D. H. Stamatis

SIX SIGMA AND BEYOND

Foundations of Excellent Performance

St. Lucie Press

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A series by D.H. Stamatis

Volume I
Foundations of Excellent Performance

Volume II
Problem Solving and Basic Mathematics

Volume III
Statistics and Probability

Volume IV
Statistical Process Control

Volume V
Design of Experiments

Volume VI
Design for Six Sigma

Volume VII
The Implementing Process

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Dedication

This volume is dedicated
to the new engineer in the family,
Cary

Preface

Whether one agrees or not with the methodology of six sigma, at this juncture, it is an academic argument. The fact of the matter is that major corporations all over the world are following this particular methodology with the hopes that customer satisfaction will increase and the financial position of the organization will strengthen.

So, what is this six sigma phenomenon? Basically, it is a statistical measure that defines variation. Specifically, if a company is operating under the six sigma philosophy, then it would produce 3.4 nonconformances per million opportunities. (We prefer the term *nonconformance* for legal reasons. The traditional verbiage has been defective.) A nonconformance is a deviation from the requirement.

Whereas the six sigma methodology is nothing new, it does provide a structured approach to improving the *process* and that in itself may prove to be worthwhile. On the other hand, we believe that the return of an organization's effort will be much more favorable to the "bottom line" if the six sigma methodology was focused on the design and not the product. More about this will be found in Volume VI of this series.

This work will attempt to focus on six sigma and beyond for both manufacturing and transactional organizations. Specifically, we will discuss the foundations of quality, and progressively, we will move into what is called the six sigma methodology from a design perspective. We will discuss some of the tools used in the methodology and close this series with an implementation scheme that, if followed, will help any organization improve both their processes and financial status.

Moreover, in this work, we are going to address the issue of quality from a fundamental point of view and continue in an advanced path to demonstrate the results of planning for quality rather than appraising quality.

Our focus is to show the tools one needs for improvement, but also to demonstrate how these tools can be used to optimize the process for six sigma (99.99966%) and beyond. To do this we have separated the work into seven volumes. Each one is independent of one another and may be read or followed in any order that the reader needs the appropriate and applicable information.

Each volume's content is summarized below.

SIX SIGMA AND BEYOND: FOUNDATIONS OF EXCELLENT PERFORMANCE, VOLUME I

In this volume, we focus on the very fundamental issues of all quality systems and we give an overview of the six sigma concept. This is the volume in which we define quality and recognize some of the elements that both management and nonmanagement personnel must understand for success.

In addition, this volume addresses the issues of team and the mechanics of teams as they relate to quality. Quality is the result of everyone, which is the premise of this work, and as such the topic of teams is a fundamental one, especially when one tries to go beyond six sigma constraints.

We believe that quality depends on the *team* effort of everyone and it is through synergy that process optimization occurs. However, since the topic of teams has been written about extensively, in this volume we focus on teams, their behaviors, their assumptions, and their benefits as they relate to quality, and we do that by question and answer rather than full text discussion. An extensive bibliography is given for the reader to pursue each topic on his own.

In this volume we also include what we think is the body of knowledge for an effective six sigma program. As of now, the body of knowledge has not been officially designated.

SIX SIGMA AND BEYOND: PROBLEM SOLVING AND BASIC MATHEMATICS, VOLUME II

In this volume, we focus on the problem solving methodology which is very fundamental to any quality initiative. We begin by addressing what is a problem and then systematically we define the process of resolving the problem.

The second part of this volume addresses basic mathematics that are used in all phases of quality. The approach we have taken is to introduce the mathematical concept, give an example, and then proceed with several exercises for the reader.

SIX SIGMA AND BEYOND: STATISTICS AND PROBABILITY, VOLUME III

In this volume, we address the essential topics of statistics and probability as they are used in the field of quality. We address topics for both measurable and attribute characteristics. In addition we make the connection between statistics, probability, and reliability.

