SIX SIGMA

Software Quality Improvement

Success Stories from Leaders in the High Tech Industry

VIC NANDA

JEFF ROBINSON, Ph.D.

6σ

Infosys
xerox
MOTOROLA
EMC² where information lives
Seagate
TATA CONSULTANCY SERVICES
IBM
CONVERGYS Outthinking Outdoing
CISCO
THOMSON REUTERS

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FOREWORD

Motorola (renamed Motorola Solutions, Inc. in January 2011) has the distinction of being both the "inventor" of Six Sigma and a major sponsor of its world-wide adoption. Over the last three decades, scores of companies have improved the quality of their products, reduced their costs, and grown their customer satisfaction using the core principles of Six Sigma. A library of business books attests to the success of the methodology. But Six Sigma was introduced 25 years ago. The world in which we operate has changed as the need for speed and agility is accelerating the pace of modern business, and as consumer-driven experience is replacing traditional product performance as the litmus test for customer satisfaction. So we are right to ask "Is Six Sigma still relevant in today's world?"

That is the real question that Vic Nanda and Jeff Robinson take on in this book, which isn't just stories about "goodness," but rather a guide to understanding how Six Sigma has evolved from its manufacturing roots into a comprehensive mindset and management system. The case studies presented here don't help us make better widgets. Instead, they provide a framework for creating an environment that fosters effective problem solving and successful innovation in the software industry. As more and more products have software as the differentiating component, they demonstrate that data mining and complexity reduction are at the heart of today's Six Sigma, and they show how to apply those lessons in actual business environments. All of this is "real world," none of the businesses profiled are perfect, and not everything goes as planned. The power of Six Sigma has always been in helping business leaders cope with these undesirable and unexpected outcomes ("defect reduction" in traditional quality terms), but the high-tech industry adds an additional layer of challenge. Software in particular is caught between competing directives: be innovative, be intuitive, be first-to-market, *and* be defect-free. It's a conundrum that software developers and software quality professionals continue to struggle with every day.

I wish that I could say that there is a magic bullet that definitively solves the riddle. There is no "one size fits all" methodology that guarantees flawless results. One of the great strengths of Vic Nanda and Jeff Robinson's work is that they don't claim that any one approach—Six Sigma or otherwise—can be successfully applied across all areas and address all problems. What they do, however, is demonstrate that many leaders in the high-tech industry have used Six Sigma to improve their operational results and profitability when they applied it judiciously.

Having had the privilege of working with both of the editors, I can attest that one of their greatest strengths—which they bring to this volume—is knowing where and when to apply the Six Sigma methodology. They show us how to avoid falling victim to the fallacy that if a little of something is good, then a lot of it must be better! The editors use the case studies in this book to make it crystal clear that the maximum value is extracted by a limited, but very targeted, application of Six Sigma principles. The winning formula isn't to make everything in your portfolio a Six Sigma project; it is identifying the key issues you need to address and then truly committing to those programs in terms of talent, time, and focus. And in my experience, there is also an additional benefit from this approach. If you understand and apply the principles of Six Sigma in major programs, a very interesting secondary effect occurs. Across the board, people become data-driven. The right questions start appearing about every undertaking, not just those that are designated as Six Sigma projects. There is a perceptible shift in the mindsets of managers who evaluate projects and developers who create them. The end result is that performance is increased across all programs, not just those that are managed under the official rubric of Six Sigma. Paradoxically, as Six Sigma is applied more sparingly, it becomes more powerful as a paradigm. And that may well be the greatest contribution of Six Sigma in today's fast-paced world of software development.

Leslie Jones
Senior Vice-President and Chief Information Officer
Motorola Solutions, Inc.

PREFACE

Why Did We Write This Book?

This book is unique, a first of its kind. It is not another Six Sigma textbook. There are plenty of books in the market that describe Six Sigma in theory but they are silent on *how to apply* Six Sigma to solve common product and process improvement challenges in the software and IT industry.

Theory is one thing; practice another. People learn best by a combination of both. A good cooking show is one that has a reputable chef, a selection of appetizing foods that an audience would be interested in preparing, and excellent demonstrations of the recipes. In the Six Sigma world, it means illustration of the Six Sigma methodology to solve real-world problems—not some unique problem specific to a company, but everyday problems in high-tech companies, problems that most of us can relate to.

This book is about reputable chefs (Six Sigma experts from today's leading high-tech companies), popular dishes (common process and quality improvement challenges in the high-tech industry), and their recipes (how to solve them using Six Sigma). In other words, this book is about Six Sigma in action, and it is Six Sigma in action in the software and IT industry.

The compelling collection of Six Sigma success stories in this book debunks the myth that Six Sigma is less relevant for software process and quality improvement. With the help of 25 Six Sigma experts from Motorola, IBM, Cisco, Seagate, Xerox, Thomson Reuters, TCS, EMC, Infosys, and Convergys, we get behind corporate walls and get a firsthand account of corporate Six Sigma programs and learn how these companies are successfully leveraging Six Sigma for software process and quality improvement.

Who Is the Audience for This Book?

We wrote this book primarily for two types of audiences: business executives and software quality professionals in the high-tech industry. If you fall into one of these categories, here is why you should read this book:

- If you are a business executive and you:
  - Have heard about Six Sigma but are unsure if it can help with software process and quality improvement, then this collection of Six Sigma success stories should convince you.
  - Have a Six Sigma program but you continue to struggle with intractable software process and quality challenges such as long cycle times, too much process complexity,

  - too many software defects, too much documentation, and more, then learn how other companies have successfully overcome these challenges using Six Sigma.
  - Are interested in trying out Six Sigma or have a Six Sigma program that needs to be revitalized, then learn about the essential elements of a robust Six Sigma program. Learn from the firsthand accounts of companies that have successfully implemented Six Sigma for demonstrable business and financial impact.
- If you are a software quality professional and you are leading a software process or quality improvement project, then learn how another company may have already solved the same or a similar problem using Six Sigma.

How This Book Is Organized

This book begins with an executive overview of Six Sigma and the rest of the book is divided into four parts.

- **Part One** begins with a primer on Define, Measure, Analyze, Improve, and Control (DMAIC) methodology and contains eight DMAIC success stories from Motorola, TCS, EMC, and Infosys. Topics include business risk reduction, cycle time reduction, defect reduction, help desk improvement, productivity improvement, and test efficiency improvement.
- **Part Two** starts with a primer on Lean Six Sigma and contains five Lean Six Sigma success stories from IBM, Motorola, and TCS. Topics include cycle time reduction, documentation streamlining, defect reduction, and help desk improvement.
- **Part Three** offers a primer on Design for Six Sigma (DFSS) and Define, Measure, Analyze, Design, and Verify (DMADV) methodology and includes six DFSS/DMADV success stories from Xerox, Seagate, and Motorola. Topics include process redesign, process improvement, productivity improvement, new product design, test effectiveness improvement, and system availability improvement.
- **Part Four** contains a description of Six Sigma programs, including lessons learned and implementation advice from Six Sigma leaders at Cisco, Thomson Reuters, and Convergys.

How to Read This Book

The success stories in Parts One, Two, and Three have two reading tracks for two types of audiences.

