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# Articles and Solutions

Six Sigma tools can dramatically improve process yields and product quality if they are applied wisely. However, traditional training in these tools often leads to application paradigms. We hope that our articles help bridge the gap between the mechanics of tool utilization and wise applications. Many of these situations are described in more detail within our book, *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999 and during our training.

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â€œImplementing Six Sigma: Part Iâ€• , Forrest W. Breyfogle III, Smarter Solutions, Inc. (Reproduced from ASQ *The Quality Managment Forum)*

â€œImplementing Six Sigma: Part IIâ€• , Forrest W. Breyfogle III, Smarter Solutions, Inc. (Reproduced from ASQ *The Quality Managment Forum)*

The Six Sigma Measurement Strategy of Smarter Solutions, Inc. by Forrest W. Breyfogle, III

Back to Top

| Home | What is Six Sigma? | Book Store | Six Sigma Training | About Us |
| Our Team | Articles & Solutions | Applications & Benefits |
| What Our Clients Say | Employment | Contact Us |

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- Contact Us


# Bottom-Line Success With Six Sigma

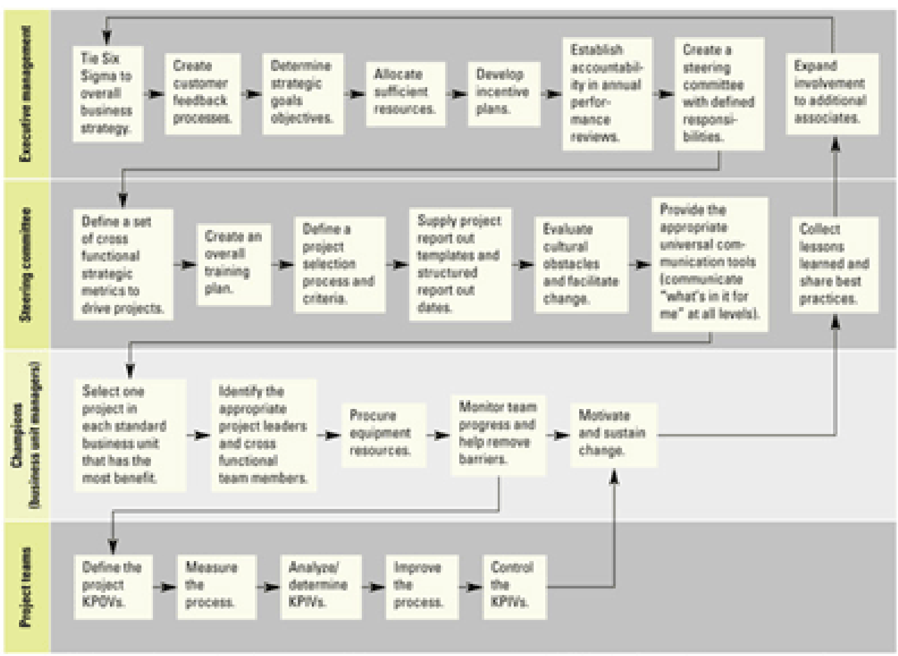
*Define key process output variables and their effects on the cost of poor quality*

**by Forrest W. Breyfogle III and Becki Meadows**

Learning disabilities are difficult, regardless of who or what they affect. Unfortunately, learning disabilities can be fatal to organizations, causing most companies to throw in the towel before hitting their 40th anniversary.1 However, more organizations are overcoming these disabilities by evolving into learning organizations. They are defying the odds stacked against them by wisely applying a particular strategy: the Six Sigma methodology.

Six Sigma offers a road map for changing data into knowledge, reducing the amount of daily firefighting and uncovering opportunities that impact both the customer and the bottom line. Some organizations, however, have had mediocre results after implementing Six Sigma. The reasons for this vary but typically lie within a company's infrastructure--the road map used for executing projects and establishing metrics.

**FIGURE 1** Smarter Six Sigma Solutions Implementation Process




KPOV: Key process output variable KPIV: Key process input variable 

Companies with profitable Six Sigma strategies are successful because they maintain effective infrastructures for selecting, supporting and executing projects. They do so by thinking of their infrastructures as ongoing processes that are continually improved and revisited through executive planning. **Figure 1** offers a version of this process.

This article focuses on the first step under the project teams category, as shown in **Figure 1**. The emphasis within this step, defining the project key process output variables (KPOVs), is given to counting defects, metrics and the cost of poor quality (COPQ), otherwise known as the cost of doing nothing (CODN).

### Counting defects

Organizations often waste time creating metrics that are not appropriate for the outputs being measured. Executive leaders can get deceptive results if they force all projects to determine a one size fits all metric in order to compare the quality of products and services from various departments. From a management point of view, having one universal metric seems beneficial. However, such a directive can lead to ineffective activities and often encourages playing games with the numbers.

Metrics that expose the hidden factory--rework within a process such as defect per million opportunities (DPMO)--can be very beneficial to some projects; however, the same metric can require a huge amount of questionably valued effort where other projects are concerned. To illustrate how metrics can be deceptive, let's look at the following scenarios:

**Scenario 1:Measuring defects in a manufacturing process.**

Consider the manufacturing of high precision sheet metal, where surface voids and scratches are unacceptable. In a one size fits all metric culture, we would be forced to define an area of the part as an opportunity (for failure) since this manufacturing process does not consist of discrete parts.

These boundaries are supposed to define customer needs, but they typically lead to inconsistencies and playing games with the numbers. For instance, one group might select a square foot area as an opportunity, while another might select a square inch or a square millimeter. If the sigma quality level or DPMO rate does not look good, a team might even believe it needs to improve the perception of product quality by changing the area considered. This can yield dramatically different results, offering little insight into the process.

**Scenario 2:Measuring defects in the service industry.**

In Six Sigma, a defect rate is one measure of the frequency that an event does not meet customer expectations. In a manufacturing environment, for example, if a shaft is larger than a diameter tolerance specification limit, the shaft could be too large to rotate freely within a bushing that is part of a later assembly. In this process, manufacturing specification limits have physical meaning; however, in a service environment this is often not the case.

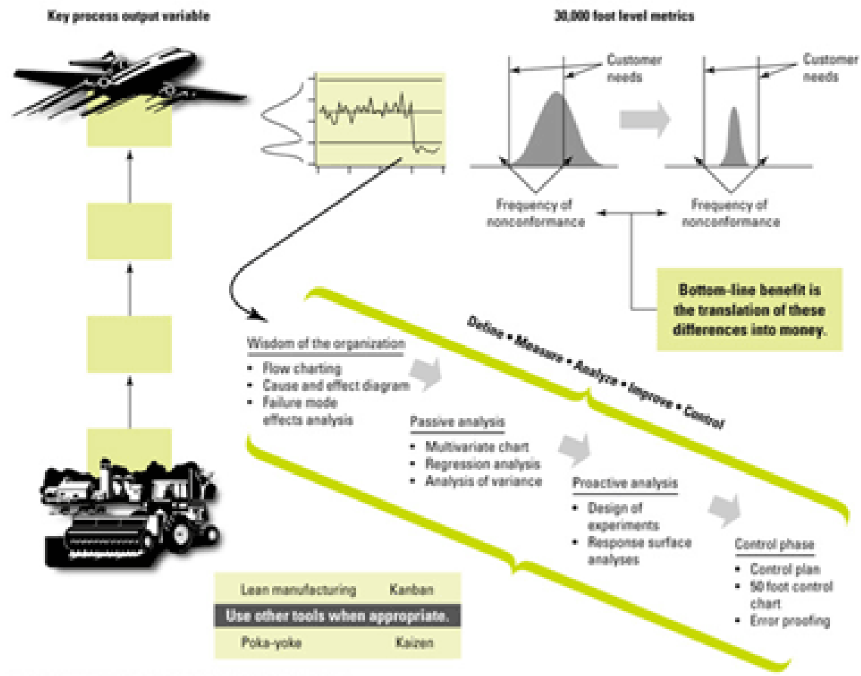
In the airline industry, whenever an airplane departs 15 minutes or more later than scheduled, the event is labeled as a defect. This defect metric is not an accurate representation of the desires of customers who are impacted by the process. If this were a good descriptive metric, passengers would be equally dissatisfied if the airplane were 16 minutes late, as if the airplane were 3 hours late. This is typically not the case since a plane departure that is off by 16 minutes might not affect an airplane transfer at another destination or cause other inconveniences. A departure that is 3 hours late, on the other hand, could cause much more passenger frustration and inconvenience.

### Choosing the right metrics

A Six Sigma business strategy should encourage creating the right metric(s) for each situation. We discourage using a sigma quality level metric (such as assigning 3.4 parts DPMO rate as a Six Sigma quality level). This metric can often lead to the wrong activity and the fabrication of numbers, an extension of the pitfalls previously described.

With a Six Sigma business strategy, we are trying to determine more than just a snapshot of the rates of occurrence for a process. We really want a picture that describes the output of a process over time, along with additional metrics, to give us insight as to where to focus our improvement efforts. Unfortunately, organizations often encourage practitioners to compile data in a format that does not lead to useful information.

**FIGURE 2** Smarter Six Sigma Solutions Measurement And Improvement Strategy With Example Tools






To avoid this pitfall, we suggest infrequent sampling from a process and the creation of "30,000 foot level" metrics for a project (see **Figure 2**). The frequency of sampling should be such that typical noise variability of the process has a chance to occur between each sampling point.

For example, if raw material changes daily, we might select one datum point daily. It should be emphasized that the intent of a 30,000 foot level control chart (and later process capability analysis) is not to understand what might be causing variability or unsatisfactory results.

Our intent is to establish a process baseline and the COPQ/CODN from the vantage point of a final customer, which in **Figure 2** is determined from the frequency of nonconformance before process change.

When organizations use this approach to track key metrics, they typically redirect resources from firefighting modes to fire prevention activities through Six Sigma projects. The reason for this is that many undesirable outcomes, previously considered special causes, would now be considered common causes that can be fixed only through systematic process improvement efforts.

This approach gives focus to what is sometimes called long-term variability within Six Sigma. When the 30,000 foot level metrics and COPQ/CODN indicate that change is needed (see **Figure 2**), teams tap into organizational wisdom to determine where to focus improvement efforts or future passive analyses. Sometimes these techniques capture low hanging fruit improvement ideas that are obviously beneficial. In other cases, there will be a need to test theories through passive analyses using advanced statistical tools (such as analysis of variance, regression analysis and variance components analyses) in order to determine the key process input variables (KPIVs) affecting the 30,000 foot level metrics.

Passive analyses can then lead to proactive testing in the improve phase of Six Sigma, using the power of design of experiments. The control phase would then be used to maintain identified KPIVs such that project improvement benefits are sustained after the Six Sigma practitioner moves on to another project. This approach is a much more powerful strategy than using short-term process entitlement as a driving metric, as suggested by some Six Sigma providers.

### Calculating the cost of poor quality

Organizations are inconsistent in how they count bottom-line Six Sigma project benefits. Some organizations count only hard savings and will not give focus to soft savings--improving efficiency where there is no immediate head count reduction. If only hard savings are considered, there will be minimal effort to improving efficiency when there is no immediate head count reduction or cost prevention activities, such as reducing development cycle times.

Both improved efficiency and cost prevention activities, however, can be very beneficial to an organization and should be, in our opinion, addressed within a Six Sigma business strategy.

In addition to being a controversial metric, soft savings can be difficult to determine. For the same process, one person can calculate a soft savings amount that is considerably different from that calculated by another person. Calculating COPQ/CODN is a subprocess of **Figure 1**, involving employees from multiple levels of the organization.

The ideal process incorporates a rough estimate of COPQ/CODN in the selection of strategic projects. The project team later refines this calculation with the help of a finance representative.

COPQ/CODN should be a common metric considered within all projects. This metric effectively communicates project worth throughout all levels of the organization and ties quality to the bottom line. Even though a COPQ/CODN metric that includes soft savings is, at times, ambiguous, with some agreed upon guidelines this metric can help lead organizations to the right activity. The wise implementation of the COPQ/CODN metric is a critical element that is necessary to any successful Six Sigma infrastructure.

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# The Six Sigma Implementation Process

**Forrest W. Breyfogle III and Becki Meadows**

Smarter Solutions Incorporated

**ABSTRACT**

Six Sigma, if implemented successfully, is a strategic business improvement approach that increases both customer satisfaction and an organization's financial health through systemic process change. In this paper we will be describing a Smarter Six Sigma SolutionsSM (S4) business strategy, which can lead to significant new opportunities and the reduction of fire fighting. This long-term, process focused strategy facilitates companies in identifying and understanding critical business processes such that they become more proactive, as well as productive.

## INTRODUCTION

There is an increasing amount of pressure on organizations to meet stringent quality and delivery specifications at lower prices. Strategic process improvements are needed to increase profit margins while meeting the dynamic needs of the customer. However, organizations often possess a firefighting mentality, becoming overwhelmed with day-to-day activities. Often

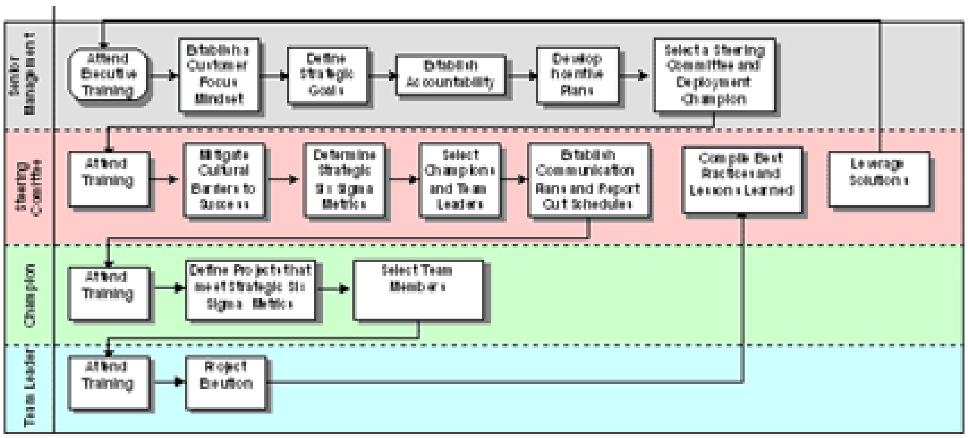


Figure 1: Implementing Six Sigma as an ongoing, closed-loop process [Copyright Smarter Solutions, Inc., used with permission.]

these problems are common cause, chronic issues where organizations losing sight of what needs to be done to make systemic process changes in order to thrive in the "long haul."

Due to excessive firefighting, organizations often incur significant costs of poor quality that are never documented and therefore never really understood. Deploying Six Sigma as a business strategy can aid in identifying focus areas that incur high costs of poor quality.

Six Sigma can be a great success or an expensive failure, depending on how it is deployed. Successful implementation should be viewed as ongoing process of infusing the Six Sigma methodology into an organization's culture such that employees use Six Sigma techniques when they approach their every day work.

The Six Sigma Implementation process, as illustrated in Figure 1 below, requires up front work to develop awareness and generate buy in before projects are started. This paper highlights key steps in this overall process.

**Step 1: Executive Level Training**

The process of implementing Six Sigma begins with the training of executive leaders. It is not enough for executives to support Six Sigma; they must lead the strategy. Senior managers who write memos on the importance of quality but still drive through volume-based metrics will not have success with projects to achieve bottom-line benefits and improve quality. A project to increase quality in this organization will not be accomplished if volume is the only measure and rewarded accordingly. What is measured and rewarded drives employee behavior.

We believe that senior management leadership was often a typical missing element for success with past Total Quality Management (TQM) initiatives. Projects were not typically selected from a strategic, executive perspective. Effective usage of statistical tools often did not get recognized and the overall company culture was not impacted. For true success with Six Sigma, executive level leadership is needed that asks the right questions leading to the wise application of statistical tools and other Six Sigma methodologies across organizational boundaries.

A question we frequently hear from executives is " How does Six Sigma fit with other corporate initiatives?" Our response is that Six Sigma should not be considered just another initiative but should integrate other programs as an overall business strategy at the executive level, as depicted in Figure 2.

High-level control charts can be used to identify common cause issues and help re-focus firefighting activity to process improvement efforts. These charts generate "30,000 foot level" metrics

that can be used to track progress in key areas or Key Process Output Variables (KPOV's) of the business at the executive level, giving insight into what areas of the business should be given focus relative to project selection. Once projects are defined, the tool/strategy that is most appropriate for the given situation (e.g., lean manufacturing, Kaizen, Six Sigma Design of Experiments, or Six Sigma Gage R&R) can then be determined.

**Step 2: Establish a Customer Focus Mindset**

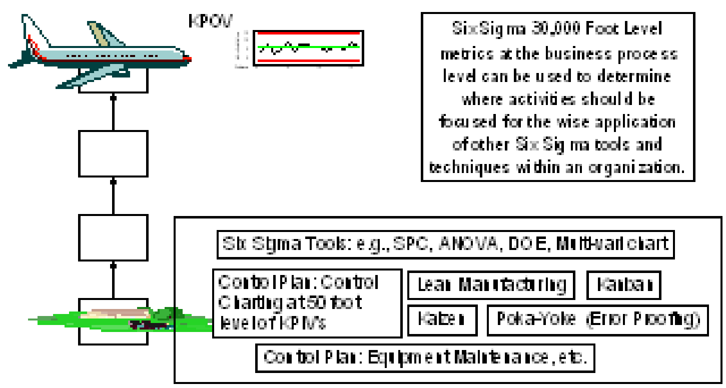


Figure 2: Six Sigma Integration with other Programs [Copyright Smarter Solutions, Inc., used with permission.]

Establishing a Customer Focus mindset within an organization goes hand in hand with Senior Management Leadership when creating a successful Six Sigma business strategy. The factors that are critical to your customers' success are necessary to a process improvement team's true success. Therefore, evaluating customers' perception of quality should be at the forefront of the implementation process.

Every complaint from a customer should be viewed as an opportunity for growth and increased market share, a spotlight on areas needing process improvement focus. The key to success in this initial step is to make it easy for your customers' comments to be heard. Accurately capturing the “voice of the customer” is a laborious process that is frequently skipped over. Organizations believe they understand what is important to their customers but are frequently surprised when they actually spend the time to quantify their actual needs.

