Six Sigma Fundamentals

A Complete Guide to the System, Methods and Tools

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To
Aristea and Boula

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Common Abbreviations Used in Six Sigma

Symbol/Acronym	Meaning	Symbol/Acronym	Meaning
ANOVA	Analysis of variance	e	Base of natural logarithm (2.718)
COPQ	Cost of poor quality	μ	Population mean
DFSS	Design for six sigma	Σ	Summation
DOE	Design of experiments	σ	Population standard deviation
Dpm (DPM)	Defects per million	σ^2	Population variance
FMEA	Failure mode and effect analysis		
LCL	Lower control limit	n	Sample size
LSL	Lower specification limit	N	Population size
PSM	Program safety management	p	Probability or sample proportion
ROI	Return on investment	r^2	Sample coefficient of determination
RPN	Risk priority number		
SOP	Standard operating procedure	s	Sample standard deviation
SPC	Statistical process control	s^2	Sample variance
UCL	Upper control limit	$\bar{x}$	Sample mean
USL	Upper specification limit		
MPIW	Mistake proofing improvement worksheet		

Preface

What do we mean by quality products, quality design, and quality improvement? Do we mean

- Fitness for function?
- Customer satisfaction?
- Conformance to design specifications?
- Conformance to requirements?
- Providing products and services that meet customer expectations over the life of the product or service at a cost that represents customer value?

While most of these words sound fine, such definitions have not been very useful in helping us do a better job. Why? Because they are attribute-based. A precise quantitative definition has not been established. In general, they prescribe that something is either in one state or another:

- Good or bad.
- Fine or not fine.
- Defective or nondefective.
- Conforming or nonconforming.

As a result, such definitions are serious inhibitors to continual and never-ending improvement. They are product-based (attribute-based) and comparative—that is, they attempt to compare the product, upon completion of manufacturing, to the input specifications of the manufacturers. As a result, they become static and passive filters through which we attempt to push product. They cannot serve as design criteria. They do not clearly distinguish between product species and product function. Species is a matter of subjective criteria (i.e., color, style, customer preference). Function, on the other hand, is a matter of loss of performance in use (i.e., useful life, power consumption, trouble in field, harmful effects, user friendliness).

A product is sold (gains market) by virtue of its species, function, and price. A product gains or loses reputation (market share) by virtue of its quality. Therefore, quality must be judged through customer loss, as a result of functional variation and harmful effects,

when the product is used. Functional variation is the deviation of performance from that intended by engineering design. Harmful effects, on the other hand, are injurious effects encountered during use, which are unrelated to function. For example, if the product is a train that can go 100 miles an hour, and the function is to reduce travel time, the harmful effect might be an uncomfortable ride due to excessive vibration.

Functional variation is manifested in two basic ways:

- Failure to meet the target (average performance).
- Variability of the target (dispersion performance).

This means that the focus in any process is to be on target with the smallest variation. So, the greatest difficulty we have with the meaning of quality centers around our inability to define it in precise and quantitative terms that can then be used as design criteria rather than simply as shipping criteria.

We therefore cannot afford to use concepts and measures of quality that:

- Do not relate the achievement of quality to the engineering design process as a criterion.
- Administer "quality control" through defect detection and containment (i.e., product control).
- Promote improvement only to some acceptable plateau of performance.
- Inhibit the continual pursuit of never ending improvement.
- Have a weak and perhaps an opposing relationship to performance in terms of productivity.
- Have a producer rather than a consumer orientation.

There is a very strong relationship between quality and productivity. Adding improvement building blocks to an ideal industrial system in any arena is possible on an appropriate and sound foundation. Competitive pressures have recently caused many companies to examine the foundations on which their improvement strategies are based.

A competitive position in the marketplace, for both manufacturing and non-manufacturing companies, depends then on two components: quality and productivity. Any improvement strategy should accordingly aim for maximum advancement within these two components and progress may be measured by monitoring

such advancements.

For a company to improve its long-term competitive position, it must focus on the process rather than on the product. Appropriately applied, the concepts and techniques embraced by the six sigma methodology help companies to maintain this focus and provide guidance for quality and productivity improvement.

The trilogy balance that guides the six sigma methodology to the improvement levels of 3.4 defects per million are the strategies of technology, people and business. Focusing on any one in particular shifts the balance and suboptimization will occur to the detriment of the entire organization.

This book focuses on the basics of the six sigma methodology. It covers the essential items and selected tools for pursuing excellence without getting bogged down with details. Specifically, on a chapter basis it discusses the following:

- *Chapter 1: Overview of six sigma.* The focus of this chapter is the essential core elements of the six sigma methodology. The chapter outlines what six sigma is and what the key questions or concerns surrounding it are.
- *Chapter 2: Customer satisfaction.* This is the cornerstone of every quality initiative. The aim of this chapter is to clearly explain why customer satisfaction is important and how it relates to six sigma.
- *Chapter 3: The DMAIC model.* This is the core model of six sigma. This chapter explains the process and requirements of this traditional approach to six sigma.
- *Chapter 4: Common methodologies (tools) used in the DMAIC model.* This chapter provides a selected review of tools and methodologies used in the DMAIC model for optimizing customer satisfaction and profitability.
- *Chapter 5: Design for six sigma.* This chapter explains the DCOV model, which is a much more powerful approach than the DMAIC model. It also addresses the process and requirements associated with this approach.
- *Chapter 6: Common methodologies (tools) used in the DCOV model.* This chapter reviews the tools and methodologies used in the DCOV approach for optimizing customer satisfaction and profitability in the design phase of product and service development.