SIX SIGMA AND BEYOND: STATISTICAL PROCESS CONTROL, VOLUME IV

Statistical Process Control (SPC) has been covered in the literature quite extensively. However, in this volume we take a simplistic approach to the topic by emphasizing the "why we do" and "how to do" SPC in all kinds of environments.

In addition, we address issues that concern measurement, service SPC, as well as issues that concern short runs and capability.

SIX SIGMA AND BEYOND: DESIGN OF EXPERIMENTS, VOLUME V

In this volume, we attempt to demystify the topic of Design of Experiments (DOE). We begin by explaining the concept of variation and the need for experimentation and we follow through with applications. The strength of this volume is in the fact that it also addresses "robust designs" by including the Taguchi methodology of experimentation.

SIX SIGMA AND BEYOND: DESIGN FOR SIX SIGMA, VOLUME VI

This volume addresses improvement from a preventive perspective by introducing the reader into a sequence of disciplines, so that a six sigma design may be reached.

The minimum required disciplines are identified as:

- Customer satisfaction
- Quality function deployment
- Benchmarking
- Systems engineering
- Value engineering
- Reliability and maintainability
- Design for manufacturability
- Mistake proofing
- Failure mode and effect analysis
- Project management
- Financial concepts

SIX SIGMA AND BEYOND: THE IMPLEMENTING PROCESS, VOLUME VII

This final volume of the series is a summary of the curriculum that a typical six sigma program should follow. It also provides what we believe are the objectives for a successful and rewarding implementation of each phase in training for the six sigma methodology.

It begins by summarizing some key objectives for a six sigma professional and then it addresses the specific requirements and training schedule for each of the categories. The categories are:

1. Champions
2. Green belts
3. Black belts
4. Shogun six sigma master

TARGET AUDIENCE

Our target audience, by design, is everyone, i.e., academics and practitioners, who desire to know about quality systems, the six sigma concept, or to review specific topics within the six sigma quality body of knowledge in a timely manner and with specificity.

The primary users will be the ones who actually are about to embark in the six sigma methodology and this work is going to help them understand the concepts and the constraints of implementation as well as the benefits of attaining the six sigma status.

The secondary users will be the individuals who want to know specific tools, concepts, definitions, and generally educate themselves about the six sigma methodology.

HOW TO USE THESE VOLUMES

By design these volumes may be used independently of each other or sequentially. Each volume obviously builds on the previous volume in the content domain, but some readers may not need that information.

Our intent for this series is to discuss the issue of six sigma from a very elementary level to an advanced level. As such some volumes, for example, Volumes III, V, and VI, are very technical and demand that the reader spend some time studying the issues and content of these volumes. For the casual reader, the series may be used as a reference to the six sigma methodology.

Acknowledgments

In a typical book, the author has several, if not many, individuals who have helped in the process of completion. In this mammoth work, I have so many individuals that have helped that I am concerned that I may forget someone.

To write a book is a collective undertaking by many people. To write a book that conveys hundreds of thoughts, principles, and ways of doing things is truly a Herculean task for one individual. Since I am definitely not a Hercules or a Superman, I have depended on many people over the years to guide me and help me formulate my thoughts and opinions about many things, including this work. For me to thank everyone by name who has contributed to this work is impossible, although I am indebted to all of them for their contribution. However, there are some organizations and individuals who do stand beyond the rest and who, without them, this series would not be possible.

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About the Author

D. H. Stamatis, Ph.D., ASQC-Fellow, CQE, CMfgE is currently president of Contemporary Consultants, in Southgate, Michigan. He received his B.S. and B.A. degrees in marketing from Wayne State University, his Master's degree from Central Michigan University, and his Ph.D. degree in instructional technology and business/statistics from Wayne State University.

Dr. Stamatis is a certified quality engineer for the American Society of Quality Control, a certified manufacturing engineer with the Society of Manufacturing Engineers, and a graduate of BSI's ISO 9000 lead assessor training program.

