WHAT IS SIX SIGMA?

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I: INTRODUCTION

Six Sigma has become part of our everyday vocabulary as its popularity has grown in today's business environment. For those who work in an organization that has embraced Six Sigma, the term is clear and the methodology is well understood. However, others are still trying to figure out exactly what Six Sigma is, and how it may be able to help them reach their goals.

A: What is Six Sigma?

One of the reasons it has been so difficult for those not working in an organization that has embraced Six Sigma to really understand it is because Six Sigma means multiple things. The term Six Sigma is used interchangeably to reflect a vision, philosophy, commitment, goal, level of performance, statistical measurement, metric, benchmark, methodology, systematic approach, set of statistical tools, and a vehicle for customer focus, breakthrough improvement and people involvement. These different definitions can be summarized in three main categories; Six Sigma the philosophy, Six Sigma the metric and Six Sigma the methodology.

Six Sigma the philosophy comprises the ideas of Six Sigma as a vision, philosophy and commitment. Used in this fashion, Six Sigma is a direction for everyone to follow and reflects a way of doing business. A customer is defined as anyone (internal or external to the organization) who receives a product, service or information. An opportunity is defined as, every occasion to do something "right" or "wrong." Six Sigma represents the commitment to our customers that ensures the results of each opportunity meet customer expectations.

Six Sigma the metric comprises the ideas of Six Sigma as a goal, level of performance, statistical measurement, metric or benchmark. This view is most popular from a quantitative point, because it provides a standard unit of measure for calculating variation in our products and services. The metric is often even extended to represent a very specific goal of 3.4 DPMO (defects per million opportunities). The standard unit of measure can be used to compare processes, business units and, furthermore, organizations.

Six Sigma the methodology comprises a systematic approach, a set of statistical tools and a vehicle for customer focus, breakthrough improvement and people involvement. This viewpoint is really the "how" for the "why" – vision and "what" – metric. Six Sigma as a methodology is the step-by-step approach to reduce variation, in everything we do, to improve customer satisfaction. This approach follows a methodology sometimes referred to as the Breakthrough Strategy, and utilizes a set of tools to accomplish the results in a project environment with dedicated personnel.

These three categories of Six Sigma can be summarized into a couple of phrases. Six Sigma is a business process that allows companies to drastically improve their bottom line, by designing and monitoring everyday business activities in ways that minimize waste and resources, while making fewer mistakes in everything they do, eliminating lapses in quality at the earliest possible occurrence. It provides specific methods to re-create the process, so that defects and errors never arise in the first place. Six Sigma represents extraordinary sense - not ordinary or common sense. [1]

Six Sigma distinguishes itself as a business improvement methodology from prior quality improvement methodologies, in that it supports the improvement in quality and customer satisfaction only as a means to an end – to improve the bottom line of the organization. It accomplishes this by defining the goals of the business, and defining performance metrics that tie to the business goals. Six Sigma then uses performance metrics-based projects that will yield clear business results by applying advanced quality and statistical tools to achieve breakthrough financial performance. These results are attained using dedicated, focused, qualified personnel working in a project environment.

ABSTRACT

Six Sigma has burst onto the business world scene and has commanded the attention of industry leaders and Wall Street analysts alike, by posting impressive success stories regarding improving the bottom line of many different types of organizations. While Six Sigma has become a common methodology, engrained into many organizations that have embraced it, several others still grapple with what Six Sigma actually is. This paper will focus on providing an introduction and overview of Six Sigma to answer the question, what is Six Sigma?