- *Chapter 7: Roles and responsibilities.* This chapter explains who does what, and where they do it. The focus is to summarize the roles and responsibilities of the people directly involved with the six sigma methodology.
- *Chapter 8: Six sigma applied in non-manufacturing.* This chapter discusses the essentials of the non-manufacturing application of six sigma. Addressing the issues and concerns of non-manufacturing in a transactional environment (i.e., businesses that focus on services other than manufacturing—for example, financial, consulting, or engineering firms). An introduction to safety and environmental issues as they relate to how six sigma is also presented.
- *Chapter 9: Training and certification.* The aim of this chapter is to address the issues and concerns of training and certification for six sigma and explain the significance of both.
- *Chapter 10: Implementing six sigma.* This chapter outlines the change process from a traditional organization to a six sigma organization and examines the problems that may be experienced during the implementation process.

As an ancillary feature to the text of the book, Productivity Press is offering a free online download of more than 75 ready-to-use Six Sigma forms. These features can easily be downloaded by going to the Six Sigma Fundamentals product page on the Productivity Press website: ProductivityPress.com. The download includes: a typical calculation for six sigma capability, a cascading model for identifying the customer's wants, and typical forms that may be used in the course of the six sigma implementation process. These items are of importance to the reader as they provide a cursory view of what it means to have the wants of the customer cascaded to develop the CTCs (critical to customer characteristics).

In addition, the download includes a glossary of terms and more than 70 forms and tables that the reader may use in the process developing the six sigma implementation process for their own organization. The forms vary from simple work sheets defining the function, to FMEA forms, to P-diagrams, gage capability and many more.

Introduction

Business methodologies, programs, and disciplines often become fashionable quickly and then drop out of fashion just as quickly. What remains constant is the relationship between people, technology and business strategy. This relationship sometimes favors one at the expense of the other two, even though the goal is always to have a balance among the three.

Rather than review a litany of past programs and methodologies, here are just a few to make the point:

1. The Allen-Bradley pyramid, which represented the structure of a manufacturing enterprise, was basic and easy to remember. It was associated with a great company but was simplistic in its top-to-bottom depiction of corporate/financial, plant, area, cell, and work units. With its clearly defined hierarchy and neatly fitting layers, the pyramid gave many people a sense of security; however, it was a false sense of security offering "good luck" rather than good judgment.
2. The CIM (computer-integrated manufacturing) wheel replaced the pyramid with integrated systems architecture at its hub and the functions and factors of CIM spread out like spokes from the hub to the wheel. It was characterized by arrows of interaction from one function and factor to another that acted as an announcement of the information age in manufacturing. The wheel reflected the great importance of computer hardware and software within the manufacturing process. It heralded the breakdown of walls between manufacturing processes. The most widely known integration in the time of the CIM wheel was between design (CAD) and manufacturing (CAM). The CIM wheel, however, was before the Internet and, like the pyramid, concentrated on manufacturing within the confines of the plant or factory. As the world hurtled toward global manufacturing, global standards, and materials procurement on an international scale, the supply chain concept was fully born.
3. The supply chain concept (SCC) supplanted the CIM wheel for many people. It is interesting to note that within the CIM wheel, there was no acknowledgment of the customer, ware-

housing, procurement, or logistics. The SCC model added a very necessary set of these dimensions. This set contained, on the input side, the supplier and procurement process; on the output side, it added the distribution and customer components. Suddenly we were out of the box—or the building—and dealing with a broadly based process from supplier's supplier to customer's customer. The model also reflected repeated phases of plan, source, make, and deliver. As time went on, it was improved by the tool kit model, which articulated more levels of detail within each zone of activity.

The key shift toward the process of work, coupled with the processing of information relating to critical factors, is easy to recognize. However, this does not come close to creating an image of the actual supply chain process and its core manufacturing function. In the six sigma methodology we talk about the supplier, input, process, output, and customer (SIPOC) model to reflect the importance of this chain.

Once again, six sigma is a methodology that attempts to create harmony between technology, people and business strategy and, at the same time, optimize each of the components with the total organization in mind. To optimize the three, it focuses on the customer and in turn on customer satisfaction. How? By adhering to the following seven principles:

1. *Always do right by the customer.* This will gratify some people and astonish the rest, including the competition. The value of customer satisfaction has been proven in many studies. Doing right by customers is both beneficial and profitable. To do this, we must understand the functionality that the customer is seeking from our products or services.
2. *It is noble to be good, and it is nobler to teach others to be good.* It is imperative that we teach the employees of our organization that keeping existing customers is easier and less expensive than finding new customers. Part of the training must be continual support of customer satisfaction initiatives including, but not limited to, customer recognition.
3. *When in doubt, tell the truth.* Indeed, it is a novel idea. However, unless there is trust in the culture of the organization, there can be no expectation of results. It is of paramount significance that employees should be trained to be truthful, and a simple job aid, for example a procedure guide-

line, may be all that is needed. This may help to remind us that we are all working to please the customer. Without a customer, we have no reason to work!