He is a specialist in management consulting, organizational development, and quality science and has taught these subjects at Central Michigan University, University of Michigan, and Florida Institute of Technology.

With more than 30 years of experience in management, quality training, and consulting, Dr. Stamatis has served and consulted for numerous industries in the private and public sectors. His consulting extends across the United States, Southeast Asia, Japan, China, India, and Europe.

Dr. Stamatis has written more than 60 articles and presented many speeches at national and international conferences on quality. He is a contributing author in several books and the sole author of 12 books. In addition, he has performed more than 100 automotive-related audits and 25 preassessment ISO 9000 audits, and he has helped several companies attain certification.

He is an active member of the Detroit Engineering Society, the American Society for Training and Development, the American Marketing Association, and the American Research Association, and a fellow of the American Society for Quality Control.

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Introduction

Acting in accord with our beliefs and values, or as some would say, walk the talk, is one of the greatest challenges each of us faces every day. It is true for individuals in all aspects of life… and equally true for organizations of every kind and size.

Most organizations talk good management through their stated mission, vision, and values. These displays of good intentions are excellent reminders of what we stand for. But the real worth of our values comes from what is practiced rather than merely professed. It is how we actually behave that ultimately defines our success and determines how we will be judged.

Since the early '80s most people have come to understand that previously acceptable norms of goods and services are no longer acceptable. Customer satisfaction, reliability, productivity, costs, market share, profitability, and even survival are directly affected by the quality of an organization's products and performance.

Quality is indeed in the forefront of every discussion that pertains to any organization's products and or performance. We have, as a society, indeed been inundated with concepts, theories, and approaches to improve, change, and modify past practices of quality because we have found that the "old" is not as good as we thought, even though it was very useful a time long ago.

Whereas these theories, concepts, and approaches do provide a different approach to looking at things from a quality perspective, all of them have advantages and disadvantages. All of them can provide a positive result if only they are adhered to. All of them will improve quality if the strategy of the organization is to improve — **for real** — the product and or performance.

So the question is: if all these theories, methodologies, concepts, and approaches are good enough, why in the world do we need one more? Why do we need a six sigma methodology? Better yet, what is so different about the six sigma that a previous methodology could not provide? The answer is simple and yet complicated.

First, let us admit that variation is indeed the archenemy of all productivity in all organizations. So far, all methodologies invented, thought of, and implemented in all organizations have indeed a common thread in their approach of eliminating variation. So does the six sigma methodology. However, that is where the similarity stops. The focus of this new approach is the definition of improved quality, which is redefined to the limit of plus or minus 6σ or 99.99966%. That means that an organization has to focus on decreasing its variability and be able to produce 3.4 nonconformances per million opportunities. Sigma is a Greek letter used in statistics as a unit of measure to identify dispersion in a distribution. In essence, this sigma reflects capability. It turns out that the sigma scale of measure is perfectly correlated to such characteristics as defects per unit, parts per million defective, and the probability of failure or error. Therefore, the six sigma has become a *goal* of many organizations, because it provides a uniform metric for measuring performance in any organization. A simple comparison of the six sigma goal can be seen in Table I.1.

TABLE I.1
Six Sigma Goal with a ±1.5σ Shift

Process Capability(ies)	Nonconformances per Million Opportunities (ppm)
6	3.4
5	233
4	6,210
3	66,807
2	308,537

From *The Vision of Six Sigma: A Roadmap for Breakthrough, 5th ed.*, 1997, vol. 1, pp. 2.12, Six Sigma Academy. With permission.

Another way to see and understand the effect of the progression in quality thinking is in Table I.2. In this table we depict the historical standard of 3σ, the current standard for most organizations which is 4σ, and the new standard of 6σ.