Depending on the size of an organization and its core values, the word customer can take on many different definitions. When collecting feedback, care should be taken to include a comprehensive view of customers. By combining external feedback with such things as internal business strategies, employee needs and government regulations, an organization will obtain a balanced list of customer needs.

Learning through customer feedback of what works and what does not, will help to establish a mindset of continual process improvement within your organization.

Jack Welch, CEO of GE and the most visible advocate of Six Sigma, himself has been quoted to say that a business strategy alone will not generate higher quality throughout an organization.

**Step 3: Define Strategic Goals**

Six Sigma must be viewed as a method to meet strategic goals; these goals need to be measurable and have the focus of executive management. Asking the right question means defining the strategic goals of your organization. It requires communicating to your employees what is strategic and why and following up those statements with executive focus and metrics.

Again, Six Sigma should not replace existing organizational initiatives, but instead create an infrastructure that offers a tactical approach to determine the best solution for a given process/situation. There has to be accountability. There must be enthusiasm.

It is similar to a self-help program. What you put into it is what you will get out of it. If you pay it "lip service," you

will get mediocre results. If it is utilized as a business strategy, it becomes a focused approach to meeting the strategic goals defined by executive management, allowing the application of resources in critical areas to the bottom-line.

**Step 8: Mitigate Cultural Barriers to Success**

Many companies attempt to improve products with numerous small changes or “tweaks” to their current processes; however, changes are frequently not documented and the associated results not reported. Substantial results are rarely obtained with this halfhearted method of change. When employees in this type of corporate culture hear of a new initiative such as Six Sigma, they wonder what will be different.

As a program or initiative, Six Sigma risks becoming the “flavor of the month” and will not capture the buy in necessary to reap a large return on the investment in training. With this approach, employees may end up viewing Six Sigma as a program similar to Total Quality Management (TQM) and other quality “programs”, which may have experienced limited success within their organization.

In today’s constantly changing market place companies that are able to embrace change in a focused and proactive manner are leaders in their field. Companies who not only master the technical side of Six Sigma but also overcome the cultural challenges associated with change can realize significant bottom-line benefits.

Companies are embracing Six Sigma not only to reduce defects, but also as a catalyst to change the culture of their company, impacting how employees engage in their every day work.

Every company that takes on Six Sigma, undergoes a unique journey of integrating the methodology into their current culture. Infrastructures vary significantly between organizations, depending upon their distinct culture and strategic business goals. Launching a Six Sigma business strategy is an excellent opportunity to assess current culture in an organization. Consider the following questions:

- How has your company historically dealt with change initiatives?
- Does your company make consistent changes that don’t last?

- How effective are your project teams?
- Are you frequently focusing on the same problem?
- How do our employees attack problems and conduct their daily work?
- What is required within your company culture to make continual process improvement a lasting change?
- What will prevent your company from achieving success with Six Sigma?

A Force Field Diagram can be created to facilitate the understanding of how well Six Sigma integrates with the current culture in an organization, as shown in Figure 3.

By evaluating and weighting the key cultural drivers and restraints to embracing Six Sigma, organizations can develop action plans that enhance the key drivers and mitigate the critical restraints.

Organizations need to have a direction that ingrains a process-focused, proactive mindset into the way all your employees approach their every day work. When successful, Six Sigma becomes part of your culture.

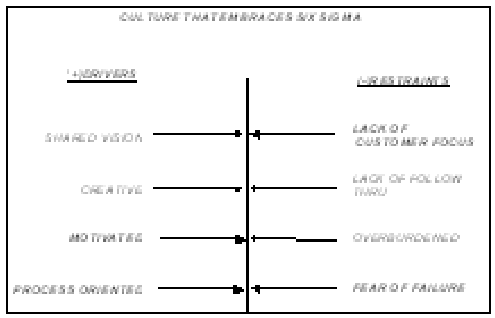


Figure 3: Six Sigma Force Field Analysis [Copyright Smarter Solutions, Inc., used with permission.]

**Step 9: Determining Strategic Six Sigma Metrics**

There is no "one size fits all" metric applicable to every Six Sigma project. Effective metrics are cross-functional, providing a holistic view of the process and contributing insight to the project team. Many resources can be wasted if Six Sigma metrics are not applied wisely [2 and 5] and subsequently used to orchestrate improvement activities, "fire prevention" as opposed to "fire fighting", as mentioned previously. Unfortunately,

much confusion exists relative to the metrics of Six Sigma.

SIGMA QUALITY LEVEL - A basic goal of a Six Sigma program might be to produce at least 99.99966% “quality” at the “process step” or part level within an assembly (i.e., no more than 3.4 defects per million parts or process steps if the process mean were to shift by as much as 1.5). If, for example, there was on the average 1 defect for an assembly that contained 40 parts and 4 process steps, practitioners might consider that the assembly would be at a four sigma quality level, since

the number of defects in parts per million is: $(1/160)(1\ 10^6) \approx 6210$.

A sigma quality level metric can be deceiving. Determining the number of opportunities for any given process can be dramatically different between individuals. For example, one process might have a 50 percent defective unit rate and a sigma quality level much greater than six, while another process might have a .01 percent defective unit rate and have a sigma quality level much worse than six. To illustrate this first consider the counting of opportunities for failure within a computer chip as junctions and “components.” The sigma quality level metric for this situation typically leads to a very large number of opportunities for failure for a given computer chip; hence, a very high sigma quality level is possible even when the defective rate per unit is high. Compare this situation to another situation where there were only a very few number of components or steps required for a process. The sigma quality level metric for this situation typically leads to a very low number of opportunities for failure; hence, a very low sigma quality level metric is possible even when the defective rate per unit is low.

The sigma quality level includes a +/- 1.5 value to account for "typical" shifts and drifts of the mean, where  is the standard deviation of the process. This sigma quality level relationship is not linear. In other words a percentage unit improvement in parts per million (PPM) defect rate (or defect per million opportunity [dpmo]) rate does not equate to the same percentage improvement in the sigma quality level; the improvement from 4.1 to 4.2 sigma quality level is not the same as improvement from 5.1 to 5.2 sigma quality level.

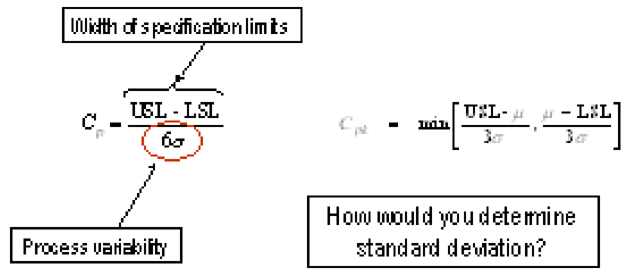


Figure 4: Process Capability Relationships [Copyright Smarter Solutions, Inc., used with permission.]

The sigma quality level metric can only be determined when there are specifications. Service/transactional applications do not typical have specifications like manufacturing does. When a sigma quality level is forced within a service/transactional situation this can lead to the fabrication of specifications and alterations of these "specifications" to make the "numbers look good."

PROCESS CAPABILITY INDICES - Another Six Sigma metric that is used to describe how well a process meets requirements is process capability. A Six Sigma quality level process is said to translate to process capability index values for Cp and Cpk requirement of 2.0 and 1.5 respectively. Unfortunately there is also much misunderstanding with this metric, even though the following basic equations for these metrics are simple. as shown in Figure 4, where USL is the upper specification limit, LSL is the lower specification limit, and is standard deviation.

Computer programs often will not even give the same process capability answer for a given set of data. Some programs consider the standard deviation to be short-term, while others consider standard deviation to be long-term. Implement Six Sigma [2] describes eight different approaches that could be used to determine standard deviation.

We believe that a wise approach to implementing Six Sigma is not to force a sigma quality metric within the various groups and/or projects within an organization.  It is most important to use the right metric for any given situation [2, 5]. However, we must also note that we believe that it is essential that the sigma quality level metric be included, along with the other Six Sigma metrics, within all Six Sigma training. The positive, negative, and controversial aspects of each Six Sigma metric should be covered within the training so that organizations can more effectively communicate with their customers and suppliers.

Often customers and suppliers ask the "wrong question" relative to Six Sigma and other metrics. When an organization understands the plusses and minuses of each metric they can work with their customers and/or suppliers to direct their efforts toward the best metric for a given situation rather than reacting to issues that result from "mandated" metrics that makes no sense.

Care must be taken that the training an organization receives in Six Sigma metrics is not "sugar coated" and/or avoided. In addition to the wise selection of metrics, Six Sigma training should also address the wise use of statistical methodologies, providing insight to how one can best determine what is truly causing a problem.

**Step 16: Project Execution**

From the process map in Figure 1, it is evident that there is much upfront work required to establish a support infrastructure and strategic goals before project work begins.

It is the job of executives and the steering committee to integrate the voice of the customer into the strategic goals of the organization. Much work is done before projects are even started to transform comprehensive customer feedback and internal business goals into strategic Six Sigma goals.

Goals without a roadmap can be detrimental. Once strategic projects are selected, many practitioners (Six Sigma Black Belts) have found our "21-step integration of tools" helpful in developing a plan for specific projects [2 and 5], offering a roadmap for combining the wisdom of the organization and data such that information is created.

**Conclusion**

Six Sigma is a long-term commitment. Treating deployment as a process allows objective analysis of all aspects of the process, including project selection and scoping. Projects should be selected that meet the goals of an organization's business strategy. Six Sigma can then be utilized as a roadmap to effectively meet those goals.

Utilizing lessons learned and incorporating them into subsequent waves of an implementation plan creates a closed feedback loop and real opportunities for improvement. Deploying Six Sigma through projects can lead to dramatic bottom line benefits if the organization invests the time and executive energy necessary to implement a process to create a successful Six Sigma infrastructure.

Creating and implementing Six Sigma does not guarantee tangible benefits within an organization. However, when Six Sigma is implemented wisely as a business strategy accompanied with effective metrics, as summarized in Figure 5, organizations can achieve significant bottom-line benefits. Through the wise implementation of Six Sigma, the success of individual projects can build upon each other gaining the sustained attention of executive management and resulting in a corporate culture change from a reactive or fire-fighting environment to a learning organization, understanding threats and recognizing new opportunities for growth, not only to survive but to actually thrive within competitive environments.

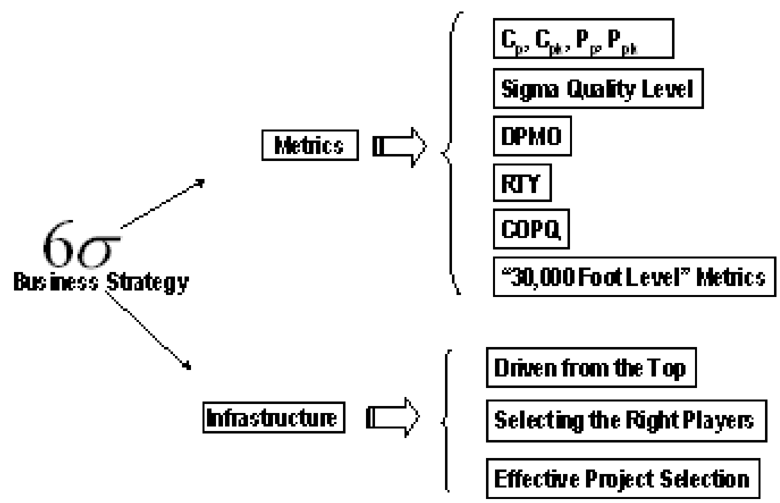


Figure 5: The SixSigma Business Strategy [Copyright Smarter Solutions, Inc., used with permission.]

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**CONTACT**

Forrest W. Breyfogle III founded Smarter Solutions Inc. in 1992 after a 24-year career with IBM. Smarter Solutions (www.smartersolutions.com) specializes in the training and coaching of wisely applied Six Sigma techniques. To expedite the understanding, application, and communication of Six Sigma techniques the training material of Smarter Solutions closely follows the chapters of our books, Implementing Six Sigma [2] and Managing Six Sigma [5]. Forrest is an ASQ fellow, certified Quality Engineer, and certified Reliability Engineer. Forrest can be reached at 13776 U.S. Highway 183 N., Suite 122-110, Austin, TX 78750-1811, 512-996-8288, forrest@smartersolutions.com.

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# Adopting Six Sigma

## A Quality Manager's Guide

## to the Statistically Based Strategy

**by Vanessa R. Franco**

So you've heard a lot during the last few years about Motorola's great squalling, overfed monster of a child Six Sigma, that overglamorized, overrated and over-just-about-everything-elsed quality fad designed to suckle money from the budgets of well-meaning companies and deposit it into the pockets of consultants, trainers, software makers and anyone else wily enough to figure out how to make a buck from a new craze.

Or maybe you've been following the remarkable successes of the Motorola-birthed, community-raised wunderkind Six Sigma, the most recent of the major advances to revolutionize the quality industry through its emphasis on objective measurements and data analysis, with the admirable goal of developing processes with no more than 3.4 defects per million opportunities.

Whatever your perspective, if you work in quality, you've no doubt at least heard of Six Sigma; the 1.5 ó shift; or the define, measure, analyze, improve, control cycle (or some variation thereof). If heard of it is all you've done, you might want to become a little more intimate with the strategy --if not because you think it might be a useful tool for making your company stronger, then at least so you'll have the information to back up your decision not to implement it. The pros and cons of Six Sigma have been frequently debated (see Quality Digest's May 2000 issue for a pair of point/counterpoint articles), so we won't go over that again here, but for those of you who are inclined to look favorably on contemporary quality movements or simply want more nuts-and-bolts information, the following is a basic guide to adopting a Six Sigma business strategy.

**Is it worth the sacrifice?**

One of the most common criticisms leveled at Six Sigma is that it's nothing new, just a repackaging of long-cherished quality techniques, but David Silverstein, managing partner at Breakthrough Management Group, disagrees.

"Six Sigma is, in fact, very special," he maintains. "There is certainly truth to the statement that few of the individual elements of Six Sigma represent new thinking. What is special about Six Sigma is that it puts all of the elements together in a comprehensive system that's structured and

**Sites for Sore Eyes**

Whether you're just now beginning to explore Six Sigma or you need some good resources for your scheme, you should be able to find help on the internet. Possibly the best place on the web to start --and perhaps the only site you'll need to visit --is iSixSigma's www.isixsigma.com. This bookmark-worthy site offers a solid overview of Six Sigma (with links from key terms), discussion forums and Six Sigma Q&As, job postings, a calendar, a daily quality tip, a very thorough quality dictionary, a process sigma calculator, and (in association with amazon.Com) a quality bookstore offering works by Six Sigma's staple contributors. More specific articles address the 1.5 Ó process shift, Six Sigma's usefulness for small companies, case studies, key success factors, and myriad other topics. The extremely handy "tools and templates" section ( www.Isixsigma.Com/tt ) offers an extensive list of links to software providers' sites, some of which offer free demos; help and examples for mistake-proofing, process mapping, creating assorted charts and diagrams, and more; links to online statistics handbooks; and a great deal more information. You can also subscribe to the organization's free e-newsletter, "isixsigma insights," through the site.

For still more information, check out insidequality, quality digest's new web portal, at www.insidequality.com. There you can visit the "ask the experts" disciplined and includes many points of accountability. I liken it to going to classes or seminars and reading books and always saying, 'Wow, that really should make my business better,' but then ultimately being disappointed. In Six Sigma, we're attacking the organizational issues that led us to be disappointed by otherwise great programs. That means tying in the management team, the support functions (human resources, finance, communications, information technology) and all other employees."

"Unfortunately, many small to mid-sized companies feel they cannot enjoy the financial benefits enjoyed by many large firms that have implemented Six Sigma," adds Chuck Mitman, executive vice president of Prism eSolutions, a provider of ISO 9000, ISO 14000 and Six Sigma training, consulting and Web-based support services. "More work needs to be done to educate all types and sizes of businesses that Six Sigma can benefit all. It's certainly important to have a financial commitment, but equally important is having the passion and support behind such a powerful initiative. Regardless of company size, the common basic ingredients to move forward are commitment, passion and financial backing. If small firms want to move forward with Six Sigma, they can choose to pilot the initiative in portions of their business."

Does Six Sigma guarantee success? Of course not. Like any other quality strategy, it's not an off-the-shelf total solution. "Six Sigma can be a great success or a dismal failure; it depends upon how you implement it," says Forrest W. Breyfogle III, president of Smarter Solutions Inc. and author of Implementing Six Sigma: Smarter Solutions Using Statistical Methods (John Wiley & Sons, 1999). "With proper Black Belt training, quality engineers discover how all the tools of Six Sigma can be linked together for effective project resolution. Both large and small companies can benefit greatly from these techniques."

**Should you?**

Perhaps your other quality programs have only produced lukewarm or dynamic but short-lived results. If you view Six Sigma as simply the next step in a string of never-ending, limited-time quality initiatives, you'll be facing an uphill battle.

"Six Sigma is most successful when it's implemented as a corporate business strategy," explains Breyfogle. "It's unfortunate that many benefits achieved from previous quality programs didn't 'stick.' Six Sigma, in contrast, includes a control phase, which is a methodology to keep process improvements from drifting back to the 'old ways.'" Additionally, he says, Six Sigma projects are linked directly to business metrics and the bottom line.

It's important to realize that Six Sigma isn't insular. As Mitman says, "It adds value to existing initiatives by ensuring steps necessary for business financial results."

**Birthing a Six Sigma strategy**

So where does one begin with such an all-encompassing project? "First, I'll suggest (with a little bias) that outside help is almost always necessary," says Silverstein. "That's because there's a lot of undocumented experience about what does and does not work. The first step is getting management on board --that's not a cliché, either. It's critical because a successful Six Sigma implementation

section to review the Six Sigma questions posed to thomas pyzdek (quality digest columnist and author of the Six Sigma handbook, mcgraw-hill, 2001) as well as ask all of your most burning questions on the topic; find online tools such as a sigma calculator and the Six Sigma statistical tool, which uses wizards to guide you one step at a time through real-life data analysis; discover other useful sites through links in the "resources" section; post a classified ad for a black belt in the career center; and watch for upcoming Six Sigma events on the calendar.