4. *It is better to listen.* We must be cognizant of the old Spartan saying: "To speak less is a true philosophy." Train your employees to listen to their customers and respond appropriately, keeping in mind that body language may be just as acceptable a response as the verbal kind.
5. *Always set a good example.* Employees and customers both constantly appraise your behavior and performance; the former we hope will emulate it, while the latter will appreciate it and ultimately repay it with more business. Setting standards is always a challenging task; the lack of standards results in failure.
6. *Where possible, a compliment should always precede a complaint.* A compliment softens resentment and ensures a courteous and gentle reception for the complaint. To be sure, we all know that the customer quite often is wrong, unreasonable and difficult to deal with. However, it is not smart to make that distinction immediately. When appropriate, the customer should be retrained to your corporate values. For any change to be successful, the customer must be on your side first.
7. *Do not let schooling interfere with education through experience.* In the final analysis all levels of management are responsible for the success of the organization—they are the ones that have to decide what level of customer satisfaction is required, how to train for it and how to nurture it. It usually requires both knowledge learned in formal education and through real world experiences. The balance between the two depends on the occasion and the specific goal. The truly educated know that education alone is not enough—experience is equally important.

In our modern world, one can see that businesses (manufacturing and non-manufacturing alike) are being put to the test. They must pursue customer satisfaction through quality initiatives, yet at the same time these programs must contribute to the organization's bottom line. Six sigma can help in this initiative, because it focuses on real improvement rather than finding scapegoats for the failures. It forces us to look at actual situations with real potential of improvement for the entire organization rather than the following:

Looking for the next sale. Looking for the next sale as a tactic for organizational survival is a sign of serious trouble. The question "Where are our sales going to come from?" is haunting most companies. While just-in-time deliveries make sense in manufacturing, expecting the next sale to come through the door at just the right moment does not. Unfortunately, too many companies insist on short-circuiting the selling process. All they want is the order. A severe disconnect, such as a terrorist attack or an economic downturn, causes sales to hit the wall, and many companies do not bounce back quickly. Before you can own the customer's wallet, you must own the customer's head. Yet many companies think expert marketing or salesmanship is the solution, and they want to make a sale before they actually have a customer. To gain and sustain the customer, an organization must have a good product or service and satisfied customers.

Deliver on false expectations. The moral here is that we must deliver on trust, or the customer will not follow through on the order. Honda Motors has long recognized that winning customer trust is the key to selling cars. Honda vehicles are very good, but they are not great. They are, however, what millions of consumers want—vehicles that are incredibly trustworthy. Once again, many other companies try to do it backward—they push to build sales before they build customer trust. They fail to recognize that trust keeps customers buying—no matter what the economic environment or competition—because they don't want to risk making the wrong purchase. Even though the economy falters and new competitors like Kia and Hyundai have assaulted its market segment, Honda sales continue to be virtually unaffected. General Motors, DaimlerChrysler and Ford are not as fortunate.

Pull the wool over the customer's eyes. Customers are more sophisticated today than they were in the past, due to the volumes of information accessible to them through the media and the Internet. Customers demand the truth from companies. With the Firestone-Ford tire debacle in 2000, we realized that our lives and those of our families were on the line, and we wanted facts, not corporate PR fluff—a lesson Ford learned far faster than Bridgestone/ Firestone. The 9/11 attacks, the ENRON, Worldcom, Merck, Johnson and Johnson, XEROX and other fiascoes, have only escalated customers' demand for the truth.

Baffle the customer with jargon and fluffiness. Customers are emboldened! Every salesperson has noted that customers have become far more aggressive in the last five years, again coinciding with the Internet's emergence. The 9/11 attacks, however, have brought out America's more serious side. We have all noted the signs—less small talk, a more no-nonsense attitude and an even higher value placed on time. This suggests that we need to probe more when dealing with customers, letting them talk more than we have in the past. Furthermore, companies can enhance the sales process by forgoing the usual corporate marketing materials that can obfuscate the facts, avoid competitor qualities and steer the customer in one direction. Customers want objective and comprehensive information that helps them become more productive.

Postpone any future problems or concerns. Take charge of the future. With the future so uncertain, this may seem like a strange suggestion. However, look at what is happening in business. Management's top priority is to address current issues, such as meeting quotas and stock analysts' (and shareholders') expectations, and trying to outdo the competition. Thinking about the future is not even on the radar screen. Yet, it's the future that fuels the present. To ignore what lies ahead spells trouble for the present. To avoid the disruptions caused by economic contractions and other changes, companies must create a constant, long-term flow of new customers by continually identifying and cultivating prospects. The future can never be known for certain, of course, and unforeseen events will surely arise, but creating a framework for the future is very much in our hands. While some company executives and business owners are panicking, the more astute are taking charge of their destiny.

Six sigma is indeed a methodology that will allow suppliers, organizations and customers to work toward robust products and services giving measurable value to the customer. This value is customer satisfaction and ultimately customer loyalty. However, in order for that satisfaction and loyalty to exist and be consistent, organizations must strive to understand customer functionality so that they can deliver to customer requirements.