- **Business Executives:** If you are an executive who wants to get the gist of each success story without getting buried in the details, then read only the executive summaries to understand the problem statement, get an overview of how Six Sigma was used to solve the problem, and see what improvement and financial benefit were realized.
- **Software Quality Professionals:** If you are a practitioner and want all the details on how to overcome problems that confront high-tech companies, then read the complete success

stories. Each success story is presented in sufficient detail to enable software quality professionals to relate to challenges within their own organizations and learn how other companies have dealt with similar challenges using Six Sigma. Recognizing that software quality professionals are interested in knowing exactly how a problem was solved, the success stories provide step-by-step instructions and demonstrate use of Six Sigma statistical tools in sufficient detail so as to allow quick replication in companies that wish to solve similar problems.

To allow for easy readability, all chapters were written using a common template and edited for consistent voice, as if written by a single author. We recognize that perhaps a vast majority of the readers are not Six Sigma experts; therefore, we do not assume advanced knowledge of Six Sigma. Six Sigma concepts are explained in sufficient detail to the extent necessary and feasible in this book. You may want to keep a good Six Sigma textbook handy if you want to develop a greater understanding of Six Sigma concepts not detailed in this book.

If you are a business executive, read the first chapter, primers, and executive summaries in Parts One through Three, and Part Four of the book. Learn how to set up a new Six Sigma program or improve your existing program, and learn how other companies have overcome software process and quality challenges that you may face as well. For such challenges, direct your software quality and process improvement leader to read the detailed success story to understand exactly how another company solved the same or similar problem.

If you are a software quality professional, read the entire book, including the detailed success stories.

In closing, while Six Sigma is slowly gaining traction in the high-tech industry, it is our belief that this book will help expedite that process. We hope that the success stories showcased in this book will help convince the nonbelievers and skeptics of the undisputable benefits of implementing Six Sigma for software process and quality improvement, and help companies that have already implemented Six Sigma learn from each other.

Vic Nanda and Jeff Robinson, Ph.D.

ABOUT THE EDITORS

Vic Nanda is a Senior Manager of Process & Quality Improvement in IT at Motorola Solutions, Inc. He has more than 15 years of experience in the software and IT industry, including various roles in software quality assurance, system testing, and software development. He has extensive experience with Six Sigma, SEI Capability Maturity Model (CMMi), IT Infrastructure Library (ITIL), TL 9000, and ISO 9000.

He is the author of *Quality Management System Handbook for Product Development Companies* (CRC Press, 2005) and *ISO 9001—Achieving Compliance and Continuous Improvement in Software Development Companies* (Quality Press, 2003; Spanish translation by AENOR, 2005).

Mr. Nanda has authored several peer-reviewed journal papers, magazine articles, and book chapters on process and quality improvement, and is a frequent speaker at process and quality conferences. He is a member of the editorial boards of the *Software Quality Professional Journal* and the *International Journal of Performability Engineering*, a member of the reviewer board for *IEEE Software* magazine, a member of the Standing Review Board of ASQ Quality Press, and a member of the ASQ National Awards Committee.

He is a certified Six Sigma Black Belt (by Motorola), a Certified Manager of Quality/Organization Excellence (CMQ/OE), a Certified Quality Auditor (CQA), a Certified Software Quality Engineer (CSQE), ITIL Foundations Certified, and a Certified ISO 9000 Lead Auditor.

Mr. Nanda was awarded the prestigious Feigenbaum Medal by the ASQ in 2006 for "displaying outstanding characteristics of leadership, professionalism, and potential in the field of quality and also whose work has been or will become of distinct benefit to humankind." He had previously been awarded ASQ's Golden Quill Award in 2003. He was profiled in the Face of Quality in *Quality Progress* magazine in November 2003.

Mr. Nanda is a member of the steering committee of the Philadelphia Software Process Improvement Network (SPIN) and a senior member of ASQ. He has an MS in computer science from McGill University, and a bachelor's degree in computer engineering from the University of Pune, India.

Jeffrey A. Robinson, Ph.D., is an IT technologist and project and program manager who has worked in software development, computer integrated manufacturing, and process and quality for more than 25 years. He has been a CMM/CMMi assessor and Malcolm Baldrige Quality Assessor, and is a certified IT Infrastructure Library (ITIL) practitioner as well.

A former USMCR jet fighter pilot, air traffic controller, and semiconductor device physicist before he ventured into IT programming and information systems, he enjoys solving problems of all kinds.

Dr. Robinson has been teaching graduate and undergraduate courses for more than 21 years and has developed and taught numerous technology courses in computer science, programming, operating systems, quantitative statistics, database design, decision theory, project management, risk management, organizational design, networking, database administration, business intelligence, data mining, and multimedia graphics. He is a frequent lecturer and an author of more than 40 technical papers, and holds four software patents in manufacturing control theory as well.

As a certified Master Black Belt, he has been applying and teaching Six Sigma techniques for more than 15 years in a broad range of environments, from semiconductor manufacturing and medical device manufacturing to IT, automotive, and financial management systems. As a consultant, he has worked with numerous companies, developing and delivering Six Sigma courses to improve process and quality programs.

He is currently a principal consultant and is serving on the American Society of Mechanical Engineers (ASME) Subcommittee on Software V&V for NQA (Nuclear Quality Assurance).

Dr. Robinson has a BA in physics from Monmouth College, a BS in electrical engineering from the University of Illinois, an MBA from Central Michigan University, and a Ph.D. in information systems from Nova Southeastern University.

An avid reader, he has also written and published science fiction and has co-edited an online SF e-zine. He is married and has two grown sons, two teenage daughters, and too many pets.

Six Sigma Software Quality Improvement

CHAPTER 1

Executive Overview of Six Sigma

> "Software Errors Cost U.S. Economy $59.5 Billion Annually!"[1]
>
> "In the Software Industry:
> - Only 35% of all projects succeed
> - 19% fail outright
> - 46% were challenged [by:]
>   - Cost overruns
>   - Late
>   - Fewer than desired features"[2]

Software is pervasive in today's world. A vast majority of today's appliances, systems, operations, and processes are powered by software. Yet, high-tech companies continue to be challenged in overcoming intractable software quality problems and process inefficiencies, while at the same time trying to deliver (and maintain) software as per agreed scope, on schedule, within budget, and per defined quality criteria. The numbers cited at the beginning of this chapter are startling and undisputable. This, despite the fact that there are so many process and quality frameworks and maturity models that have been around for quite some time and have been widely adopted in the IT industry, such as CMMI, ISO 9001, TL 9000, ITIL, and others.

Let's face it. Just like the fact that an organization's products or services are likely to have defects (even the achievement of Six Sigma quality assures the near-elimination of defects but not the absence of defects), likewise, any organization, no matter how mature and what quality framework it uses, will face operational problems. These include but are not limited to product quality problems, process complexity problems, process effectiveness problems, process efficiency problems, cycle time problems, estimation problems, execution problems, and so on. This is because while the aforementioned maturity models and quality frameworks embody best practices that certainly enhance an organization's ability to meet its commitments, they do not provide, nor do they intend to provide, complete methodologies and comprehensive toolkits of statistical and quality tools to solve different types of problems. That is precisely what Six Sigma provides. Significant financial returns from Six Sigma are not limited to manufacturing environments. The following success stories illustrate how these principles can provide significant payback in the software and IT industries.

What Is Six Sigma?

