Plenty of complexities and nuances come with using these tools. Unusual situations actually are typical in the real world, and thus it can take more than a bit of experience to learn the ins and outs of statistical analyses.

Correlation and Regression Analysis

Correlation and regression analysis encompass a family of tools that analyze the relationships among two or more factors. The basics of correlation were introduced with scatter plots in Chapter 14 (see the Overview on p. 273 and the example on p. 315). When two factors are correlated, a change in one will be accompanied by a change in the other. By applying statistical calculations to those data, we can measure the *strength* of a possible relationship among the factors and draw a number of other helpful conclusions besides.

Across the various types of correlation and regression, you will find tools that can help you to:

- Test root-cause hypotheses by finding links between the suspected cause (the X) and the response or output (the Y).
- Measure and compare the influence of *various* factors (Xs) on the results (Y).
- Predict the performance of a process, product, or service under certain conditions.

Correlation and regression can be used *only* when you have data for two or more factors that are matched on individual items. (This contrasts with the statistical tests, which compare *groups* of data.) Table 17.1 shows a situation in which you might test a correlation.

To do a correlation analysis, you would need to have data *both* for time between maintenance *and* for copy defects from copier A, B, C, and so on.

TABLE 17.1 CORRELATION TEST EXAMPLE

Unit or Item	Factor 1 (X, or independent variable)	Factor 2 (Y, or dependent variable)
Copier	Time elapsing between maintenance	Copy defects

Particularly in analyzing causes, and depending on the nature of your data, correlation and regression tools can bring some important advantages over such tools as chi-square and ANOVA. They allow you to see finer patterns in smaller samples of data, and to see how the changes in different variables directly affect a unit

Types of Correlation and Regression Analysis

Again, computers, spreadsheets, and statistical software have made these tools accessible to many people. The following paragraphs describe some of the common uses and a few key concepts, followed by Exhibit 17.3, which lists the “dos and don’ts” of using correlation and regression analysis.

Correlation Coefficient. The same data used to draw a scatter plot can be crunched into a number—noted *r*—that tells you whether and how strongly the factors are correlated. The *r* correlation coefficient ranges from −1 to 1; generally an *r* score of below −.7 or above .7 would be worthy of serious further investigation. (Negative *r* results indicate a negative correlation.)

Correlation Percentage. Another number, r^2, is preferred by many because it reflects the amount or percent of variation in the Y or dependent factor that seems to be caused by the X factor. (You get r^2 just by “squaring” *r*.) For example, let’s say you found an apparent positive correlation for the time between copier maintenance and copy defects, with an *r* value of .72. Therefore, $r^2 = .52$, which means that roughly 50 percent of the increase in defects correlates with the time between maintenance. Note that how you will interpret and respond to either *r* or r^2 will depend on the purpose of your analysis and on your type of data.

Regression. The various forms of regression analysis concentrate on using existing data to predict future results. The most common is linear regression (or simple regression), which is used for two variables.

We can illustrate with a case study.

Case Study #15: Percy's Copy Repair Analyzes Defect Rates for Its Clients

Percy's wants to show clients the value of its maintenance service contract. Having gathered data on the relationship between time maintenance and copy defects, they found that defect rates tend to increase by 15 percent for every two-week period without maintenance.

Using the tool of linear regression, they were able to predict for a prospective customer that by the third month after their last emergency service call, they would reach about 25 percent "defective" copies. The prediction turned out to be accurate, and now the customer has a biweekly service agreement with Percy's.

Multiple Regression. Multiple regression, like multivariate analysis, examines the relationship among *several* factors and the results. In a process environment, examples could include all those shown in Table 17.2.

Using multiple regression, you would be able to quantify the impact of each of these Xs on the Ys—and to see how they interact. In more advanced applications, multiple regression is applied to create *models* to predict the results when combinations of factors interact under various conditions.

TABLE 17.2 MULTIPLE REGRESSION ANALYSIS EXAMPLES

Process	Unit or Item	X_1 (Input variable	X_2 (Process variable)	X_3 (Process variable)	Y (Output or result variable)
Software installation	Software package	Size of software (MB)	Number of users on network	Server processor speed (MHz)	System downtime during install (minutes)
Hotel reservation and check-in	Reservation	Hold time to talk to reservation agent (seconds)	Number of days reserved	Number of agents on duty in call center	Time to check in a guest (minutes)

Exhibit 17.3

"DOS AND DON'TS" FOR USING CORRELATION AND REGRESSION ANALYSIS

- Do—*Make sure you have paired data.*
  - The ability to do correlation and regression is predicated on how you collect and compile data. If the values of the factors being analyzed do not match for a single item, you cannot do correlation analysis.
- Do—*Use the correlation coefficient and percentage (r and r^2) to better understand scatter plot data.*
  - As one of the easiest statistical indicators, it can be a huge help to you as you try to interpret the mass of dots on a scatter diagram.
- Do—*Apply more advanced methods—when you're ready—to learn more about your processes and products.*
  - Used properly, correlation and regression can add significantly to your understanding of how and why variation occurs in your business, and how to control it.

- Don't—*Take predictions drawn from data as fact.*
  - The predictions made from regression analysis are in most cases based on *tendencies*, which means you may still encounter a lot of variation you do not understand, and can lead to results you did not expect.
- Don't—*Look at the data in only one way.*
  - If a strongly suspected correlation does not show up, it may be hidden. You might want to consider stratifying your data or gathering them over a longer period before you conclude absolutely that no relationship is present.
- Don't—*Assume that correlation means causation.*
  - As we discussed in Chapter 14, two items that correlate may not cause one another at all—something else may be affecting them both.

Design of Experiments (DOE)

DOE is a method used for testing and optimizing the performance of a process, product, service, or solution. It draws heavily on the techniques just reviewed (i.e., tests of statistical significance, correlation, and regression) to help you learn about the behavior of a product or process under varying conditions. The unique aspect of DOE is the opportunity it gives you to plan and control the variables using an *experiment*, as opposed to just gathering and observing real-world events in the manner known as empirical observation.

DOE has plenty of potential application in a Six Sigma organization. It can allow you to:

- Assess voice of the customer systems to find the best combination of methods producing valid feedback without annoying customers.
- Assess factors to isolate the vital root cause of a problem or defect.
- Pilot or test combinations of possible solutions to find the optimal improvement strategy.
- Evaluate product or service designs to identify potential problems and reduce defects right from day 1.