Chapter 1

Overview of Six Sigma

Few quality-focused initiatives have generated as much interest and debate as six sigma. This methodology, developed at Motorola, has been adopted by companies such as General Electric, Allied-Signal, Ford Motor Company and others. It is routinely debated in periodicals, and dozens of books, courses and consulting firms promote it. However, many executives, managers and engineers still do not understand what six sigma is or how it can help them.

The basic elements of six sigma are not new—statistical process control, failure mode effects analyses, gage repeatability and reproducibility studies and other tools and methodologies have been in use for some time. Six sigma offers a framework that unites these basic quality tools with high-level management support. The keys to the program's success are the commitment of resources and a rigorous methodology to identify and eliminate sources of variability.

The practitioner of the six sigma methodology in any organization should expect to see the use of old and established tools and approaches in the pursuit of continual improvement and customer satisfaction. So much so that even TQM (total quality management) is revisited as a foundation of some of the approaches. In fact, one may define six sigma as "TQM on steroids." However, it must be emphasized over and over again that the difference between the

established quality initiatives and six sigma is the packaging of the tools, the systematic implementation of the tools, a commitment to extensive training and, perhaps the most important ingredient of them all, the commitment of the executives in the organization. This commitment is quite unique—quality initiatives in the past have been identified and promoted but were never made available to the boardrooms of American organizations, until the six sigma.

It is this presence in the boardroom that has made the difference, because suddenly we are all looking at specific ROI (return on investment) that can help the organization through specialized projects. This is indeed a new approach.

However, what is six sigma? In the narrow statistical sense, six sigma is a quality objective that identifies the variability of a process in terms of the specifications of the product, so that product quality and reliability meet and exceed today's demanding customer requirements. Specifically, six sigma refers to a process capability that generates 3.4 defects per million opportunities. Most organizations today operate in the four-to-five sigma range (6,000–67,000 defects per million opportunities); moving to six sigma is a challenge. The DMAIC (define, measure, analyze, improve and control) process is the key to achieving this breakthrough improvement in performance. It is a nonlinear process—if any step yields new information, earlier steps in the process must be reevaluated.

Successful use of the data-driven six sigma concepts helps organizations to eliminate waste, hidden rework and undesirable variability in their processes, resulting in quality and cost improvements, driving continued success. The following sections examine the six sigma methodology in detail.

What are the most important ingredients in the six sigma methodology?

To successfully implement the six sigma methodology, executives and practitioners in the organization must have the following characteristics:

- *A realistic outlook.* We all have a tendency to avoid reality, so we try many things in the name of problem-solving, but realistically we are not accomplishing very much. Six sigma is a data-driven methodology that helps the organization to see the true picture and act accordingly. In other words, it helps us to identify and accept good as well as bad results. It forces us to be realistic.

- *A positive approach.* Six sigma encourages us to try something risky before complaining about it.
- *The habit of questioning the status quo.* Action does not take place unless something changes. Unless you question the way things are done today, you are unlikely to devise ways of doing them better in the future. It is that simple.
- *Flexibility.* Dealing successfully with change requires flexibility. Six sigma is a drastic change on many fronts, but perhaps the most important one is the notion of making decisions on data. (Data is the engine that makes six sigma what it is.)
- *The desire to follow up.* Although in the six sigma methodology the ability to delegate is one hallmark of effective management, it does not end there. At some point delegation must be succeeded by some kind of follow-up for best results. Managers must remember that good plans by themselves do not ensure good results, that the job that gets followed-up is less apt to get fouled up.

What are the goals of six sigma?

Among the many goals of this methodology, six stand out:

- Reduce defects.
- Improve yield.
- Improve customer satisfaction.
- Reduce variation.
- Ensure continual improvement.
- Increase shareholder value.

In some organizations the concept of "defect" has many legal ramifications, therefore the term "non-conformance" may be substituted.

What is the typical methodology of six sigma?

There are several approaches to six sigma. The three predominant ones are:

- *The Motorola approach.* Motorola was the first company to develop the methodology and they focused on six steps:
  1. Identifying the product you create or the service you provide.
  2. Identifying the customers for your product or service and determining what they consider important.

3. Identifying your needs (i.e., to provide products or services that satisfy the customer).
4. Defining the process for doing the work.
5. Mistake-proofing the process and eliminating wasted effort.
6. Ensuring continual improvement by measuring, analyzing and controlling the improved process.

- *The Six Sigma Academy approach.* This is the first commercially accepted methodology of six sigma, with minor variations, from the original Motorola approach. Indeed, it is the first six sigma methodology to which most organizations were exposed early in the life of the methodology. It is a simple, popular and straightforward approach. It focuses on four major phases:
  1. Measure.
  2. Analyze.
  3. Improve.
  4. Control.
- *The General Electric approach.* General Electric was the company that continued the progress of Motorola and standardized the methodology. GE's approach has become the de facto approach of most organizations with some very small variations. GE focused on the following five steps, which together make up the DMAIC model:
  1. Define—identify the improvement opportunity.
  2. Measure—account for the current performance.
  3. Analyze—evaluate the primary contributors.
  4. Improve—enhance the operation or process.
  5. Control—regulate (verify) the improved operation or process.