Six Sigma is a proven, data-driven suite of improvement methodologies based on a common philosophy and supported by measurements and tools for process and product improvement. Simply put, it is management by facts, not opinion.

Sigma is a statistical term that measures how far a given process deviates from its goal. The main idea behind Six Sigma is that if you can measure how many "defects" you have in a process or product, you can systematically determine how to eliminate them and get as near as possible to "zero defects."

The Six Sigma Philosophy

The Six Sigma philosophy states that by reducing variation, that is, by getting a process or product to perform within customer specifications, one can eliminate defects, which results in improved customer satisfaction, reduced operating costs, and increased profitability. This is because defects are directly correlated with operating costs (higher rework cost or cost of poor quality results in higher operating costs and thus, lower profits) and inversely correlated with customer satisfaction (the greater the number of defects, the lower the customer satisfaction). Indeed, Six Sigma pioneers such as Mikel Harry argue that Six Sigma is fundamentally about improving profitability, although improved quality and efficiency are immediate by-products of Six Sigma.[3]

The Six Sigma Approach

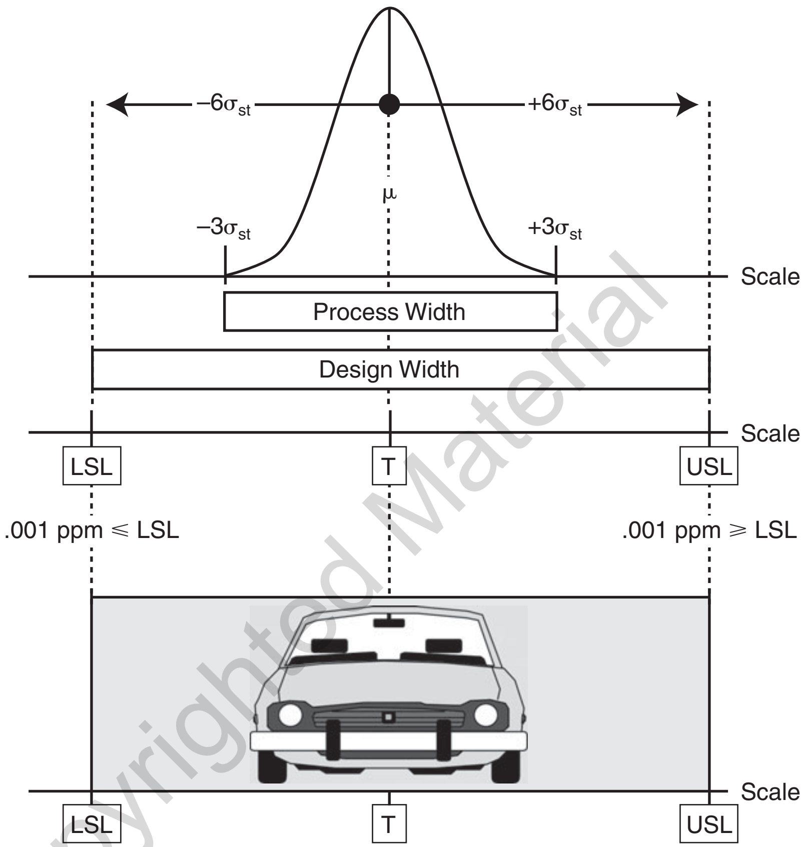
In order to eliminate defects, Six Sigma focuses on minimizing variation, because variation results in inconsistency in meeting customer specifications (defects), which in turn leads to dissatisfied customers.

The *sigma level* corresponds to where a process or product performance falls when compared to customer specifications. In other words, the difference between the upper and lower bounds of the customer specification (denoted by the Lower Specification Limit, or LSL, and Upper Specification Limit, or USL, respectively, in Figure 1.1) represents the range within which the product or service must fall in order to meet customer specifications, with optimum design or target (T) at the center. This range is called the *design width*. The actual range in which the developed product or service falls, or the process spread, is called the *process width*.

A process that is centered has a normal distribution (or can be represented by a bell curve) with mean (μ) aligned with target (T), and the specifications placed six standard deviations to either side of the mean, as shown in Figure 1.1. Due to the natural drift that occurs in process execution, it is observed that over time the process mean drifts from the target by as much as 1.5 standard deviations. In the manufacturing world, such drift is typically due to tool wear and tear, while in the software world, it is due to reduced process adherence by humans over time,

Figure 1.1

The concept of Six Sigma.[4]



or changes in processes and tools. The consequence of this drift is that a small portion of the distribution extends beyond the specification limits—3.4 parts in 1 million to be precise.

Let's use a simple example from everyday lives to understand these concepts. As shown in Figure 1.1, think of a garage in which you park your car every day. Let's say you purchase an expensive new car and you are parking it in the garage for the first time. The first few days, you will obviously be very careful to make sure you center it nicely, away from the walls, so you don't accidentally scratch it (especially the side mirrors!) while getting it in and out of the garage. In this case, the width of the garage is your specifications limit, or design width, while the actual width of your car is the process width. Having gotten used to parking your new car in the garage for a few days, you will grow increasingly confident and most likely a little less cautious, and as a result you will no longer be centering the car on target, but perhaps drifting a bit to the left or right (although you can't afford to drift too much, else you again risk scratching the car). This is the concept of process drift that was illustrated earlier.

Another concept that is relevant to understanding variation is that of accuracy and precision. The process width, or the standard deviation of a distribution, is also referred to as *precision*. The difference between the mean and target is referred to as *accuracy*. Therefore, as a process spreads, its precision decreases. Likewise, the further away the mean is from the target, the less accurate the process is. We will pictorially depict the difference between accuracy and precision momentarily.

In Six Sigma, the quest to reduce variation consists of two primary goals to be achieved in the following sequence:

1. **Reduce spread:** Reduce process width so that less and less of the product or process falls outside of the specification limit. In other words, increase process precision (or reduce variation).
2. **Center the process:** Center the process mean on the center so that more and more of the process or product average (mean) falls on target (T). In other words, increase process accuracy.

To illustrate this, let us consider a man who is doing some shooting practice. As shown in Figure 1.2, the target area is represented by the circle, and the goal for the shooter is to shoot at the center of the target area—the bull's eye, represented by "T." In the current situation, the shooter is accurate because the bullet holes are close to the bull's eye (he can, of course, *improve* his accuracy by shooting closer to the bull's eye). However, notice that the shooter has poor repeatability; that is, as the shooter takes *repeated* shots, his shots are not clustered tightly together. The cluster would be precise if all the shots were close to each other, even if they were not close to the bull's eye. The shooter's first goal is to improve his precision, because in order to have high accuracy, it would require that the shooter's repeated shots cluster on or very close to the target. In other words, the shooter would not be able to improve his accuracy without first improving his precision. Once he has improved his precision, his second goal is to aim to hit the bull's eye by improving his accuracy.

In the analogy just described, think of each of the bullet holes as data points. Another way to monitor whether or not a process or product is within specification limits is by plotting these data points using a control chart, as shown in Figure 1.3. In addition to the customer specifications (USL and LSL), the control chart uses additional safeguards (represented by

Figure 1.2
Accuracy versus precision.