If you have enough information to grasp the theory behind Six Sigma but aren't sure how a company applies it in real life, perhaps a few case studies would help. Best practices llc's www.bestpracticedatabase.com provides a host of documents, usually two pages to 12 pages when printed, that focus on what the successful subject companies did right. Most of the documents are available for purchase starting at $4.95, But several are offered as free samples. Companies profiled include General Electric, Motorola, Honeywell, Citigroup and Honda. Finally, if you're serious about your Six Sigma commitment, you may want to check out the International Society of Six Sigma professionals. According to its web site, the isssp's goal is to promote the advancement of the Six Sigma methodology and its practitioners. To this end, the organization provides conferences, symposiums, workshops and roundtable benchmarking sessions. To take full advantage of the site and receive the members-only "extraordinary sense" newsletter, join for free at www.isssp.org.

### Six Steps to Six Sigma Success

Forrest W. Breyfogle III'ss six major steps for completing Six Sigma projects:

**1**. Select one or more key process output variables as primary project metrics.

**2**. Create a methodology to track the key process output variables of the process over time.

**3**. Baseline project relative to customer needs and monetary benefits.

takes a lot of effort, a lot of energy, and time, which means there needs to be real commitment to stick with it. The next step is to build a supporting infrastructure of policies and guidelines on everything from the selection of Black Belts to how to value Six Sigma projects. Only after the support systems are developed is a company ready to launch into training. Once training begins, it's important to monitor your program and to always keep the focus on results. Don't let Six Sigma become a training exercise."

"It's important to have a sponsor and senior leadership support," adds Sandra Muggler of Sigma Leaders, a training and consulting firm. "And,in order to ensure business financial results, it's important to recognize the financial commitment and resources necessary to make Six Sigma successful. Developing a Six Sigma roadmap includes sound infrastructure and planning. It involves completing a baseline assessment in every process to include mapping and measures that always keep the customers and their requirements as the priority. Six Sigma is also a leadership philosophy and steps need to be taken in order to engage passion and commitment from all employees of an organization."

**Six Sigma care and feeding**

Certainly, Six Sigma requires money, time and personnel to implement, and a company planning to adopt it must be prepared for the cost. However, "Six Sigma should be viewed as an investment that has a significant rate of return," Breyfogle says. "Companies that are not 'penny wise and pound foolish' when implementing Six Sigma can have very large benefits."

Silverstein points to consultants, including trainers and facilitators, as the biggest expense. "The other things we like to help people plan for include travel expenses for trainees, laptop computers, new software and training facilities," he adds. "Also, the salaries of Black Belts need to be factored into the equation."

On the subjects of consultants and Black Belts, Mitman agrees. "More and more companies are turning to established Six Sigma professionals to lead their Six Sigma efforts," he says. "However, even the most experienced professional still needs assistance in terms of training materials or Web-based tools in order to implement Six Sigma."

There's no getting around the expense of Six Sigma, but you'd be hard-pressed to find a quality program that wouldn't pose the same problem. If Six Sigma interests you, you'll need to realistically analyze your budget and your resources to determine the source of the initial investment.

**Rethinking Six Sigma**

Six Sigma is a big step to take, and only your company can decide how, when and in what way you wish to adopt it, if at all. A wealth of information is available on the Internet, including articles for and against, case studies, consultants and software galore. Ultimately, though, planning is key: Do your research, ask a lot of questions, and (as always) caveat emptor.

**4**. Determine the key process input variable that drive the kpovs using specific steps (21-step road maps are noted in Breyfogle's books implementing Six Sigma, 1999, and managing Six Sigma, 2000, both John Wiley &Sons).

**5**. Make improvements to key process input variables that have positive impact on kpovs.

**6**. Establish control mechanisms to monitor KPOVd and control KPIVs.

**Watch Out!**

Forrest w. Breyfogle III and David Silverstein cite Six Sigma pitfalls:

* Not building an effective Six Sigma implementation strategy

* Trying to implement a one-size- fits all metric within Six Sigma (Organizations should choose the best metric for each project situation.)

* Trying to "go it alone," using their own training material when implementing Six Sigma

* Having weak, uncommitted leadership

* Failing to recognize the need for a supporting infrastructure

* Not committing Black Belts 100 percent of the time

* Pursuing poorly defined projects that are too broad in scope

**Bona Fide Black Belts?**

Our experts answer the question, "What do you think of the attempt to standardize Black Belt designations by means of certification courses, as American Society for Quality and International Quality Federation are doing?

**Forrest Breyfogle:** There's a lot of variability between the content and quality of Black Belt training offered by providers. Documented project successes and the passing of a certification test should help employers determine whether candidates will adequately fill their Black Belt job openings.

**Chuck Mitman:** I believe there must be a common platform of knowledge and experience level to be in a Black Belt position, and many organizations are offering certifications to answer this. The certifications include passing a detailed exam and at least showing success on two projects along with affidavits from sponsors. Unfortunately, there will be many Six Sigma professionals not able to participate in current certifications simply because they've led projects with different companies and cannot get an affidavit from sponsors to prove successes. Does this make them less qualified than new Black Belts who have just passed a new certification test? Absolutely not! We still have some work to do in terms of agreeing on levels of experience.

**David Silverstein:** I think attempts to create standards for Six Sigma will ultimately fail. That's because, unlike with other initiatives (ISO 9001, for example), companies are implementing Six Sigma in order to drive results. Accordingly, every company I've ever worked with has made changes --and continues to make changes -- to Six Sigma to best meet its own needs. It doesn't need to look the same everywhere. With that said, I would like to see some minimum standards created because it does bother me when I see people advertising things like two-week Black Belt classes. We're hard-pressed toteach Black Belts everything they need to learn in four weeks.

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# Six Sigma and Lean Manufacturing

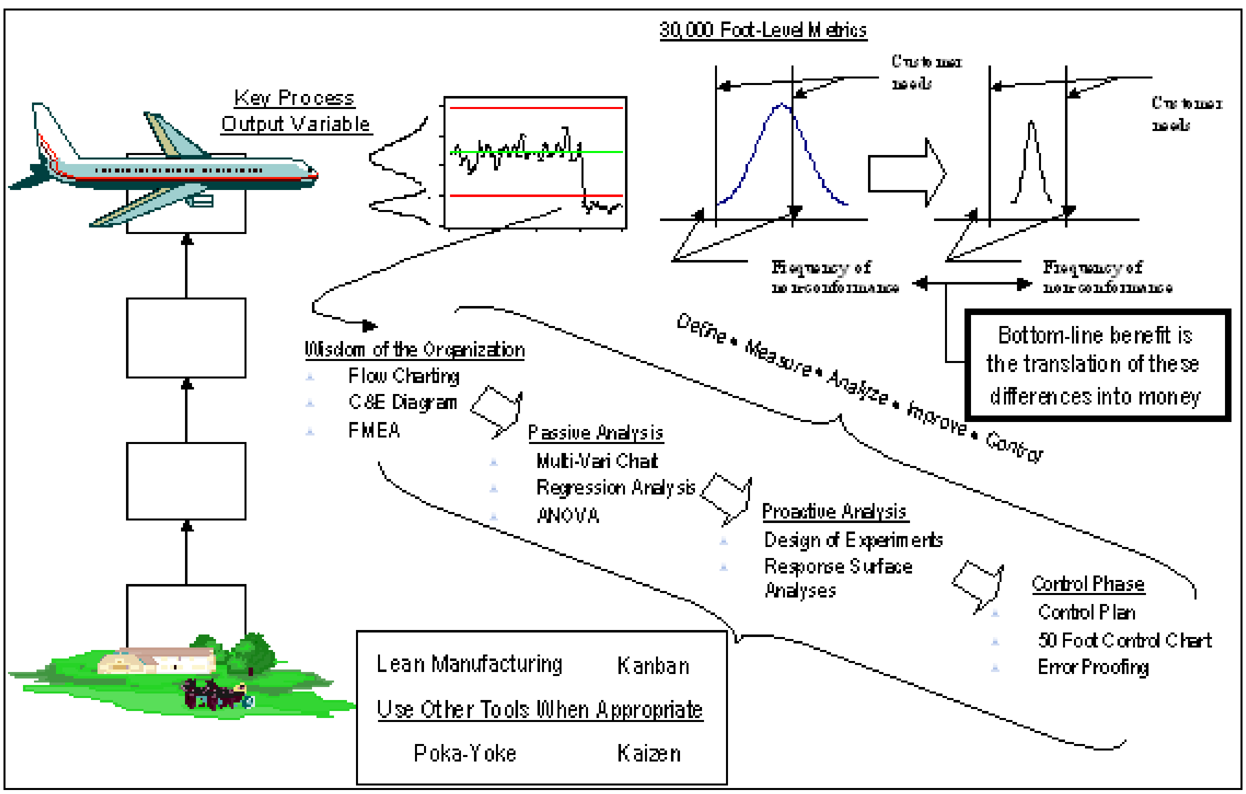
| Return to Articles |

**Purpose -** Described in this paper are the benefits of wisely integrating Six Sigma with Lean Manufacturing.

## Description

Lean evaluates the operation of the factory and restructures the manufacturing method to reduce waste in activities such as waiting, transportation, material hand-offs, inventory, and production. It co-locates the process in sequential order and, in so doing, reduces variation associated with manufacturing routings, material handling, storage, lack of communication, and batch production. However, the implementation of Lean Manufacturing without Six Sigma could lead to an activity focus that is misdirected.

The S4 (Smarter Six Sigma Solutions) view of Six Sigma emphasizes an intelligent blending of the wisdom within the organization with proven statistical tools to improve both the efficiency and effectiveness of the organization in meeting both business and customer needs. The ultimate goal is not improvement for improvement's sake, but rather the creation of economic wealth for the customer and provider alike. Our S4 approach utilizes Six Sigma as a strategic business strategy rather than as a quality program. This does not imply that Six Sigma is to replace existing and ongoing initiatives within an organization. However, this does imply that senior management focus on those processes that are identified as key to the business. These critical systems are then to be the subject of intense Six Sigma Black Belt scrutiny and improvement efforts, using the most powerful soft and hard skills the organization can bring to bear.



We suggest creating a 30,000-foot-level view metric of Key Process Output variables, as shown in the figure above. The organization should then utilize the skills of trained Six Sigma Black Belts to pick the right tool for the right situation when working a project. If a particular 30,000-foot-level metric involves the cycle time of a process, lean manufacturing tools would be a very likely candidate to use within this improvement process, along with other Six Sigma tools that may be appropriate.

Companies that choose to embrace only Lean Manufacturing without Six Sigma concepts are missing out and can have the following problems:

- · Poor choice of the best projects to work on, which could result in either sub-optimizing the system or making the system worse
- · Typically Six Sigma tools such as Design of Experiments (DOE) are not formally considered

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Managing Six Sigma: A Practical Guide to Understanding, Assessing, and Implementing the Strategy That Yields Bottom-Line Success, Forrest W. Breyfogle III, James M. Cupello, and Becki Meadows, Wiley 2001

Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, Wiley, 1999

Smarter Six Sigma Solutions (S4) Workshop Material, www.smartersolutions.com

## About the Author

Forrest W. Breyfogle III is the president of Smarter Solutions Inc., a Six Sigma business solutions company that provides on-site training, public sessions, consulting, and licensing. He authored the leading Six Sigma texts Implementing Six Sigma and Managing Six Sigma and is also the subject matter expert for AQPC's current Six Sigma benchmarking study.

Back to Top

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# Application of Six Sigma To DRG 209

**Arvind Salvekar, Ph.D., Black Belt**
**Smarter Six Sigma Solutions**
**Austin, Texas**

**Introduction:**

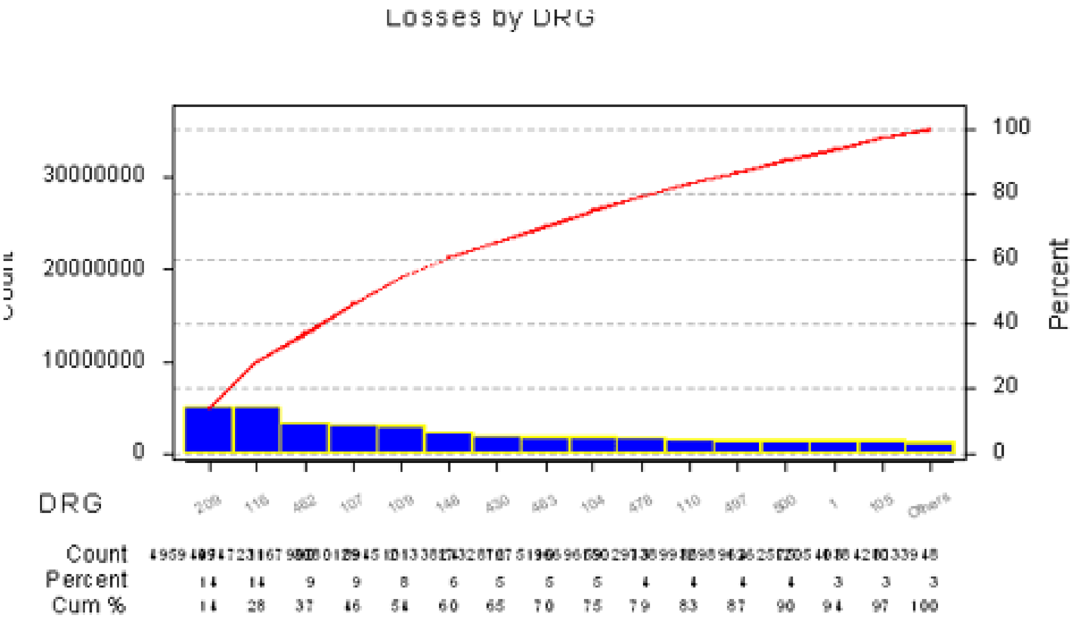
Healthcare delivery by hospitals has become extremely competitive. The reimbursement for the inpatients has been reducing for a long time and it continuously seems to be going down. The inpatient length of stay also has declined significantly over the past decades. Many patients which used to be admitted, e.g. hysterectomy patients, are being treated on an outpatient basis. The reduction of inpatients and reduction in reimbursement for inpatients has reduced the profit margins significantly.

The inpatients have been paid on a prospective basis based upon the disease category. The federal government has designated diagnosis related groups (DRGs) since 1984. Starting in year 2000 it started paying for outpatients on prospective payments basis as well. This particular study investigated application of Six Sigma to DRGs in order to increase the profit potential. The study took place in a community hospital in the Midwest.

This community hospital admits about 14,800 inpatients and about 75,000 outpatients per year. The total revenue of the hospital is about $220 million per year.

**DRG Payments and Profit Margins:**

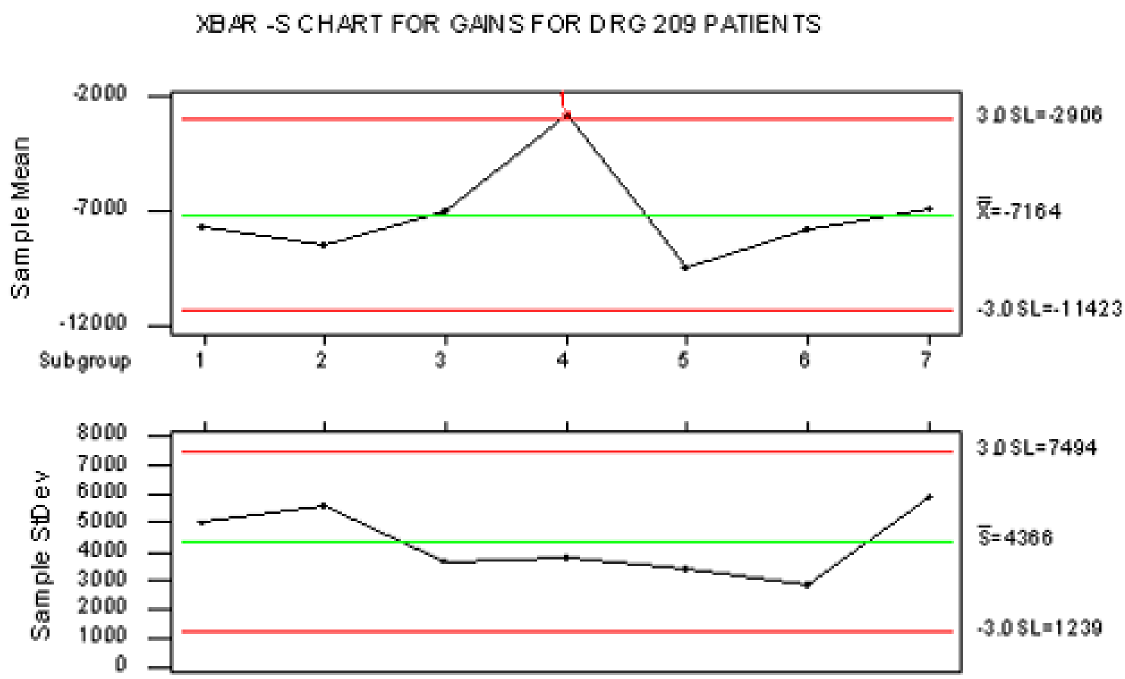
A high level analysis of the DRG payments and the bills was conducted from October 1, 1999 through April 30, 2000. The gain for each patient and each DRG was calculated. A Pareto chart of the DRG losses shows that about 15% of all the high losses are accounted by DRG 209.