Yet another approach to six sigma is the understanding that improvement may be attained in current and future products and services. As a result of this thinking, design for six sigma (DFSS) came to be an addition to the traditional approach. The traditional approach is the DMAIC model and the define, characterize, optimize, verify (DCOV) is the newer addition.

Where did six sigma begin?

Six sigma started as an improvement program at Motorola in 1982. At the time, Motorola needed new analytical tools to help reduce costs and improve quality. As a result, the initial six sigma tools

were developed. In the meantime, General Electric started to use them (with some modifications) in 1995. Since then, other companies such as Polaroid, DuPont, Crane, Ford Motor Company, American Express, Nokia and others have followed.

Is six sigma a problem-solving methodology?

The simple answer is that six sigma is a very formal, systematic approach to solving problems. It follows a somewhat generic pattern. However, it takes a more holistic approach for the entire organization. Rather than sub-optimizing the solution to a specific problem or concern, it forces the experimenter to see the whole solution and its effects. The problem-solving approach that six sigma takes is basically:

- *Defining the problem.* Listing and prioritizing problems, defining the project and the team.
- *Diagnosing the problem.* Analyzing the symptoms, formulating theories of causes, testing these theories, and identifying root causes.
- *Remedying the problem.* Considering alternative solutions, designing solutions and controls, addressing resistance to implementation, implementing solutions and controls.
- *Holding the gains.* Checking performance and monitoring the control system.

What exactly is six sigma?

Sigma (σ) is the Greek letter associated with standard deviation. However, in six sigma it takes on various definitions and interpretations, such as, a metric of comparison, a benchmark comparison, a vision, a philosophy, a methodological approach, a symbol, a specific value, or a goal. All of these present the holistic definition of what six sigma can do, but none of them accurately depict what six sigma really means. This convoluted explanation has contributed to the confusion of a standard definition, and that is why there are so many different interpretations.

In simple terms, six sigma engages each employee of the organization from the top executive to the employee on the manufacturing or service floor. It focuses on quality improvement, cost reduction, cycle time reduction and improved delivery performance. This results in higher profits and customer satisfaction. It also improves the relationship between the management and employees. Consistency of

quality at all levels of the organization is easy through the use of common metrics that compare the quality of both technical and transactional processes. In addition, this powerful approach to improvement focuses on critical to customer (CTC) characteristics. The CTC is the first step of understanding in pursuing the six sigma methodology. It all starts with the functionality that the customer is seeking from either a product or a service. The more we understand this functionality (the Y in the six sigma equation $Y = f(x)$, which is discussed later in this chapter), the more accurate will be our focus on the variables that control this functionality (the $F(x)$). However, we must not forget that this methodology is an approach that has borrowed many systems, tools and best practices from previous approaches and has combined them in a bundle called six sigma. It is precisely this bundle of tools and methodologies, in addition to the management commitment and overall attitude change, that has contributed to why the six sigma approach may be applied to every process in any organization.

Finally, six sigma integrates technology, company assets, management and employees with continual improvement practices such as:

- Project management.
- Team problem-solving.
- Statistical process control.
- Measurement system assessment.
- Process FMEA (Failure Mode and Effect Analysis).
- Mistake-proofing.
- Team-building.
- Applied statistics.
- Design of experiments.
- Cost of quality.
- Process mapping.
- Product reliability and other disciplines.

What are the major objectives in the six sigma methodology?

In the six sigma methodology there are three broad levels of objectives. They are:

- *Problem-solving.* These are fixes of specific areas.

- *Strategic improvement.* These are targets of key strategic or operational weakness or opportunity.
- *Business transformation.* This is a major shift in how the organization works (i.e., a culture change).

Is six sigma another quality fad?

This is a very difficult question to answer. Many professionals and practitioners have opinions about the status of the six sigma methodology. For example, five years ago, there were consultants who thought that the life cycle of six sigma would be about 10 years. There are other consultants who claim that six sigma is going to be here for good, but will be constantly adapting. Regardless of the long-term outcome, the systematic approach of the six sigma methodology can indeed produce results. The fact that upper management has embraced it shows that commitment, at least for now, is strong and, therefore, it offers the possibility of longevity.

Is six sigma compatible with other methodologies and tools?

Six sigma is extremely compatible with other quality initiatives that may already be in place in an organization. It has the capacity to be implemented as a macro and in the micro level of an organization. More important, it can be successful with both elementary graphical tools as well as very advanced statistical tools.

What are the levels of responsibility in a typical six sigma organization?

In a typical organization, the levels of responsibility are:

- Executives, who authorize and follow up the program.
- Champions, who mediate resources and eliminate roadblocks for the projects.
- Master black belts, who are the technical resource and experienced in the six sigma methodology.
- Black belts, who are the project managers for the project.
- Green belts, who are the helpers of the black belts in the work environment.

More is discussed regarding these levels in chapter 7. However, it is very important to note that the essential participants of any six sigma implementation process are the black belt and the green belt.

Their role is extremely important, so here we identify the core minimum requirements for each of the roles.

The green belt must be familiar with and competent in the following concepts:

- The six sigma approach.
- Basic statistical process control.
- Classical design of experiments.
- Basic measurement system assessment.
- Statistical analysis for process improvement.
- Process FMEA.
- Team problem-solving.
- Cost of quality.