TABLE I.2
Comparison of Standards

Sigma	Time	Distance	Area	Money	Spelling
3σ	3.5 months per 100 years	New York to California trip	Approximately the floor space of a small hardware store	For every $1 billion in assets, there is $2.7 million indebtedness	1.5 misspelled words per page in an 8 × 11 book
4σ	2.5 days per 100 years	45 minutes of freeway driving in any direction	Approximately the average floor space of a living room	For every $1 billion in assets, there is $63,000 indebtedness	1 misspelled word per 30 pages in an 8 × 11 book
5σ	30 minutes per 100 years	A trip to the local gas station	Approximately the size of the bottom of an average telephone unit	For every $1 billion in assets, there is $570 indebtedness	1 misspelled word in a typical set of an encyclopedia
6σ	6 seconds per 100 years	4 steps in any direction	Approximately the size of a typical diamond	For every $1 billion in assets, there is $2 indebtedness	1 misspelled word in all of the books found in a small library

From *The Vision of Six Sigma: A Roadmap for Breakthrough, 5th ed.*, 1997, vol. 2, pp. 21.33, 22.6, Six Sigma Academy. With permission.

Second, the six sigma methodology asks the organization to have a paradigm change in everything it does. This change is essential and it demands not only flowery words, slogans, and exhortations, but real actions all the way from senior management to the lowest level of employee. It demands commitment from the leadership and demands accountability and acceptance of ownership from those individuals who will partake in the change process.

The goal of all this? Six sigma is the methodology that will harvest and uncover potential improvements in the organization, by (1) focusing on specific items and (2) bringing all the resources together to identify, measure, analyze, improve, and control the process. This is indeed revolutionary if it can be done. At least in theory it is possible and some organizations have claimed success using this methodology. Examples are General Electric, Motorola, and others.

In our opinion, to implement such a megamethodology demanding so much from everything and everyone it becomes essential to develop attitudes and systems — at all levels of an organization — that promote and implement continual improvement of procedures, processes, products, and services. The implementation, however, of these attitudes and systems in any organization must take into consideration such factors as the organization's unique product or service, culture, customers, employees, level of both corporate and employee knowledge, and experience. As a consequence, in the process of implementing a quality system in any organization, innovative approaches are encouraged.

To be sure, the six sigma methodology is not a novice idea for improvement. However, this idea needs an innovative approach for implementation; otherwise, it will end as other methodologies of the past. One of those innovative approaches has been the introduction of teams. Increasingly, organizations of all types are using teams in the workplace to pursue the power of collective wisdom and effort. Organizing workers, from assembly line to boardroom, into teams seems to be part of the natural order of business in the '90s, and the new millenium.

Teams are indeed an integral part of the human experience and the more we understand their dynamics the more effective we can make them. From the beginning of time, humans have recognized the power of collective wisdom and effort. However, in the last 10 to 15 years, the effort of understanding the makeup, behavior, and the general dynamics of teams has been accelerating beyond everyone's expectations.

Often, teams don't realize their full potential and in some cases they do not work at all. The reason for such failure is that what organizations expect from teams is fundamentally different from what individuals expect. Recognizing the difference and learning to integrate them is the key to building and perpetuating successful teams in any organization.

Strictly speaking, the notion of team is an abstraction. There is no team that does the work however defined. There are only individuals working together as a team.

The concept of team and teamwork in the workplace can elicit strong emotional responses that have their origin in early experiences with teams. It is not unusual, when teams are introduced in the organization, to have potential members exhibit fear of the unknown, anxiety, and an attitude of wait and see.

Another innovative approach to the six sigma methodology is the focus on the customer from a quality system criteria perspective. The six sigma methodology is unique in this respect for it focuses on:

Driver. Senior executive leadership guides the sustained pursuit of customer value and improvement of organizational performance via the six sigma methodology.

System. Processes are well-defined and well-designed to meet organization's customer requirements as well as quality and performance requirements for the profitability of the organization.

Measures of Progress. These are established on a results-oriented basis for channeling actions and delivering verifiable improvements not only to the customer value but also to the organizational performance. This performance is based on specific goals from the organization with the intent to ever improve value to customers. To pull this together the following four items are necessary.