Even though DOE tends to be easier to apply to *things* than to people, it is possible to conduct experiments in service environments. They tend to be real-world tests in which the variables are controlled in the actual process and the results then compared. For example, a large sales organization tested 14 variables over a four-month period in an effort to find the best sales-boosting combination. Based on solutions identified in the field experiment, sales volume jumped by more than 50 percent even in the firm's top-producing region.[1]

Basic Steps in Design of Experiments

The basic steps for you to take in a designed experiment are described here, followed by Exhibit 17.4, which lists the "dos and don'ts" for using design of experiments.

Step 1. Identify the factors to be evaluated. What do you want to learn from the experiment? What are the likely influences on the process or product? As you select factors, keep in mind the importance of balancing the benefit of getting additional data by testing more factors with the increased cost and complexity.

Step 2. Define the levels of the factors to be tested. In the case of such variable factors as speed, time, and weight, you could test them at an infinite number of levels. Thus in this step you choose not only which values, but also how many different levels you want to test. In the case of discrete data, levels may be either/or; for example, in testing a form we could (a) include our e-mail address, or (b) not include our e-mail address.[2]

Step 3. Create an array of experimental combinations. In DOE, you usually want to avoid the one-factor-at-a-time (OFAT) approach, where each variable is tested in isolation. Rather, arrays of conditions are examined to obtain representative data for all the factors. Possible combinations or arrays can be generated by statistics software tools or found in tables, and their use helps you to avoid having to test every possible permutation.

Step 4. Conduct the experiment under the prescribed conditions. A key here is to avoid letting other, untested factors influence your results.

Step 5. Evaluate the results and conclusions. If you are going to see patterns and draw conclusions from DOE data, tools like ANOVA and multiple regression are a must. From the experimental data you may get clear answers, or additional questions may arise that you will then test in additional experiments.

Exhibit 17.4

"DOS AND DON'TS" FOR USING DESIGN OF EXPERIMENTS

- Do—*Be prepared to apply DOE concepts to real-world processes.*
  - Outside of product design, engineering, and manufacturing, most other business activities won't fit in a laboratory. You may need to conduct your experiments on real people (e.g., in piloting a new solution).
- Do—*Take advantage of experimental arrays.*
  - One way that the discipline of DOE can bring you big time and resource savings is by producing more data from fewer tests. Done right, you *can* take the time to conduct experiments you might otherwise not have considered.
- Do—*Include problem prevention in your DOE plans.*
  - If something goes wrong in your experiment, would the consequences be serious? If so, you need to plan preventions and contingencies to make sure an experiment does not backfire.

For example, piloting a solution with customers is fine, as long as you do not put your business with them at undue risk.

- Don't—*Fail to consider a variety of factors or influences.*
  - It is the unanticipated variables that mess up lots of experiments.
- Don't—*Get stuck on the experimental treadmill.*
  - As in the analyze phase of DMAIC, you can always do more tests and gather more data. Use DOE as a *tool*, not as an *end*.

Failure Modes and Effects Analysis (FMEA)

Failure modes and effects analysis is a set of guidelines, a process, and a form to identify and prioritize potential problems (failures). By basing their activities on FMEA, a manager, improvement team, or process owner can focus the energy and resources of prevention, monitoring, and response plans where they are most likely to pay off. Borrowed from high-stakes industries such as aerospace and defense, FMEA is a more rigorous application of the potential problem analysis concept discussed in Chapter 15.

The FMEA method has many applications in a Six Sigma environment in terms of looking for problems not only in work processes and improvements but also in data-collection activities, voice of the customer efforts, procedures, and even the rollout of a Six Sigma initiative. The only prerequisite is to have a complex or high-stakes situation in which you want to place a special emphasis on keeping problems at bay.

The steps and key concepts for using FMEA are as follows:

1. **Identify the process or product/service.**
2. **List potential problems that could arise (failure modes).**[3] The basic question is "What could go wrong?" Ideas as to potential problems may come from various sources including brainstorming, process analysis, and benchmarking. They can be grouped by process step or product/service component. Avoid trivial problems.
3. **Rate the problem for severity, probability of occurrence, and detectability.** Using a 1–10 scale, give a score on each factor to each potential problem. More serious problems get a higher rating; harder-to-detect problems also get a higher score. Again, these scores may be judgments or be based on historical or test data.

4. **Calculate the risk priority number (RPN) and prioritize actions.** Multiplying the three scores together gives this overall risk rating. By adding the RPNs from all problems, you get a total risk figure for the process or product/service. (Maximum RPN = 1,000.)
5. **Develop actions to reduce the risk.** Focusing first on potential problems having the highest priority, you then can devise actions to reduce one or all factors: seriousness, occurrence, and detectability. A key benefit of the tool is to make your problem management resources, which always are finite, go to best benefit.

Let's take a look at how FMEA can be used.

Case Study #16: An E-Commerce Company Uses FMEA to Make Sure It Catalogs Are Updated Accurately

Managers and engineers at e-commerce company Nitwit.com wanted to make sure nothing went wrong with its process for updating the online catalog. Here are two of the problems they identified and the analysis they did:

1. The wrong artwork is used with a new item.
   Severity = 5
   Occurrence = 5
   Detection = 3
   RPN = 5 × 5 × 3 = 75
2. Buyers can't place an order for an item.
   Severity = 8
   Occurrence = 5
   Detection = 6
   RPN = 8 × 5 × 6 = 240

Based on this assessment, they focused on the concern about not being able to place orders and developed preventive measures to ensure that all new product numbers are posted to the ordering system.

Mistake-Proofing (or *Poka-Yoke*)

Mistake-proofing can be thought of as an extension of FMEA, or as an extra-disciplined way of shedding those final pounds (i.e., defects) in our Six Sigma diet. Whereas FMEA helps in the prediction and prevention of problems, mistake-proofing emphasizes the detection and correction of mistakes before they become defects delivered to customers. It puts special attention on the one constant threat to any process: *human* error.

The basic ideas behind mistake-proofing—also known by the Japanese name *poka yoke* (*POH-kuh YOH-kay*)—were developed by a management consultant in Japan, Shigeo Shingo. Shingo's ideas were controversial, partly because he proposed a method whereby "inspection" (the word he chose) becomes an integral part of every step in a process, as opposed to being solely a separate responsibility. When one looks more closely, however, one sees that the heart of mistake-proofing is simply to pay careful attention to every activity in the process and to place checks and problem prevention at each step. It is a matter of constant, instantaneous feedback, rather like the balance and direction data transmitted from a cyclist's ears to brain, keeping his or her bike upright and on the path.