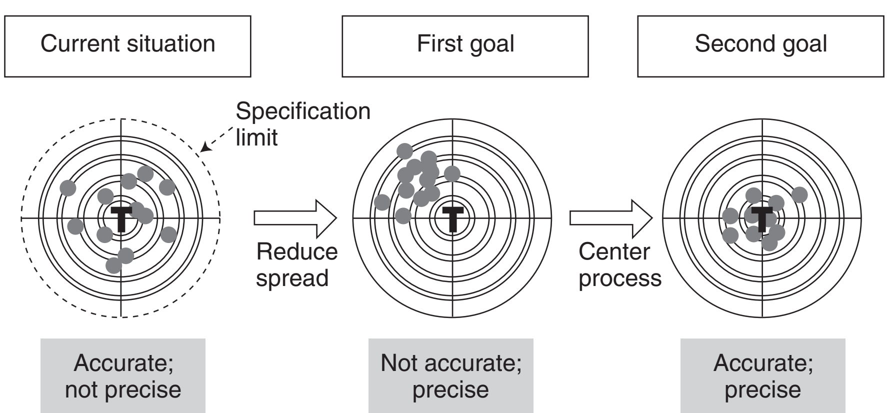
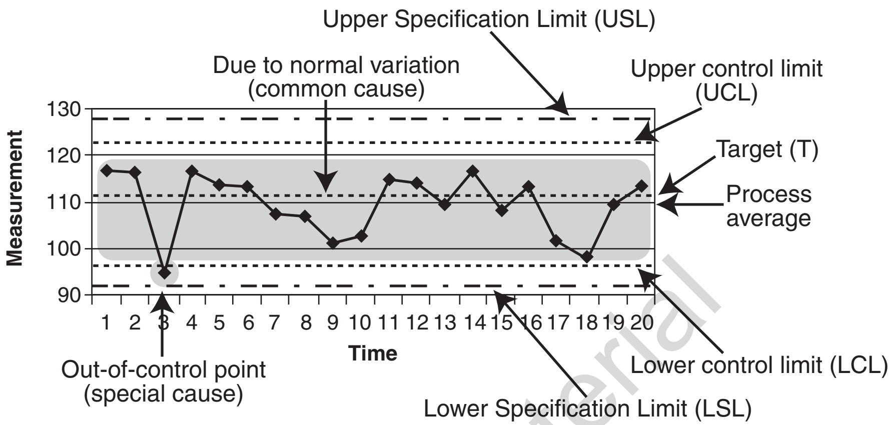


Figure 1.3
Control chart.



upper control limit, or UCL, and lower control limit, or LCL), which represent thresholds that, if breached, indicate "special cause" variation that, if left unchecked, will result in the customer specifications being breached (defect). This is the reason why the UCL and LCL fall within the USL and LSL. Such special-cause variation thus indicates the need for corrective action to bring the process back under control so that the customer specification limits are not breached and no defects result.

Indeed, from a Six Sigma perspective, when the control chart for a process or product is plotted, the first order of business is to look for any such "out of control" data points representing special-cause variation and to bring them back within the UCL and LCL control limits. In other words, reduce process spread and improve process precision. The next step is to look at the process average (or mean) to see how far from target it is in order to determine ways to improve the process average so that it falls on target. In other words, center the process and improve process accuracy.

Returning to our analogy of parking the car in the garage, our first objective, even before we purchase the new car, should be to make sure that it is not wider than the garage or is so wide that one would not be able to easily enter and exit the garage. This is because the width of the car is our "process width," and we know that once we have purchased the car, there is nothing we can do to reduce its process width. Once we have purchased a car that we know will easily fit in the garage, our second objective is to make sure that each time we park the car in the garage, we center it adequately so there is no risk of damage. And there you have it, the basic concept of Six Sigma!

The Concept of Sigma Levels

Higher levels of sigma correspond to fewer and fewer defects, and thus higher and higher levels of customer satisfaction. In fact, each additional sigma level results in an *exponential* reduction in defects. For example, a move from four sigma to five sigma requires 27 times improvement in performance, and a move from five sigma to six sigma requires more than 60 times improvement in performance. Six Sigma (6σ) represents the near elimination of defects at 99.9997 percent goodness, or only 3.4 defects per million opportunities (DPMO)—a quality level that is synonymous with world-class quality (see Table 1.1).

Table 1.1 Practical Impact of Process Capability[5]

Sigma Level	DPMO	Cost of Poor Quality (% of sales)	Benchmark
6	3.4	<10%	World-class
5	233	10–15%	
4	6,210	15–20%	Industry average
3	66,807	20–30%	
2	308,537	30–40%	Noncompetitive
1	690,000		

To put it in perspective, here is why the industry average of four sigma is usually not good enough:

- If your electricity provider operated at four sigma, you would be without power for more than an hour every week.
- If your cell phone company operated at four sigma, you would have no cell phone service for more than four hours every month.
- If book publishers operated at four sigma, you would see one misspelled word in every 30 pages of text. By contrast, two sigma is 25 misspelled words in every page, and six sigma is one misspelled word in all the books of a small library.[6]

It ultimately boils down to an organizational decision on what sigma level is the most appropriate from a cost-benefit perspective. In other words, every process or product does not have to reflect Six Sigma quality. Generally, products and processes involving human safety, health, and money are most likely to strive for Six Sigma quality.[7] Indeed, the airline industry operates with less than one fatality per million travelers, which is better than the Six Sigma level of 3.4 fatalities per million travelers.

Six Sigma Improvement Methodologies and Tools

The suite of Six Sigma improvement methodologies comprises three key methodologies, each appropriate for use for a specific purpose:

- **DMAIC (Define, Measure, Analyze, Improve, Control)** for process improvement by reducing process variation and defects.
- **DFSS (Design for Six Sigma)** for designing new processes and products. This methodology has different variants, which we will read about in Chapter 16.

- **Lean Six Sigma (or simply, Lean)** for improving process efficiency and speed.

As a rule of thumb, a DMAIC project may result in anywhere from a modest to a significant improvement, typically up to 50 percent improvement. On the other hand, a DFSS or Lean Six Sigma project is more likely to result in a radical or breakthrough improvement, and it may deliver as much as 100 percent or more improvement to a process or product.

Key measurements used in Six Sigma include critical to quality (CTQ), mean (μ), standard deviation (σ), DPMO, and process capability (Cp, Cpk). For a definition of these terms, refer to Appendix C.

Tools used in Six Sigma include qualitative and quantitative (statistical) tools for data analysis, root cause analysis, root cause validation, and identification and selection of improvements.

- Qualitative tools include but are not limited to process mapping, fishbone diagram, cause and effect matrix, five whys, failure mode effects analysis (FMEA), and so on.
- Quantitative tools include but are not limited to Kruskal-Wallis, one- and two-sample T-test, analysis of variance, confidence intervals, F-tests, one- and two-proportion tests, Monte Carlo simulation, regression, Design of Experiments (DOE), and so on.

DMAIC Overview

Explained in simple terms, in DMAIC methodology, the purpose of the:

- Define phase is to define the problem or improvement opportunity (Big Y) and translate it into critical customer requirements (CCRs)
- Measure phase is to gather data on current process performance
- Analyze phase is to analyze the data to gather information on the causes that are resulting in the problem(s), or the factors that can be adjusted to improve performance (Small Xs)
- Improve phase is to identify the specific improvements to be implemented
- Control phase is to ensure that there is a plan in place to secure the gains and make them permanent, including mechanisms for detection of deviation in process or product execution from desired levels

The DMAIC phases are executed sequentially, although there may be some overlap and iterations between phases, as well as feedback from subsequent phases to previous ones.