1. Senior executive leadership.
2. Customer focus.
3. Human resource development and management quality and operational results.
4. Customer satisfaction.
   - Customer satisfaction relative to other organizations.
   - Customer retention.
   - Product and service quality.
   - Productivity improvement.
   - Waste reduction and elimination.
   - Supplier quality.

This organizational quality performance is further enhanced by a strong:

Information analysis. The drive here is to become a data-driven company for all decisions. Information analysis is a push to effectively manage and use data and information for an optimum decision. With the proper and appropriate information we can examine the scope, validity, and analysis of data used to improve operational performance. How do the data and information systems support improvement efforts toward customer focus? What about products or services? What's the impact on internal operations? These questions help you learn more about the organization's ability to improve operational and competitive performance. Of course, to do this, statistical tools are necessary.

Strategic quality planning. What planning process do you use in your organization? What long- and short-term plans are produced by a process within your organization? How are all the key quality requirements integrated into the overall plan? These questions help guide the initial steps of the strategic

quality planning process. Make sure your plans include mission performance goals. You should include, too, improvement plans for enhancing performance in all key areas for both short and long term.

We hope that in this volume the reader will be able to understand the foundations of quality and find the critical elements, as well as the issues affecting the team process, for an effective implementation of the six sigma methodology.

In the other volumes we will address specific issues and concerns for optimizing performance using the six sigma methodology and its tools.

1 The Foundations of Any Quality System

This chapter addresses the definition and characteristics of any quality system. Progressively, it introduces and discusses some of the essential items that are imperative in the success of pursuing excellence.

Attempting to write a series on the six sigma phenomenon reminds me of a saying that is credited to Abraham Herscel. He said that, "Faith is not the clinging to a shrine but an endless pilgrimage of the heart. Audacious longing, burning songs, daring thoughts, an impulse overwhelming the heart, usurping the mind — these are all a drive toward…."

Quality is no different. One must have a passion for it. One must have a drive for it. One must never rest with conspicuous results, rather one must pursue excellence all the time. Quality, after all, is a pilgrimage to perfection. Unless one understands that pilgrimage, unless one has a burning desire for perfection, unless one has an audacious longing for delighting the customer, all will be for naught.

There are many ways you may attempt to cultivate and maintain quality. One is to talk about quality as though you know something about it. In fact, the sheer conviction and the tone of the discussion will be the proof of quality efforts, rather than the results that were expected.

A second attempt to cultivate and maintain quality is to talk in contradictions and every so often change direction in the name of continual improvement. With this excuse, many quality initiatives have come and gone with no specific results nor substantial benefits. In fact, one may say that the self-fulfilling prophecy of "continual change" perpetuates contradictions in both old programs and new ones. It reminds us of a passage in the *Bible* in Psalm 137(138), verse 9, which states: "O daughter of Babylon… Happy shall he be, that taketh and dasheth thy little ones against the stones." It is obvious that the verse not only does not make sense, but it is also offensive to our modern minds — never mind that it comes from the *Bible*. It is similar with quality initiatives. As long we are doing something, even though we do not understand it, it is okay, because we are dealing with *quality.*

Yet a third attempt to cultivate and maintain quality is to follow the path of continual improvement. It is a difficult path and the rewards do not come easily. However, the rewards are worth the effort. Learning about the organization, and the specific process, will indeed take time and effort. After all, *all* achievements require hard work. We persevere because we believe rewards will come. Quality perseverance is no different. The more we persevere, the more we understand; the more we understand, the more capable we become of offering solutions and suggestions to organizational and/or process improvement.