Mistake-proofing can be used to:

- **Fine-tune improvements and process designs from DMAIC projects.** How can those rare, most challenging errors be avoided or managed?
- **Gather data from processes approaching Six Sigma performance.** The more "perfect" a process is, the harder it can be to measure.
- **Eliminate the kinds of process issues and defects needed to take a process from 4.5 to 6 Sigma.**

Basic Steps in Mistake-Proofing

Mistake-proofing is best applied after completion of a thorough FMEA prediction and prevention review. The following paragraphs describe the steps in mistake-proofing; then Exhibit 17.5 lists the "dos and don'ts" you should keep in mind when using this tool.

Step 1. Identify possible errors that might occur despite preventive actions. Review each step in the existing process while asking the question "What possible human error or equipment malfunction could take place in this step?"

Step 2. Determine a way to detect that an error or malfunction is taking place or about to occur. For example, an electric circuit in your car can tell if you fastened your seatbelt. E-commerce software is programmed to tell whether any piece of data is missing from a field. In an assembly plant, trays holding parts help the worker to see whether an item is missing.

Step 3. Identify and select the type of action to be taken when an error is detected. The basic types of mistake-proofing device include:

- **Control.** An action that self-corrects the process, like an automatic spell-checker/corrector.
- **Shutdown.** A procedure or device that blocks or shuts down the process when an error occurs. The automatic shutoff feature of a home iron is one example. Another is sophisticated investment software that bars the entry of certain investments in accounts decreed to be off-limits to those investments.
- **Warning.** As the name implies, this alerts the person involved in the work that something is going wrong. A seatbelt buzzer is an example. So is a control chart that shows that a process may be out of control. Warnings too often are ignored, so controls and shutdowns usually are preferable.

Coming up with methods to detect, self-correct, block/shut down, or warn of a problem can require real imagination and creativity. Some common types of mistake-proofing measures include:

- Color- and shape-coding of materials and documents
- Distinctive shapes of such key items as legal documents
- Symbols and icons to identify easily confused items
- Computerized checklists, clear forms, best-in-class, up-to-date procedures and simple workflows to help prevent errors from becoming defects in the hands of customers

Dave Boenitz of semiconductor equipment manufacturer Applied Materials (quoted in Chapter 3) says that mistake-proofing has been the focus of their improvement and lean manufacturing efforts. "We've looked for ways to make the assembly so foolproof that it's impossible to assemble it the wrong way. So we've done things like more visual displays; we've got colored schematics of how the part is supposed to go together." Also, a variety of jigs and fixtures are used to make it difficult to assemble items in the wrong way, much like a key that can fit only a certain lock.

Extra care is taken to check the work at each step as well: "Those people who do the work inspect their product before it moves on; then those people who *receive* it inspect the product. Through this orchestrated movement, they are able to eliminate most of the manufacturing assembly errors that can occur."

Exhibit 17.5

"DOS AND DON'TS" WHEN USING MISTAKE-PROOFING

- Do—*Try to imagine all conceivable errors that can be made.*
  - Here is where the truly negative and paranoid people in your organization can at last be of real help!
- Do—*Use all of your creative powers to brainstorm clever ways to detect and correct errors as part of the work process itself.*
  - To leave the detection of defects to downstream inspectors, or to the customers, is to court disaster.
- Don't—*Fall into the "to err is human" mindset.*
  - "To get things right most of the time" is also a human trait. Find out how your people are self-correcting problems that are not prevented upstream, and share best practices.
- Don't—*Rely on people to catch their own errors all the time.*
  - If your process is chugging along at just 2 Sigma, you cannot eliminate the safety net of downstream inspection.

Quality Function Deployment (QFD)

Quality function deployment is a method for prioritizing and translating customer inputs into designs and specifications for a product, service, or process. Although the detail of the work involved in QFD can be both complex and exhaustive (not to mention exhaust*ing*), the essentials of the QFD method are based on commonsense ideas and tools we have already seen.

QFD is a robust method having many variations, so its uses can be quite broad. It can be applied to:

- Prioritize and select improvement projects based on customer needs and current performance.
- Assess a process's or product's performance versus competitors.
- Translate customer requirements into performance measures.
- Design, test, and refine new processes, products, and services.

QFD is by no means a stand-alone tool. To work well, it relies on a variety of other methods from voice of the customer input to design of experiments.

Basics of Quality Function Deployment

A special multidimensional matrix, dubbed the "House of Quality," is the best-known element of the QFD method. A full QFD product design project will involve a series of these matrices, translating from customer and competitive needs all the way down to detailed process specifications. Among all the detail included in the QFD documentation, however, lie two core concepts:

1. **The QFD Cycle.** An iterative effort to develop operational designs and plans in four broad phases:
   - **a.** Translate customer input and competitor analysis into product or service features (basic design elements).
   - **b.** Translate product/service features into product/service specifications and measures.
   - **c.** Translate product/service specifications and measures into *process* design features. (How will the process deliver the features per specification?)
   - **d.** Translate process design features into process performance specifications and measures.
2. **Prioritization and correlation.** Detailed analysis of the relationships among specific needs, features, requirements, and measures. Matrices like the House of Quality or the simple L-Matrix (see Figure 17.2) keep this analysis organized and document the rationale behind the design effort.

In essence, the QFD cycle develops the links from downstream Ys (customer requirements and product specifications) back to upstream

	Choice of point sizes	Variety of ink colors	Choice of finishes	3 price levels ($12, $40, $75)	Available neck chain	Nontoxic ink	Retailed at jewelers	Sold direct online
Stylish			●	△	△		●	△
Multiple choices	●	●	●	●	○		○	○
Safe to use			△		△	●		
Value for money	△		△	●			△	●
Hard to lose			△		●			

CONTRIBUTION: ● Strong ○ Moderate △ Weak

FIGURE 17.2 EXAMPLE: SIMPLIFIED L-MATRIX FOR DESIGNING A PEN

Xs (process specifications) *right in the design process.* With an existing process or product, it can be used to clarify and document those relationships never investigated before. Another benefit of the House of Quality is a "diagonal" relationship test afforded by the matrix, testing combinations that may not have been considered by our standard human linear thought processes.

Exhibit 17.6 lists the "dos and don'ts" to keep in mind when using quality function deployment.

