1 Principles of Six Sigma

1.1 OVERVIEW

A Closer Link to Executive Thinking. Within a business, Six Sigma has different meanings for different groups; this difference depends on one's level and respective job role in an organization. At the *enterprise level*, Six Sigma is often deployed as a strategic business initiative. In this context, it focuses on making significant improvements in areas such as business growth, capacity, investor relationships, and customer satisfaction. At the *operations level*, Six Sigma is tactical in nature and is most often directed toward improving delivery time, cost of poor quality (COPQ), defects per unit (DPU), and a host of other critical measures of operational effectiveness and efficiency. At the *process level*, Six Sigma is used to reduce process variability. Reducing variability minimizes the number of defects, shortens process cycle times, and decreases direct costs. At this level, the motto is simple—if you make an improvement, then on a timely basis the gains should be verifiable. In this context, the elimination of a defect, mistake, fault, or error within the "system" must directly translate into a measurable benefit such as reduced headcount, less material, and lower overhead cost. In other words, Six Sigma is a strategic and tactical system for managing total business enterprises. From this perspective, Six Sigma has the capacity and capability to deliver customer and provider satisfaction, which are key ingredients for business success. In short, Six Sigma epitomizes the ideals of business success and optimizes the control function of an enterprise. In its most elemental form, Six Sigma represents 3.4 defects per million opportunities for defect. This perspective of Six Sigma is related to a single opportunity for defect for a single critical-to-quality (CTQ) characteristic. The fundamental idea of Six Sigma is that as performance is improved, quality, capacity, cycle time, inventory levels, and other key factors are also improved. Thus, when these factors are improved, both the provider and the customer experience greater satisfaction in performing business transactions.

1.2 SIX SIGMA ESSENTIALS

The abatement of business risk is essential to Six Sigma. In this text we will explore many of the key concepts underpinning a new definition of quality. We will describe quality as the state in which value is realized for the customer and provider in every aspect of the business relationship. Simply stated, performance meets expectations; in doing so, we will demonstrate that Six Sigma is far more than a simple quality target. The fundamental tenets of Six Sigma are as follows:

Thinking Six Sigma. Explore the big ideas that power the realization of breakthrough performance and then gain insight into how these ideas create value for any type of enterprise.

Practitioner's Guide for Statistics and Lean Six Sigma for Process Improvements. By Mikel J. Harry, Prem S. Mann, Ofelia C. de Hodgins, Christopher J. Lacke, and Richard Hulbert

Applying Six Sigma. Profile the vital improvement tools that Six Sigma players use when executing their application projects and then grasp how such "mind tools" can be used to solve virtually any problem.

Targeting Six Sigma. Identify, scale, define, empower, and execute Six Sigma projects that achieve higher organizational goals and then learn how to track and validate progress in these projects.

Leading Six Sigma. Identify, select, and train Six Sigma leaders at all levels of an organization without backfilling the vacated positions, and then effectively motivate and retain those leaders to continually achieve forward momentum.

Enabling Six Sigma. Understand the information and reporting needs that underlie the global deployment of Six Sigma and then effectively integrate and fulfill those needs at the local level of the enterprise.

Deploying Six Sigma. Study the essential guidelines for scaling and creating a global Six Sigma deployment plan that will create a critical mass of focused management activity and then put momentum behind that mass at the local level of an enterprise.

Initializing Six Sigma. Interrogate the top programs that support the rapid initialization, deployment, and implementation of Six Sigma and then fully leverage such programs at all levels of an enterprise.

1.2.1 Driving Need

From a layperson's viewpoint, the world appears to be quite predictable at times but unpredictable at other times, although it appears that little has changed. From this perspective, we can appreciate why the human species has been obsessed with the idea of control. Perhaps this driving need for understanding and repeatability of results led to the idea of science. In some cases, we seek to enhance our ability to replicate some object, situation, or phenomenon. We recognize that to replicate a successful business transaction, the provider must establish processes that are capable of yielding high-quality outcomes that are both efficient and effective in terms of cost and time. Today, many businesses deploy such processes both vertically and horizontally throughout their organizations, often interfacing with their customers and suppliers. To this end, the provider must minimize average transactional costs, as well as that of time, while concurrently seeking to maximize quality and volume. At least so goes the theory in the executive mind. Senior executives are always on the lookout for innovative ways to reduce their cost and expand market share. Doing so creates value for all stakeholders. To achieve this, business leaders aspire to increase their organization's capability and capacity with minimal resource investment. They understand that quality and customer satisfaction must be continually improved.

1.2.2 Customer Focus

What is the nature of a customer–provider relationship? Most businesses claim to be customer-focused; however, these same businesses show little or no evidence to support this claim. An organization that is honestly committed to customer satisfaction will implement multiple customer feedback channels and a structured methodology for integrating data into their service delivery processes. The dictionary defines the term *customer* as a person who buys something. Simply stated, this implies that the customer is a person (or perhaps an organization) that receives some form of value in exchange for another form of value, held or originated (fully or partially), by the provider. Obviously, the customer and provider both seek to maximize their respective benefits. The dictionary definition provides us with a fairly large keyhole for viewing satisfaction. Such a state of being is related to the idea of conducting a successful business transaction. The customer has a sense of the extent to which her/his standards have been met by a business transaction, as does the

provider. In other words, they both seek a quality transaction. Essentially, customer and provider expectations form the basis on which the idea of quality is based. It is precisely this interaction between the customer and provider that governs the "quality" of the business relationship. For every aspect of producing and consuming a product or service, there are rightful levels of expectation that can be identified and improved only through careful and detailed analysis. A company can meet or exceed these expectations only by deploying performance metrics to guide and manage each key aspect of the business relationship, whether that aspect is making a product on an assembly line or broadcasting a news show.

Here quality is not an absolute standard but rather a relative measure of the gap between rightful expectation and actual performance. As the gap diminishes, the quality of interaction improves in all aspects of the business relationship. In this sense, the Six Sigma definition of quality serves as a management framework for focusing a business and launching actions that yield consistent and dramatic results for the customer and provider. It is a divergence from tradition in that the pursuit of value entitlement, not blind conformance to standards, drives the business relationship.

1.2.3 Core Beliefs

What is the fuel that propels the success of six sigma? We must all remember that Six Sigma is the epitome and embodiment of "hope" that fuels the collective will. It is hope that moves people to align their values, aims, and goals in a common direction. This is what leaders do; where it exists they sustain it; where it does not exist, they create it. Leaders create and energize hope by realizing visible and measurable success, not just one project at a time, but by achieving many simultaneous successes. Hope drives the human spirit to accomplish great things, and thus hope is the muscle of leadership. Without hope, leaders have nothing to sell. Without something to sell, they are just another player on the field of mediocrity. The collective "shock and awe" of Six Sigma projects is one way to ignite the stove of executive hope. It is the sudden, collective, decisive, and repeatable successes of Six Sigma that cause employees to believe their company is the best. When this attitude pervades an organization, it becomes boundaryless. As this occurs, innovation takes hold. Essentially, the Six Sigma initiative was designed to raise the bar so high that employees would be forced to individually and collectively reexamine the way in which work was done, not just tweak the existing work processes. Given this inaugural aim, it should be apparent that Six Sigma is about innovating new ways of doing things, not just making incremental gains to existing processes.

How is Six Sigma superior to other improvement programs? Simply stated, Six Sigma has produced astounding economic benefits that have hit the proverbial bottom line of many fine corporations in a verifiable and consistent way, year after year. We have a saying in Six Sigma work, "let the data do the talking." In this spirit, the financial performance achieved by Six Sigma says it all, not to mention the quantum gains in customer satisfaction. Unlike the philosophical and prophetic nature of *total quality management* (TQM), Six Sigma is a repeatable management process based on the idea of measurement. It is a goal-driven, result-oriented, fact-based management system based on scientific principles. Thus, Six Sigma requires that any type or form of business improvement must be verifiable through measurement in everything that a company does or seeks to do everyday in every way. Today, few corporate executives believe that TQM is a viable system of business management. The conclusions were quite apparent in a 1996 study, "Measuring performance after meeting award criteria," published in *Quality Progress* magazine, that TQM practices had less impact than most thought. After examining data from Baldrige and state quality award winners, applicants and nonapplicants, the study's authors concluded that they could not conclusively determine whether quality award-winning companies perform better than others.