Key activities in the Define phase are:

- Define the problem statement or improvement opportunity in a way that effectively articulates why the Six Sigma project is necessary and why it is necessary *right now*.
- Develop the project charter.
- Map the current process.
- Gather the voice of the customer (VOC).
- Form the project team.

Key activities in the Measure phase are:

- Identify the measurements to collect.
- Develop and execute the measurements collection plan.
- Develop and validate the measurement system.
- Identify baseline performance measurements as Cp/Cpk or DPMO (and sigma level).

Key activities in the Analyze phase are:

- Stratify data to identify the underlying problem(s).
- Identify root causes.
- Validate root causes.

Key activities in the Improve phase include the following:

- Identify potential solutions.
- Evaluate and select potential solutions.

Key activities in Control phase include the following:

- Pilot potential solutions (if needed).
- Evaluate pilot results (if applicable).
- Develop the control plan.
- Develop the change implementation plan.
- Develop procedures, standards, and training material.
- Deliver training.
- Communicate improvements.
- Implement improvements.

DFSS Overview

The DFSS methodology is appropriate for designing new products or processes, or redesigning existing ones if incremental improvements are not sufficient and breakthrough improvements become necessary.

The most widely used framework for DFSS is DMADV (Define, Measure, Analyze, Design, and Verify). In this methodology, the purpose of the:

- Define phase is to define the design goal or improvement opportunity (Big Y) and translate it into CCRs
- Measure phase is to identify and gather data for key metrics that best quantify the VOC
- Analyze phase is to identify key design factors that influence the CCRs, identify design alternatives, and select a design approach
- Design phase is to identify design parameters, flow down the CCRs to design parameters, assess the impact of variability in design parameters on CCRs, assess design gaps, and identify corrective actions
- Verify phase is to identify potential design failure modes, exercise the new design via pilots and prototypes, and prepare for deployment of the new design

Besides the DMADV framework, other popular DFSS frameworks include:

- Identify, Design, Optimize, Verify (IDOV)
- Concept, Design, Optimize, Verify (CDOV)
- Define, Measure, Analyze, Design, Optimize, Verify (DMADOV)

Lean Six Sigma Overview

Lean Six Sigma is focused on eliminating waste and reducing capital investment in an organization by focusing only on activities that create value. Principles of Lean include:

- Zero waiting time
- Zero inventory
- Scheduling (internal customer pull instead of a push system)
- Batch to flow (reduced batch sizes)
- Line balancing
- Reducing actual process cycle times

Given that Lean Six Sigma is focused on improving process efficiency and speed, one may wonder what Lean Six Sigma has to do with solving problems, improving performance, reducing defects, and improving sigma levels. Let us consider a couple of different perspectives.

One view is to consider Lean and its tools such as value stream mapping, cycle time analysis, and pull systems (kanban) as yet another toolkit that is part of the overall Six Sigma toolkit. This means that within the scope of a traditional DMAIC project, where the Big Y is to reduce cycle time, one can leverage Lean tools such as value stream mapping to map out the current process and perform a cycle time analysis to identify improvement opportunities that help achieve the Big Y of the project, and thus help solve a problem or improve performance.

Another view is that by eliminating nonvalue-added steps in the process, Lean Six Sigma helps reduce the number of opportunities, which in turn results in fewer defects and thus increases the "percentage good" for the same sigma level. As an example, if a 20-step process operating at four sigma is made lean by eliminating 10 steps, the percentage good improves from 88.29 percent to 93.96 percent. Now, if one were to apply the traditional DMAIC methodology of Six Sigma to improve the process to five sigma, the percentage good improves dramatically—to 99.768 percent![7]

Brief History of Six Sigma

As with any improvement methodology and quality framework, Six Sigma has evolved over the years. Six Sigma was developed by Motorola in the early 1980s in response to then-CEO Bob Galvin's challenge to the company to improve the quality of Motorola products tenfold within five years. As Motorola's executives explored ways to meet the challenging objective set by the CEO, an engineer by the name of Bill Smith worked behind the scenes to study the correlation between a product's field life and how often it had been repaired during the manufacturing process. In 1985, Smith presented a paper that concluded that if a product was found defective and corrected during the production process, other defects were bound to be missed and found later by the customer during early use of the product. On the other hand, if the product was assembled error free, it rarely failed during early use.[3]

Smith's research was the genesis of Six Sigma. In its early days, Six Sigma was simply a metric, a measure of goodness. The pursuit of Six Sigma quality at Motorola meant the pursuit of no more than 3.4 DPMO from a baseline of about four sigma, which was costing the company 5 to 10 percent in annual revenues, and in some cases, as much as 20 percent of revenues to correct.[3,8] By 1993, through systematically detecting and fixing defects in the manufacturing process and proactively improving the manufacturing controls and product design to prevent the introduction of defects, Motorola had achieved Six Sigma quality level at several of its manufacturing facilities.[3] In part due to its pioneering Six Sigma work, Motorola won the prestigious Malcolm Baldrige National Quality Award in 1988. Other companies began to sit up and take notice. The Six Sigma revolution was now well underway.

In the early 1990s, Motorola set up the Six Sigma Research Institute in collaboration with Honeywell (then Allied Signal), Texas Instruments, Eastman Kodak, and other early adopters. This is when Six Sigma started to evolve into an improvement methodology denoted by MAIC (Measure, Analyze, Improve, Control). In 1995, General Electric (GE) embraced Six Sigma, and its CEO Jack Welch became its leading advocate. That year, GE estimated the opportunity loss at 3.5 DPMO to be 10 to 15 percent of annual revenues, or about US$7 billion.[9] By 2001, as a direct result of pursuing Six Sigma, GE had realized net cumulative cost savings of approximately $4.5 billion.[10] During these years, as it adopted and used Six Sigma, GE also refined the MAIC methodology to add "Define" as the first phase, and the MAIC methodology thus evolved into today's DMAIC. In the early 2000s, DFSS and Lean were added to the suite of Six Sigma methodologies.

Since its initial development, Six Sigma is said to have had three waves of adoption:

- In the 1980s, due to Motorola's pursuit of Six Sigma quality levels at its manufacturing facilities, Six Sigma came to be viewed as an improvement methodology relevant only to the manufacturing industry.
- Beginning in the late 1990s, service industries such as financial, healthcare, insurance, and others started to adopt Six Sigma.
- In the early 2000s, high-tech companies started embracing Six Sigma for process and quality improvement in software, systems engineering, and IT.

Six Sigma Program Success Factors

Six Sigma has now been around for close to 25 years. Six Sigma as an improvement methodology, however, is more recent—only about 15 years old. Over these years, Six Sigma has been effectively deployed by companies such as Motorola, GE, Xerox, IBM, and other companies showcased in this book. There is a lot to gain from the collective experience and wisdom of these companies that have successfully implemented Six Sigma. By learning from them, we can emulate their successes and learn how to steer clear of pitfalls and roadblocks.