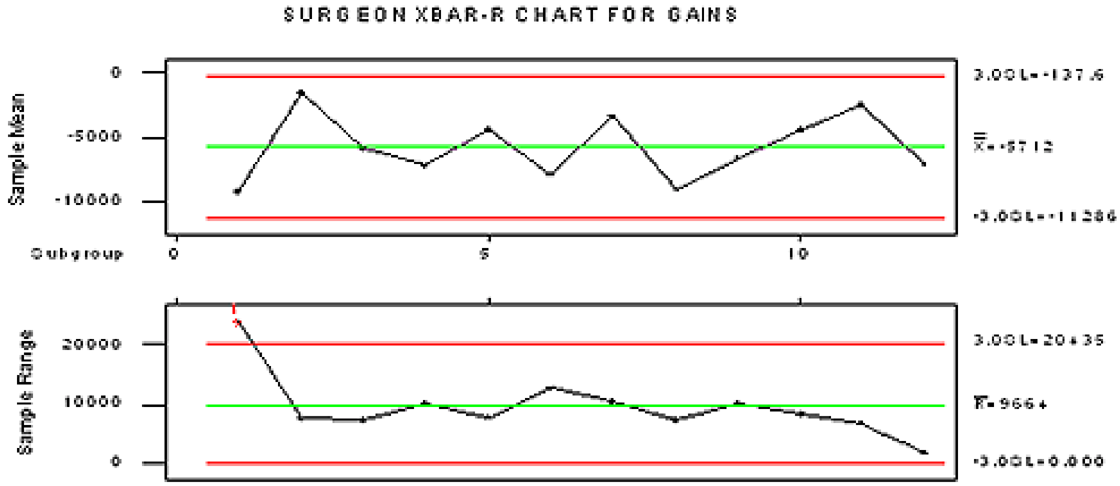

The number of patients expected in this DRG is about 760, one of the highest. Hence it was decided to apply Six Sigma process improvement to DRG 209 patients

**First Level Analysis:**

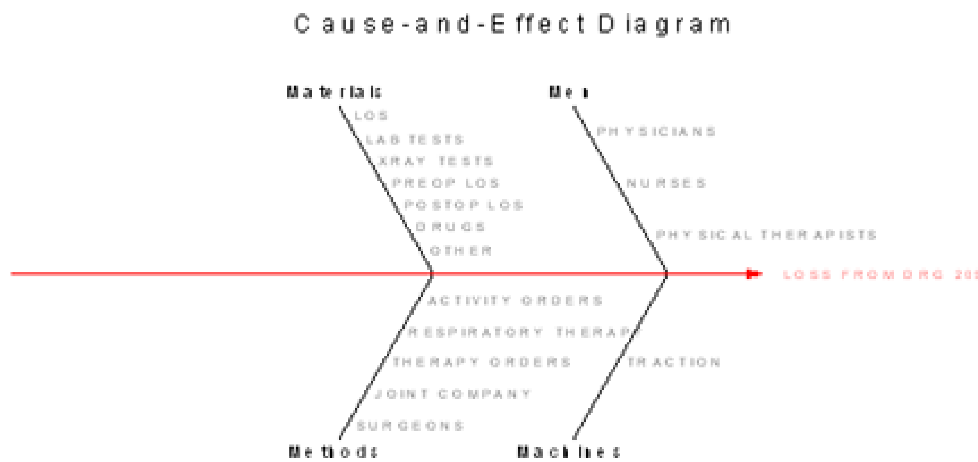
The analysis of DRG 209 loss by patient shows that the losses fit normal distribution with a mean of $6730 and a standard deviation of $671. Random samples of losses were chosen to draw a 30,000 feet level Xbar and S chart. It shows the following:




One of the point is out of control, but generally the process is under control. A similar Xbar â€“ R chart of random samples by surgeons shows the following:

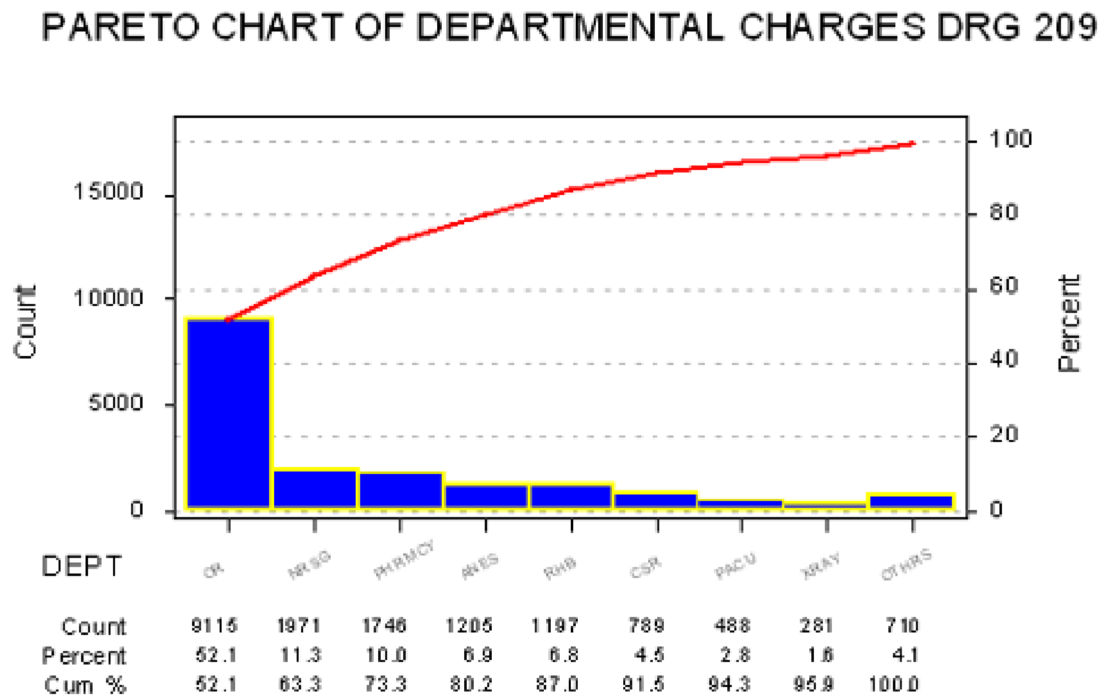



It can be seen that one point is out of control. The annual losses are estimated to be about $5 million per year. Hence further investigation is warranted. The cause and effect diagram shows the following:




**Second Level Analysis:**

All the orders for patients are given by the physicians and are carried out by various departments. A Pareto chart of departmental charges is shown below.




It can be seen from the Pareto chart that about 85% of the charges are generated by surgery, nursing service, pharmacy, anesthesia, and rehab services.

The Xbar â€“ S control charts of all departments except rehab services show that the processes are out of control and there is an opportunity to improve the processes. Analysis of variance (ANOVA) shows the following:

Analysis of Variance Procedure

Dependent Variable: AVGCHRG

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 480 | 27166727021 | 56597348 | 46.95 | 0.0001 |
| Error | 3523 | 4246734955 | 1205431 | | |
| Corrected Total | 4003 | 31413461976 | | | |

| R-Square | C.V. | Root MSE | AVGCHRG Mean |
|---|---|---|---|
| 0.864812 | 54.43674 | 1097.9214 | 2016.8759 |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| ATTNDMD | 25 | 97110400 | 3884416 | 3.22 | 0.0001 |
| PTTYPE | 1 | 558596 | 558596 | 0.46 | 0.4961 |
| DEPT | 8 | 26450801817 | 3306350227 | 2742.88 | 0.0001 |
| ACCTNO | 446 | 618256208 | 1386225 | 1.15 | 0.0217 |

The factors: physician, service department and each patient are statistically significant.

**Level Three Analysis:**

All the patient service orders are given by the physicians. Hence, we need to investigate the physicianâ€™s orders for each department and patient. We will do the analysis in order of charges: surgery, nursing service, pharmacy, anesthesia and rehab services.

**Surgery Department â€“**

The biggest cause of variation is found to be: orthopedic implants and additional OR time.

Let us look at the basic statistics for the charges for orthopedic implant devices.

There is very significant variation in the implant costs. The products can be standardized and a saving of about $1000 per patient can be achieved. This will save about **$750,000** per year.

The analysis of regular allowances for surgeries show that they are quite adequate for the surgeries performed. Only one third of the surgeons use additional OR time. It is possible to learn from other surgeons the techniques that work well and eliminate the use of additional OR time. This will save about **$167,000** per year.

**The total savings in surgery will be $917,000 per year.**

**Nursing Service:**

The biggest charge in nursing service is for routine room and nursing care. These charges are dependent upon the length of stay (LOS). The ANOVA for LOS shows the following:

```
Source     DF        SS        MS        F        P
ATTNDMD    14    91.324     6.523    10.30    0.000
Error     396   250.719     0.633
Total     410   342.044
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           8    5.8750    0.8345            (-----*----)
2          73    4.4932    1.1319  (-*-)
3          28    5.7143    0.7127             (--*--)
4          23    5.8696    0.8689              (---*--)
5          35    5.6571    0.6835             (--*-)
6          15    5.4667    0.6399          (---*---)
7          22    4.8182    0.5885    (--*---)
8          28    5.8571    0.5245               (--*--)
9           4    5.2500    0.5000    (-------*------)
10         17    5.5882    0.6183           (---*---)
11         98    5.5204    0.7493             (*-)
12         31    5.2903    0.6925         (--*--)
13         11    5.7273    0.4671            (---*----)
14          1    6.0000    0.0000   (---------------*---------------)
15         17    5.7647    0.7524             (---*--)
                                   -------+---------+---------+---------
Pooled StDev =   0.7957                  5.0       6.0       7.0
```

The LOS by attending physician are statistically significant. Physicians 2 and 7 may be able to teach other physicians about managing LOS. If we maintain the LOS of 4.8 we will be able to shave 0.7 days from the average LOS and save 532 days per year for a saving of **$226,000 per year.**

**Pharmacy Charges:**

Medication charges are the third most expensive charges for these patients. ANOVA of pharmacy charges by physician shows:

```
Analysis of Variance for AVGCHRG
Source     DF        SS        MS        F        P
ATTNDMD    25  84439085   3377563    15.91    0.000
Error     421  89348607    212229
Total     446 173787692
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1          12    2697.8     634.4               (-*-)
2          77    1366.4     378.1        (*)
3          30    1689.2     299.4          (*)
4          24    2070.8     690.3             (*)
5          36    1615.3     692.2          (*)
6          16    1994.5     373.7            (*-)
7          24    2900.9     575.7                  (*-)
8           2    1481.0      11.7     (---*---)
9          30    1733.4     569.1          (-*)
10          4    1702.0     388.8        (--*--)
11         17    1605.2     258.7         (-*)
12        100    1458.7     321.6         (*
13         33    2120.9     501.8             (*)
14         11    1465.8     244.8        (-*-)
15          3    2400.4     594.4             (--*--)
16         18    1705.1     453.3          (*-)
                                   ------+---------+---------+---------+
Pooled StDev =    460.7               1500      3000      4500      6000
```

The above analysis shows statistical significant difference among the physicians. The pharmacy charges may be related to LOS. So let us develop a regression relationship of charges with LOS.

```
The regression equation is
AVGBILL = 1033.51 + 159.875 LOS

S = 536.218       R-Sq = 30.3 %       R-Sq(adj) = 29.4 %

Analysis of Variance

Source          DF        SS        MS         F       P
Regression       1   9372169   9372169   32.5955   0.000
Error           75  21564701    287529
Total           76  30936870
```

The R square of the equation is only 29.4%. Hence, the LOS does not explain the difference among the pharmacy charges well. This will have to be studied further. However, for the purposes of this paper it is safe to assume that about 10% of the pharmacy charges can be reduced, which will save about **$131,000 per year.**

**Anesthesia Charges:**

Anesthesia is the next most expensive department. ANOVA shows the following tables

```
Analysis of Variance for CHRG1
Source     DF        SS        MS        F        P
MD         25   5034218    201369     4.09    0.000
Error     408  20068551     49188
Total     433  25102769
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           9    1746.1     310.7                              (---*--)
2          77    1217.0     225.6                   (*-)
3          29    1159.1     217.4                 (-*-)
4          23    1178.2     171.9                 (-*--)
5          36    1068.1     208.7               (-*-)
6          14    1211.2     172.7                 (--*--)
7          21    1259.0     238.1                   (-*--)
8           2    1332.5     512.7                ( ------*-------)
9          29    1229.4     244.0                   (-*-)
10          4    1164.5     300.0              (----*-----)
11         17    1143.2     252.3                (--*-)
12         99    1127.2     198.2                 (*)
13         33    1236.5     246.5                   (-*-)
14         11    1367.5     232.9                     (--*--)
15          3    1442.0     102.5                    (-----*-----)
16         17    1110.6     228.1               (--*-)
                                   ---------+---------+---------+-------
Pooled StDev =      221.8                800      1200      1600
```

The results show that the anesthesia charges are statistically different by the surgeons. These charges are related to the amount of surgical time used. The allowable time has been found to be satisfactory by 67% of the surgeons. Hence, if the surgeons would adopt the techniques of others who do not need additional time, it will save the anesthesia charges as well. For the purposes of this analysis it is assumed that about 10% of anesthesia charges can be reduced for a saving of **$49,500 per year.**

**Rehab Therapy Charges:**

The joint replacement patients need a large amount of rehabilitation therapy. ANOVA shows:

```
Analysis of Variance for CHARGE

Source     DF        SS       MS        F        P
MD         25   46203118  1848125    12.24    0.000
Error     421   63562479   150980
Total     446  109765597
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean    StDev   ----+---------+---------+---------+--
1          12    1163.9    224.3                (--*-)
2          77     551.6    362.6            (*
3          30    1365.4    388.0                   (-*)
4          24    1207.4    431.4                  (*-)
5          36    1250.8    306.7                  (-*)
6          16    1255.7    441.8                  (-*)
7          24    1196.3    353.1                 (-*-)
8           2    1365.0     83.4               (-----*----)
9          30    1480.3    456.5                     (-*)
10          4    1386.8    331.3                 (---*---)
11         17    1317.5    395.5                  (-*-)
12        100    1460.2    430.4                     (*
13         33    1215.8    307.5                  (*)
14         11    1359.0    380.4                  (--*-)
15          3    1076.3    348.8             (----*---)
16         18    1328.0    443.7                  (-*-)
                                   ----+---------+---------+---------+--
Pooled StDev =   388.6                 0      1000      2000
```

The results show a significant difference in charges by physician. The rehab therapy charges may be dependent upon the LOS. The regression equation shows:

```
The regression equation is
BILL = 26.1 + 213 LOS

Predictor        Coef     SE Coef          T        P
Constant        26.08       88.90       0.29    0.769
LOS            212.72       15.74      13.51    0.000

S = 418.2       R-Sq = 29.1%      R-Sq(adj) = 28.9%
```

The regression equation is not much helpful in predicting the rehab charges.

Pareto chart of rehab charges show that therapeutic exercises, gait training, athrombic pump, evaluation, passive knee account for 75% of all the rehab therapy charges for these patients.

**Therapeutic Exercises:**

ANOVA of therapeutic exercise shows the following table:

```
Analysis of Variance for BILL
Source       DF        SS        MS        F        P
ATTNDMD      25   3408187    136327     4.00    0.000
Error       400  13633268     34083
Total       425  17041455
```

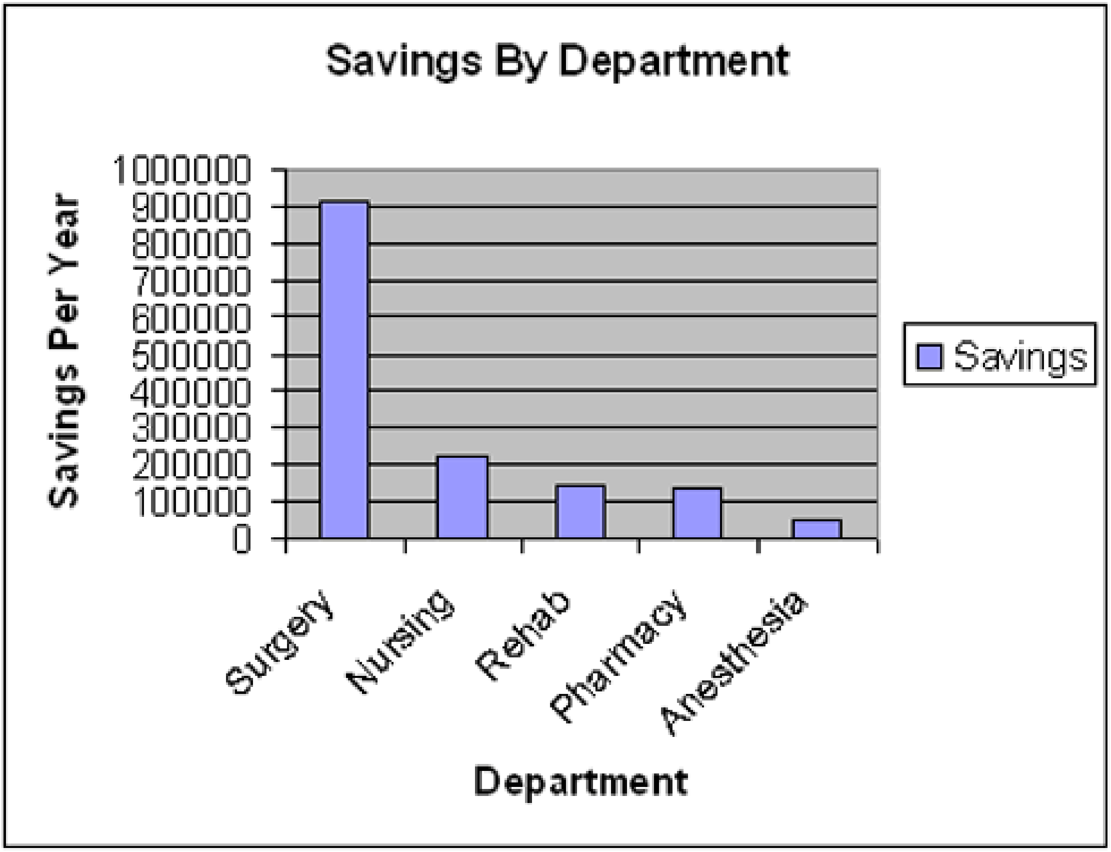
The attending physicians are statistically significant. An analysis similar to others shows that if we hold these charges to about $350 per patient on the average, we could save about **$44,500 per year.**

**A similar approach for gait training will save about $26,500 per year. The savings for all other**

**modalities will be about $66,500 per year. The total saving will be $137,500 per year.**

**Summary:**

The analysis of five departments covers about 85% of the costs of DRG 209 patients. Very conservative recommendations provide the following saving per year:




The total saving proposed by this study is about **$1.5 million per year.**

Back to Top



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Six Sigma Business Strategies
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Training for Excellence

| Return to Articles |

# Training for Excellence: Practitioners Give Best Practices for Teaching Six Sigma

Reproduced from *The New Corporate University Review*, May - June 2000

Six Sigma saved General Electric $1.5 billion in 1999, increased the market value of Allied Signal by 700 percent and boosted sales by more than 300 percent at Motorola.