Even before this, TQM skepticism was already building. Consider the April 1994 article, "Is TQM dead?" featured in *Quality Digest* magazine. Editor Scott Madison Patton cited study after

study that brought the viability of TQM into serious question. Only 20% of *Fortune 500* companies are satisfied with the results of their TQM processes, according to a 1992 Rath & Strong survey. Florida Power & Light remains the only US company to have won Japan's coveted Deming Prize. Its winning strategy was largely dismantled after complaints of excessive bureaucracy and red tape. Patton continued, stating that a survey of 300 electronics companies by the American Electronics Association found that 73% had quality programs in place, but of these, 63% said they had failed to improve quality by even as much as 10%. A study of 30 quality programs by McKinsey & Co. found that two-thirds of them had stalled or fallen short of yielding real improvements. Unlike TQM, Six Sigma is a management tool that astute leaders can employ to masterfully intertwine their personal destiny with that of the corporation. Only when this happens does the potential for business magic begin to surface. Not the smoke-and-mirrors variety of magic, but the kind of real stuff from which dreams are made.

The creation of operational magic is what sound business is all about. When this magic begins to unfold, good leaders suddenly edge toward greatness, followers begin to consciously work smarter and harder, and the world (at large) takes notice. This is the magic of Six Sigma; it can transform good corporations into exemplars. As great leaders wield the power of Six Sigma and begin to leverage the tools of breakthrough, they cross the threshold of destiny. At this point the corporation, its employees, shareholders, and all of those so connected prosper. Employees across the corporation rise to the challenge. When this occurs, an unstoppable revolution begins.

What are the boundaries of Six Sigma? First, a host of well-respected global corporations have directly experienced the promised benefits of Six Sigma. Most of these highly diverse corporations have carefully documented their Six Sigma journey and published their notable successes. Many of their senior executives are outspoken on the merits of Six Sigma and corroborate its power as a management system. In fact, Mr. Jack Welch (former CEO of General Electric) stated that Six Sigma was the most significant undertaking in GE history. He also said that Six Sigma, as a management tool, reaches the control function of a corporation. These facts speak volumes about the power and reach of Six Sigma. At any level of an enterprise, a mix of resources are required to fix a defect or error. If the given defect is eliminated (or otherwise prevented by process or product design), then the improvement is verifiable. In other words, the improvement is real. If an improvement is verifiable, we should see a corresponding savings in labor, material, and/or overhead. If such a savings does not materialize or cannot be verified, then the improvement was not real. Such is the way of Six Sigma. In a nutshell, Six Sigma is about the creation of global value, whereas TQM was generally limited to local quality improvements. In this sense, Six Sigma is about sudden and quantum breakthroughs in business performance (vertically and horizontally), whereas TQM was concerned mostly with achieving gradual improvements in product defect rates (at the local level of an enterprise). Six Sigma is a top–down business imperative (based on cascading performance expectations), whereas TQM is a bottom–up quality program (based on disconnected quality improvements). Again, it is easy to see that TQM is mostly constrained to the business of quality, whereas Six Sigma is concerned with the quality of business.

1.2.4 Deterministic Reasoning

The Nature of Determinism and How It Fits with Six Sigma. In a purely deterministic world we recognize that at any moment in time, a change in some object, event, or phenomenon is dependent on a change in one or more of its underlying determinants. In its simplest form, we can express this idea by the relation $Y = f(X)$, where Y is the dependent (outcome) variable, X is the independent (causal) variable, and f is the function that defines the relationship between Y and X. For example, a sonic boom (Y) is a function of an airplane's speed (X). Physics and mathematics are based on this simple concept. In the real world, life is not that simple; we recognize that other factors exert an influence on Y. Coming back to our analogy, in addition to speed, most of us realize that the existence and strength of a sonic boom depends on other contributing factors such as altitude, wing design, and atmospheric conditions.

Simply knowing the airplane's speed is not enough, by itself, to fully explain the boom effect. Hence, we must extend the relationship $Y=f(X)$ in such a way that $Y=f(x_1, \ldots, x_n)$, where $x_1, \ldots, x_n$ becomes a set of determinants. The world of Six Sigma has been built around this simple belief; without the idea of determinism, the practice of Six Sigma could not exist.

1.2.5 Leverage Principle

What is the leverage principle, and how is it used in the practice of Six Sigma? Not all variables are created equal; some exert more influence than others. This idea is exemplified by the relation (transfer function) $Y=f(x_1, x_2, \ldots, x_n)$. Given such a deterministic model, we understand that a certain amount of change in a particular x may not induce or otherwise cause the same amount of change in Y as some other X. Thus, it can be said that every X may have a different influence on Y. Those x's (x values) that exert a large influence are said to have leverage. Similar to a lever that is used to move a large rock, an "X" with leverage can cause a significant change in Y when compared to the influence of other x's within the same set of causative factors. Those x's that exert a disproportionately large amount of influence on Y are often called the "vital few" variables. These vital few variables stand in stark contrast to the less influential factors, often called the "trivial many" variables.

1.3 QUALITY DEFINITION

Quality and How It Fits in Six Sigma. In general, quality is defined as conformance to standards; however, some authors define quality as a subjective term for which each person has his/her own definition, based on the perceived degree to which the product or service meets customer's expectations. Quality has no specific meaning unless related to a specific function or object. Quality is a perceptual, conditional, and subjective attribute. On the other hand, the Six Sigma view of quality differs from this perception–definition. For Six Sigma, quality is a state in which value entitlement is realized for the customer and provider in every aspect of the relationship. Therefore, the central question for the practitioners regarding quality is: Is my organization in the business of quality? Or, is my organization in the quality of the business? A guide for the practitioner is to determine whether his/her organization is in the business of quality. If the organization is in the business of quality, the key determinant for customer need is utility and the key determinant for the provider is to achieve. If the organization is in the quality of the business the key determinant for customer need is value and the key determinant for the provider is to create. The importance of quality improvement is that it starts with finding the root cause of a defect; this includes problem analysis and problem solving. On the other hand, it is known that Six Sigma is a business improvement method that searches for the causes of the defect and then eliminates these causes by focusing on outputs according to the customer's key needs. From this, we could say that a phase of quality is the quality of the product or the quality of service. Another phase of quality is *product or service offering*—when an organization makes the product or service within the options that customers want, the customers will buy it. Another phase is the *quality of cost conformance*—if the organization meets customer's price better than other offerings, customers will buy it from the organization. Another phase of quality is *provider cost reduction* and therefore, improvement of business margins. Yet, another phase of quality is the *quality of creating value*—if an organization creates value, customers will buy the product or service.

Plainly stated, the Six Sigma definition of quality is a state in which value entitlement is realized for the customer and provider in every aspect of the business relationship. By this definition, quality is not exclusively related to a thing, but rather to a state applicable to all aspects of the business relationship; there exists a perceived state of quality as well as a real state. Thus, quality now encompasses the idea of value and a rightful expectation of entitlement. This definition of quality has spread around the world as Six Sigma quality professionals have become more sophisticated about how they measure and improve what companies do and how companies do it. Specifically, they

have expanded the quality envelope to include not only the utilitarian aspects of products and services but also their availability and worth aspects. The value aspects of a product or service should exclude variation, should exclude defects, and should include time reduction. The customer and provider have every right to expect that form, fit, and function requirements for a deliverable (e.g., product, service) process will be created and provided in a quality way. Even when this sounds redundant, customers can reasonably expect that deliverables will be presented to them on a timely basis and in the quantity ordered. Finally, the overall worth of each transaction should always be present in the minds of both customer and provider. Inherently, customer and provider must find economic, social, intellectual, and/or psychological value in each transaction. Since these forms of value are shaped by laws, rules, and regulations and translated by the processes of dictation and negotiation into performance requirements, it is obvious that quality begins with the first customer contact and continues throughout the lifecycle of the business process relationship. In business terms, this is known as delivery.