Exhibit 17.6

"DOS AND DON'TS" FOR USING QUALITY FUNCTION DEPLOYMENT

- Do—*Adapt the complexity of the method to your situation.*
  - Designing a complex product can involve many layers and much detail. Simply creating measures for an existing process should be much simpler. (Software packages are available for simpler or detailed House of Quality matrices.)
- Do—*Concentrate on getting good input and data, not just on "filling boxes."*
  - A QFD matrix can have a lot of white space. Often, you will fill it in best just using your own judgment; if however you are putting something in a box merely to fill the space, don't.

- Do—*Use the competitor analysis feature of QFD to factor other external data into your designs and specifications.*
  - Design for the customer, with an eye on the competitor.
- *Don't—Forget to apply other tools to the method.*
  - For example, design of experiments can be critical to maximizing performance on various design features. You also can use tools such as project charters to help lay the foundation for a design effort.

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CONCLUSION

Twelve Keys to Success

As we approach the end of our journey along the Six Sigma Way, we hope it is a beginning for you. In some ways, this book has just scratched the surface in outlining the ideas, tools, and disciplines that make up this system for management. (Some points we likely repeated often enough that the diligent reader by now is saying "Enough! I get it!") To wrap up, we summarize some of the key points of this book and the experiences of various organizations trying to become master Six Sigma methods and build a culture of continuous improvement with a list of keys to success. Hopefully, this list will make up for the areas we did not cover in greater depth, and help you glean the key points from topics covered in detail.

Keys to Success

1. Tie Six Sigma Improvement Efforts to Business Strategy and Priorities

Even if your first efforts focus on fairly narrow problems, their impact on key business needs should be clear. Show how projects and other activities link to your mission, customers, financial performance, and competitiveness whenever possible.

2. Position Six Sigma as an Improved Way to Manage for Today

The methods and tools of Six Sigma make sense for successful organizations in the twenty-first century. They are a product of lessons learned by enlightened companies and managers, which address the challenges of rapid change, intense competition, and increasingly demanding customers.

3. Keep the Message Simple and Clear

Beware of alienating people with strange terms and jargon that create classes in a Six Sigma environment. Although new vocabulary and skills are obviously part of the Six Sigma discipline, the core of the system and your company's vision for improvement should be accessible and meaningful to everyone.

4. Develop Your Own Path to Six Sigma

Your themes, priorities, projects, training, and structure all should be decided based on what works best for you. Think about it: Why would a rigid formula for an approach create a more flexible, responsive organization?

5. Focus on Short-Term Results

The proof is in the power of what Six Sigma can do to make your organization more competitive and profitable and your customers more loyal and delighted. Develop and push forward a plan that will make initial achievements concrete in the first four to six months.

6. Focus on Long-Term Growth and Development

Balance the push for early results with the recognition that those gains must lay the foundation for the real power of Six Sigma: creation of a more responsive, customer-focused, resilient, and successful company for the *long term*.

7. Publicize Results, Admit Setbacks, and Learn from Both

Don't expect—or claim—that Six Sigma works perfectly in your company. Recognize and celebrate successes, but pay equal attention to challenges and disappointments. Be ready to continuously improve and even redesign your Six Sigma processes as you progress.

8. Make an Investment to Make It Happen

Without time, support, and money, the habits and existing processes in your business will not change much. The results are likely to bring a quick return on investment, but first you have to *make* the investment.

9. Use Six Sigma Tools Wisely

No single tool or discipline in the Six Sigma system can create happier customers or improve profits. Statistics can answer questions, but cannot deliver outstanding service. Creative ideas may hold potential, but without processes to develop and deliver them, they are just dreams. Your success in Six Sigma will depend on applying all the methods, in the right balance, to maximize your results. And using the *simplest* tool that works rather than the most complex should be highly valued.

10. Link Customers, Process, Data, and Innovation to Build the Six Sigma System

These core elements are brought together in the Six Sigma approach. Understanding your markets and your operations and being able to use measures and creativity to maximize value and performance create a *potent combination that can make life miserable for your competitors.*

11. Make Top Leaders Responsible and Accountable

Until senior managers of the organization, unit, or even department accept driving improvement as an integral part of their jobs, the true importance of the initiative will be in doubt, and the energy behind it will be weakened. To get there, they will need to examine and improve *their own* management processes and leadership habits.

12. Make Learning an Ongoing Activity

A few months of training, however intensive, cannot cement all the new knowledge and skills needed to sustain Six Sigma. Over time, you should look outside the continuous improvement discipline for other methods and ideas that complement the tools reviewed in this book.

BONUS—Make Six Sigma FUN!

Yes, this stuff about business survival, competition, and measurement is serious, sometimes confusing, and even a bit scary. But the Six Sigma Way opens the door to new ideas, new ways of thinking, and a new breath of success. Putting humor into it and having a good time with Six Sigma will only *raise* your chances for success: Any time people enjoy something, they almost automatically put more energy and enthusiasm into it.

A Final Word

In business-speak we are compelled to use short phrases to describe complicated ideas. "Six Sigma" is no more a *thing* than is "economic policy" or "organizational excellence" or any dozens of other shorthand terms we use every day. As we noted from the start of this book, what we label Six Sigma is really a *system* that encompasses many concepts, tools, and principles. It's not the label that's important, but how you use and adapt it to meet the needs and goals of your organization.

We believe, and we hope you agree, that the elements of the Six Sigma system are essential, powerful, and valuable in some way as part of *every successful business.* At the same time, we strongly encourage you to adapt the discipline and methods of Six Sigma to best influence your unique culture, industry, market position, people, and strategy. Our biggest fear is that people will accept or reject Six Sigma as if it were a *thing* (falling victim to the Tyranny of the Or) and not use it as a flexible system.

Finally, having worked with this big topic and the companies applying it for quite a few years now, we are continually startled at how much we still have to learn and how many new perspectives emerge. We would be thrilled to hear your comments, new ideas, and your thoughts on whether and how *The Six Sigma Way* has helped you. You can reach us via e-mail at *ssw@pivotalresources.com.*

We hope to hear about your successful journeys on the way to Six Sigma.

APPENDIX

Sigma Calculation Worksheet

Sigma levels of a process can be determined several ways. The steps below use the simplest method, based on number of defects at the *end* of a process (usually called, appropriately, "process sigma").