In addition to the requirements of the green belt, the black belt must have expertise in the following areas:

- Advanced statistical process control.
- Taguchi and classical design of experiments.
- Advanced measurement system assessment.
- Project management fundamentals.
- Short run SPC.
- Mistake-proofing.
- Lean manufacturing.
- Advanced product quality planning (APQP).

Is it the intent of the six sigma methodology to reduce the number of employees in the organization?

Strictly speaking, not at all. The intent of the methodology is to reduce variation and to increase the profitability of the organization. However, if in the scope of the project too many employees are identified, then perhaps re-engineering the process could cause reduction in the work force.

Can six sigma be applied equally to both manufacturing and non-manufacturing organizations?

Yes. Six sigma methodology may be introduced to any organization that deals with processes, variation and customer complaints.

How long does it take to implement a six sigma program in a typical organization?

For the organization to be following the six sigma methodology, a critical mass must be present. Critical mass is when enough personnel have been trained to carry out the methodology of six sigma in the organization. The initial steps are to select key individuals for black belt training and then progressively train more employees until there are enough trained individuals to attack problems throughout the organization. Some organizations have not recuperated their costs within two to three years. On the other hand, some have claimed that the payoff of implementation came in less than a year.

Is there anything that can derail the six sigma methodology?

Successful six sigma implementation is an issue of understanding and support. If we are not careful to generate that understanding and provide that support, the methodology is not only not going to be implemented successfully in the organization, but it is also going to leave a bad taste. There are many things that can derail the process. Some of the key ones are:

- Success is not fast enough, so the organization gives up.
- There is no priority for selected projects.
- Too many projects are identified and the methodology is overloaded, so no results are apparent.
- Undoable objectives and timelines are established and the organization expects the methodology to deliver results from the impossible.
- Past experience is ignored, including organizational cultural issues. Unless the organization recognizes the shortcomings of the past and is willing to address new cultural objectives, the six sigma methodology will fail.
- The organization lacks flexibility; it must be prepared for the unexpected. Interruptions will occur, but organizers should not give up, instead, they should focus on the goal and target of the improvement.
- The organization doesn't devote enough resources and/or training to the project. Without a commitment for personnel, training and other appropriate resources, the six sigma transformation will not be successful.

- False euphoria—that is, the tendency to think that you reached six sigma prematurely (usually after the first or second completed project)—leads to less attention paid to six sigma, less follow-up, and fewer benefits achieved.

What does the "1.5σ shift" mean?

Without getting into a statistical and lengthy discussion on what the famous "shift" is, let us say that all processes produce variations over time. In the six sigma methodology (at least in the electronics industry), it was empirically validated that the shift of the distribution was about 1.5σ. This does not mean that with all processes, and in all industries, this shift is always within this ±1.5σ. It does vary. For example, in the automotive industry we know, at least since 1980, that the shift is ±1σ and not ±1.5σ. Convention now has it that everyone follows the 1.5σ. One may simplify the interpretation of the shift as a drift of the process in the long term.

What is the difference between 3σ and 6σ?

Most companies have been following a standard of performance for ±3σ. There is nothing wrong with ±3σ for certain products and certain industries. However, there is a tremendous difference between ±3σ and ±6σ. For example, a ±3σ capability accounts for 93.32 percent long-term yield (this is the historical standard for most organizations). By comparison, a ±4σ accounts for 99.38 percent long-term yield (this is a standard that some organizations operate currently). If an organization wants to account for 99.99966 percent long-term yield, then the move to ±6σ is inevitable. When the ±6σ philosophy is implemented, expect your organization to perform at 3.4 defects per million opportunities. That is truly a breakthrough in performance! The percentages presented here have been adjusted for the long-term shift.

What is the DMAIC model?

The DMAIC model is the official methodology for the six sigma problem resolution approach. It stands for define, measure, analyze, improve, control. Fundamentally, the model helps in the following:

- Knowing what is important to the customer.
- Identifying the target.
- Minimizing variation.
- Reducing concerns.

Chapter 3 is devoted to explaining this model.

What is the DCOV model?

The DCOV model is the official model methodology design for six sigma. It stands for define, characterize, optimize and verify. Fundamentally, the model helps in the following:

- Defining what the customer needs, wants and expects.
- Defining the specifications for those needs, wants and expectations.
- Optimizing the specifications for the specific needs, wants and expectations.
- Verifying that the needs, wants and expectations are indeed what the customer wanted.

Chapter 5 is devoted to looking at this model in depth.

Is there a real difference between the DMAIC and DCOV models?

Yes, the DMAIC model focuses on appraising quality—it identifies and then tries to "fix" the problem. One may say it is a formal approach to solving problems when they occur. On the other hand, the DCOV model is a proactive approach trying to prevent problems from happening. The DCOV model would give a better return on investment and better customer satisfaction.

What does the $Y = f(x)$ expression mean?