This section lists key Six Sigma program success factors and roadblocks culled from literature.[11,12,13] They are summarized here to help you plan for success—whether you are planning to launch a Six Sigma program or need to revitalize a languishing Six Sigma program. The firsthand accounts from Cisco, Thomson Reuters, and Convergys of their Six Sigma programs provide fascinating insight into what worked and what didn't work for these companies, what lessons they learned along the way, and how we can enhance our own Six Sigma programs.

Key Six Sigma program success factors are:

1. **View Six Sigma as a management system**
   Companies that have successfully deployed Six Sigma have taken a holistic view, wherein Six Sigma is seen as a management system as opposed to just being considered a metric or improvement methodology to solve problems. This requires a change in mindset and a cultural shift in the organization. It requires the willingness to gather data, to perform qualitative and quantitative analysis to arrive at the best solution, and to embrace Six Sigma as the "way we work." Quite often, people are inclined to jump straight to the solution with confident assertions of "I know how to fix *this* problem!" when, in fact, the solution they may be recommending is suboptimal, completely ineffective, or perhaps they are solving the *wrong* problem. This is where the importance of data comes in. Management by facts and data is always better than management by opinion. Data mining will provide you with the information to correctly formulate the problem statement (or validate a problem statement that is already formulated), and help drive corrective actions in the right direction.
2. **Management commitment and visible support**
   If an organization is going to make this fundamental shift in how it approaches problem solving and improvement opportunities, it needs the strong and visible support of senior management to make that transition. Companies that first embraced Six Sigma and implemented robust Six Sigma programs such as Motorola and GE were able to do so because of the active support of their CEOs—Bob Galvin at Motorola and Jack Welch at GE.

   In addition, for Six Sigma to take hold in an organization, middle managers are the key to success, because often they are project sponsors or project champions. Many companies have trouble getting middle management (who will be directly affected by Six Sigma measurements) to embrace Six Sigma. In the worst case, this can lead to active resistance to change, thus resulting in a failed deployment or a suboptimal deployment, with pockets in the organization that use Six Sigma and others that don't.[12]

   Senior and middle managers can show active support for the Six Sigma program by:
   - Taking the training themselves
   - Sponsoring Six Sigma projects
   - Attending project reviews and asking probing questions

- ▲ Asking the Six Sigma class participants to communicate their expectations and emphasize the importance of the program to the success of the business and employee growth
- ▲ Publicly recognizing successful Six Sigma projects and teams
- ▲ Making Six Sigma a criterion for incentive compensation and promotions

3. **Develop the infrastructure**
An effective Six Sigma program requires a robust supporting infrastructure. Such an infrastructure includes but is not limited to:
   - ▲ Definition of a process for the identification of Six Sigma projects so that the organization invests Six Sigma resources in solving the *right* problems
   - ▲ Definition of a process for how Six Sigma projects are governed (initiated, reviewed, tracked, cancelled, assessed for financial benefits, and concluded)
   - ▲ Investment in skilled resources
   - ▲ Investment in tools for recording, tracking, and reporting on Six Sigma projects
   - ▲ Specification of the organizational process and criteria* for achieving Green Belt (GB), Black Belt (BB), and Master Black Belt (MBB) certification
   - ▲ Implementation of a Six Sigma training program
   - ▲ Definition of how Six Sigma projects are to be executed (project roles, templates, extent of rigor, reporting, and project reviews)

4. **Invest in skilled resources**
Companies that have had good results with their Six Sigma programs are those that have invested in *skilled* resources to act as MBBs to train, coach, mentor, and support their BBs and GBs and to help groom them as future MBBs and BBs, respectively.

   A good MBB is not just someone who is good with the use of statistical tools, but one who is an effective change agent and also has good business acumen. In fact, Volvo refers to them as future leaders, and GE views MBBs as likely candidates for future senior management positions.

   Quite often, Six Sigma projects fail and Six Sigma either fails to take hold in an organization or loses momentum because project teams run into problems with using statistical tools or other barriers that they do not know how to circumvent. This is where a good MBB can be invaluable in showing the way past an organizational roadblock or out of a statistical quagmire.

   An investment in MBBs, BBs, and GBs is one good investment with enormous payback—anywhere from US$100,000 to US$200,000 per improvement project, with a return on investment (ROI) often between five and ten times the original investment.[12] BBs, with 100 percent of their time allocated to BB projects, can execute five or six projects during a 12-month period, adding approximately $1 million in annual profits. In fact, with a cost

* Black Belt certification typically requires four weeks of training, generally spread over a few weeks, plus two completed projects, each with a benefit of at least US$175,000.[20] GB training typically consists of one week of training and one completed project of at least US$50,000 benefit.

of poor quality as a percentage of sales between 15 and 30 percent (for a company operating at four sigma or s Sigma level) (see Table 1.1), and given the fact that consequences of many quality failures such as customer dissatisfaction and loss of market share cannot be quantified, the opportunity lost for a company that does not invest in Six Sigma is staggering.

5. **Invest in training**

   Companies that have effectively implemented Six Sigma have made significant investments in training and made a concerted effort to do it right. This means not cramming scores of employees in Six Sigma training classes to hit some target goal of percentage of employees trained in Six Sigma. Instead, begin with carefully identifying who needs to be trained and provide them with the right training, with adequate rigor and ongoing support of MBBs so they are well equipped to successfully execute Six Sigma projects.

   Best practices with respect to Six Sigma training include but are not limited to:[12,13,14,15]

   - The training program should be a good combination of theoretical instruction and practical application using real-life examples relevant to the students' daily jobs.
   - Do not focus just on statistical tools, but ensure the training content adequately covers customer orientation, project management, organizational change management, and behavioral techniques that are so vital to effect change in an organization.
   - Ensure the instructors are Six Sigma experts with excellent communication skills.
   - Customize the training material to your company and its needs, especially the examples. This may require changing and enhancing the standard training material.
   - Spread the Six Sigma training program and make it *hands-on* to allow the students to take a real problem from their daily jobs and apply Six Sigma techniques to solve the problem.
   - Instead of overwhelming all BBs and GBs with training on advanced statistical tools, ensure that the MBBs can help them with the use of those tools when necessary.

6. **Value results**

   It is important that the Six Sigma program be monitored with the right metrics. Right metrics are those that value results, that is, that show meaningful financial and operational benefit (refer to the success stories later in this book for several examples). Metrics are meaningless if they tout the number of employees trained on Six Sigma or the number of completed Six Sigma projects without an indication of quantified results. Metrics need to show which measures and objectives on the senior leadership's dashboard have been favorably affected by Six Sigma projects (see item 10: *Select projects that matter*).

7. **Recognize and quantify all financial benefits**

   Closely related to valuing results is quantifying *all* financial benefits as best as you can. If you are going to gain management attention and retain the management commitment that helped launch your Six Sigma program, you need to demonstrate that Six Sigma is helping to move the needle on financial measures. For this, you need to quantify not just the operational benefit (such as reduction in percentage defectives or improvement in cycle time), but also translate the improvement in currency terms and categorize it as cost savings, cost avoidance, or revenue gain.

- How many dollars of your current spending has the Six Sigma project been able to reduce (cost savings)?
- How many dollars in future cost has your Six Sigma project helped avoid (cost avoidance)?
- By designing a process or product (using DFSS) or improving it (using DMAIC), what is the estimated revenue opportunity for your company, and what is the best estimate of how much of that revenue can be realized (revenue gain)?