STEP 1: Selecting the Process, Unit & Requirements

➢ Identify the process you want to evaluate: ____________ (process)

➢ What is the primary "thing" produced by the process? ____________ (unit)

➢ What are key customer requirements for the unit? ________________

____

____(requirements)

STEP 2: Defining the "Defect" and "Number of Opportunities"

➢ Based on the requirements noted above, list all the possible *defects* in a single unit (e.g. late, missing data, wrong size, delivered to wrong address, etc.). Be sure the defects described can be identified *objectively*.________________________

____

____ (defects)

➢ How many defects could be found on a *single* unit? _________ (opportunities)

STEP 3: Gather Data & Calculate DPMO

➢ Collect end-of-process data: _______ (units counted) _______(*total* defects counted)

➢ Determine Total Opportunities in data gathered:

Units Counted x Opportunities = _________ (total opportunities)

➢ Calculate Defects per Million Opportunities:

(# Defects Counted ÷ Total Opportunities) x 10^6 = _________ (DPMO)

STEP 4: Convert DPMO to Sigma

➢ Use Sigma Converstion table on reverse and note estimated sigma here: ____________

NOTES: 1) The table will give you a very rough range of your sigma level 2) Your sigma figure can vary significantly based on the accuracy of your data and the number of opportunities you identify on a unit.

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NOTES

Introduction

1. James Collins and Jerry Porras, *Built to Last* (New York: Harper Business, 1994), p. 44.
2. Since the first edition of this book, author Pande expanded on the "Genius of the And" concept as a theme for a book on leading a changing organization, entitled *The Six Sigma Leader*, also published by McGraw-Hill.

Chapter 1

1. Address to General Electric Company Annual Meeting, Cleveland, Ohio, April 21, 1999.
2. Six Sigma was adopted as the theme linking all of AlliedSignal's diverse quality initiatives in about 1995. In a sense Allied's decision, and its influence on GE, is what brought Six Sigma back to its original role at Motorola where, as we've noted, it was a full culture-change process.
3. AlliedSignal, *1998 Annual Report*, p. 8.
4. GE Annual Meeting, April 24, 1996, quoted in Slater, p. 209.
5. *AlliedSignal Annual Report*, 1998, p. 2.
6. Quoted in *Fortune* (September 27, 1999), p. 132.

Chapter 2

1. We owe credit for this phrase to our friend and colleague Chuck Cox, whom we will be quoting later in the book.
2. The curve metaphor is reflected in a core concept presented by Intel chairman Andy Grove in his book *Only the Paranoid Survive:* the "strategic inflection point." Grove points out that a company's failure to adjust its strategy at the right moment can mean disaster. We suggest that many smaller "inflection points" can have a huge impact

on a corporation or its business units, and that Six Sigma is a way to better negotiate both the strategic and the daily curves. See Andrew Grove, *Only the Paranoid Survive* (New York: Currency Books, 1996), p. 32.

3. A couple of points to make our comments more precise: First of all, σ is used to represent the standard deviation of a population or an entire group. Usually, standard deviations are calculated based on a sample from the population, for which the notation is *s* (for sample standard deviation). Thus you'll usually see *s* in statistics formulas, and not σ.

   Second, the letter *z* gets used in this context, too. The distance from the mean in numbers of standard deviations is measured in what statisticians call *z units*, but the scale is the same (e.g., 1.65 *z* units from the mean equals 1.65 standard deviations). Also, the percentage of the sample or population represented by a slice of the bell-shaped curve is often called the *z*-score. So when we noted that 34.1 percent of your trips were between 18 and 20.7 minutes, 34.1 percent is the *z*-score.
4. Deming called this the *Shewhart Cycle*, after his friend and mentor, Walter Shewhart. It is sometimes called PDSA for Plan-Do-Act-*Study*-Act.
5. This particular model got its start at GE Capital and was later adopted by all of GE. The original model—still used in some companies—included only four steps: measure, analyze, improve, control.
6. Interview with Devin Rickard of Adobe Systems, June 2013.

Chapter 3

1. The discipline of activity-based accounting is giving finance people new perspectives and tools to help them link costs and process tasks more closely.
2. ISO9000 is an internationally recognized set of standards used to validate the consistency of processes, usually in product manufacturing and design but in other areas as well. A company is certified by a recognized independent auditor, primarily indicating that (a) the company has properly documented processes, and (b) the processes are being followed as documented. A number of other industry- and customer-specific certifications can be sought by

manufacturing organizations as well—usually as a basic requirement for consideration as a potential vendor.

Chapter 4

1. We know of a car dealer who visited Detroit in the 1970s to plead for more fuel-efficient, well-made economy vehicles. After listening (or seeming to), the Big Three executives patted the dealer on the shoulder and sagely counseled: "Just sell what we build."

Chapter 5

1. These figures are drawn from the presentation "Training Six Sigma Quality in a Service Organization," given at a meeting of the American Society for Training and Development National Conference in Atlanta, Georgia, on May 26, 1999.

Chapter 7

1. We've seen some *good* change marketing efforts, too. For example, when a major bank was moving a regional headquarters to a new building and shifting people from offices to cubicles (a jarring change), the switch was accompanied several months in advance by a slogan ("It's Your Move"), sweatshirts, parties, brochures, etc.—all just to help people feel better about the new environment.

Chapter 8

1. The roles and structure noted here are common to Six Sigma and quality efforts in a number of organizations, including GE.
2. Note that we are focusing here only on Black Belts as the workhorse role in most Six Sigma initiatives. Some of the same considerations apply to preparing and deploying Master Black Belts.

Chapter 10

1. This great analogy is borrowed from a book by consultant Jill Janov, who actually came across the "dried peas" effect while learning to write billboard ad copy. See Jill Janov, *The Inventive Organization* (San Francisco: Jossey-Bass, 1994), pp. 11–12.

Chapter 11

1. See a classic study: Alfred Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, MA: Harvard University Press, 1977), p. 462.
2. Michael Porter, *Competitive Advantage* (New York: The Free Press, 1985), p. 36.
3. Porter, p. 38.

Chapter 12

1. We use the single term *voice of the customer* throughout the book to signify *both* efforts to understand current and future needs of existing and prospective customers, *and* activities to gather information on competitors, new technologies, etc.—also called *voice of the market* systems.
2. *Note:* Although most of this chapter uses a focus on external customers and markets, we encourage those in *internal* organizations or support processes to adopt a similar perspective, which will help them to better understand customers and markets.
3. Jan Carlzon, *Moments of Truth* (Cambridge, MA: Ballinger, 1987).
4. We learned of this performance standard from Barbara Friesner, director of training for Loews Hotels, which uses "10, 5, First and Last" extensively in their evaluations of service performance. In the next chapter, discuss how Loews measures against this standard.