With these kind of results, it's a wonder that Six Sigma isn't adopted by every business interested in improving performance and boosting revenue. The reason lies in the expense and time it takes to train an employee to implement this quality improvement process.

It is executed by Black Belts, employees who have undergone more than four months of training, which cost their companies a minimum of $ 10,000 per person.

And that's not all a company pays to train for Six Sigma. To do it correctly, experts recommend that the company's upper echelon receive "leadership" or "executive" training so they understand and support the process. Additionally, employees on the production floor should be trained as Green Belts  a level below Black Belts so they can effectively execute Black Belts' instructions.

While the cost and effort sound daunting, particularly for small and midsized companies, when properly executed Six Sigma brings companies thousands, even millions of dollars in cost, time savings and increased revenue. Below, experts give advice and insight on training techniques that get the most return for the cost of implementing this quality improvement process.

**Black Belts**

Six Sigma uses statistical and other analytical tools to reduce the number of defects per million. To implement this process, a company needs to have at least one person qualified to apply the fivestep Six Sigma process: define, measure, analyze, improve and control.

Projects that can be broken down into distinct, manageable components are good candidates for Six Sigma. These include reducing the response time to customer inquiries, improving the accuracy of employee feedback by revising an internal survey, reducing the cost of improving a car's aerodynamic profile or shortening the time it takes to replace an employee.

Becoming a Black Belt usually requires undergoing extensive training in applying Six Sigma tools, which usually takes place outside of the company. Motorola is one of the few companies that provides its own training through its Six Sigma Institute at Motorola University (MU) located in Schaumburg, IL.

There are two basic approaches to implementing Six Sigma, according to Forrest W. Breyfogle III, founder of Smarter Solutions, Inc., an Austin, TX firm that offers Six Sigma training.

"One approach focuses on teaching the tools of Six Sigma," he explains. "The other on first building an infrastructure that supports Six Sigma in project selection, management of projects that lead to bottomline benefits and customer satisfaction improvements."

The latter emphasizes making Six Sigma tools applicable to the projects that attendees bring to the course, which in Breyfogle's opinion makes it "by far the most effective approach for implementing Six Sigma."

With this approach, which takes four months to complete, participants are required to come prepared with a specific project to work on and a laptop computer loaded with Minitab, or other statistical software, and Microsoft Office. The training typically alternates between one week of classes followed by three weeks of applying the newly learned tools to the selected project. Six Sigma training providers typically offer onsite coaching and mentoring for an extra charge.

"In our training, we like to discuss how Six Sigma techniques are best applied to real projects that are brought to the training sessions," Breyfogle explains. "We believe that an understanding of how Six Sigma tools build upon each other is essential. At the beginning of our week two, three and four sessions, we review possible linkages of these tools. We have also found that attendees really like how our training links directly to sections of our book."

Breyfogle uses his own book Implementing Six Sigma: Smarter Solutions Using Statistical Methods, (Wiley 1999), as the text for his classes.

Instruction in various Six Sigma courses include process mapping, causeandeffect diagrams, failure mode and effects analysis (FEMA), process capability analyses, probability, hypothesis testing, analysis of variance, regression, design of experiments (DOE) and statisticalprocess control (SPC).

"Some Six Sigma providers teach Six Sigma metrics using a onesize-fitsall strategy," Breyfogle says. "In my classes, I have noticed that this can lead to students forcing certain measurement techniques to projects where they don't fit. That can be detrimental, because it causes frustration and can lead to the wrong set of actions."

Breyfogle prefers that organizations create a set of metrics appropriate to a particular project.

There are less expensive ways to learn Six Sigma. Some companies opted to adopt the aforementioned first approach and simply to learn the statistical tools required to determine defects per one million opportunities. Instruction on using these tools is now readily available on software programs and various books. But if expert guidance during training and implementation is not available, and company leaders are leery of the changes required in implementation, most will fail in their attempts, experts say.

"An unsuccessful Six Sigma training session occurs when just the tools and mechanics are taught with no plan on how to apply them," says Breyfogle. "[Six Sigma] won't be implemented because people are not asking questions that lead to their maximum utilization."

At the end of the four months, participants present their projects and describe how much they saved their companies in money and production time, or earned in increased revenue. After successfully completing several more projects, a Black Belt is eligible to undergo training to become a Master Black Belt, considered to be the highest degree of proficiency.

After a Six Sigma project is implemented, the last phase, control, starts. The work involved in a Six Sigma project identifies key process input variables that affect process and product criticaltoquality (CTQ) characteristics. After a project is completed, the process input variables are monitored and controlled so that the benefits of a project are sustained after implementation is complete.

**Six Sigma = big changes ahead**

It's understandable that workers on the production line who are affected by changes proposed during Six Sigma implementation be trained to understand the process, but is it so important that the CFO and CEO cost the company thousands of dollars to learn how to get involved? Given the ambitious goal set by Six Sigma, and the degree of change necessary to attain it, the answer from experts, trainers and consultants is always in the affirmative.

To reach this objective, companies must go beyond simply fine tuning existing systems, or teaching workers new skills, and be willing to throw out old processes and methods and start fresh. This is where teaching the company's top executives about Six Sigma plays an important role.

Six Sigma training for company leaders usually takes place in oneto twoday workshops called "Executive Overview," "Senior Executive Program" or "Leadership Training." The purpose of these classes is the same, to gain support and assistance from upperlevel executives by teaching them about Six Sigma and the implementation process.

Six Sigma Qualtec, a training organization in Tempe, Ariz., offers a leadership symposium and an executive overview, two twoday long courses that introduce company leaders to the process. The courses include case studies, explain related terms and provide each participant with a "leadership tool kit" which includes the statistical software used in determining defect rates.

Executives are also shown examples of Black Belt final reports and deployment strategies, the implementation process, successful examples of Six Sigma application and how to benchmark results.

By giving senior managers and executives a clearer picture of the process, leadership training helps them be better leaders in implementing Six Sigma. The training enables senior managers to participate in selecting potential Six Sigma projects and Black Belt candidates and ultimately take more ownership, says Breyfogle, whose company also offers leadership training.

"The reason that Six Sigma is now the "in thing" is because of GE's success with it," he explains. "GE's success with Six Sigma resulted because they created an infrastructure that supported Six Sigma methodologies."

**Requires commitment**

Successful implementation of Six Sigma requires a major obligation on the company's part both during and after Black Belt and leadership training Because Six Sigma is a continuous improvement process, and works best on a per-project basis, Black Belts are best utilized if they aren't returned to their old positions but rather are reassigned to oversee quality improvement projects.

"Six Sigma is not a product you can buy," Motorola's senior corporate vice president and quality director Dennis Sester told the Harvard Management Update. "It's a commitment."

The companies that have had success with Six Sigma say their efforts have been rewarded with significant savings from improved efficiency and quality. Savings usually start at $75,000 per project. Overall, the benefits for companies have been much higher. Polaroid increased annual sales by $1 million because of Six Sigma and Navistar, a truck components manufacturer, saved more than $20 million in the two years that it implemented Six Sigma through Six Sigma Qualtec.

Back to Top

---

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Locations
Our Team
Articles & Solutions
Applications & Benefits
What Our Clients Say
Employment
Contact Us

| Return to Articles |

# Designed for Six Sigma (DFSS): Improving and Quantifying Hardware Test and Software Test Coverage *

***Forrest W. Breyfogle, III**
**Smarter Solutions, Inc., Austin, Texas**

The described procedure can useful when effort is given to making a product Designed for Six Sigma (DFSS) quality. Capturing integration problems during hardware testing and software testing is getting more difficult as time progresses because the number of possible user applications and situations is growing at an increasing rate. In many instances it is impossible to test all possible combinations of input parameters when attempting to insure that there is no combination that can cause failure. The following described methodology can, for example, reduce test resources significantly, while improving the test coverage and effectiveness of hardware test and software test evaluations. This methodology can, for example, efficiently detect a computer product design failure condition that occurs when a particular video driver is used in conjunction with a highly loaded serial port and a new supplier's modem. Supplied also is a test coverage statement (e.g., 90%) for this and other similar failure considerations.

There are many applications, including the System Test of computers before first customer shipment, where this test strategy can yield significant savings. One user reports savings of $30,000 from a reduction in personnel needs and scheduling time. Another user reports with a typical product this approach now reduces prototype costs by an average of $50,000, reduces test labor by $5,000, and gets products to market by an average of 3 days earlier.

To illustrate the basic approach, consider the following, which is described in more detail in reference 1. A company is considering buying several new personal computers to replace its existing equipment. The company has some atypical configurations for its computers; hence, the company wishes to conduct a test to verify that the product will work with its existing peripheral equipment and software. The company believes that there will probably be no future problems if it can find no combination of the levels of three factors that cause failure. Test considerations are to be the type of printer, display, word processor, database manager, spreadsheet, plotter attachment, and network type. Often organizations consider testing each factor individually; however, this approach does not address the above concerns of three factor levels causing a problem. In lieu of a one-at-a-time approach let's first consider only two-level extreme conditions for each factor. This leads to 128 test trials for the two-level combinations from these seven factors (two to the power of seven = 128), which is typically not a reasonable test to conduct using normal test time and resource constraints.

An alternative approach to assessing all combinations of factor levels is to use a Design of Experiments (DOE) or Multivariable Testing (MVT) matrix to define a subset of all possible combinations. Table M from reference 1 describes the tests for 8-test trial combinations from the 128 test trial possibilities, while Table O quantifies the 3-factor test coverage to be 90% for this particular test. In general Table M from Reference 1 describes test matrices and Table O describes the corresponding test coverage where:

- up to 7 two-level factors can be assessed in 8 trials
- up to 15 two-level factors can be assessed in 16 trials
- up to 31 two-level factors can be assessed in 32 trials
- up to 63 two-level factors can be assessed in 64 trials

**Example:**

A product will be "put together" (i.e., configured) in many different ways by a customer. Because of possible design flaws, it is of interest to discover when things will not work together before first customer shipment. In many situations the number of test combinational possibilities can be very large (i.e., 10,000 and more). A DOE or MVT matrix can expedite this test process.

Consider that for this example the system can be comprised of the factors levels in the following table. For example, a customer might have a Mother board with a Network Interface Card, SCSI hard drive, Tape backup from supplier B, slow speed CD-ROM, a fast modem speed, Normal video memory size, and monitor from supplier A.

| **Factor** | **Levels** | |
|---|---|---|
| A. Mother Board | w/ Network Card Interace | w/o Network Card Interface |
| B. Hard Drive | SCSI | IDE |
| C. Tape Backup | Supplier A | Supplier B |
| D. CD-ROM | Slow Speed | Fast-Speed |
| E. Modem Speed | Slow Speed | Fast Speed |
| F. Video Memory | Normal Size | Large Size |
| G. Monitor | Supplier A | Supplier B |

Consider now that it was unknown to the test group that a configuration failure would occur when the Mother board has a Network Interface Card and is used in conjunction with a monitor from supplier B and a large video memory size.

A one-at-a-time approach to test these factors (e.g., evaluating the Mother board's Network Interface Card, Monitor suppliers, and then video memory size) would not typically detect this type of problem. However, chances are that a DOE and MVT matrix of only 8-trials would detect this problem. The following describes this approach.

An eight-trial Design of Experiments (DOE) and Multivariable Testing (MVT) matrix (from Table M2, [1]) takes the form

| **Trial #** | **A** | **B** | **C** | **D** | **E** | **F** | **G** |
|---|---|---|---|---|---|---|---|
| **1** | + | - | - | + | - | + | + |
| **2** | + | + | - | - | + | - | + |
| **3** | + | + | + | - | - | + | - |
| **4** | - | + | + | + | - | - | + |
| **5** | + | - | + | + | + | - | - |
| **6** | - | + | - | + | + | + | - |
| **7** | - | - | + | - | + | + | + |
| **8** | - | - | - | - | - | - | - |

In general Table M [Reference 1] describes test matrices for the following:

- up to 7 two-level factors can be assessed in 8 trials
- up to 15 two-level factors can be assessed in 16 trials

- up to 31 two-level factors can be assessed in 32 trials
- up to 63 two-level factors can be assessed in 64 trials

For example, trial 3 in the above matrix would be:

| Trial # | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| **3** | + | + | + | - | - | + | - |

Which physically is described in the following table with bold faced type.

| Factor | Levels | |
|---|---|---|
| A. Mother Board | w/ Network Card Interace | **w/o Network Card Interface** |
| B. Hard Drive | SCSI | **IDE** |
| C. Tape Backup | Supplier A | **Supplier B** |
| D. CD-ROM | **Slow Speed** | Fast-Speed |
| E. Modem Speed | **Slow Speed** | Fast Speed |
| F. Video Memory | Normal Size | **Large Size** |
| G. Monitor | **Supplier A** | Supplier B |

The question is whether the test will capture the problem described (i.e., a mother board with a Network Interface Card will not perform satisfactorily with monitors from supplier B and a large video memory size). The answer to this question is yes. To illustrate why this is true, the failure would occur when A = -1 (Mother board with Network Interface Card), F= +1 (large size video memory), and G = +1 (Monitor supplier B). This combination of factor levels exists for trial 7; hence, trial 7 would fail. Reference 1 describes a search pattern strategy that could next be followed, if necessary, to determine why this particular trial failed.

Table O within reference 1 can be used to determine the test coverage when no fails occur, along with the number of possible combinations of three factor levels. For the group of concern (i.e., three) the test coverage is 90%.

| | Number of Groups | | | | | |
|---|---|---|---|---|---|---|
| | **2** | **3** | **4** | **5** | **6** | **7** |
| **Percentage of coverage** | 100 | 90 | 50 | 25 | 12 | 6 |
| **Number of possible combinations** | 84 | 280 | 560 | 672 | 448 | 128 |

A computer program [2] extends this basic concept to test designs where any number of factors and levels can be assessed efficiently with calculated test coverage.

Design of Experiments (DOE) and Multivariable Testing (MVT) techniques are also useful to efficiently create test performance models [3]. With this approach someone can, with only a few tests, describe the performance of a computer system or processor relative to user configurations and/or design changes/modifications.

Additional information and a roadmap for integrating measurements with process improvement activities can be found within Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration of hardware/software testing and other Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.

**Reference**


1. *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, Wiley 1992.
2. For more information about a computer program that expedites the creation of test configurations contact Forrest Breyfogle, SmarterSolutions, Austin, Texas (forrest@smartersolutions.com, 512-996-8288).
3. "Improving Processes Using Multivariable Testing (MVT) and Design of Experiments (DOE) Matrices" Forrest W. Breyfogle III, Available at http://www.smartersolutions.com.




Back to Top

---

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Employment
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| Return to Articles |

# Quantifying Variability Using Contributions from Taguchi *

**Forrest W. Breyfogle, III**
**Smarter Solutions, Inc., Austin, Texas ****

The described approach parallels the intent but gives more descriptive information than the Taguchi loss function. When this methodology is integrated wisely with Six Sigma techniques one can expect reduced defects, reduced cycle time, reduced variability, improved customer satisfaction, and improved quality with less effort.

Why in the 1980's did the doors of Japanese automobiles often sound better when they were closed than the doors of automobiles manufactured in America? Upon examination we might find that the two types of doors have a similar basic design; however, there are noted differences when several doors of each type are examined. The component parts of the better sounding door typically measure closer to the nominal specification requirements and exhibit less part-to-part variability. A higher quality sound is then possible since the clearance between mating parts is less, resulting in a tighter fit and better sound when the door is closed. This basic "reduction in variability" and "striving for the best dimension" strategy is consistent with the philosophy of Genichi Taguchi, which differs from traditional industrial practices often found in American industry.

The experimentation procedures proposed by Taguchi have brought both acclaim and criticism. Some claim that the procedures are easier to use than classical statistical techniques, while statisticians have noted problems that can lead to erroneous conclusions. However, most statisticians and engineers will probably agree with Taguchi on the issue that, in the past, more emphasis should have been given to the reduction of process variability within the product design and manufacturing processes.

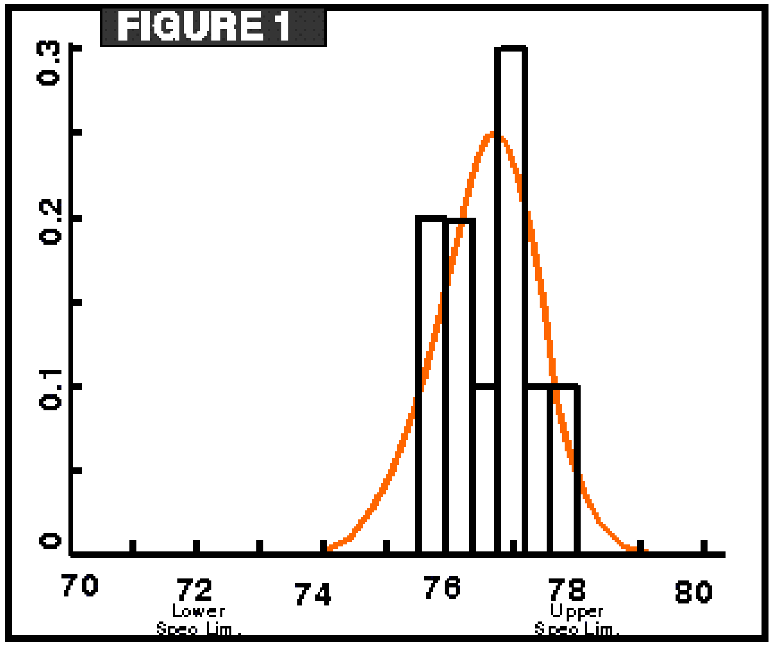
Many articles have been written on the positive and negative aspects of the mechanics used by Taguchi. Rather than dwell upon all the specific mechanics proposed by Taguchi, an overview of a strategy is given here that illustrates the application of Taguchi philosophy with classical statistical tools, at times noting differences between the mechanics.