In simple mathematical terms, this means that the Y is a function of x. In plain language, it means that changes in the x (i.e., inputs and processes) will determine how the Y (i.e., the output) will turn out. In the six sigma methodology the Y may mean profits, customer satisfaction, strategic goal, efficiency and so on. On the other hand, the x may mean actions that achieve the strategic goals, influences on customer satisfaction, process variables and so on. Another way of thinking about this equation is to think of the Y as the dependent variable and the x as the independent variable.

What does the $Y = f(x,n)$ expression mean?

In simple mathematical terms this means that the Y is a function of x and n. In plain language it means that changes in the x (inputs and processes) and some noise (n) will determine what will happen to the Y. (Noise means factors that are uncontrollable or that the experimenter chooses not to control.) In the six sigma methodology, the Y may mean any company aim, such as profits, customer

satisfaction, strategic goal and efficiency. The x may mean actions that are important enough in the presence of noise that achieve the strategic goals, influences customer satisfaction, processes variables and so on. The n is a noise that is present in the process, however, it does not effect the x in any significant way. This is called the principle of robustness. Finally, the formula $Y = f(x,n)$ is used primarily in the DFSS approach of the methodology

Is six sigma just a version of TQM or another cost-efficiency program?

TQM principles are scattered throughout the six sigma methodology and one will have a difficult time separating the two. We like to think that the six sigma methodology is TQM on steroids, primarily because it uses the tools and approaches of TQM, but it takes them one step further, in terms of effectiveness, analysis and profitability. As for six sigma being just another cost-efficiency program—that is not quite accurate. Cost of quality is used through the six sigma methodology, as well as a cost/benefit analysis. However, both of these devices play a much greater role than other tools/devices in the context of the total organization and the optimization of the particular process under evaluation. The efficiency through cost is optimized through the elimination of the hidden factory (see the next question).

What is the hidden factory?

The hidden factory is the hidden cost of a process, due to unaccounted and unrelated costs associated with the standard process. Examples are inspection, delays, rework, and extra processing. The hidden factory deals with throughput in the process and tries to calculate the probability of an item passing through the process the first time without any defects. Anything else is a loss, and therefore should be counted as the hidden factory.

What does the equation $Q \times A = E$ have to do with six sigma?

This equation was introduced first by Eckes (2001, p. 3) and refers to the acceptance of the methodology within organizations. It means: Q = quality of the technical and strategic six sigma activities; A = cultural acceptance, and E = excellence of the six sigma results.

In relation to this success, we must also be cognizant of the change and paradigm shift. In other words, we must be aware that

the acceptance is a function of how we see our future. In an earlier work (Stamatis 1996, p. 52), I pointed out that, to want to bring about a change, you must be dissatisfied with the way things are right now and have a positive vision of the future following such change. This may be shown with the mathematical equation of $D \times V \times F > R$ where: D = dissatisfaction with the current situation, V = vision of a better future, F = the first step of a plan to convert D to V, and R = resistance to change.

What is the SIPOC model?

Traditionally, in the quality field we talk about a process model which is the input, process and output. In the six sigma methodology we talk about SIPOC. SIPOC is a variation of the process model—supplier, inputs, process, output and customer. It is through this model and process mapping that we identify the hidden factory and throughput yield. Throughput yield is the probability that all defect opportunities produced at a particular step in the process will conform to their respective performance standards. Roled throughput yield is the probability of being able to pass a unit of product or service through the entire process defect-free. These definitions of course, have to be understood in light of a) the normalized yield which can be thought of as the average throughput yield result one would expect at any given step of the process b) first time yield, which measures how well companies process units and c) final yield which reports on the proportion of product or service units that pass inspection. In other words, it tells us what we did. The reader may want to see item 75 of the downloadable forms (ProductivityPress.com) for an example.

What is defects per opportunity (DPO)?

Defects per opportunity is the proportion of non-conformities (defects) within the total number of opportunities in a particular unit. For example, 43 errors (defects) were found in reviewing 445 leasing contracts. There are 5 items that present themselves as possible errors. In other words, the reviewer must make sure that these 5 items are correct. The DPO can be calculated as: 43/445x5 = .019 DPO. The opportunity has to be correlated with the critical to quality (CTQ) requirement. The CTQ characteristic is closely related to the customer, and it is this relationship that we want to maximize, free of any defects. A caution is necessary here. The opportunity identified and calculated can have a direct impact on the sigma

value. Therefore, make sure that the opportunity identified and evaluated is the same before and after the analysis, otherwise the experimenter may be comparing apples and apricots.

What is defects per million opportunity (DPMO)?

This is the classic standard measure of the six sigma methodology, which indicates how many defects would arise if there were one million opportunities. It is calculated as:

DPMO = 1,000,000 x (total defects) / (total opportunities)

In our example from the previous question the
DPMO =106 × .019 = 19,000

What are the CTX (process) and CTY (product) trees?