Because the customer has the rightful expectation that the utility of a product or service will be present at the time of purchase, on delivery, and during its defined lifetime, the provider seeks to reduce the cycle time of its systems, operations, and processes, thereby reducing the time between order entry and shipment. The provider expects to make full use of the capacity and capability inherent to the systems, operations, and processes that realize the product or service. The same could be said for the provider's stakeholders, as they can rightfully expect that their capital investments will yield an attractive return. This same line of reasoning holds throughout the value chain (vertically and horizontally). In addition to utility, availability aspects of value entitlement are part of the total business relationship. Finally, as quality practice becomes integrated with the financial domain of business, Six Sigma metrics and improvement efforts become focused on the "worth" aspects of products and services. Simply stated, the customer can rightfully expect to minimize his/her economic outlay while the producer is entitled to make the highest possible profit. Obviously, this can occur only when the previously mentioned quality aspects achieve their respective levels of entitlement. In summary, and from this perspective, it is clear that quality professionals should focus on the quality of the business (quality of cost) and not on the business of quality (cost of quality). In other words, it is more important to ensure that every dollar spent on the business produces a dollar's worth of value for the customer and provider, than it is to measure how much money is lost as a result of poor quality that is a posteriori focus. The practitioner should again recognize that the idea of worth embodies many aspects, such as emotional and intellectual fulfillment to the customer and provider in maintaining the business relationship. Whereas the customer feels good or satisfied after purchasing a product or service, the provider has these same needs while producing a product, delivering a service, or performing a transaction. In addition, the customer has a rightful worth expectation related to various societal considerations such as the product will not degrade the environment, will not be a hazard to her/his health, or cause harm to others. As may be apparent, the notion of value entitlement turns the classic idea of quality that is conformance to standards, instead of a singular focus on conformance to standards (customer satisfaction). Six Sigma companies strive to determine the customer's and the company's rightful level of expectation in all aspects of the business relationship. Such expectations, some set by the laws of physical possibility and some negotiated, form the quality standards for that relationship. Given this, the inherent meaning of quality constantly changes as a function of the interaction between customer expectations and provider capabilities.

Node Levels. These are the basic units of data structures. Information is contained in data structures such as trees and linked lists. Each node contains data and links. Chains of interlinked nodes create large complex data structures. The node level is similar to the product or service level. While a product or service design has certain performance specifications, real or theoretical levels of process capability and capacity are required to achieve the database designers' aims. Only when the two are properly identified and integrated can we measure and then reduce the gap between rightful expectation (e.g., design specifications) and actual performance (e.g., process capability). As these

gaps are diminished, the quality of interplay improves, thereby cascading to the system level and ultimately to the customer. Thus, we turn to Six Sigma to qualify our designs through the prudent and scientific process of measurement, analysis, and optimization of producibility. As may be intuitively reasoned, the vast majority of ideas, methods, tools, and practices related to the field of producibility analysis can be effectively used by all vertical and horizontal functions within the organization. Only in this manner can we begin to design in quality. By the simple domino effect, we break through to a new level of performance and begin to create the quality of business rather than just using the philosophy of quality in products.

1.4 VALUE CREATION

Value Creation and How It Aligns with the Aims of Six Sigma. From the customer's viewpoint, Six Sigma translates into higher-quality products and services, delivered on time, at the lowest possible cost. In this sense, Six Sigma offers tremendous value. Through Six Sigma, a customer has better access to products and services, enjoys a significantly higher level of product and service utility, and pays less for these benefits. So, in the customer's head and heart, Six Sigma is about the creation of value. This makes Six Sigma a value proposition for both the customer and the provider. In its first generation, (1984–1994), Six Sigma was initiated at Motorola. At that time, Six Sigma focused primarily on the reduction of defects through quality improvements. It was widely believed that the reduction of defects would naturally and invariably offer economic benefits even though such benefits could not be readily verified by commonly accepted accounting conventions. During the second generation, (1994–2001), Six Sigma was initiated at Asea Brown Boveri (within their large-scale transformer business). Here, Six Sigma was directed toward achieving verifiable cost reductions. Thus, Six Sigma focused on cost reduction, and that became the battle cry for quality improvement. Essentially, this reversed the emphasis of the previous Six Sigma generation. Obviously it worked as evidenced by the wide adoption of Six Sigma since that time. Interestingly, the third generation of Six Sigma (2001–present) is focused on the creation of value. This generation is based on a careful examination of the lessons learned from the application of Six Sigma by more than 30 global organizations over the previous twenty years.

1.4.1 Value

Business improvement is much like filling a bucket with water; of course, you must stop the leaks, but you may also have to use a larger bucket, increase the flow rate, or some combination thereof. In other words, value creation moves the focus of quality closer to the customer (and the provider). Such a shift in emphasis is augmented by the concurrent and increased focus on the key dimensions of quality—utility, availability, and worth. In this context, we can describe value by the simple equation.

$$V = \frac{U \times A}{C}$$

where V = value of cost product or service, event or activity; U = utility of the process that delivers the product/service in terms of form, fit, and function; A = access by the customer to the product/service in terms of volume, timing, and location; and C = cost.

Hence, value is "bang for the buck" from the customer's perspective. Value (per se) is realized when the need for low-cost utility is fully satisfied. However, to create such value, we must employ the four phases of Lean Sigma—innovation, configuration, realization, and attenuation. Low-cost solutions should be developed to meet the customer's utilitarian and access needs. To meet these needs, we must first propose a plan/design to deliver the needed product or service. Then, we must realize the physical form of those ways and means, and finally, we must reduce the value gaps that will usually emerge over

time. To implement the Lean Sigma strategy, we employ certain tools and methods. In the course of the innovation phase, we apply these methods and techniques associated with *marketing for Six Sigma* (MFSS). During the configuration phase, we seek to leverage the practices of *design for Six Sigma* (DFSS). During the realization and attenuation phases, we use the tools commonly associated with *processing for Six Sigma* (PFSS). Underlying the Lean Sigma strategy are the principles and practices associated with *leading for Six Sigma* (LFSS).

Through these programs, an organization becomes empowered and is able to upgrade its knowledge base. From this perspective, we realize that the progressive application of Six Sigma tools across the total product lifecycle can have a profound impact on value. In fact, Six Sigma not only preserves value but also seeks to create value. Thus we can define quality as a state in which the customer and provider realize full value entitlement in every aspect of the business relationship.

1.5 BUSINESS, OPERATIONS, PROCESS, AND INDIVIDUAL (BOPI) GOALS

The Vertical Goals of Six Sigma and How They Are Connected to the Bottom Line. In a strict sense, the goal of Six Sigma is to realize no more that 3.4 adverse consequences per million risk exposures. However, this goal is merely a "model" of what an organization should strive for at the molecular level of its endeavors (e.g., at the opportunity level of a product, process or service). In practice, the Six Sigma goal varies from enterprise to enterprise, as well as within and across organizational functions of each enterprise. This third-generation Six Sigma goal is applicable to each of the four basic tiers of an enterprise—*business, operations, process* and *individual* (BOPI). Thus, we have the BOPI acronym. However, it should be noted that each BOPI level has different yet interrelated Six Sigma goals. By level, the BOPI goals are as follows:

Business Level. Achieve best-in-class performance for each critical-to-business (CTB) characteristic over a 5-year period. CTBs are those business measures that are considered to be the most important for the organization's economic survival. For example, CTBs include, but are not limited to market share, return on net assets, and customer satisfaction.