To illustrate the strategy, consider a specification of 75±3 (i.e., a measurement between 72 and 78 is within specification), where a sample of parts measured the following, relative to this specification:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **75.7** | **75.9** | **76.1** | **76.3** | **76.7** | **76.8** | **76.9** | **77.1** | **77.4** | **77.7** |

A traditional American industry evaluation would be to look at each component part from this type of data as either passing or failing specification. With this line of thinking there often persists either the naive expectation that "all" parts from the population will be within specification or the statement that "out of specification" parts will be discarded/fixed after inspection.

This type of thinking does not typically lead to the consideration of what could be done to improve the process for the purpose of better meeting the needs and desires of the customer. If an industry were to use this alternative line of reasoning, there would be typically less rejected components, and often, less money would be spent on inspection. Instead of evaluating the measurements as pass/fail, the process is better understood if the actual measurement values are examined. One form of pictorially looking at the data is to present the information in the histogram form shown in Figure I with an estimate for the shape of the probability density function (e.g., the bell-shaped PDF shown). From this type of plot we see that the data is skewed toward the upper specification limit, and a noticeable portion of the PDF curve extends beyond the upper specification limit.



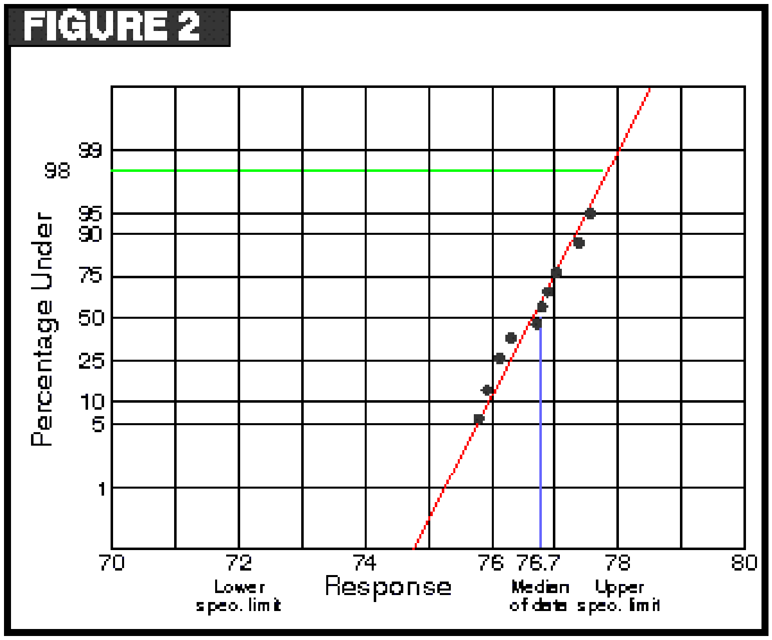

**Histogram and Probability Density Function (PDF) of Data**

The percentage of the total area under the PDF curve beyond the specification limits is an estimate of the total percentage of parts that is expected to be outside these limits. By examining the data from this point of view, we could change our previous "no defect" statement to a percentage failure rate estimate of approximately 3%. However, the accuracy of this estimate is questionable since, firstly, the data may not be normally distributed, which is an important assumption that can dramatically affect an estimated PDF. Secondly, eyeballing this area percentage relative to the total percentage is subject to much error and inconsistencies between people. A better approach to determine this estimate is to make a probability plot of the data.

If data are plotted on normal probability paper and they follow a straight line, then the data are presumed to be from a normal distribution and a percentage of population estimate is obtainable directly from the probability paper. Because of this more direct approach, the inaccuracies from the two previously discussed problems are reduced, yielding a more precise estimate. Some computer programs can create a normal probability plot for the previous data, such as the one shown in Figure 2. This type of plot can also be created manually by using special probability paper (Breyfogle 1992), where the ranked data values are matched with plot positions that can be determined from tables or equations.

The normal probability plot shown in Figure 2 for the above set of data indicates (if the samples are random) that approximately 2% (i.e., 100 - 98 = 2) of the population would be outside the upper bound of the specification limit of 78. We also note that the median, or mean, is skewed by approximately 1.7 from the nominal specification criterion (i.e., 76.7 - 75.0 = 1.7).

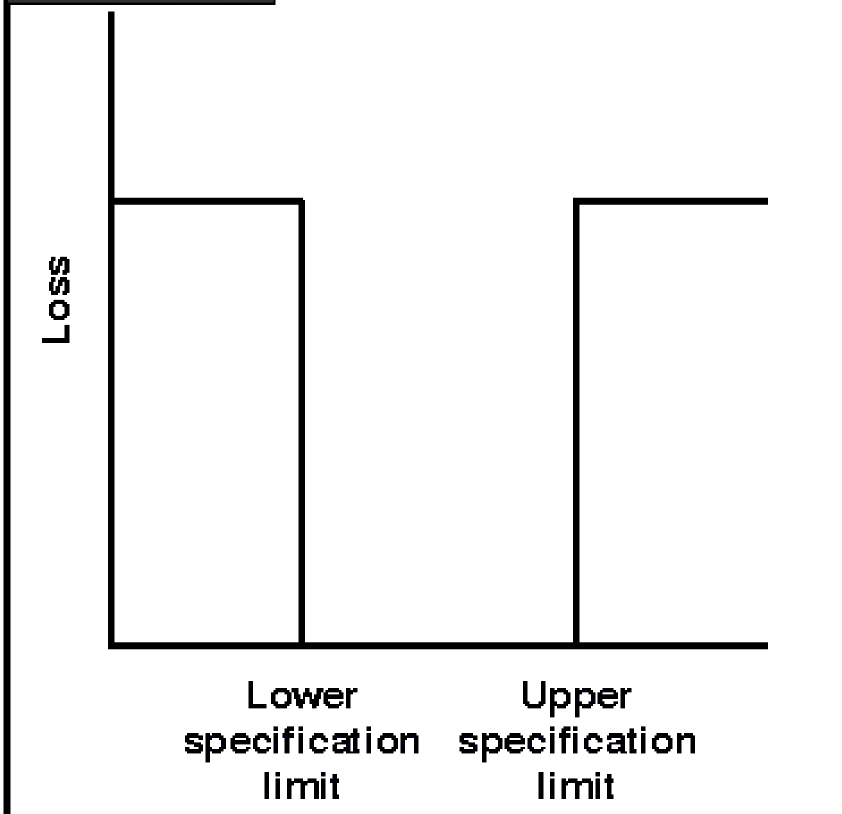
By looking at the actual data values in lieu of making pass/fail component judgments, we are now able to make an assessment with a relatively small sample size that the process mean should be adjusted lower to decrease the amount of unsatisfactory production parts. We also note the amount of variability that the process is producing relative to specification (i.e., 98% of the part-to-part variability
consumes approximately 50% of the specification range). In some situations this amount of variability could lead to a noticeable amount of inconsistency in part-to-part performance, even though all components may be within specification. A Taguchi philosophy stresses the importance of reducing variability; however, management is often more interested in explanations that relate to monetary units, than in part tolerances and data variability. To make this translation, Taguchi suggests using a loss function.




**Normal Probability Plot of Data**

To illustrate the Taguchi loss function, consider first Figure 3, which shows how component loss is typically viewed by American industries. From this figure, it seems reasonable to question the logic of considering that there is no loss if a part is at a specification limit, while another part has a loss value equal to its scrap value if it is barely outside its specification criteria. An alternative is to consider a "loss to society," as expressed in Taguchi's Loss Function. Figure 4 shows a quadratic loss function where scrap loss at the specification limits equates to that shown in Figure 3. However, with this strategy a component part has an increasing amount of loss as it deviates from its nominal specification criterion, even though it may be within its specification limits. Unlike Figure 3, the curve in Figure 4 does not have the illogical dramatic shift in loss when a part exactly meets specification versus when it is slightly beyond the specification limits.

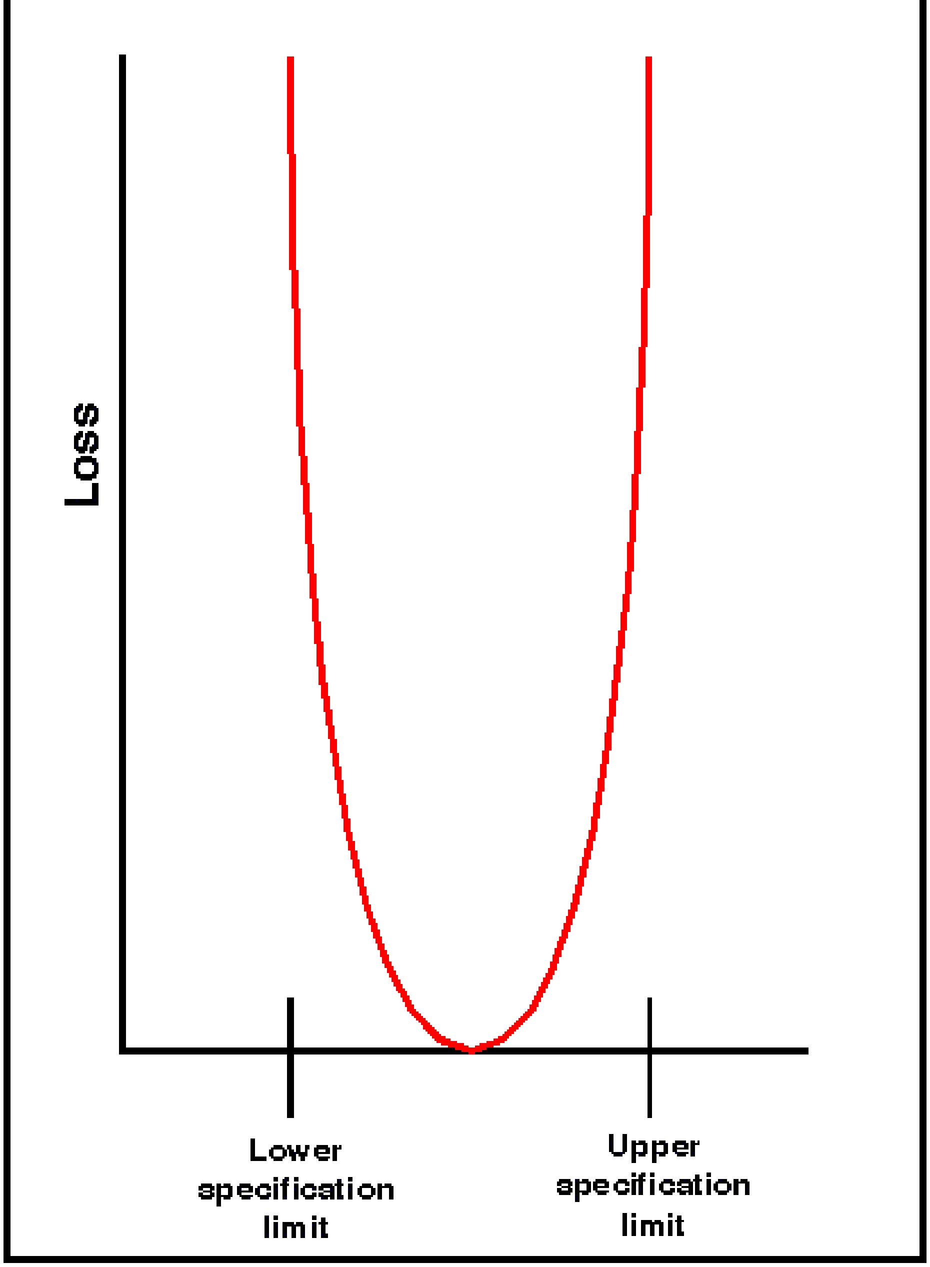
FIGURE 3




**Traditional Method of Interpreting Manufacturing Limits**
**(Reproduced from Implementing Six Sigma: Smarter Solutions using Statistical Methods Forrest W. Breyfogle III, Wiley, 1999)**

A Taguchi loss function strategy emphasizes reducing variability and striving for a process mean that equates to the nominal specification. Companies using the basic philosophy of examining key specifications and striving for a mean of measurements equating to nominal specification values, along with a reduction in data variability, can expect to produce products that are perceived by customers to have higher, more consistent quality. In the television industry, for example, the quality of a television picture would then be expected to be consistently good from television to television (as opposed to a picture on many televisions that is good enough when they barely met specification).

FIGURE 4




**Taguchi Loss Function**
**(Reproduced from Implementing Six Sigma: Smarter Solutions using Statistical Methods Forrest W. Breyfogle III, Wiley, 1999)**

Manufacturers often need to break the paradigm of simply assessing whether component parts are "good enough," relative to specification limits. More effort should to be given to identifying continuous response specifications that are an important part of meeting the needs and desires of customers. These responses should then be monitored to assess product performance relative to nominal specification criteria. If a probability plot or Taguchi loss function analysis indicates that a response parameter needs improvement, statistical tools are often useful to gain insight to the effects from various process input parameters. Design of Experiments (DOE), for example, can be used to efficiently identify the most beneficial process parameters to change.

Management should consider the questions they are asking of their subordinates. The wording of their current questions might be leading employees to an inefficient 100% go/no-go evaluation, in lieu of an efficient sampling plan using continuous variables. By simply rewording their request, management could get more information with less resources.

Additional information on Taguchi methodology and a roadmap for integrating measurements with process improvement activities can be found within Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and

Sons, New York, NY, 1999. The wise integration of Taguchi techniques and other Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.

** From *Tools & Manufacturing Engineers Handbook*, Volume 7, "Continuous Improvement," Society for Manufacturing Engineers, 1993, pp. 10-14 through 10-19.



Back to Top

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| Return to Articles |

# Designed for Six Sigma (DFSS): Improving the Failure Rate or Mean Time Between Failure(MTBF) of Products *

**Forrest W. Breyfogle, III**
**Smarter Solutions, Inc., Austin, Texas**

Described is a methodology that can dramatically reduce the reliability testing time for products where effort is given to determine product failure rates and Mean Time Between Failure (MTBF) rates. In addition, this reliability assessment and improvement approach can yield a more accurate projection of MTBF and failure rates for future product designs than with a traditional approach. The reliability assessment and improvement approach is applicable to both components and repairable systems (constant and non-constant failure rates), which might follow a Weibull, Poisson, or some other distribution. This approach not only quantifies a rate but also focuses on what could be done to improve the design to achieve the best possible reliability and customer satisfaction for the current technology.

Often test organizations are asked to predict or certify future field failure rates or the reliability of a device that is to be released from development. This question is basically impossible to accurately answer using only prototype samples. To support the logic behind this statement consider the following. First, prototype samples can not really be considered a random sample of future product since the variability of future manufacturing processes over time is not represented in the sample. Secondly, test acceleration models often do not accurately correlate and project field failure rates. Thirdly, usually there is not enough time and/or samples to adequately test the device or system.

There is an alternative to this traditional reliability test approach that can give more information with less effort; however, some issues need to be addressed differently. First, we need to recognize that the failure rate of a product cannot be any better than the technology within the product. To illustrate this, consider televisions from the 1950's. A company could specify a Mean Time Between Failure (MTBF) rate target of 100,000 hours; however, that does not mean the product could physical achieve such a criterion. Television reliability is not only a function of manufacturing processes it is also a functional of the technology that comprises the television. Television reliability can not be improved to meet such an aggressive reliability criterion until tubes are replaced with a newer technology. The best product developers and manufacturers can expect to do is to create a design that will yield the lowest failure rate within current technology and monetary constraints.

This test dilemma does not mean an organization has no hope of estimating a failure rate or Mean Time Between Failure (MTBF) for a product. Typically one can determine an expected failure rate of a new product by looking at field data from previous product designs that are similar. These different product design vintages can be combined using control charts and normal probability plotting techniques [1] to describe expected product-to-product variabilities that were developed using the same basic process. Technology changes within a new product could be addressed as percentile uplift or degrade to a historical average number. This evaluation would be much less costly than performing an elaborate test that tries to quantify this number and would probably be more accurate.

It is not suggested here that all tests be abandoned since an accurate failure rate cannot be determined. However, instead of using a test that is to certify or predict a failure rate, a more powerful test is one that focuses on potential problem areas of a new design. These problem areas can be determined by examining field data using a Pareto chart and/or through a brainstorming session that identifies high risk new technology areas. Identification and then resolution of these problem areas will reduce future field problems.

Multivariable Testing (MVT) and Design of Experiments (DOE) techniques are an efficient approach to quickly address issues in high risk areas. Example 43-3 [1] describes a situation where a sophisticated power supply design needed to be tested 23x10*6 hours with no failures in order to "certify" a 100,000 hour Mean Time Between Failure (MTBF) criterion [1]. In lieu of this expensive/impossible approach, a Multivariable Testing (MVT) and Design of Experiments (DOE) approach [2] using 11 factors in 32 trials on one power supply identified a design problem. This type of problem would not, in all likelihood, have been detected by the previously described "traditional" reliability test.

An extension of traditional Multivariable Testing (MVT) and Design of Experiments (DOE) techniques is described in reference 3. In this reference a methodology is described that can efficiently detect combinational problems, which could affect the field failure rates of products.

Additional information on this reliability test strategy and a roadmap for integrating measurements with process improvement activities can be found within Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration of reliability assessments and other Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.

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Back to Top

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---

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| Return to Articles |

# Reengineering a Customer Satisfaction Survey Questionnaire Yields Improved Customer Feedback *

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Consider how you reacted when asked to complete a recent survey questionnaire.

- Did you think that the survey was beneficial?
- Did you think that your feedback would generate improvements?
- Did you think there were too many questions?
- Did you complete the survey form?

When reviewing survey feedback do you ask any of the following questions?

- Are these response levels okay?
- Are there any improvement trends?
- What should be done differently to improve faster?
- Might the results be different if the survey were taken a month later (e.g., a gloomy time of year might yield a less favorable response than a bright time of year.)

With traditional surveys it is difficult to answer these questions. Why?