Chapter 13

1. Bob Lawson and Ron Stewart, *Measuring Six Sigma and Beyond: Continuous vs. Attribute Data* (Schaumberg, IL: Motorola University Press, 1997), p. 16.
2. A warning for the technical types: PPM and DPMO are not really synonymous, so be careful. Many people assume or intend PPM to signify defectives units—so 6σ would mean 3.4 "bad" units for every million produced. In our electronic components example, however, we noted that each item has roughly 4,000 opportunities. Using the DPMO calculation, you would therefore reach 6σ performance with 3.4 defects for every 250 units (250 units × 4,000 = 1,000,000 opportunities). If defects were one to a unit, your yield would be 98.64 percent and your total *defectives* for every million electronic

components would be 13,600. Pretty good for a complex product, but a lot more than 3.4!

3. For our discussion and examples here, we assume only *one* defect opportunity in our Sigma calculations. Determining opportunities gets trickier for internal process measures.
4. Another method to calculate the internal yield is called “rolled throughput yield.” YRTP is generated by multiplying the yields from each of the substeps. In our example, this would be: .98 × .99 × .97 = .94.
5. Cost of poor quality (which we introduced in Chapter 5) also is known as price of nonconformance (PONC). The related measure, cost of quality, includes the costs of *both* rework and defects (i.e., poor quality), as well as the costs of solutions, prevention, and appraisal/prevention (i.e., achieving good quality).

Chapter 15

1. See “GE’s Quality Gamble,” *ComputerWorld*, June 8, 1998.
2. Like the one in Chapter 14, this scenario is based on several real organizations. It has been fictionalized for the reader’s enjoyment and to avoid inflicting any embarrassment on real people.
3. Other “value” dimensions influence organizational decisions as well, including, for example, integrity, respect for diversity, environmental consciousness, support for employees’ personal lives, and so on. These other factors may serve to justify activities not technically value-adding to the customer.

Chapter 16

1. Robert S. Kaplan and David P. Norton, *The Balanced Scorecard* (Boston: Harvard Business School Press, 1996).

Chapter 17

1. See “Numbers Tell the Story,” *Selling Power* (July–August 1999), pp. 58–64.
2. If we wanted to test *where* on the form to put the e-mail address, several more possible levels could be included. Few factors are *really* binary, but it is often simpler to handle them that way.

3. Some practitioners differentiate between "failure modes," which refer to system and equipment problems, and "*error* modes" (or EMEA) that refer to human error. We prefer to combine the two into a single analysis.

GLOSSARY

Affinity chart (diagram) Brainstorming tool used to gather large quantities of information from many people; ideas usually are put on sticky notes, then categorized into similar columns; columns are named giving an overall grouping of ideas.

Analyze DMAIC phase where process detail is scrutinized for improvement opportunities. Note that (1) data are investigated and verified to prove suspected root causes and substantiate the problem statement (*see also* Cause and effect); and (2) process analysis includes reviewing process maps for value-adding/non-value-adding activities. *See also* Process map; Value-adding activities; Non-value-adding activities.

Balanced scorecard Categorizes ongoing measures into four significant areas: finance, process, people, and innovation. Used as a presentation tool to update sponsors, senior management, and others on the progress of a business or process; also useful for process owners.

Baseline measures Data signifying the level of process performance as it is/was operating at the initiation of an improvement project (prior to solutions).

Black Belt A team leader, trained in the DMAIC process and facilitation skills, responsible for guiding an improvement project to completion.

Cause-and-effect diagram Also known as a "fishbone" or "Ishikawa diagram"; categorical brainstorming tool used for determining root-cause hypothesis and potential causes (the bones of the fish) for a specific effect (the head of the fish).

Charter Team document defining the context, specifics, and plans of an improvement project; includes business case; problem and goal statements; constraints and assumptions; roles; preliminary plan; and scope. Periodic reviews with the sponsor ensure alignment with business strategies; review, revise, refine periodically throughout the DMAIC process based on data.

Checksheet Forms, tables, or worksheets facilitating data collection and compilation; allows for collection of stratified data. *See also* Stratification.

Common cause Normal, everyday influences on a process; usually harder to eliminate and require changes to the process. Problems from common causes are referred to as "chronic pain." *See also* Control charts; Run chart, or time plot; Special cause; Variation.

Continuous data Any variable measured on a continuum or scale that can be infinitely divided; primary types include time, dollars, size, weight, temperature, and speed; also referred to as "variable data."

Control DMAIC phase C; once solutions have been implemented, ongoing measures track and verify the stability of the improvement and the predictability of the process. Often includes process-management techniques and systems including process ownership, cockpit charts and/or process management charts, etc. *See also* Process management. Also, a statistical concept indicating that a process operating within an expected range of variation is being influenced mainly by common-cause factors; processes operating in this state are referred to as "in control." *See also* Control charts; Process capability; Variation.

Control charts Specialized time plot or run chart showing process performance, mean (average), and control limits; helps determine process influences of common (normal) or special (unusual, unique) causes.

Cost of poor quality (COPQ) Dollar measures depicting the impact of problems (internal and external failures) in the process as it exists; include labor and material costs for handoffs, rework, inspection, and other non-value-adding activities.

Criteria matrix Decision-making tool used when potential choices must be weighed against several key factors (e.g., cost, ease to implement, impact on customer.). Encourages use of facts, data, and clear business objectives in decision making.

Customer Any internal or external person/organization who receives the output (product or service) of the process; understanding the impact of the process on both internal and external customers is key to process management and improvement.

Customer requirements Defines the needs and expectations of the customer; translated into measurable terms and used in the process to ensure compliance with the customers' needs.

Cycle time All time used in a process; includes actual work time and wait time.

Defect Any instance or occurrence where the product or service fails to meet customer requirements.

Defect opportunity A type of potential defect on a unit of throughput (output) that is important to the customer; e.g., specific fields on a form that create an opportunity for error that would be important to the customer.

Defective Any unit with one or more defects. *See also* Defect.

Define First DMAIC phase defines the problem/opportunity, process, and customer requirements; because the DMAIC cycle is iterative, the process problem, flow, and requirements should be verified and updated for clarity throughout the other phases. *See also* Charter; Customer requirements; Process map; Voice of the customer (VOC).

Discrete data Any data *not* quantified on an infinitely divisible scale. Includes a count, proportion, or percentage of a characteristic or category (e.g., gender, loan type, department, location, etc.); also referred to as "attribute data."