Operations Level. Realize an annualized 78% baseline improvement over a 5-year period for each critical-to-value (CTV) characteristic that links to a business goal. In particular, CTVs are the operational metrics that relate directly to customer satisfaction and market performance. CTVs include, but are not limited to total defects per unit, late deliveries, and warranty returns.

Process Level. Realize no more than 3.4 defects per million opportunities for each critical-to-quality characteristic (CTQ) associated with the organization's key products, services, and transactions. CTQs are the conditions that must be "right" when to the product or service is being produced. For example, CTQs include, but are not limited to, part thickness, absolute weight, reaction speed, material strength, and telephone hold time.

Individual Level. Achieve a level of capability equivalent to $Cp = 2.0$ and $Cpk = 1.5$ (please see Section 1.2.6) for every critical-to-process (CTP) characteristic that underpins each core process. From this perspective, CTPs are located at the key "adjustment points" within a process. Achieving and sustaining optimal control over the CTPs is essential to effectively and efficiently improve CTQs. For example, CTPs for a machine include but are not be limited to temperature, squeeze pressure, and cutting speed. To translate these idealized goals into the real world, let us consider a corporation's Six Sigma aims. We assume that executive management has issued a directive to improve the company's profit margin by $X\%$ over some defined period of time (say, Z years). In turn, this business goal has been allocated (i.e., flowed down) to the various operations of the business. At this level, the apportioned business goal is translated into expected improvements in certain operational performance metrics such as customer satisfaction, total defects per unit, on-time deliveries, product yield, and service performance. Thus, by closing the "performance gaps" at the operations level, the "economic gaps" can be

reduced or eliminated at the business level. Next, these operational goals must be translated into process level objectives. Thus by focusing on critical processes, higher-order goals become actionable. For example, suppose that one of the operational goals is to improve total defects per unit (DPU). To accomplish this objective, the average capability of one or more critical processes must be improved. To illustrate, it might be necessary to improve the *ABC* and *XYZ* process capability from 4σ to 5σ (over the defined period of time to reduce DPU by *X*%). To achieve this aim, the *ABC* and *XYZ* processes must be fully characterized and subsequently optimized. Naturally, some knobs may have great leverage while others may have little effect on the processes. Once the "vital few knobs" have been identified, each must be fine-tuned to achieve the overall process improvement. In other words, each key process knob must be centered on its ideal operating condition. In addition, the time-related variations around the ideal centering condition must be minimized. Thus, we can now better understand the linkages across the hierarchy of an organization (BOPI). To achieve the global aims of Six Sigma in body and spirit, measurable and verifiable linkages between the business, operations, process, and individual levels of a company must be made.

1.5.1 Differences between Product and Process Capability from a Six Sigma Perspective

Process Capability. This is defined as the spread within which almost all of the parts or values within a data distribution will fall. It is usually described as being within plus (+) or minus (−) three standard deviations ($\pm 3\sigma$) or six standard deviations (6σ) from the mean value of the dataset. This baseline definition enables us to compare the process capability with the process or specification tolerance. Many quality practitioners treat product and process capability as if they were interchangeable concepts. Presumably, this convention has evolved over time because of the naturally strong correlation between the two. Although related, these two concepts should not be viewed in the same light. At the risk of leading a dead horse to water, we should recognize two things.

Specified Tolerance and Distance to Nearest Specification (DNS). These values are commonly translated into other capability measures. Capability ratios are a simple way of expressing the relationship between the *voice of the process* and *voice of the customer* (VOC). The result is generally expressed as either a dimensionless number or a percentage. The capability ratio is calculated by dividing the difference of the specification limits [*upper specification limit* (USL) and *lower specification limit* (LSL)] by the spread of the data under the area of the normal distribution curve (6σ). The *capability ratio* is denoted by the symbol C_p

Therefore, C_p is expressed as

$$C_p = \frac{\text{USL} - \text{LSL}}{6\sigma}$$

Another quantity, denoted by C_{pk}, is also called the *capability ratio*. This is defined as the distance to nearest specification (in sigma units) divided by 3:

$$C_{pk} = \frac{\text{DNS}}{3}$$

This ratio characterizes the process centering relative to specifications. Some authors do not distinguish between this measure of process centering and the distance between the specification limits.

1.6 UNDERPINNING ECONOMICS

Cost-of-Poor-Quality (COPQ) and How It Should Be Used in a Six Sigma Program. Today, corporations of all types and sizes are looking for top-line growth, reduction in cost structure,

and increased capacity, without capital investment. In addition, these organizations are looking for improvements in customer satisfaction, investor relations, supplier quality, not to mention the need for gains in organizational capability and capacity. It can be said that the ability of senior management to yield an additional 5–6% return is no longer a stretch goal; it is fundamental to business growth. Of course, these imperatives are just one of the tasks that senior executives must pursue on an ongoing basis. In short, a business enterprise must be able to create and sustain value. Few companies are aware that the typical corporation leaves the equivalent of 15–25% of every sales dollar on the table and that about 5–6% of sales can be recovered in hard savings through the use of Six Sigma. Such hidden losses result from the untapped capability and dormant capacity in everyday activities. These organizations are usually not aware that achieving a Six Sigma performance level delivers a $1800\times$ improvement over the global 4σ average. They fail to recognize that achieving even a 0.5σ improvement in their operation could create a huge competitive advantage. Unfortunately, these beliefs will directly impact the future of their corporation. Most corporate accounting systems are unable to capture a large part of the true cost of poor quality (COPQ). For example, lost customer opportunities (due to quality issues) are real; however, the organization's financial systems are not designed to detect or report this economic impact. Thus, many executives falsely believe what appears on the accounting dashboard that indicates that the COPQ is about 1% or 2% of sales. In short, this level of COPQ does not trigger any management alarms; thus, the business continues its operations as usual, blinded to the true cost of quality. Even more tragic, the senior leadership team falsely believes that their overall quality level is excellent because their COPQ is low. The best wakeup call for senior leadership teams is "sigma benchmarking." For example, such benchmarking has revealed that the average global corporation operates at roughly a 4σ level. This translates to about 6810 defects per million opportunities (on average). Even more shocking is that the average COPQ for a typical company is 25% of sales. But when we consider a Six Sigma company that produces only 3.4 defects per million opportunities, we realize that this organization is about 1800 times better than its average competitor. This means that a Six Sigma business will experience a COPQ of about one percent of sales. One must wonder how a 4σ company can ever hope to compete with a Six Sigma company? The answer is simple—a 4σ business cannot compete with a Six Sigma business. Of course, everyone thinks their company is the best in existence. We have all heard executives, managers, and employees boast that *nobody does it better than we do*. Around the globe, senior management teams base decisions on the belief that their organization is best in class. Many also falsely believe that they are already at or near the Six Sigma benchmark. When confronted with the results of a sigma benchmarking study, they initially reject the conclusion that they are performing far below a superior level. They often say, we are not that bad. But sooner or later, most organizations come to the realization that they are only average after completion of the benchmarking (test and inspection) phase. On the upside, it is at this point that the senior management team understands their true status and sounds the call to action.

1.6.1 Sigma Benchmarking

The best wakeup call for senior leadership teams is sigma benchmarking. Such benchmarking has revealed that the average global corporation achieves about 4σ. This translates to about 6810 defects per million opportunities (on average). Even more shocking is that the COPQ of average companies is about 25–30% of sales. When we consider a Six Sigma company that produces only 3.4 defects per million opportunities (on average). A Six Sigma organization is about 1800 times better than its average counterpart (4σ). This means that a Six Sigma (6σ) business will experience a COPQ equal to $\cong 1\%$ of sales. From this point of view, how can a 4σ company ever hope to compete with a 6σ company? The answer is simple—a 4σ business cannot compete with a 6σ business.