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II: DISCUSSION

A: A History and Business Case

In 1979, Six Sigma was initiated at Motorola in response to declining performance, due to quality issues. Motorola changed the current paradigm regarding quality and profitability. Motorola proved that the highest quality producer could also be the lowest cost producer by developing a system centering on eliminating defects rather than detecting them. By 1993, most of Motorola's facilities were operating at levels near Six Sigma. During the same period, Motorola's sales productivity had increased from $68.9K to $110.1K per employee, and USA savings from operations improvements increased to more than $2.2 billion. [1]

Former General Electric CEO Jack Welch is probably the most famous backer of Six Sigma. Lawrence Bossidy of AlliedSignal originally introduced GE to Six Sigma. In 1995, Jack Welch mandated that each GE operation work towards achieving Six Sigma. He described Six Sigma as "...the most important initiative GE has ever undertaken." GE's margin increased from 10% in the decades prior to 1995, to 13.6% in 1995 and 16.7% in 1998. In 1997, Six Sigma delivered $300 million to GE's operating income. [1]

Based on the financial performance of Motorola, General Electric and many other subsequent organizations, a typical payback model has been developed for each dedicated Six Sigma project leader (termed Black Belt). Each Six Sigma Black Belt is presumed to be capable of delivering $250,000 hard dollar cost savings per project, and execute 4 projects per year, contributing $1 million each year to the bottom line.

Since its inception, numerous companies have joined the Six Sigma ranks including companies such as Texas Instruments, Bombardier, Nokia, Ford, Visteon, Kodak, Toshiba, Dupont, Dow Chemical, Johnson Controls, Lear, etc. Historically, the bulk of companies involved in Six Sigma have been manufacturing oriented. However, most recently there has been a surge of organizations from the service / transactional sectors. Financial companies such as American Express, Citicorp, Merrill Lynch and Bank of America now have formal Six Sigma efforts. Additional transactional-based companies (e.g. Hyatt, Starwood Vacation Properties, Home Depot, Sears) are currently active in Six Sigma. Continued steady growth in manufacturing organizations is anticipated. An even more rapid expansion into transactional applications is believed to stem from the fact that historically there has been little emphasis on measuring these types of processes, leaving an even greater potential for savings.

TABLE II. SIGMA LEVEL TABLE

Sigma Level	DPMO	Yield
1	692,462	30.9%
2	308,537	69.1%
3	66,807	93.32%
4	6,210	99.379%
5	233	99.9767%
6	3.4	99.99966%

B: The Six Sigma Methodology

As previously stated, the sigma level corresponds to the level of performance within a process, and Six Sigma as a metric corresponds to 3.4 DPMO or a yield of 99.99966%. With regards to process performance in Six Sigma, this is considered almost perfect. Listed below in the Table is a summary of various sigma levels with their corresponding DPMO and yield.

A basic premise of Six Sigma is that a yield of 99% or 3.8 Sigma is no longer an acceptable level of process performance. When the cost of operating a manufacturing or transactional process at 3.8 Sigma is calculated, the numbers are often astronomical. The idea behind Six Sigma is a constant never ending journey toward perfection in our processes, by application of the Six Sigma methodology.

Historically, most companies operate between 2 and 4 Sigma level. At this level, they are applying the basic quality tools and may even have formal quality systems, but fail to see the breakthrough improvement they desire. Companies are typically stuck at this level due to a number of issues, including: arrogance bred from past success, dependence on inspection and rework, reliance on trial and error methods of problem solving, emphasis on fire fighting, minimal focus on quality measurements, and because of functional silos that inhibit collaboration.

In order to breakthrough this performance level and achieve the type of performance they desire, these companies, trapped between 2 and 4 Sigma, need to change their culture to one that values a high level of process knowledge. They need to be open to challenging the status quo, and have conviction in the opportunity to improve with belief in the Six Sigma methodology. It is necessary to have driven personnel and to dedicate them to the business of process improvement, providing them with the new skills, tools and

information to make a difference. Lastly, they need to reinforce new behaviors for managers that support and reward the new culture. This transformation is one of moving from dealing with processes as an art form, in a firefighting mode, with chaos and waste, to one that is science / knowledge based, in a preventive / problem solving mode, with good decision making based on facts and data. This transformation is often called the operational excellence leap.