Downstream Processes (activities) occurring after the task or activity in question.

DFSS Acronym for "Design for Six Sigma." Describes the application of Six Sigma tools to product development and process design efforts with the goal of "designing in" Six Sigma performance capability.

DMAIC Acronym for a process improvement/management system, which stands for define, measure, analyze, improve, and control; lends structure to process improvement, design, or redesign applications.

DPMO, or **defects per million opportunities** Calculation used in Six Sigma Process improvement initiatives indicating the amount of defects in a process per 1 million opportunities; number of defects ÷ by (the number of units × the number of opportunities) = DPO × 1 million = DPMO. *See also* DPO; Six Sigma; Defect opportunity.

DPO, or **defects per opportunity** Calculation used in process improvements to determine the amount of defects per opportunity; number of defects ÷ (the number of units × the number of opportunities) = DPO. *See also* Defect; Defect opportunity.

Effectiveness Measures related to how well the process output(s) meets the needs of the customer (e.g., on-time delivery, adherence to specifications, service experience, accuracy, value-added features, customer satisfaction level); links primarily to customer satisfaction.

Efficiency Measures related to the quantity of resources used in producing the output of a process (e.g., costs of the process, total cycle time, resources consumed, cost of defects, scrap, and/or waste); links primarily to company profitability.

External failure When defective units pass all the way through a process and are received by the customer.

Force-field analysis Identifies forces/factors supporting or working against an idea; restraining factors listed on one side of the page, driving forces listed on the other; used to reinforce the strengths (positive ideas) and overcome the weaknesses or obstacles.

Goal statement Description of the intended target or desired results of process improvement or design/redesign activities; usually included in a team charter and supported with actual numbers and details once data has been obtained.

Handoff Any time in a process when one person (or job title) passes on the item moving through the process to another person; potential to add defects, time, and cost to a process.

Histogram, or **frequency plot** Chart used to graphically represent the frequency, distribution, and centeredness of a population.

Hypothesis statement A complete description of the suspected cause(s) of a process problem.

Improve DMAIC phase in which solutions and ideas are creatively generated and decided upon; once a problem has been fully identified, measured, and analyzed, potential solutions can be determined to solve the problem in the problem statement and support the goal statement. *See also* Charter.

Input Any product, service, or piece of information that comes into the process from a supplier.

Input measures Measures related to and describing the input into a process; predictors of output measures.

Institutionalization Fundamental changes in daily behaviors, attitudes, and practices that make changes "permanent"; cultural adaptation of changes implemented by process improvement, design, or redesign, including complex business systems such as HR, MIS, training, etc.

ISO-9000 Standard and guideline used to certify organizations as competent in defining and adhering to documented processes; mostly associated with quality assurance systems, not quality improvement.

Judgment sampling Approach that involves making educated guesses about which items or people are representative of a whole, generally to be avoided.

Management-by-fact Decision making using criteria and facts; supporting intuition with data; tools used include process measurement, process management techniques, and rational decision-making tools (e.g., criteria matrix).

Measure DMAIC phase M, where key measures are identified, and data are collected, compiled, and displayed; a quantified evaluation of specific characteristics and/or level of performance based on observable data.

Moment of truth Any event or point in a process when the external customer has an opportunity to form an opinion (positive, neutral, or negative) about the process or organization.

Multivoting Narrowing and prioritization tool; when faced with a list of ideas, problems, causes, etc., each member of a group is given a set number of votes, and those receiving the most votes get further attention/consideration.

Non-value-adding activities Steps/tasks in a process that do not add value to the external customer and do not meet all three criteria for value-adding; includes rework, handoffs, inspection/control, wait/delays, etc. *See also* Value-adding activities.

Operational definition A clear, precise description of the factor being measured or the term being used; ensures a clear understanding of terminology and the ability to operate a process or collect data consistently.

Output Any product, service, or piece of information coming out of, or resulting from, the activities in a process.

Output measures Measures related to and describing the output of the process; total figures/overall measures.

Pareto chart Quality tool based on Pareto principle; uses attribute data with columns arranged in descending order, with highest occurrences (highest bar) shown first; uses a cumulative line to track percentages of each category/bar, which distinguishes the 20 percent of items causing 80 percent of the problem.

Pareto principle The 80/20 rule; based on Vilfredo Pareto's research stating that the vital few (20 percent) causes have a greater impact than the trivial many (80 percent) causes with a lesser impact.

Pilot Trial implementation of a solution, on a limited scale, to ensure its effectiveness and test its impact; an experiment verifying a root-cause hypothesis.

Plan-Do-Check-Act (PDCA) Basic model or set of steps in continuous improvement; also referred to as "Shewhart Cycle" or "Deming Cycle."

Precision The accuracy of the measure you plan to do, which links to the type of scale or detail of your operational definition, but can have an impact on your sample size, too.

Preliminary plan Used when developing milestones for team activities related to process improvement; includes key tasks, target completion dates, responsibilities, potential problems, obstacles and contingencies, and communication strategies.

Problem/Opportunity statement Description of the symptoms or the "pain" in the process; usually written in noun-verb structure; usually included in a team charter and supported with numbers and more detail once data have been obtained. *See also* Charter.

Process capability Determination of whether a process, with normal variation, is capable of meeting customer requirements; measure of the degree a process is/*is* not meeting customer requirements, compared to the distribution of the process. *See also* Control; Control charts.

Process design Creation of an innovative process needed for newly introduced activities, systems, products, or services.

Process improvement Improvement approach focused on incremental changes/solutions to eliminate or reduce defects, costs or cycle time; leaves basic design and assumptions of a process intact. *See also* Process redesign.

Process management Defined and documented processes, monitored on an ongoing basis, which ensure that measures are providing feedback on the flow/function of a process; key measures include financial, process, people, innovation. *See also* Control.

Process map, or **flowchart** Graphic display of the process flow that shows all activities, decision points, rework loops, and handoffs.

Process measures Measures related to individual steps as well as to the total process; predictors of output measures.

Process redesign Method of restructuring process flow elements eliminating handoffs, rework loops, inspection points, and other non-value-adding activities; typically means clean-slate design of a business segment and accommodates major changes or yields exponential improvements (similar to reengineering). *See also* Process improvement; Reengineering.

Project rationale (aka "Business Case") Broad statement defining area of concern or opportunity, including impact/benefit of potential improvements, or risk of not improving a process; links to business strategies, the customer, and/or company values; provided by business leaders to an improvement team and used to develop problem statement and project charter.