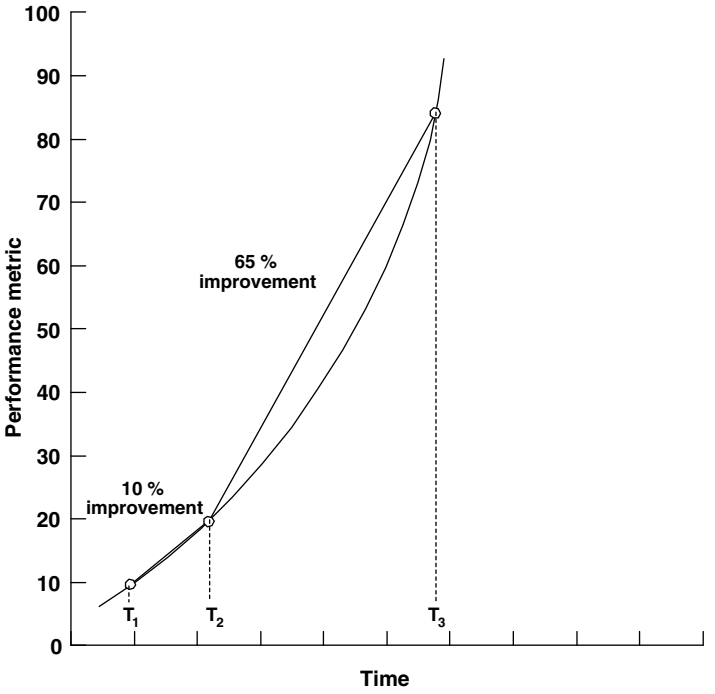

Figure 1.1 Graphical representation of a breakthrough improvement (65%) from T_2 to T_3 (from 10% to 55%).

1.6.2 Breakthrough Goals

Breakthrough goals are sudden departures from historical trends. For example, a change is considered to be small when it does not result in a large jump/change. Thus a change from 10% to 55% (from T_1 to T_3 as the one illustrated in Fig. 1.1) would represent a breakthrough jump while a change from 10% to 25% (from T_1 to T_2 as the one illustrated in Fig. 1.1) would not be a breakthrough because the processes could be easily tweaked to achieve this change. However, a large change cannot occur by simply tweaking the process.

1.6.3 Performance Benchmark

It is reasonable to assume that everyone believes their company to be the best. We all have heard our executives, managers, and employees say: "Nobody does it better than we do." All around the world, senior management teams believe that their organization or corporation is best in class. Many believe that they are already at, or near the Six Sigma benchmark. However, when comparing the empirical evidence with the Six Sigma benchmark chart, their first reaction is to reject the data. However, sooner or later most organizations or corporations come to the realization that they are only average. On the upside, it is at this point that senior management becomes enlightened and sounds the call to *action*.

1.7 PERFORMANCE METRICS

What are ''performance metrics,'' and how are they used by Six Sigma? At a global level, the reader should recognize that many well-respected organizations consider the use of metrics to be

the foundation of success. Within these organizations, it is well understood that periodic reviews of key business indices or metrics causes employees to focus on those indices that are essential to the business. Obviously, if the employees are not focused, improvement will be more difficult. These metrics include, but are not limited to, cycle time, field performance, and delivery delinquencies. With such data, a standardized system of feedback and control can be implemented and institutionalized. To ensure consistent and uniform use of performance metrics, many companies prepare and distribute a *metrics manual*, similar to the Performance Metrics Manual published by the Government Electronics Group of Motorola Inc., Scottsdale, Arizona.[1] During the implementation of Six Sigma, we often believe that there are no readily available information or numbers to estimate our existing level of process performance and we believe that considerable effort will be required to measure and identify trends, strengths, and areas for improvement. However, companies measure certain activities and record the data that could provide a valuable starting point for a capability evaluation.

There are many performance metrics available to define and communicate the capability of processes. Each has a unique function, and each individual or organization has its favorites. Specific combinations are useful, and many times several metrics are used together, or in a specific order to gain a deeper knowledge of a process. The appropriate metric to use in a particular situation is a function of the type of data involved, i.e., discrete or continuous, and whether the capability being evaluated is short-term or long-term. It is difficult to compare various metrics because they are defined differently. With a mix of various metrics, it is impossible to say which process is better. To overcome this difficulty, one should be aware that the sigma value (z) is the only metric that applies in all cases allowing direct comparison of one process with another, or one product with another, regardless of their unique characteristics or complexities.

1.8 PROCESS

Almost everything done by a company or organization involves a process. A *process* is any activity or group of activities that takes an input, adds value through these activities, and provides an output to an internal or external customer. Companies and organizations, regardless of size, use thousands of processes every day to create their products, deliver their services, or complete transactions.

1.8.1 Process Models

When at least 80% of the product or service value is derived from machinery, we classify it as an industrial process. It does not include shipping, distribution, or billing activities. When 80% or more of a process depends on human activity, we classify it as a commercial process. A commercial process, such as ordering materials, payroll, or processing customer orders, may support industrial processes or stand on its own as a separate and unique business. The profitability of banks, insurance companies, brokerage firms, credit card financial organizations, and similar organizations depend primarily on their business quality. On the other hand, manufacturing companies prosper only when the quality of their industrial and commercial processes meets or exceeds customer expectations.

1.9 DESIGN COMPLEXITY

Design Complexity and Its Importance to the Vision of Six Sigma. The basic concept of complexity has a long history and still bewilders the human species today. The dictionary defines complexity as that which is made up of "many elaborately interrelated or interconnected parts, so that much study is needed to understand or operate it." Needless to say, it is likely that each of us have felt this way

about something at one time or another. From a theoretical perspective, it is doubtful that we (as humans) will ever be able to fully grasp the limit of its meaning, much like the idea of infinity. Fortunately for those of us involved in Six Sigma work, the idea of complexity takes on a slightly different meaning. From this perspective, we define the complexity of a product or service as the simple sum of all its features (i.e., characteristics), from the interactive system level through the discrete node level. From a practical viewpoint we can ask "How complicated is this unit?" By a simple but perhaps time consuming tally, we could answer this question, particularly so in this age of computers. However, we shall make the definition even simpler; complexity is the aggregate quantity of all independent critical-to-quality (CTQ) characteristics that are assignable to a unit of product or service. Inferentially, we can say that a set of critical features is generally proportional to the larger parent set of all possible features. Given this, we do not have to count all things, just those that are "critical to mission success." Thus, the operational notion of unit complexity is given as the summation of CTQ's, where a CTQ can be generally thought of as a unique "circumstance" related to the "unit" that maintains enough value (of a positive or negative nature) that we seek to periodically assess its content.

1.10 NATURE AND PURPOSE OF SIX SIGMA

Six Sigma is a strategic and tactical system for managing the total business enterprise. From this perspective, Six Sigma has the ability to concurrently deliver customer and provider satisfaction, the key ingredients of business success. In short, this view of Six Sigma epitomizes the ideals of business success and optimizes the control function of an enterprise. Remember that in its most elemental form, Six Sigma represents 3.4 defects per million opportunities for defect. This perspective of Six Sigma is related to a single opportunity for defect or a single critical-to-quality (CTQ) characteristic.

1.10.1 Not Just Defect Reduction

Given that Six Sigma is primarily a business initiative that contains business metrics and is not just another quality program, we can now begin to see that it is more closely aligned with risk abatement than with defect reduction. By focusing on the sources of risk commonly associated with the operation of systems and processes, we can reduce the extent of risk that customers are exposed to when they purchase products and/or services. At the same time, the provider of such products and services benefits from the reduction of process and operational risks. This is how we concurrently realize customer and provider satisfaction. In other words, when businesses apply Six Sigma to reduce exposure to risk, customers increase their confidence of achieving entitlement performance in everything they do.