8. **Focus on the customer**

Businesses exist for one purpose—to make a profit. Simply cutting costs will not take a company far enough. Ultimately, it comes down to increasing revenue and gaining and retaining market share. Therefore, the traditional use of Six Sigma as a methodology to reduce cost of poor quality and improve the bottom line is limited to realizing only half of the benefits that Six Sigma can deliver. A Six Sigma program is realizing its true potential if it is making a meaningful difference to the customer. Favorable impact to the customer will help retain the customer, or win new business from the customer, or help gain new customers—the latter two directly result in top-line growth.

Back in the late 1990s when GE launched Six Sigma, it was used primarily for reducing variation and taking cost out of production. Customers felt left out. In the GE annual report of 1998, Jack Welch quoted the customers as asking "When do I get to see the benefits of Six Sigma?" This led to the introduction of the *outside-in* thinking concept at GE, with the goal of focusing on CTQs that mattered to the customer. In subsequent years, GE reported not only internal savings from Six Sigma, but customer benefit as well.[13]

In order to be customer focused, the improvement goal (CTQ) for a Six Sigma project needs to be customer focused and completed projects should be evaluated from a customer perspective.

9. **Adapt Six Sigma to your organization's needs**

When it comes to Six Sigma deployment, the age-old adage "one size does not fit all" is certainly true. Depending on your business, you will need to adapt Six Sigma to your needs.

- As stated earlier, you will need to customize the training to your organization.
- You will also need to review the Six Sigma tools to see which ones are more relevant to your business. Statistical tools that are more relevant to manufacturing processes or product design processes may be less relevant in transactional processes.
- You will need to adapt the Six Sigma program to your company's size. Many of the early adopters of Six Sigma in the software and IT industry are the larger and more established companies. Small and medium-sized companies do not need to implement a Six Sigma program that is as elaborate or sophisticated as at a larger company. For example, smaller companies have a smaller portfolio of Six Sigma projects and less complex organization structure; therefore, they may not need sophisticated tools to track, roll up, and report on projects. Likewise, they may not need the breadth of training curriculum and advanced statistical training classes that a larger company

might offer its employees. In cases where the cost of licenses for certain statistical tools from larger vendors is prohibitive, smaller companies can explore cheaper and less sophisticated offerings by other vendors or use home-grown tools.

- You will need to consider which Six Sigma methodologies (including specialized DFSS methodologies described in Chapter 16) would be beneficial for your company. In most companies, a majority of the Six Sigma projects are DMAIC projects, along with a smaller number of Lean and DFSS projects.

10. **Select projects that matter**

Ultimately, Six Sigma is about results. It is about solving problems—solving the *right* problems. In any company, the number of project opportunities is usually far more than the resources available to work on them. The same is true of Six Sigma. Therefore, the Six Sigma program needs to be selective in what improvement projects to launch. Improvement opportunities need to be prioritized in order to select projects that matter.

Before we review the process for project selection, let's review the characteristics of a Six Sigma project. Remember, any improvement opportunity where Six Sigma tools may be applicable is *not* necessarily a Six Sigma project. There is overhead associated with planning, managing, and reporting on any project, not just Six Sigma projects, so think carefully if the improvement opportunity can be handled as a quick win with the targeted use of one or more (usually one) Six Sigma tools, or if a formal Six Sigma project needs to be initiated.

Characteristics of Six Sigma projects are:

- **Alignment:** The project is either directly connected to or has a clear linkage to senior management's documented goals and objectives.
- **Importance:** The project is of major importance to the company in terms of expected operational and financial impact.
- **Goal:** The project has a well-defined goal statement.
- **Scope:** The project has a reasonable scope that can be completed in three to six months.
- **Complexity:** Problems are one of two types: solution known and solution unknown. Six Sigma projects are aimed at problems with solution unknown. These include complex problems where many alternatives exist.
- **Impact:** Six Sigma projects should have a minimum financial impact as specified by the company. As an example, Black Belt projects at Motorola must have a minimum financial impact of US $250,000, and Green Belt projects must have a minimum financial impact of US $50,000.
- **Management Support:** The project has management support.

In order to ensure that the organization initiates projects that matter the most, it will need to follow a systematic approach to identifying and selecting projects:

- **Form a steering committee:** Begin by forming a project selection steering committee comprising senior management. You will need the involvement of these decision makers, because they are the best people to determine the relative priority of the management objectives for the year and to sift through the voice of the customer to identify improvement opportunities.

- **Determine improvement opportunities:** For each management objective, discuss major challenges and improvement opportunities. Review external and internal voice-of-the-customer information to identify customer issues. If there are a large number of objectives and customer issues and the team wants to focus on the higher-priority ones for generating project ideas, techniques such as multivoting may be used to eliminate lower-priority items from consideration.
- **Generate project ideas:** For the management objectives and customer issues under consideration, brainstorm project proposals and list them as shown in Table 1.2.

  Establish a ranking scale that will be used to assign weights to each of the management objectives and customer issues. The committee may assign the ranking by working together as a group or individually, and then take an average. This is how Objective #2 and Issue #2 receive a ranking of 7, even though the scale only has scores of 0, 3, 5, 8, and 10.

  Next, establish a proposal ranking scale to define the relationship between project proposal and management objective or customer issue. Again, the committee may establish the ranking scale collectively or individually.

  Each committee member then uses the ranking system to score how well the proposal addresses the management objective or customer issue. The average for each cell is then multiplied by the corresponding importance weight, and all such values for the proposal are added to arrive at the overall project score.
- **Prioritize proposals:** The proposal list can then be sorted in descending order of project scores to produce a prioritized list of proposals (see Table 1.3).

  The proposal priority list should be maintained on an ongoing basis, and it should be dynamic. As management objectives and customer issues are effectively addressed, they may be removed and new ones added. This may result in reprioritization of proposals, and in some cases, may result in lower-priority projects being put on hold or cancelled in order to allow for reassignment of resources to higher-priority ones.

11. Implement project reviews

One major pitfall companies need to guard against is letting Six Sigma projects languish, because that can quickly cause the overall Six Sigma program to sputter, lose momentum, and come to a grinding halt. The most direct benefit of a project review (with management participation) is that it keeps a project team on its toes—the steady and healthy pressure of regular project reviews assures that the train keeps moving in its tracks and does not stall or derail altogether. But there are several reasons why project reviews are critically important. They:

- Provide regular insight to the project sponsor with what is actually happening in the project

Table 1.2 Project Selection Matrix

Management Objective or Customer Issue	Objective #1	Objective #2	Objective #3	Issue #1	Issue #2	Issue #3	
Importance	8	7	3	10	7	5	
Project Proposal							**Project Score**
Name of Proposal #1	3	5	0	7	0	5	154
Name of Proposal #2	0	8	4	5	4	0	146
Name of Proposal #3	5	3	5	5	0	7	161
Name of Proposal #4	0	0	0	7	8	0	126
Name of Proposal #5	8	0	5	5	3	5	175
Name of Proposal #6	3	4	0	0	5	3	102
Name of Proposal #7	0	9	0	5	0	8	153
Name of Proposal #8	7	0	5	5	6	0	163
Name of Proposal #9	0	0	9	7	0	7	132
Name of Proposal #10	10	5	0	0	0	3	130