CT stands for critical to, and this characteristic is always a function of the $Y = f(x)$, where Y is the product requirement that impacts quality delivery or cost, and $f(x)$ is one of the vital few process variables that can influence the Y. Another way to view this relationship is to think of Y as the dependent variable and x as the independent variables (factors) that define Y. In other words, as the experimenter defines and understands the x or multiple xs, the better the chance that the Y will be understood, controlled or predicted. On the other hand, CTY is a visual representation of the individual levels of the product. It must be remembered that both the CTX and CTY trees give the opportunity to select the strategy for improvement. Whereas the CTY will help in the area of defect opportunity, the CTX will help in controlling the opportunities in the process. Therefore, it is imperative that we understand both trees, as they will guide us to better results in our analysis. For example, if we consider the Ys and Xs involved in a good meal the CTY and CTX trees will look like: A good meal = Y = service, quality, price, location, ambiance and so on. Now if we take the quality of food as our new Y then we have. Quality of food as the new Y= freshness, wait time for meal, preparation, presentation and so on. A downloadable form (ProductivityPress.com) also shows a similar example of cascading the requirements.

What is the significance of the project?

The aim of the six sigma methodology is improvement in specific projects, authorized by the management, which black belts attack with the intention to remove the "specific" problem. The project has to be worth pursuing with regard to ROI, as well as customer

satisfaction. The project is the lifeblood of the entire methodology, and it requires very rigorous investigation, analysis, implementation and follow-up to make sure that the gains claimed become gains realized. It usually follows this pattern:

- Develop the problem statement.
- Determine the problem objective.
- Determine the COPQ parameters.
- Identify CTQ and operational definitions.
- Determine which tools should be used to measure the current status and to prioritize the input variables that contribute to the problem as defined.
- Validate improvement to determine the relationship of $Y = f(x...)$.
- Institutionalize the results in such a way that the gains are sustained.

A suitable project may be identified in various ways. However, the main factors that make a project a suitable candidate for six sigma are that it has:

- Recurring events.
- Narrow scope.
- Available metrics or measurements that can be developed quickly.
- Control of the process.
- Customer satisfaction.
- An annual cost savings target of 250K.

For the project to be effective there are two issues of concern: the project objective and the problem statement. The project objective provides a clear macro statement of the problem. This allows the process owner and team members to focus on what needs to be improved (*Y* variables). Team members should be specific about the defect, but not include possible solutions. A useful problem statement must have the condition, the criteria, and the measurement. For example, product returns will be reduced to 4% of sales, resulting in a profit impact of $4 million and customer dissatisfaction of 5 percent decrease in the next 12 months.) The problem statement states the goal(s) of the project. It also links to the business objectives through expected output variable performance, ROI

impact and project timing. It is important to use enough detail to define success.

What is the cost of poor quality (COPQ)?

The costs of poor quality are the items that drive the project's ROI improvement. Typical examples may be the cost of scrap, the cost differential of reduced quality material, headcount reduction, and transportation costs, both to receive defective products and to send new.

What is customer and CTQ identification?

The customer is typically the one who dictates your output specifications (Y's in the statement $Y = f(x)$). That is why it is very important to specify project customers (and to prioritize if there are more than one). In other words, the more you know about the customer's needs, wants and expectations, the more precise and accurate the project requirements will be to satisfy them. Customers may be internal or external. In conjunction with the appropriate customer, it is imperative that we also specify and operationally define the project in terms of critical to quality (CTQ) and variable measurements. This means that the more we know about the customer's needs, wants and expectations, the more we can align our project to satisfy the CTQ requirements as well as focus on variable measurements for evaluating our success

What is the significance of a data collection plan?

Data is the driving force for any analysis. Therefore, it is important to know and identify a data plan, explaining what data you will need to collect and how you will collect it. Without appropriate and applicable data, project results may be questionable.

Is six sigma related to Deming's philosophy?

Yes, very much so. Deming, through his fourteen obligations for top management, communicated the need for improvement of quality, productivity, and competitive position. For the list of the fourteen points see the glossary.

It is very important to recognize that, even though Deming never mentions six sigma, he was very well attuned to the benefits of ever-improving quality. Deming also wrote about some of the negative forces that would stop an organization from embracing

the fourteen points and the notion of continual improvement, in general. He called them the seven deadly sins and they are:

- Lack of constancy of purpose.
- Emphasis on short-term profits.
- Evaluation of performance, merit rating or annual review.
- Mobility of management.
- Management by use of visible figures.
- Excessive medical costs.
- Excess costs of liability.

These deadly sins are the same as the deadly sins for the six sigma initiative. Any one of these can torpedo six sigma beyond repair.

In six sigma, there is much talk about quality needs and overall strategic plans. What does this mean?

In order for six sigma to survive, quality needs and overall strategic plans must exist in the organization. That is, there must be a system established in the organization to address the following:

- *The link between quality function needs and overall strategic plan.* Perhaps this is the most important issue in six sigma, but also in any endeavor that tries to address improvement of any kind. The focus here is on the quality function needs and the plan to support these needs, both now and in the future. Of course, these needs have to be in line with organizational aims, policies and plans. Some key considerations are: competition, cost, differentiation of product and usage of appropriate tools.
- *The link between strategic plan and quality plan.* The second most important issue in six sigma methodology is to correlate the strategic plans with an actual quality plan. That means that the organization either has, or is willing to develop, programs that deal with feedback, corrective action, data collection, processing and analysis and process and product development. In addition, it means that the organization has, or is willing to develop, an infrastructure to address such issues as organization, administrative support, control processes, internal audits, processes that identify customer needs and policies for inspection and testing.
- *The theory of variation (common and special causes).* It is beyond the scope of this book to have a lengthy discussion on variation.