1.11 NEEDS THAT UNDERLIE SIX SIGMA

What are the cultural challenges associated with Six Sigma? In the book *Organizational Behavior* by Robert Kreitner and Angelo Kinicki, the culture of an organization is defined as the set of shared, taken-for-granted implicit assumptions that determine how a group perceives, thinks about, and reacts to its various environments. On the basis of this definition, an organization's observable artifacts, espoused values, and basic assumptions characterize its culture. In turn, these continually shape the organization's design and reward systems in a dynamic, ongoing manner. In a domino-like way, the latter two factors mold certain group and social processes, such as decision making, patterns of socialization, group dynamics, communication, and leadership. Of course, such processes determine work attitude, job satisfaction, and motivation. Ultimately, an organization's effectiveness (and its

ability to innovate) can be derived by careful analysis of the aforementioned factors. In fact, research has shown that

- Organizational culture is strongly correlated with employee attitudes and behavior.
- The extent of congruence between an individual's values and the organization's values is associated with such things as organizational commitment, job satisfaction, and turnover.
- Organizational culture cannot be used to predict a company's financial performance.
- Business mergers frequently fail from incompatible cultures.

Building on this knowledge and research, we can identify several tried-and-proven ways to create or otherwise embed a certain culture into an organization. Kreitner and Kinicki argue that these ways and means include

- Formal statements of organizational philosophy, mission, vision, and values
- Materials used for recruiting, selection, and socialization
- Design of physical space, work environments, and buildings
- Slogans, acronyms, and sayings
- Deliberate role modeling, training programs, teaching and coaching by managers and supervisors
- Explicit rewards, status symbols (e.g., titles), and promotion criteria
- Stories, legends, or myths about key people and events
- Organizational activities, processes, or outcomes that leaders pay attention to, measure, and control
- Leader reactions to critical incidents and organization crises
- Workflow and organizational structure
- Organizational systems and procedures
- Organizational goals
- Recruitment, selection, and development criteria
- Promotion, layoff, and retirement standards

Is Six Sigma a culture? The answer is a resounding: "*YES*" Why? Consider how Six Sigma is a fact-based, metric-driven, problem-solving, project-oriented initiative. Furthermore, Six Sigma ties performance to pay, has a formal vision, constitutes a value, has defined roles, is deployed by way of knowledge transfer (training), and involves coaching by internal leaders. As is widely known, Six Sigma has an established workflow called DMAIC (define–measure–analyze–improve—control). Finally, we recognize that Six Sigma has its own work design and structure. For these reasons, and many others, we conclude that Six Sigma can significantly influence the existing corporate culture; it can even be a culture, in and of itself.

1.11.1 Looking Across the Organization

It is apparent that the term Six Sigma can carry different (but related) meanings across the vertical and horizontal planes of an organization. Let us now explore Six Sigma across these planes. To unify these divergent views of what Six Sigma really is, we must examine its inner core. The fundamental tenets of Six Sigma are rooted in the abatement of risk in everything a business does or delivers. At a basic level, we recognize that Six Sigma embodies the idea that all defects or errors represent risk but not all forms of risk can be characterized in terms of defects.

1.11.2 Processing for Six Sigma

The first vehicle, *processing for Six Sigma* (PFSS), focuses on reducing risks of systems and processes regardless of their basic nature (industrial or commercial) or vertical strata (business, operations, process). More specifically, PFSS is concerned with reducing the extent of risk exposure inherent in the operation of an existing system or process throughout its useful lifespan. Inversely, PFSS is employed to increase confidence that a system or process will achieve operational entitlement in the short term and Six Sigma performance in the long term. PFSS exercises the breakthrough strategy to the extent that each value risk point critical to the operation of a system or process experiences no more than 3.4 risk exposures per million opportunities for such exposure. We must recognize that this goal exists in light of uncertainties that cannot be feasibly managed. This goal is often translated into the language of quality, 3.4 nonconformances per million opportunities for nonconformance. Still, another way of stating this goal would be to say that Six Sigma is equivalent to one defect (error) per 294,118 CTQs.

1.11.3 Designing for Six Sigma

The second vehicle, *designing for Six Sigma* (DFSS), focuses on reducing the various forms of risk attributable to the design of a product, system, or process, regardless of its nature (industrial or commercial). DFSS is concerned with two equally important and often related aims: (1) it is concerned with reducing the extent of risk exposure inherent in the functional performance and physical attributes of a design (customer satisfaction issues), and (2) it is concerned with reducing the risks associated with the business and operational viability of a design (provider satisfaction issues). Inversely, DFSS can increase our confidence that a product, system or process design will perform to its entitlement level in the presence of uncertainties that cannot be feasibly managed. The goal of DFSS is simple: to exercise the Breakthrough Strategy such that each critical value risk point associated with the functional properties and processability of a design are limited to no more than 3.4 risk exposures per million opportunities for such risk.

1.11.4 Managing for Six Sigma

The third vehicle, *managing for Six Sigma* (MFSS), is the underlying foundation for delivering the breakthrough Six Sigma initiative. It is concerned with the creation, installation, initialization and utilization of the deployment plans, reporting systems, and implementation processes that support PFSS and DFSS. The ultimate goal of MFSS is to attain best in class business performance by improving the operational capability of an organization at an annualized rate of approximately 78% (Fig. 1.1). We can also view MFSS as the unifying component of Six Sigma that encompasses the aims of PFSS and DFSS for the purpose of synergistically maximizing the confidence in realizing value entitlement for both customer and provider in every aspect of the business relationship. Embodied in the new definition of quality, MFSS is the primary agent to effectively and efficiently plan, organize, initialize, execute, and sustain breakthrough improvement for a corporation, business unit, or facility.

1.11.5 Risk Orientation

Six Sigma is about the abatement of risk in all its forms. Although Six Sigma has been driven by this idea from its inception, many quality professionals have inadvertently constrained its full power and potential through the lack of knowledge about its developmental evolution. From this perspective, risk orientation represents a higher level of Six Sigma thinking and practice that is more closely aligned with the language of business (risk, opportunity, time, cost), than with the language of quality (defects, errors). As the number of quality professionals with this expanded orientation reaches critical mass, the conventional interpretation will give way to new ideas. New ideas will stimulate innovation. And innovation will lead to business success. The conventional approach used to encourage executives to think in terms of defects and to speak the language of quality is over; it is time for the world of quality

to think in terms of risk and speak the language of business. As this happens, business leaders will view quality professionals in a more opportunistic manner.

1.12 WHY FOCUSING ON THE CUSTOMER IS ESSENTIAL TO SIX SIGMA

A focus on quality is essential to evaluate how well the provider's capability (and capacity) matches customer requirements. Measurement of the scope and depth of this match is critical to producibility analysis. As a result, this writer often refers to producibility analysis as confidence analysis, encouraging a less restrictive definition of the term. Regardless of terminology, each of these shares the same goal and provides the same ways and means to achieve that goal. The reader is strongly encouraged to extend this discussion beyond the matching of product requirements to manufacturing capability, although this is a major factor.

It is equally important, if not more so, to apply the scientific methods of Six Sigma to sales, accounting, legal, engineering, production control, purchasing, and other areas where the idea of confidence engineering applies. Each of these areas implements designs, directly or indirectly, deliberately or unintentionally by careful thought or by historical precedent. While each must consider customer needs/requirements and judiciously match capabilities to these requirements if some form of satisfaction is to result. They must design and produce documents, proposals, or processes. In short, the same ideas, methods, tools and practices that apply to the industrial base of the economy also apply to the commercial base (Fig. 1.2). This presents an overly simplistic view from the provider's perspective. Since customers and providers are both concerned with the minimization of transactional cost and time, there will be competing goals for quality and volume. In management terminology, this commonality becomes visible as quality and volume are translated into process capability and capacity. However, the idea of variation sometimes escapes executives who are often consumed with averages, medians, percents, and baselines. They thus limit their statistical insights to processes and products and fail to recognize their ever-widening range of applications.