- The time between surveys is too long.
- There is an upper response limit (e.g., 5 is assigned "Excellent").
- There is no formal communication channel that collects and prioritizes Improvement opportunities. Often only average responses are considered.
- Typically the comment section contains the most beneficial information. However, it is often difficult to quantify and react to these issues.
- People do not see the benefits of surveys.

In addition, many internal opinion surveys are in contradiction to Edwards Deming's management principles. Opinion surveys are sometimes used to reprimand individuals for not performing satisfactory. Surveys do not often give meaningful insight to what should be done different to improve the processes. Customer feedback is important; however, there has to be a better way to get it!

A Statistical Process Control (SPC) based survey using the tools Six Sigma can

- Give better information that is more timely.
- Give direction on what should be done different to improve processes.
- Use less questions and get a higher return rate.
- Get more information with less work.
- We helped one company institute an internal opinion survey based upon SPC techniques so that it addressed all the above issues. A few of the differences from this survey are listed below.

- The survey consisted of only three questions.
- One out of every 12 of the total population is surveyed monthly.
  Results are analyzed monthly for special and common cause variation using control charts.
- Normal probability plotting techniques graphically illustrated the variability of question responses when common cause variability existed.
- A Pareto chart of votes from "improvement suggestions" led to a more efficient and effective approach to obtaining direction when desiring constructive change that would eventually yield better survey responses.

Customer feedback is important; however, often much money is spent on surveys with minimal gains. Wisely applied SPC techniques can lead to surveys that give more information with less work.

Additional information about this application example and a roadmap for integrating measurements with process improvement activities can be found within Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.



Back to Top



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| Return to Articles |

# Business Process Reengineering (BPR) Case Study: Reducing Product Development Cycle Time *

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This case study illustrates how the application of Business Process Reengineering (BPR) does not just apply to large organizations. It can also apply to department and functional units using team brainstorming techniques. To be competitive, it is important to develop new products quickly. The following steps led to a ranked list of improvement opportunities for a hi-tech product development organization and a specific action item. **

- A big picture view of the process steps to develop a new productwere identified as Design, Test, and then Manufacture.
- Brainstorming sessions in department meetings identified improvement opportunities. Voting created a prioritization list of these ideas.
- The top 10 items from each department list was combined and then reduced to the most frequent and/or best perceived issues
- This shortened summary was presented back to all employees as a survey where they selected opportunities they thought were the most important to implement. Results were put in a Pareto chart format.
- Interestingly, one improvement opportunity receiving many votes was not a high-tech issue. The issue was that the length of time to procure capital equipment was excessive and increased the product development cycle time.
- A team investigated this procurement process improvement opportunity further.
- The procurement process for both capital and non-capital equipment was documented and a scenario was created where a $1,000 piece of equipment could cost over $20,000 because of lost productivity. This large amount of loss occurred because the procurement of capital equipment involved a lengthy justification process which yielded a long period of inefficiency.
- A brainstorming session searching for process improvement ideas in this area of the business yielded an improvement suggestion that the current capital equipment and expenses processes should be abolished. The rationale was that the company could save a lot of resources if capital and expense equipment budgets were created and implemented collectively. The suggestion was that budget items such as new computers (capital equipment) lumped together with expense items such as travel, education, and supplies (with some tax consequence weighting). A company could then easily allocate their total expense and capital equipment budget dollars at the department level as a percentage of gross salaries of the individual departments (perhaps each department would receive a total budget amount of 10% of their gross salaries). This process improvement could also save managers a very large amount of time fighting for budget dollars.

**Conclusion**: Often much effort is given to improving individual processes. If this approach were taken in the previous scenario, much effort would be given to improve the expense and capital procurement processes individually. Much larger process improvement could also save managers a great deal of time fighting for budget dollars.The referenced articles can give insight to efficient approaches for measurements and improving customer satisfaction.

Additional information and a roadmap for integrating measurements with process improvement activities can be found within *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.

**** Excerpts from *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY 1999**



Back to Top

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| What Our Clients Say | Employment | Contact Us |

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| Return to Articles |

# Improving Processes using Multivariable Testing (MVT) and Design of Experiments (DOE) Matrices *

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A Forbes article, " The new mantra: MVT" [1], describes the benefits of a technique called multivariable testing (MVT). The approach is more typically described as Design of Experiments (DOE). The name, MVT or DOE, does not matter. What matters is that the approach is very powerful and can help organizations improve their "bottom line" and/or be the difference between survival or not. The technique can also be very powerful when making a product Designed for Six Sigma (DFSS).

Applications of approach described in the article are:

- reducing the rejection rate of a touch-sensitive computer screenfrom 25% to less then 1% within months.
- maintaining paper quality at a mill while switching to a cheaper grade of wood. reducing the risks of misusing a drug in a hospital by incorporating a standardized instruction sheet with patient-pharmacist discussion.
- reducing the defect rate of the carbon-impregnated urethane foam used in bombs from 85% to zero.
- improving the sales of shoes by using an inexpensive arrangement of shoes by color in a show chase, rather than an expensive flashy alternative.
- reducing errors on service orders, while at the same time
- improving response time on service calls.
- improving bearing durability by a factor of five.

These referenced examples represent only a small portion of possible money saving opportunities for organizations. These techniques are truly very powerful. However, implementation issues can arise. Organizations can have problems:

1. determining how to apply the techniques to "their situation."
2. selecting the important variables and levels of variables to use in an experiment.
3. determining what test matrices to incorporate.
4. analyzing data and presenting results so that the best corrective action is taken.

Organizations wanting to use MVT (DOE) can save a lot of time and resources by addressing these issues up-front in conjunction with other Six Sigma tools.

To illustrate the power of the concept, consider that a brainstorming session was conducted and there were 7 factors that were thought could affect a response. Factors for a computer performance test might include load on the system, network type, and number of stations. Factors for a reduction of high school absenteeism study might include age of student, economical background of student, and whether the student would be called if they were absent. Factors for the development of pharmaceutical products might include quantifying an ingredient, age of patient, and sex of patient. Factors for the improvement of product reliability might include various design options and supplier considerations as a function of user configurations.

The seven factors are then described as A, B, C, D, E, F, or G, where each factor has two-level possibilities described by a + or - sign. For example Network type might be designated as an "A" with level possibilities of type 1, designated as a "+", and type 2, designated as a "-". An 8-trial design of the 7-factors considerations determined from a table M with reference 2 is

| Trial # | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | + | - | - | + | - | + | + |
| 2 | + | + | - | - | + | - | + |
| 3 | + | + | + | - | - | + | - |
| 4 | - | + | + | + | - | - | + |
| 5 | + | - | + | + | + | - | - |
| 6 | - | + | - | + | + | + | - |
| 7 | - | - | + | - | + | + | + |
| 8 | - | - | - | - | - | - | - |

A response is then obtained for each trial. The "best estimate" effect for each factor is determined by subtracting the average "-" response for a factor from the average "+" response. Significance tests using effects plots, t-tests, and/or analysis of variance (ANOVA) determine if each factor effect significantly affects the response. The significant effects can be used in a model that predicts a response for other factor level settings and/or directing process improvement activity.

An extension of traditional MVT and DOE techniques is described in reference 3. In this reference a methodology is described that can efficiently detect combinational problems, which could affect the field failure rates of products.

Additional information and a roadmap for integrating measurements with process improvement activities can be found within Implementing *Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration of MVT (DOE) and other Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.

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Back to Top

---

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Home
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What Our Clients Say
Employment
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| Return to Articles |

# Six Sigma Measurements and the Implementation TQM, BPI, and the Philosophy of Deming *

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**Smarter Solutions, Inc., Austin, Texas**

An organization is in trouble. It needs to improve now or it will not survive!! However, which roadmap is best? There is Total Quality Management (TQM), Business Process Engineering (BPR), Business Process Improvement (BPI), the philosophy of Deming, and other "new" programs. Confusing?-Yes. However, if change is approached wisely, organizations and employees gain much. Unfortunately, if change is not approach wisely, the effort can create more harm than good.

Rather than trying to improve and/or re-engineer all manufacturing, development, business, and/or service processes within an organization, it is best to start by looking at the big picture and work down. Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999 describes a roadmap that helps with this effort. An organization might start by control charting monthly profits for the last several years. A normal probability plot of common cause variability from recent months of this metric will show expected month-to-month variability that could be representative of future results unless something is done different.

After observing the control chart and normal probability plot of month-to-month variability, it might be apparent that change is needed. This type of situation can lead to excellent candidates for Six Sigma projects. A Pareto chart is often helpful to identify opportunities for improvement. Teams working with Pareto charts can brainstorm for improvement opportunities or focus areas for other team concentrations. After viewing the financial information of an organization presented in Pareto chart format, a cross functional team might be formed to focus on reducing the number of manufacturing defects using Six Sigma tools.

This new cross-functional team should then focus on measurements and improvements for this target area. This work might then lead to the reengineering of a process using Design of Experiment (DOE) techniques targeting the reduction of insufficient solder defects (identified as the largest root failure case in a Pareto chart). Improvements in this manufacturing process and other focus areas (e.g., business, service, and development processes) will cause our big picture control chart of the financial metric to then go out of control to the better.

Target areas are added and deleted as necessary through this tops down approach. Organizations find that they reap more benefits in a shorter period of time by focusing on monetary issues that are important to executives. When employees at all levels within an organization participate with process improvement and reengineering changes instituted by executives, organizations find that improvements are more beneficial and long lasting.

Additional information and a roadmap for integrating measurements with process improvement activities can be found within Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration of TQM, BPI, and the philosophy of Deming, with Six

Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.



Back to Top

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| Return to Articles |

# Measurement of Process Capability: Cp, Cpk, Pp, Ppk, Probability Plotting, and Six Sigma *

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Process capability and process performance index studies are to assess a process relative to specification criteria. Quantification of this measurement is often reported using units Cp, Cpk, Pp, and/or Ppk. Statisticians often challenge how well commonly used capability indices do this; however, the fact remains customers often request these indices when communicating with their suppliers. A customer might set process capability/performance targets then ask their suppliers for their level of conformance to these targets.

The equations for process capability/performance indices are basically very simple; however, they are very sensitive to the input value for standard deviation (s ). Unfortunately there can be differences of opinion on how to determine standard deviation for a given situation. Some organizations consider Cp and Cpk are a measure of "short-term" capability, while Pp and Ppk are a measure of long-term capability; however, all organizations don't agree with this procedure. Motorola considers Cp and Cpk to be long-term. An internal or external process is considered to be Six Sigma if Cp is equal to or greater than 2.0 and Cpk is equal to or greater than 1.5. A process with these indices has a calculated defect rate of 3.4 parts per million. In addition, it should be noted that the traditional equations are for normally distributed data. Computer programs can often address situations where data are not from a normal distribution.

When using process indices to describe the quality of a process, we need keep in mind that this calculation quantifies the tails of a distribution and the uncertainty of the result from this calculation is typically very large. To illustrate how this can impact an organization, consider using reported process capability number(s) to choose the best supplier. Differences between reported numbers are not all attributable to process quality. Issues often not considered when comparing reported process indices is sample size, data normality, data outliers, and samples not being representative of future product. One supplier might report a very good process capability value using only five samples produced on one day, while another supplier of the same commodity might report a somewhat lesser process capability number using data from a longer period of time that more closely represents the process. If we were to only compare these two process index numbers when choosing a supplier, the best supplier might not be chosen.

It can sometimes be more meaningful when comparing and quantifying process capability to rely on a slightly different approach. With this approach, there is no need for specifications; hence, management can use this approach to describe their important business processes. In addition, this measurement approach can be an integral part of a process quantification and improvement program. This process measurement approach consists of two steps. First, a control chart identifies special cause problems for resolution. Secondly, a normal or Weibull probability plot of the common cause variability from the control chart describes the capability of the process as a picture.

Consider how difficult it is to physically picture the capability of a process that, for example, has reported Process Capability Index (Cp) = 1.6 and Process Capability Index (Cpk) = 1.1. A probability plot overcomes this confusion by describing the process in terms that are easy to understand (e.g. 80% of the time it takes 2 to 40 days to fill an order or it is estimated that specification limits are exceeded 2% of the time). With this tool, you can make definitive statements and pictorially describe the capability of a process. Specifications and normality are not required. Also, this analyses can detect outliers, address bimodal distributions, and consider more than one distribution for a process.

It often appears that organizations get so involved in trying to determine the capability of their process that they loose sight of an important issue -- identifying and implementing improvement opportunities. Measurements are useful to help baseline current processes; however, measurements alone don't improve anything.

Additional information and a roadmap for integrating measurements with process improvement activities can be found within *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Forrest W. Breyfogle III, John Wiley and Sons, New York, NY, 1999. The wise integration of process capability measurements and other Six Sigma tools is described within our training. Focus during the training is given to building effective implementation procedures that have bottom line results for the application situations described by attendees.



Back to Top

| Home | What is Six Sigma? | Book Store | Six Sigma Training | About Us |
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| Return to Articles |

# Implementing Six Sigma: Part I

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Reproduced from *The Quality Management Forum*, ASQ, Summer 1999



In recent years there has been much interest in the application of Six Sigma techniques to process improvement. CEO's are hearing about the monetary benefits that others have achieved through Six Sigma and are ready to cash-in on the benefits offered by the techniques within their organizations.

General Electric (GE) CEO Jack Welch describes Six Sigma as "the most challenging and potentially rewarding initiative we have ever undertaken at General Electric" (Lowe 1998). The GE 1998 annual report states: "more than three quarters of a billion dollars in savings beyond our investment (in Six Sigma quality) with a billion and a half in sight for 1999." However, everybody has not been so enthusiastic --- there have been failures too.

Consider the illustrations sited in a *USA Today* article (Jones 1998):

- " After four weeks of classes over four months, you'll emerge a Six Sigma "black belt." And if you're an average black belt, proponents say you'll find ways to save $1 million each year."
- " ... nobody gets promoted to an executive position at GE without Six Sigma training. All white-collar professionals must have started training by January. GE says it will mean $10 billion to $15 billion in increased annual revenue and cost savings by 2000 when Welch retires."
- " It will keep the company (AlliedSignal) from having to build an $85 million plant to fill increasing demand for caperolactan used to make nylon, a total savings of $30-$50 million a year."
- "Lockheed Martin used to spend average of 200 work-hours trying to get a part that covers the landing gear to fit. For years employees had brainstorming sessions, which resulted in seemingly logical solutions. None worked. The statistical discipline of Six Sigma discovered a part that deviated by one-thousandth of an inch. Now corrected, the company saves $14,000 a jet."
- "Lockheed Martin took a stab at Six Sigma in the early 1990s, but the attempt so foundered that it now calls its trainees "program managers," instead of black belts to prevent in-house jokes of skepticism ... Six Sigma is a success this time around. The company has saved $64 million with its first 40 projects."
- "John Akers promised to turn IBM around with Six Sigma, but the attempt was quickly abandoned when Akers was ousted as CEO in 1993."
- "Marketing will always use the number that makes the company look best ... Promises are made to potential customers around capability statistics that are not anchored in reality."
- "Because manager's bonuses are tied to Six Sigma savings, it causes them to fabricate results and savings turn out to be phantom."
- "Six Sigma will eventually go the way of other fads, but probably not until Welch

and Bossidy retire."

- "History will prove those like Smith wrong, says Bossidy, who has been skeptical of other management fads. Six Sigma is not more fluff. At the end of the day, something has to happen."

I believe that Six Sigma can be the best thing that ever happened to a company. Or, a company can find Six Sigma to be a dismal failure. It all depends on implementation. Organizations need to follow a road map that leads an organization away from a Six Sigma strategy built around "playing games with the numbers" to a strategy that yields long lasting process improvements with significant bottom-line results.

## *Background of Six Sigma*

Motorola coined the term "Six Sigma" and created the original formulas in the 1980's. "The result was a culture of quality that permeated throughout Motorola and led to a period of unprecedented growth and sales. The crowning achievement was being recognized with the Malcolm Baldrige National Quality Award." (Wiggenhorn 1999)

The term sigma is a Greek alphabet letter ($\sigma$) used to describe variability, where a classical measurement unit consideration of the program is defects per unit. A sigma quality level offers an indicator of how often defects are likely to occur, where a higher sigma quality level indicates a process that is less likely to create defects. A Six Sigma quality level is said to equate to 3.4 defects per million opportunities (DPMO). [Pat Spagon from Motorola University prefers to use the terminology "sigma quality level" to distinguish this quality measurement from the sigma nomenclature that quantifies the spread of a distribution. (Spagon 1998).]

Many companies have recently experienced success using Six Sigma as a business strategy. When a company implements a Six Sigma business strategy, statistical tools are used in a structured fashion within processes to create products or services that are improved, less expensive, and more timely. Repeated use of the tools by practitioners on a project by project basis can significantly improve the bottom line; however, if the techniques are not used *wisely* there is a very large danger that the effort will be counterproductive and frustrating.

## *Six Sigma Implementation Issues*

Organizations can sometimes get too involved in "how to count defects" and report defect rates that they lose sight of the real value of Six Sigma -- orchestrating process improvement and re-engineering (and bottom-line benefits) through the *wise* implementation of statistical techniques. If an organization does not apply Six Sigma techniques *wisely*, it will fail. When this occurs there is the tendency to believe that the statistical techniques are not useful, when in fact the real problem is how the program was implemented and/or how the techniques were not effectively applied.

A good Six Sigma business strategy involves the measurement of how well business processes meet their objectives and offers strategies to make needed improvements. The application of the techniques to all functions results in a very high level of quality at reduced costs with a reduction in cycle time, resulting in improved profitability and a competitive advantage. It needs to be emphasized that organizations do not need to use all the measurement units that might be associated with Six Sigma. It is most important to choose the best set of measurements for their situation and focus their emphasis on the *wise* integration of statistical and other improvement tools.

A good Six Sigma implementation plan defines Six Sigma projects in critical areas of the business. A road map for selected projects involving the phases of measure, analyze, improve, and control is described in Breyfogle (1999) as a Smarter Six Sigma Solutions ($S^4$) approach. [Smarter Six Sigma Solutions and $S^4$ are service marks of Forrest W. Breyfogle III, as described in the referenced book.]