Importance (of Mgmt. Objective or Customer Issue)	Rating	Proposal Rank	Rating
0	Not important	0	No correlation
3	Slightly important	3	Very little correlation
5	Important	5	Some correlation
8	Very important	8	High correlation
10	Critical	10	Complete correlation

Table 1.3 Proposal Priority List

Management Objective or Customer Issue	Objective #1	Objective #2	Objective #3	Issue #1	Issue #2	Issue #3	
Importance	8	7	3	10	7	5	
Project Proposal							**Project Score**
Name of Proposal #5	8	0	5	5	3	5	175
Name of Proposal #8	7	0	5	5	6	0	163
Name of Proposal #3	5	3	5	5	0	7	161
Name of Proposal #1	3	5	0	7	0	5	154
Name of Proposal #7	0	9	0	5	0	8	153
Name of Proposal #2	0	8	4	5	4	0	146
Name of Proposal #9	0	0	9	7	0	7	132
Name of Proposal #10	10	5	0	0	0	3	130
Name of Proposal #4	0	0	0	7	8	0	126
Name of Proposal #6	3	4	0	0	5	3	102

- Provide an excellent opportunity to the project sponsor and senior management to visibly demonstrate their commitment to the project and the Six Sigma program
- Allow the project sponsor and other stakeholders to assess whether the project is following the Six Sigma methodology and using the correct tools to systematically arrive at the final solution
- Provide an excellent opportunity to the project leader to seek the sponsor's support to remove barriers and address risks that the project team may be encountering

Project reviews are meant to be short and crisp, with probing questions from the sponsor and other stakeholders that challenge the project team and enable them to remain focused on the end goal. Recommended questions for project reviews, depending on the current status of the project, are[17]:

- What is the problem statement and goal statement?
- Has your project charter been approved?
- Is your project on track per the schedule? Are there any risks or roadblocks you need help with?
- Based on your data analysis, what are the top four or five causes that account for 80 percent of the problem?
- Based on the root causes, what corrective actions do you recommend?
- What is the status of the implementation of corrective actions?
- What is the actual or anticipated improvement in performance as a result of these actions?
- What is the financial benefit from your project? Show how you arrived at this benefit.
- How will you ensure that the improvements resulting from this project will be permanent, and how will we be able to detect any deviation from expected performance levels?

12. **Develop a robust deployment plan**

There is no sure-fire and quicker way to a failed Six Sigma implementation than a poor deployment plan. Committed senior management is a prerequisite to institutionalize Six Sigma in a company, but it is not a guarantee for success. Therefore, it is important that the deployment team carefully strategize about how it will deploy Six Sigma. Fascinating stories from Cisco, Reuters, and Convergys appear later in the book, but here is some quick advice to get you started:

- Start with senior management and educate them on Six Sigma—what it is and how they can benefit from it. Be sure to include success stories and benefits realized by other companies in the same industry or, even better, from direct competitors.
- Train a small team of improvement specialists who will participate in piloting or proving out the relevance and benefits of Six Sigma to your company. Pilot projects should be those whose importance is readily apparent to the workforce, can be accomplished in a relatively short amount of time, and whose resulting operational and financial benefits can be easily quantified. Successfully concluded pilot project(s) will provide you with the credibility, management support, and impetus to move

forward with the program (refer to Chapter 11 for an example of a pilot project).

- Expand the Six Sigma rollout either to the entire company or to functions that have been identified as early adopters (your senior management will need to decide this). Additional successful Six Sigma projects executed by these early adopters will enable Six Sigma to spread and take root in the rest of the company.
- Ensure a robust process, support infrastructure, resources, and training are in place to support the continued use of Six Sigma as it becomes a part of your organizational DNA.

13. Communicate

This is all about developing an effective communications campaign, alleviating anxiety about the change, minimizing resistance to change, enabling the organization to transition from its current way of working to the new way of working, and celebrating successes. Key elements of organization change management are:

- Communications begin with explaining what Six Sigma is; why the company is adopting Six Sigma; anticipated benefits of implementing Six Sigma; showing a vision of the future state; and allaying fears by explaining what the deployment plan is, how employees are affected, and what training and support would be available.
- During the pilot phase, communications shift to explaining what projects are being piloted and what benefits have been realized.
- Closer to deployment, communications pertain to the training plan, training events, and training status reporting.
- After deployment, communications are for the purpose of maintaining and enhancing the commitment to Six Sigma. This is accomplished by regular communications to socialize the successes of Six Sigma projects, publicly recognize the project team members, and celebrate major improvements.

Financial Benefits of Six Sigma

Fundamentally, Six Sigma is about improving a company's competitive advantage and boosting its *profitability*. Therefore, a key characteristic of good Six Sigma projects is well-documented, rigorous, and audited financial benefit approved by a person in the finance organization.

The success stories showcased in this book not only provide an excellent illustration of using Six Sigma for problem solving, but they also describe compelling financial benefits ranging from an average benefit of approximately US$600,000 in some cases (Chapters 3, 4, 5B, 6A, 7B, 14, and 18) to an average savings of US$5 million in other cases (Chapters 6B, 6C, 7A, 12, 19, 20, and 21).

In addition to the financial benefits of the Six Sigma projects showcased in this book, here are some other notable examples that provide additional proof of Six Sigma's relevance to the high-tech industry:

- The IT organization at Raytheon Aircraft saved US $500,000 from a single project in 2002.[18]

- The nine CIOs at Textron saved a total of US $5 million in six months.[18]
- Raytheon Aircraft's IT department used Six Sigma to improve claims processing and save the company $13 million.[19]
- Seagate's IT department booked direct savings from Six Sigma analyses of US $3.7 million in one year. Since instituting Six Sigma, the IT department has saved US $4.5 million overall in two years.[19]

Six Sigma and Software

The high-tech industry is fundamentally different from the manufacturing industry in many ways, which has a direct bearing on how Six Sigma is used in this industry. For example:

- Software product is nonphysical while a manufactured product is tangible, with physical attributes such as length, breadth, height, volume, color, and so on.
- Software development focuses on building a unique product. Once that product is developed, it can be replicated easily with no part-to-part variation. That is why software quality professionals focus their attention on the software development process rather than on the manufacturing process of reproducing the duplicate copies.[21]
- The software development process relies heavily on people and their skills, and the most important factor is human intelligence. Manufacturing activities are machine-intensive and targeted to minimize cognition.[22]
- The behavior of a software process is difficult to predict, while the behavior of a manufacturing process is predictable.[23]
- The software development process is invisible, and it has to be made visible with flowcharts, use cases, dataflow diagrams, and so on. The manufacturing process, on the other hand, is inherently visible.[21]
- Process variation in software development is affected by large differences in skills and experience from one software developer to another. Key sources of variation in manufacturing are differences between components and runs of assembly processes.[21]
- The overall process cycle time may be much longer for creating a software product than a manufactured item. Therefore, Six Sigma projects in software may take longer or may need to be conducted with greater risk, due to smaller amounts of data.[7]

Companies that are successfully using Six Sigma in the software and IT domains are those that have been innovative and creative in applying Six Sigma when the opportunity to apply the methodology and tools may not seem as intuitive to everyone. This is because they have been open-minded, flexible, and eager to adapt and apply. Along the way, they have overcome intractable problems and recognized stellar performance and financial gains. Let's see how they did it…

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