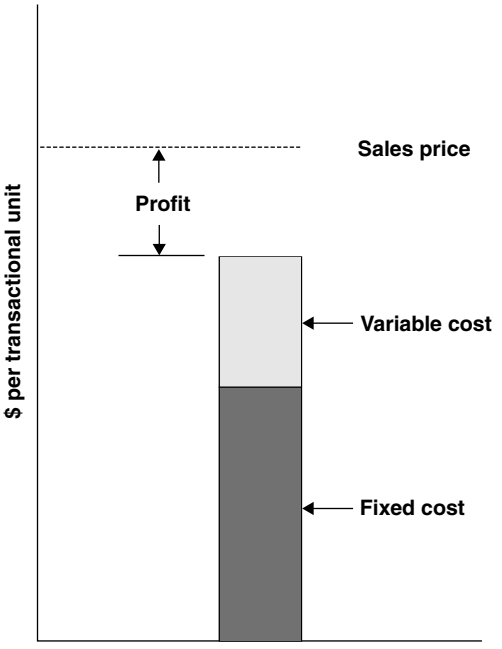

Figure 1.2 Provider's view of business.

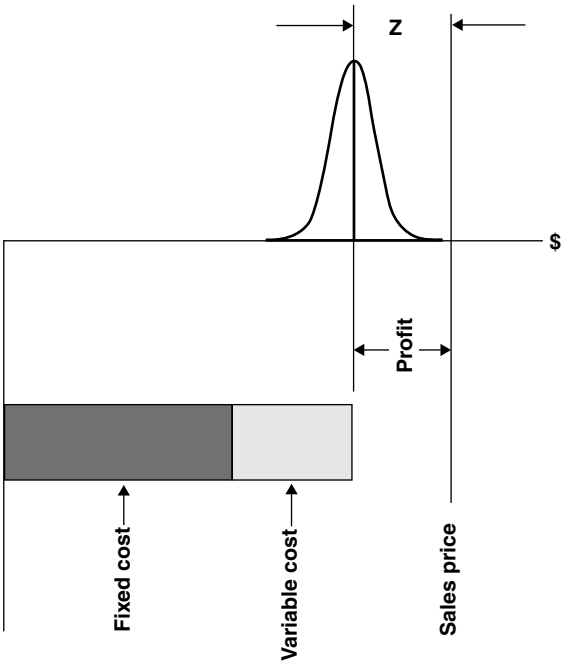

Figure 1.3 The Six Sigma view of business.

For example, if we consider the idea of variable cost as presented in Fig. 1.3, it occurs to this researcher that the term variable cost means just that, its variable. However, the bar chart limit of variable cost is displayed as a point estimate. Is this terminal point of the variable cost represent a central value, or does it represent the $+3\sigma$ limit of its corresponding distribution? Let us assume that it is the average. We also may assume that the underlying distribution of this variable is relatively independent and normal. We recognize its potential covariance with fixed cost but will ignore such second-order details at this time. From our discussion concerning the distribution of variable cost, it should be apparent that we could compute the probability of exceeding the sales price. In other words, we are free to estimate sales and discover the likelihood that the total cost of any given transactional unit will exceed the sales price per unit. Given this, we would then know the confidence of profit by virtue of $1 - R$, where R is the risk. In fact, we could compute this confidence for any given level of profit. Figure 1.3 provides a graphical representation to better facilitate the understanding of this concept. Also, we could approach the problem backward from a statistical perspective. This can be readily accomplished by first establishing a desired sales price and confidence level for the variable called *profit*. Next, we would easily back compute the specific variable cost goals for $\bar{f}$ and $\bar{v}$. Although this is just a simple example, it certainly pragmatically illustrates how we could better study and improve business quality.

However, in many cases the organization's existing accounting system is not properly configured to smoothly facilitate the application of such Six Sigma methods. Often it is easier to just keep doing it the way we always have. Interestingly, it is usually organizations of this type that also expound on their desire to become world-class. Perhaps they simply do not recognize the paradoxical nature of their thinking. The practitioner can now understand why 4σ companies tend to remain 4σ. If a company is to grasp the "golden Six Sigma ring," they must understand that Six Sigma products and services cannot be realized with 4σ business systems supported by 4σ thinking. To do Six Sigma, businesses must think Six Sigma. In this sense, the goal of Six Sigma is just a very small piece of the puzzle. It is important to emphasize that the real leverage of Six Sigma is in the *thinking* piece. Only when we think differently will we *do* differently, and only when businesses think and do things differently only then they will we be able to alter their historical business continuum.

From this discussion, it is easy to synthesize the key points and realize what customers and providers exchange is the value through and the need–do interaction. Simply stated, the idea of business becomes fully realized only when the need–do interactions are fully optimized. Only when such optimization is realized, can we say that the business relationship was abundantly successful. To realize this entitlement level of business, the practitioner must think about the quality of the business processes. Of course, this leads to the idea of breakthrough improvement in process capability and capacity, not just in physical processes, but in mental processes as well; one drives the other. Given this understanding, the practitioner may characterize the idea of business by the relation

$$C_N \overset{\text{exchange}}{\longleftrightarrow} P_D$$

where the symbolic notation represents the iterative and often interactive operation of those processes necessary to the realization and exchange of value, C_N denotes the many needs of a customer, and P_D is the myriad capabilities and inherent capacity offered by the provider. This bidirectional view of business necessarily broadens the scope of quality from a singular state (customer satisfaction) to a two-dimensional state (customer and provider satisfaction) that matches the very purpose of the business relationship, the optimal exchange of value between the provider and the consumer. Through a more traditional lens, the historical idea of quality was focused solely on the customer. This definition of quality demands that both the customer and provider be recognized as contributory factors/agents within a larger state of quality.

1.13 SUCCESS FACTORS

In the beginning, Six Sigma was a tough sell. One must realize that in 1987 Motorola promised to make a 1800× improvement in 5 years. At that time, an army of corporations that had already experienced any benefits of Six Sigma did not exist. In the 1980s organizations had only theories, beliefs, and faith. Of course, there were many times that organizations felt like throwing in the towel and calling it quits, but somehow these organizations persevered through the natural criticisms, relentless naysayers, and many other obstacles. Perhaps their biggest discovery was that organizations don't have to achieve Six Sigma to beat the competition hands-down. Many times, a half-sigma gain (or less) provided the market momentum necessary to capture more business. In addition, it has been discovered that there is no "point of diminishing return" where quality improvement is concerned (as the world previously believed). In addition, businesses have learned that a progressively higher level of quality demands more and more innovation. It forced them to become more innovative in all of their functions. In a nutshell, these organizations ultimately discovered that Six Sigma brought out the best in all of them. Businesses must always remember that the senior executives within a corporation are the ones who render judgment about the success or failure of an initiative. Simply stated, senior executives are in general concerned with one matter, to demonstrate results that are overtly visible and economically aligned with larger aims, not hidden somewhere in the bowels of the organization under the guise of cost avoidance or future realization. This sheds light on why the quality function in most corporations has remained largely disconnected from the sanctum of managerial (financial) control. While many quality professionals have been overly focused on incremental, perennial, long-term improvement, the senior executives of a corporation still remain focused on the *here* and *now*. Most of the world's greatest business leaders desire changes in orders of magnitude not in small fractions or small percentages. Yesterday's world is simply not the world we live in today. Perhaps Francis Gouillart and James Kelley said it best in their 1995 McGraw-Hill book entitled *Transforming the Organization*. It was here that they wrote: "We once assumed that corporate evolution consists of long periods of stasis, punctuated by periodic adaptations, but the pace of change is too fast for that now. In today's market, companies need to adapt every day." Tom Peters called it "perpetual revolution." Joseph Schumpeter called it "creative destruction." Peter Drucker called it "destabilizing the organization." Alvin Toffler called it the "flex firm." They were all referring to an organizational mentality that refuses to tolerate business as usual. For years, these