So, how do we focus on this continual improvement path? We suggest 10 steps. They are

1. **How you think is everything.** Always be positive. Think success, not failure. Be aware of a negative environment and do not look for any opportunity to blame anyone in particular.
2. **Decide upon your true dreams and goals.** Write down your specific goals and develop a plan to reach them. This is where the mission statement and values of the organization come in.
3. **Take action.** Goals are nothing without action. Do not be afraid to get started now. Just do it. We learn by doing and we become better by practicing. Learn to prioritize. Not everything is important at the same time. Learn to choose between alternatives.
4. **Never stop learning.** Upgrade your knowledge and skills on a continual basis. Recognize that things change, and that everything changes. It is up to the organization and the individual to be responsible for new knowledge and the introduction of new skills in the work environment.
5. **Be persistent and work hard.** Success is a marathon race, not a sprint. Never give up. Rather, reposition your organization and/or yourself for the next time. I remember reading some time ago about Lance Armstrong and his 1996 win in the Tour de France. Reporters wrote that he was flying in the hills and mountains of France during the race. When he was asked about it, he replied, "But you do not fly up a hill. You struggle slowly and painfully up a hill, and maybe, if you work hard, you get to the top ahead of everybody else."
6. **Learn to analyze details.** Get all the facts, all the input from all possible sources. Learn from your mistakes and replicate your successes. Analysis sometimes means to recognize patterns that repeat.
7. **Focus your time and money.** Everything has limitations. Constraints must be identified as early as possible. However, never allow others to distract you from your goals. Focus will keep you going when things get tough.
8. **Do not be afraid to innovate; be different.** Following the herd is a sure way to mediocrity. Be careful when benchmarking is conducted. Always ask the question: "Is this the best practice or is this the best that the competitor is doing?" If the answer is "yes" to the second question, then your organization is in trouble. The best it can hope for is to continue to be second best.
9. **Deal and communicate with people effectively.** No person is an island, no matter what the position and/or title. Learn to understand and motivate others.
10. **Be honest and dependable; take responsibility.** Otherwise, all the above points are meaningless.

Let us then begin to understand quality and its foundations by addressing the components that must be satisfied, so that quality is indeed a way of life and not a mere word of the everyday language. To begin our journey let us focus on the

customer and progressively examine the issues and concerns that people who deal with quality are asked to come to grips with daily.

SET TRUE CUSTOMER REQUIREMENTS

For a long time "quality" meant some type of conformance based on a set of customer requirements that, if met, resulted in a product that was fit for its intended use. The trick, however, was to have knowledge of the user's needs, wants, and expectations — from both the internal and external perspective.

It is critical that these requirements be understood and reflected accurately in specifications for products, services, and processes. One of the fundamental principles is that "conformance to requirements" only leads to user satisfaction when there is alignment between user expectations and user requirements. On the other hand, one of the most practical definitions of quality is that *quality is defined by the customer.* To understand this definition, which is quite broad, it means that not only quality professionals, but everyone in the organization must understand the implications of the Kano Model (needs, wants, expectations, and performance).

Successful organizations consistently meet or exceed customers' needs. This category addresses the interface between each organization and those outside organizations (or individuals) it supports.

CONCENTRATE ON PREVENTION, NOT CORRECTION

There is no doubt that prevention has more leverage when improving quality than correction does. Therefore, the efforts of quality should be focused on prevention, because the quality payoff is maximized when considered during early phases of developing a product or service. It is then that many problems can be prevented. Thereafter, the leverage of prevention is reduced as correction of problems — a more costly procedure — becomes the dominant mode. A key aspect of this concept is designing products and services that can be produced with high yield within the capability of the manufacturing or service process. Designs that are immune to manufacturing and operational use variability are said to be robust.

REDUCE CHRONIC WASTE

Everyone involved with quality has figured out that the cost of waste in all sizes of organizations is significant. Whatever the exact numbers are, they illustrate the extraordinary opportunity for reducing costs through improvement of quality. Much of the high cost of poor quality comes from processes that are allowed to be wasteful. This waste is often chronic and is accepted as the normal cost of doing business. The conventional approach to quality is not to get rid of chronic waste but to prevent things from getting worse by "putting out the fires." Chronic waste of time, material, and other resources can be driven down by implementing continual process improvement. Typical waste items are shown in Table 1.1.