Once an implementation plan is in place, the issue of deployment comes to the fore. In Part II of this article some specific steps in a sound deployment strategy will be discussed.

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## *Author*

Forrest W. Breyfogle III founded Smarter Solutions, Inc. in 1992 after a 24 year career with IBM. Smarter Solutions, Inc. specializes in the training and coaching of "Smarter Six Sigma Solutions." His second book, *Implementing Six Sigma: Smarter Solutions using Statistical Methods,* was published in 1999 by John Wiley & Sons, New York, NY. Forewords within this book were written by the president of Motorola University, a principal at IBM Consulting, and the statistical methods manager at SEMATECH. Described benefits of the 800 page book include the wide scope and integration road map of the tools. The author can be reached at 1779 Wells Branch Pkwy., #110B-281, Austin, TX 78728, (512) 996-8288, forrest@smartersolutions.com, or www.smartersolutions.com

Back to Top



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# Implementing Six Sigma - Part II

**Forrest W. Breyfogle III**

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In the part I of this article ( Breyfogle 1999b ) Six Sigma techniques were described and some of the background of Six Sigma was provided.



A good Six Sigma implementation plan defines Six Sigma projects in critical areas of the business. A road map, or visual description, is useful in developing a sound deployment. The phases of deployment are: measure, analyze, improve, and control. These four phases, referred to as S4 (Smarter Six Sigma Solutions) [ Breyfogle 1999a ] can be cast in the form of a project. [Smarter Six Sigma Solutions and S4 are service marks of Forrest W. Breyfogle III]

A visual description of this project-based implementation of S4 within an organization is shown in Figures 1- 3 for a key process output variable (KPOV) that has direct monetary implications. The following elaborates more on these figures and this strategy.

**Deployment of Six Sigma: Projects with Bottom-line Benefits**

Often organizations do not look at "their" problems as the result of current process conditions. However, if they did, their situation might be described by Figure 1. They might also have a variety of key process output variables (KPOV's). A KPOV could be a critical dimension, overall cycle time, a DPMO rate (i.e., a defects per million opportunities metric could expose a "hidden factory" that has much rework that is not currently being reported), customer satisfaction, and so on.

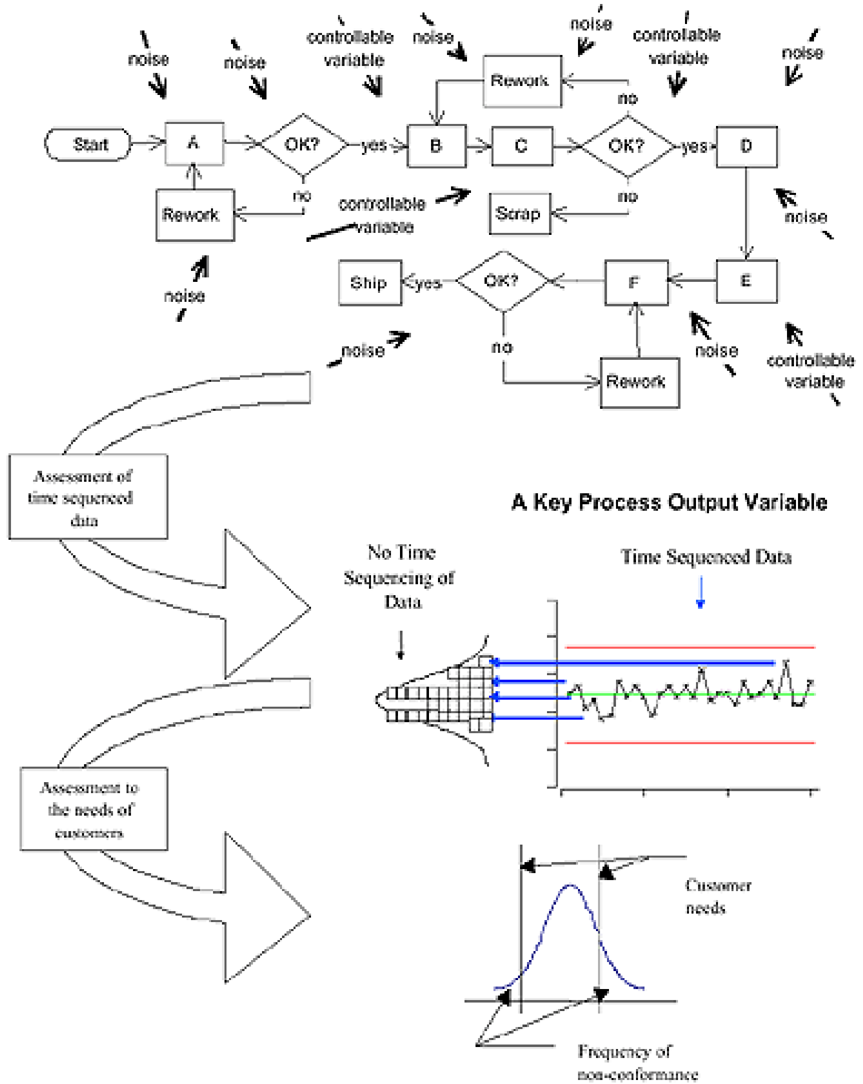


Figure 1. Example process with a key process output variable (Reproduced from Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, Wiley, copyright 1999)

For this type of situation, organizations often react over time to the up and down movements of the KPOV level in a "fire fighting" mode, "fixing" the problems of the day. Practitioners and management might even think that this type of activity is making improvements to the system. However, in reality they are often spending a lot of resources without making any process improvements. Unless process changes are made the proportion of non-compliance, as shown in the figure, will remain approximately the same. Arbitrary tweaks made frequently in an attempt to control process variability and "noise" (e.g., material differences, operator-to-operator differences, machine-to-machine differences, and measurement imprecision) can impact a KPOV to a level that results in a large non-conforming proportion. Organizations who frequently encounter this type of situation have much to gain from the implementing an S4 program. They can better appreciate this potential gain when they consider all the direct and indirect costs associated with their current level of non-conformance.

The suggested S4 methodology is not only a statistical methodology but also a deployment system of statistical techniques, as described in Figure 2. For a S4 program to be successful it must have upper level management commitment and the infrastructure that supports this commitment. Deployment of the S4 techniques is most effective through practitioners, sometimes called black belts, change agents, top guns, or another term given by a company within its deployment approach. These practitioners are to work full time on the implementation of the techniques through S4 projects selected on business needs (i.e., have a very beneficial return on investment). Direct support needs to be given by an executive management committee who has high level managers champion S4 projects.

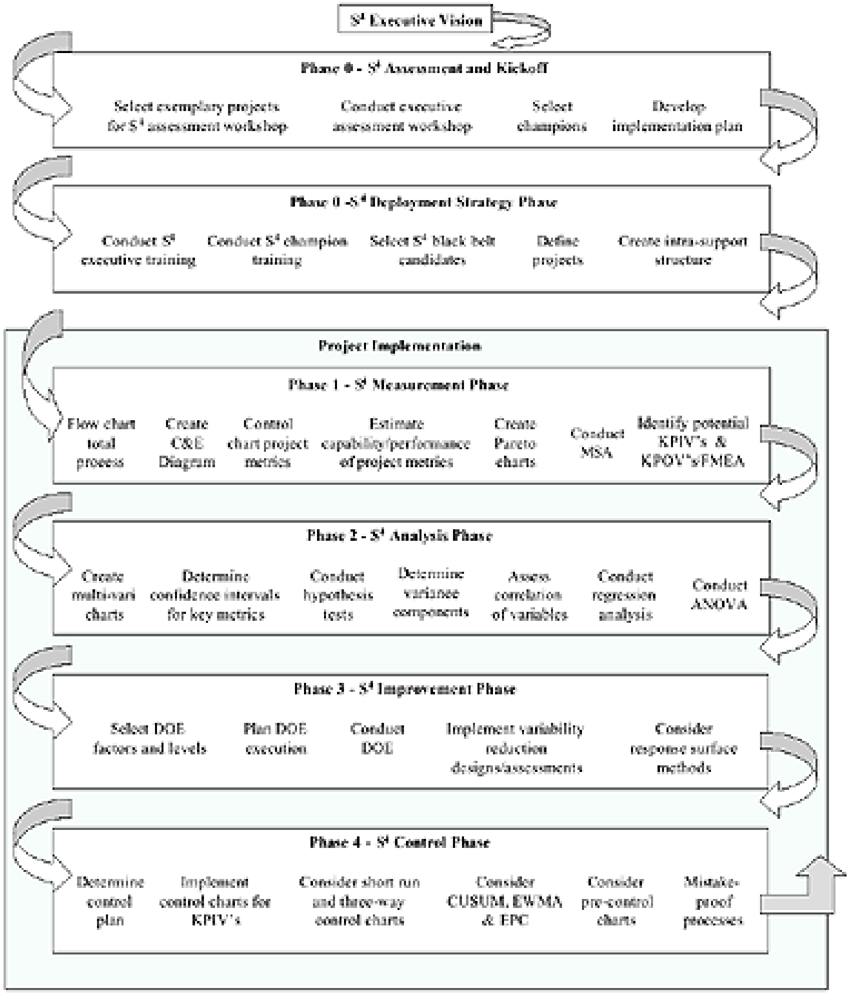


Figure 2. Pictorial representation of the implementation an S4 business strategy. (Reproduced from Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, Wiley, copyright 1999)

When a practitioner utilizes the steps summarized in Figure 2 either during a workshop or as a project after a workshop, the type of process improvement described in Figure 3 can result, where the process has been simplified, designed to require less testing, and/or become more robust (i.e., indifferent) to the noise variables of the process. This effort can result in an improvement shift of the mean along with reduced variability that leads to quantifiable bottom-line monetary benefits.

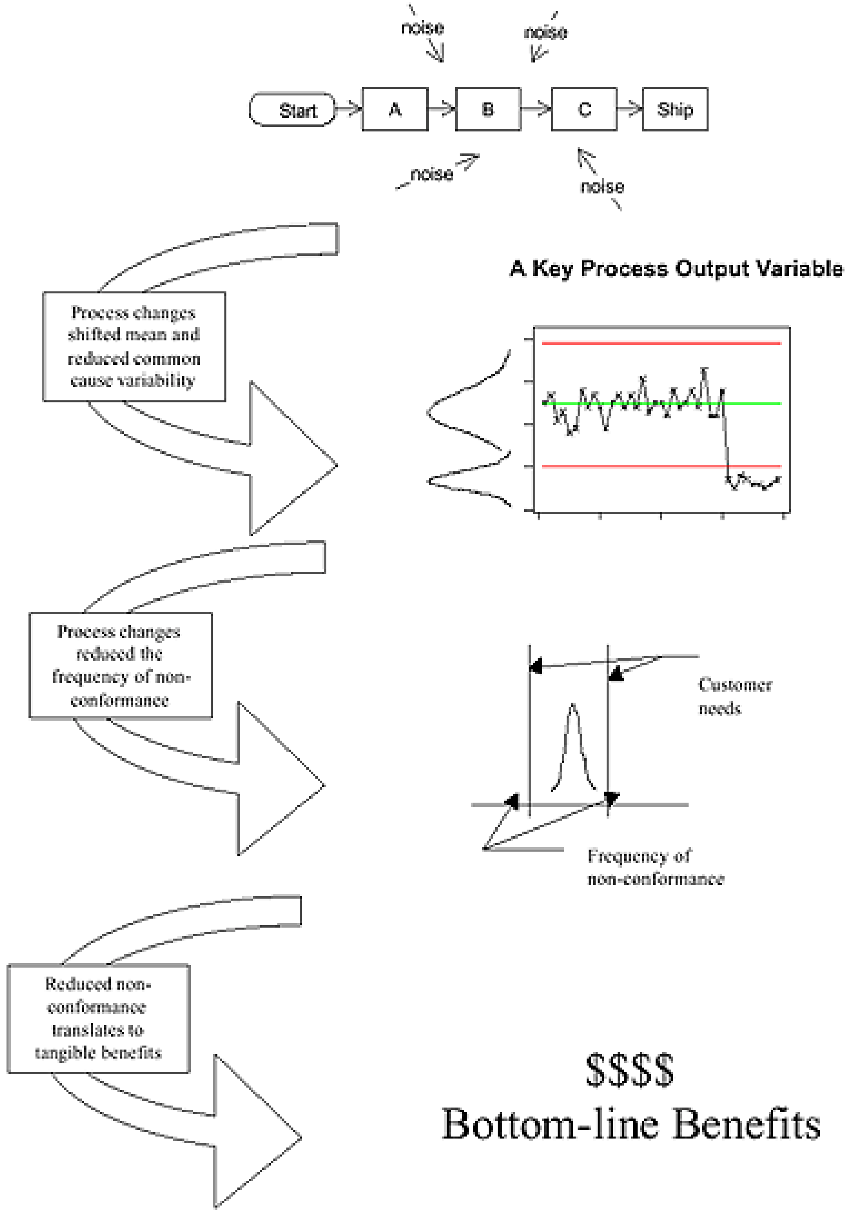


Figure 3. Example process improvement and impact to a key process output variable. (Reproduced from Implementing Six Sigma: Smarter Solutions using Statistical Methods, Forrest W. Breyfogle III, Wiley, copyright 1999)

**References**

Breyfogle III, Forrest W. (1999a) Implementing Six Sigma: Smarter Solutions using Statistical Methods, Wiley, New York, NY.

Breyfogle III, Forrest W. (1999b) "Implementing Six Sigma," ASQ The Quality Management Forum, Summer 1999, Volume 25, Number 2 (see http://www.smartersolutions.com/html/impl_six_sigma_i.htm)

**Author**

Forrest W. Breyfogle III founded Smarter Solutions, Inc. in 1992 after a 24 year career with IBM. Smarter Solutions, Inc. specializes in the training and coaching of "Smarter Six Sigma Solutions." His second book, Implementing Six Sigma: Smarter Solutions using Statistical Methods, was published in 1999 by John Wiley & Sons, New York, NY. Forewords within this book were written by the president of Motorola University, a principal at IBM Consulting, and the statistical methods manager at SEMATECH. Described benefits of the 800 page book include the wide scope and integration road map of the tools. The author can be reached at 1779 Wells Branch Pkwy., #110B-281, Austin, TX 78728, (512) 996-8288, forrest@smartersolutions.com, or

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Back to Top

| Home | What is Six Sigma? | Book Store | Six Sigma Training | About Us |
| Our Team | Articles & Solutions | Applications & Benefits |
| What Our Clients Say | Employment | Contact Us |

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- Book Store
- Six Sigma Training
- About Us
- Locations
- Our Team
- Articles & Solutions
- Applications & Benefits
- What Our Clients Say
- Employment
- Contact Us


# The Six Sigma Measurement Strategy of Smarter Solutions, Inc.

Six Sigma is more than a quality improvement program. The methodologies of Six Sigma should be an integral part of the operations and measurements of a company. A Six Sigma Business Strategy should lead to process improvements and re-engineering projects that are aligned to business needs.

***Smarter Solutions***$^{SM}$ discourages the use of the commonly used metric, sigma quality level (e.g., a 3.4 parts per million defect rate equals a six sigma quality level). We have several reasons for taking this position. One issue is that this metric is a quality metric. For someone to apply this metric to the other measures of a business, such as a reduction of cycle time and waste, one has to define a specification. This creation of a specification often leads to playing games with a value in order to make the sigma quality level number look good. This is one reason why many organizations are having trouble integrating Six Sigma with Lean Enterprise or Lean Manufacturing methodologies; i.e., cycle time and waste do not really have specification limits like manufactured products.

We will next describe the approach we use for measurements within our ***Smarter Six Sigma Solutions***$^{SM}$ ***(***$S^4$ $^{SM}$***)*** strategy. With the ***$S^4$*** methodology, key business metrics such as ROI and Inventory are tracked using a high-level tracking chart such as an *XmR* statistical control chart. The sampling rate for this control chart would be infrequent, e.g., monthly. Our ***Satellite-level***$^{SM}$ measurement strategy for these high-level business metrics separates common cause variability from special cause variability. The separation of variability types offers organizations a means to get out of the fire-fighting mode, in which common cause variability issues are often attached as though they were special cause.

When common cause variability with a ***Satellite-level*** metric is unsatisfactory, the organization should then define a Six Sigma project(s) leading to improvement of this business measurement. With our ***$S^4$*** strategy, the output from the processes that these projects are to improve would be tracked using our ***30,000 Foot-Level***$^{SM}$ measurement strategy. With this strategy, at least one Key Process Output Variable (KPOV) metric for each project is tracked, using a *XmR* statistical control chart that has an infrequency sampling period, i.e., one unit per day or week.

The purpose of a Six Sigma project is to find a Key Process Input Variable(s) (KPIVs) driving the KPOV; e.g., the temperature used within a plastic injection molding machine affects the overall dimension of a part. With our ***$S^4$*** strategy we would focus on what should be done to control this KPIV through our ***50 Foot-Level***$^{SM}$ measurement and improvement strategy. The tracking of this metric would utilize an *XmR* statistical control chart that has a frequent sampling period, e.g., one unit sampled, measured, and tracked every minute or hour. When an improvement is made to our process, the ***30,000 Foot-Level*** strategy measurement should go out-of-control to the better attaining a new level of common cause variability for the KPOV of the project. In addition, the ***Satellite-level*** metric should in time be impacted favorably and also go out of control to the better.

Within a Six Sigma business strategy, we are trying to determine the pulse of the business, which requires more than just a "snapshot" of the latest results from a process or business metric. There is a real need to create a continuous picture that describes key outputs over time, along with other metrics that give insight on focus areas for improvement opportunities. Unfortunately, the policy of organizations often encourages practitioners to compile data in a format that does not lead to useful information. This problem is overcome when an organization follows our ***S4*** strategy and uses the described measurement strategy.

## References


- *Implementing Six Sigma,* Forrest W. Breyfogle III, Wiley 1999
- *Managing Six Sigma,* Forrest W. Breyfogle III, James M. Cupello, and Becki Meadows, Wiley 2001
- *Wisdom on the Green,* Forrest W. Breyfogle III, David Enck, Phil Flories, Tom Pearson, Smarter Solutions, Inc., 2001


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