visionaries have foreshadowed that leading corporations will reinvent themselves again and again. In the words of Tom Peters: "Improvement will not do. . . only revolution will." This means, in the words of Peter Drucker, systematically abandoning the established, the customary, the familiar, and the comfortable. The practitioner must recognize that without revolutionary thinking, corporations simply cease to grow, cease to prosper, and cease to survive, as this is the law of Darwinian economics. The only way they can survive is through a high-quality, short-cycled process that can produce cash. In other words, corporations rapidly evolve as a result of judicious planning, careful design and coordinated execution in the interest of quantum, fast-track improvement. At the same time, such a short-cycled orientation exists in symbiotic fashion with a viable long-term vision. This holds true, and must be brought into the forefront of consciousness at all levels, across all boundaries and within each and every compartment of a corporation. To unlock the momentum required to drive quantum improvement, an organization must approach Six Sigma in a holistic manner. This means that the initial focus of a Six Sigma curriculum in the short term should be directed toward achieving dramatic and visible financial results. It is when the cash register starts to ring, so to speak, that management sits up and notices and it is only then that curriculum development specialists can start to mold and evolve the content of Six Sigma training in the direction of meeting longer-term needs.

1.14 SOFTWARE APPLICATIONS

1.14.1 Explore Excel

Microsoft Excel®, a Microsoft Office™ product, will provide an elementary view of metrics for Six Sigma by utilizing the graphs and chart features. Charts are visually appealing and make it easy for users to see comparisons, patterns, and trends in data. For instance, rather than having to analyze several columns of worksheet numbers, you can see at a glance whether sales are falling or rising over quarterly periods, or how the actual sales compare to the projected sales.

Excel does have limitations. For example, Excel can only manage 65,534 rows of data. Thus, Minitab is the proper tool for addressing problems requiring large amounts of data.

Visit www.microsoft.com/excel for additional information and customer stories.

1.14.2 Explore MINITAB

MINITAB™ Statistical Software is the ideal package for Six Sigma and other quality improvement projects. From statistical process control (SPC) to design of experiments (DOE), it offers the methods required to implement every phase of your quality project, along with features like Stat Guide and Report Pad that help you understand and communicate your results. No package is more accurate, reliable, or easier to use. In addition to statistical power Minitab offers many exciting features such as

- A powerful graphics engine that delivers engaging results that offer tremendous insight into your data
- An effortless method to create, edit, and update graphs
- The ability to customize your menus and toolbars so you can conveniently access the methods you use most

Visit www.minitab.com for additional information and customer stories.

1.14.3 Explore JMP

JMP®, desktop statistical discovery software from SAS, uses a structured, problem-centered approach for exploring and analyzing data on Windows, Macintosh, and Linux. The intelligent interface guides

users to the right analyses. JMP automatically displays graphs with statistics enabling users to visualize and uncover data patterns. JMP has comprehensive statistics software that combines interactive data mining, design of experiments, and statistical quality control in a single package. In addition to its statistical capabilities, JMP also contains

- Interactive graphs and data tables, allowing the user to identify data points of interest by selecting specific data table rows or by clicking on regions of interest in graphs.
- The ability to save output in a variety of useful forms, such as a Microsoft Word document, HTML, and a number of graphics files, including JPG.
- The ability to customize output preferences for repeated use.
- A scripting language suitable for the creation of specialized programs and GUIs.

Visit www.jmp.com for additional information and customer stories.

GLOSSARY

applying Six Sigma Profiling the vital improvement tools that the Six Sigma practitioners must be able to utilize when executing their applications projects and then grasp how such mind tools can be used to solve virtually any problem.

business, operations, process, individual (BOPI) The business "goal" for the four basic tiers of an enterprise.

characteristic Definable or measurable feature of a process, product, or variable.

control specifications Specifications for the product being manufactured or service delivered.

cost of poor quality (COPQ) COPQ consists of those costs that are realized as a result of producing defective material.

C_p Process capability: a simple and straightforward indicator of process capability.

C_{pk} Process capability index: an adjustment of C_p for the effect of noncentered distribution.

critical to quality (CTQ) CTQs are the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. They align improvement or design efforts with customer requirements.

data Factual information used as a basis for reasoning, discussion, or calculation. Often refers to quantitative information.

deploying Six Sigma Studying the essential guidelines for scaling and creating a global Six Sigma deployment plan that will originate a critical mass of focused management activity and then learning how to put momentum behind that mass at the local level of an enterprise.

defect Output that doesn't meet specification(s).

defective Unit that contains at least one defect.

defective parts per million (Dppm) or parts per million (ppm) Metric that estimates the number of "escapes" reaching the customer.

defects per million opportunities (DPMO) Compares dissimilar processes and products. This metric is essentially DPU normalized by process complexity.

design for Six Sigma (DFSS) A data-driven quality strategy for designing products and processes, and an integral part of a Six Sigma quality initiative. DFSS consists of five interconnected phases: define, measure, analyze, design, and verify.

DMAIC Acronym for define–measure–analyze–improve—control; refers to a data-driven quality strategy for improving processes.

DPU Average number of defects per unit.

enabling Six Sigma Understand the information and reporting needs that underlie the global deployment of Six Sigma and then learning how to effectively integrate and fulfill those needs at the local level of an enterprise.

final test yield (FTY) Counts defectives at final test.

initializing Six Sigma Interrogation the of top programs that support the rapid initialization, deployment, and implementation of Six Sigma and then learning how to fully leverage such programs at all levels of an enterprise.

leading for Six Sigma (LFSS) Understanding how to identify, select, and train Six Sigma leaders at all levels of an organization without backfilling the vacated positions and then learning how to effectively motivate and retain those leaders so as to continually enrich forward momentum.

managing for Six Sigma Metholology for delivering outstanding business results.

P_p Process performance: a simple and straightforward indicator of process performance; the index used to show long-term potential.

marketing for Six Sigma Customer-facing business units applying the concepts of Six Sigma to quantify and boost results.

P_{pk} Process performance index; adjustment of P_p for the effect of noncentered distribution.

processing for Six Sigma (PFSS) A strategy concerned with reducing the extent of risk exposure inherent to the operation of an existing system or process throughout its useful lifespan.

RTY (rolled throughput yield) Counts defects throughout the process.

Six Sigma A fact-based, goal-driven, results-oriented, strategic, and tactical system of management for the total business enterprise.

statistical process control (SPC) Statistical process control is the application of statistical methods to identify and control the special cause of variation in a process.

statistical process monitoring Every new point is statistically compared with previous points as well as with the distribution as a whole in order to assess likely considerations of process control (i.e., control, shifts, and trends). Forms with zones and rules are created and used to simplify plotting, monitoring, and decisionmaking at the operator level.

targeting Six Sigma Discovering how to best identify, scale, define, empower, and execute Six Sigma projects that are progressively connected to higher organizational goals and then learning how such projects can be effectively tracked, validated, and closed.

total quality management (TQM) A conceptual and philosophical context that requires management and human resources commitment to adopt a perpetual improvement philosophy, through succinct management of all processes, practices, and systems throughout the organization to achieve effectiveness in the organizational performance and fulfilling or exceeding the community expectations.

total defects per unit (TDPU) The total number of defects observed when sampling a population.

REFERENCES

1. Government Electronics Group, *Performance Metrics Manual.*
2. R. Kreitner and A. Kinick, *Organizational Behavior*, 6th ed., 2006.
3. S. M. Patton,"Is TQM dead," *Quality Digest Magazine*, (April 1994).
4. F. Gouillart and J. Kelley, *Transforming the Organization*, McGraw-Hill, 1995.
5. F. Gouillart and J. Kelley,"Measuring performance after meeting award criteria," *Quality Progress Magazine* (1996).