Proportion defective Fraction of units with defects; number of defective units divided by the total number of units; translate the decimal figure to a percentage. *See also* Defect; Defective.

Quality A broad concept and/or discipline involving degree of excellence; a distinguished attribute or nature; conformance to specifications; measurable standards of comparison so that applications can be consistently directed toward business goals.

Quality assurance (QA) Discipline (or department) of maintaining product or service conformance to customer specifications; primary tools are inspection and statistical process control (SPC).

Quality council Leadership group guiding the implementation of quality or Six Sigma within an organization; establishes, reviews, and supports the progress of quality improvement teams.

Random sampling Method that allows each item or person chosen to be measured is selected completely by chance.

Reengineering Design or redesign of business; similar to process redesign, though in practice usually at a much larger scale or scope.

Repeatability Measurement stability concept in which a single person gets the same results each time he/she measures and collects data; necessary to ensure data consistency and stability. *See also* Reproducibility.

Reproducibility Measurement stability concept in which different people get the same results when they measure and collect data using the same methods; necessary to ensure data consistency and stability. *See also* Repeatability.

Revision plans A mechanism (process) for updating processes, procedures, and documentation.

Rework loop Any instance in a process when the thing moving through the process has to be corrected by returning it to a previous step or person/organization in the process; adds time, costs, and potential for confusion and more defects. *See also* Non-value-adding activities.

Rolled-throughput yield The cumulative calculation of defects through multiple steps in a process; total input units, less the number of errors in the first process step number of items "rolled through" that step; to get a percentage, take the number of items coming through the process correctly divided by the number of total units going into the process; repeat this for each step of the process to get an overall rolled-throughput percentage. *See also* Yield.

Run chart, or **time plot** Measurement display tool showing variation in a factor over time; indicates trends, patterns, and instances of special causes of variation. *See also* Control chart; Special cause; Variation.

Sampling Using a smaller group to represent the whole; foundation of statistics that can save time, money, and effort; allows for more meaningful data; can improve accuracy of measurement system.

Sampling bias When data can be prejudiced in one way or another and do not represent the whole.

Scatter plot or diagram Graph used to show relationship or correlation between two factors or variables.

Scope Defines the boundaries of the process or the process improvement project; clarifies specifically where opportunities for improvement reside (start- and end-points); defines where and what to measure and analyze; needs to be within the sphere of influence and control of the team working on the project; the broader the scope, the more complex and time-consuming the process improvement efforts will be.

Should-be process mapping Process-mapping approach showing the design of a process the way it *should* be (e.g., without non-value-adding activities; with streamlined workflow and new solutions incorporated); contrasts with the "As-Is" form of process mapping. *See also* Process redesign, Value-adding activities; Non-value-adding activities.

SIPOC Acronym for suppliers, inputs, process, outputs, and customer; enables an at-a-glance, high-level view of a process.

Six Sigma Level of process performance equivalent to producing only 3.4 defects for every 1 million opportunities or operations; term used to describe process improvement initiatives using sigma-based process measures and/or striving for Six Sigma–level performance.

Solution statement A clear description of the proposed solution(s); used to evaluate and select the best solution to implement.

Special cause Instance or event that impacts processes only under special circumstances (i.e., not part of the normal, daily operation of the process). *See also* Common cause; Variation.

Sponsor, or **champion** Person who represents team issues to senior management; gives final approval on team recommendations and supports those efforts with the quality council; facilitates obtaining of team resources as needed; helps Black Belt and team overcome obstacles; acts as a mentor for the Black Belt.

Statistical process control (SPC) Use of data gathering and analysis to monitor processes, identify performance issues, and determine variability/capability. *See also* Run charts; Control charts.

Storyboard A pictorial display of all the components in the DMAIC process, used by the team to arrive at a solution; used in presentations to sponsor, senior management, and others.

Stratification Looking at data in multiple layers of information such as what (types, complaints, etc.), when (month, day, year, etc.), where (region, city, state, etc.), and who (department, individual).

Stratified sampling Dividing the larger population into subgroups, then taking your sample from each subgroup.

Supplier Any person or organization that feeds inputs (products, services, or information) into the process; in a service organization, many times the customer is also the supplier.

Systematic sampling Sampling method in which elements are selected from the population at a uniform interval (e.g., every half-hour, every twentieth item); recommended for many Six Sigma measurement activities.

Upstream Processes (tasks, activities) occurring prior to the task or activity in question.

Value-adding activities Steps/tasks in a process that meet all three criteria defining value as perceived by the external customer: (1) the customer cares; (2) the thing moving through the process changes; and (3) the step is done right the first time.

Value-enabling activities Steps/tasks in a process enabling work to move forward and add value to the customer but not meeting all three of the value-adding criteria; should still be scrutinized for time and best practices—can it be done better?

Variation Change or fluctuation of a specific characteristic that determines how stable or predictable the process may be; affected by environment, people, machinery/equipment, methods/procedures, measurements, and materials; any process improvement should reduce or eliminate variation. *See also* Common cause; Special cause.

Voice of the customer (VOC) Data (complaints, surveys, comments, market research, etc.) representing the views/needs of a company's customers; should be translated into measurable requirements for the process.

X Variable used to signify factors or measures in the input or process segments of a business process or system.

Y Variable used to signify factors or measures at the output of a business process or system; equivalent to "results"; a key principle of Six Sigma is that Y is a function of upstream factors; or $y = f(x)$.

Yield Total number of units handled correctly through the process step(s).

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For the Second Edition

Updating and revising a book turns out to be a tricky proposition: You don't want to lose the essence of the original, but it has to bring new insights and information. Completing this second edition would not have been possible without the expert guidance and significant contribution of Ruth Mills, a veteran editor who (we think) helped find the right balance and who shouldered a lot of the work to make it happen.

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For the First Edition

We now understand why the awards shows on TV always run long. Partly, of course, it is due to slow delivery of canned jokes by the presenters. Usually, though, it is that the winners need to thank so many people. We have not won an award, but we could go on for a while thanking people. Our friends at McGraw-Hill have threatened to cut to a commercial if we run long, however, so we will try to keep this brief.

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her sense of humor is representative of the general reading public), did graphics and countless other small acts, including shipping out the manuscript. (Our worry now is that Percy will quit and go write her own d—n book.)

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Note: page number followed by "n" refer to endnotes.

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