After organizations make the operational excellence leap, they will hit another wall at 5 Sigma. This is an indication that their processes are operating as effectively and efficiently as possible, without major re-design and re-configuration. This is often called the Design for Six Sigma (DFSS) wall. Since the majority of defects are designed into processes, most processes will not be able to obtain 6 Sigma without re-design. However, at this point there has been such considerable savings due to improvements, it is not difficult to justify the expenditure required to invest in re-design.

As previously stated, Six Sigma allows for organizational transformation by developing the culture that supports continuous improvement based on financial gains. Acquiring highly trained and superior skilled project leaders, called Six Sigma Black Belts, to lead process improvement projects, achieves this transformation. One by one, these projects improve process potential, improve customer satisfaction and eliminate waste, providing a means to the end of improved financial performance of the organization. The Black Belts are trained in Six Sigma methodology and statistical thinking, and are given the tools to operate in their role dedicated to process improvement. Black Belts are the backbone of Six Sigma, leading teams comprised of personnel from functional responsibilities to improve the process. Six Sigma Black Belts are supported by a number of other positions including Master Black Belts, Green Belts, Champions and Executives.

When executing Six Sigma projects, the Black Belts analyze the process to a deeper level than has been done previously. Traditional focus on process monitoring has been on the process output (also called Y, the dependent variable, effect, or symptom). Many current measurement and monitoring systems have concentrated on inspecting and managing the process output, leading to a reactionary mode of operation and poor results. Black Belts focus on the inputs to the process (also called X's, independent variable, cause, problem). By focusing on the process inputs and understanding the relationship to the output, the Black Belt can often obtain the results desired from the output by controlling the input variables. This is the key to the BlackBelt'ssuccess,andistheobjectiveofthe statistical tools that are used. By controlling the independent variables, breakthrough type improvements can be realized with the dependent variables.

The key to understanding the relationship between the process inputs and outputs is the analysis of data. Data provides a common language in order to make better decisions. It allows communication to occur in an objective manner and provides the facts to continue problem resolution, including justifying the extension of the solution. In short, data builds knowledge. There are seven levels of analysis of data, as indicated in Table II, and Six Sigma encourages continual advancement in the levels of analysis.

TABLE II. SIGMA LEVEL TABLE

Level	Description of Analysis
1	Experience and Intuition
2	Collect Data But Only Look at the Number
3	Graphical Data Analysis
4	Descriptive Statistics on Census Data
5	Descriptive Statistics on Sample Data
6	Inferential Statistics on Sample Data
7	Math Modeling and Development of Predictions

C: What Makes Six Sigma Different?

Six Sigma methodology as a business improvement strategy is different from prior quality improvement strategies, due to a number of reasons. While many other improvement strategies stressed leadership commitment, competence and involvement, provided a methodology, and were team based and focused on proactive, data driven problem solving, they missed some key points.

Six Sigma speaks the language of executives: money. Six Sigma projects improve process performance and customer satisfaction only as a means to an end – financial performance. Six Sigma also differs in that it operates in a project type environment, with the highest potential employees dedicated to improving process performance. Lastly, no other predecessor to Six Sigma has placed the level of emphasis on the commitment to continuous training with the realization that the key to success is through education and knowledge.

D: Cost of Quality

Traditionally, emphasis to improve quality has been placed on inspection. The issue associated with inspection is that it is not typically 100% effective, and it is a non-value added activity that increases cost. At a typical manual inspection effectiveness of 80%, it would take 8 consecutive inspectors looking for the same defect to inspect in Six Sigma level of quality. Obviously, this is not an effective method for obtaining the process quality level desired. The Six Sigma approach is to improve quality by eliminating the possibility of the defect ever occurring, rather than to inspect for it. In addition to being more effective and reducing cost, this approach is a break from the traditional cost of quality model paradigm. The traditional cost of quality model includes a point of diminishing economic returns from investments targeted at improving quality. *See Figure I for the traditional cost of quality model*. With this model the highest quality producer is not necessarily the lowest cost producer.

Six Sigma offers a break in the traditional paradigm, where

FIGURE I. TRADITIONAL COST OF QUALITY MODEL

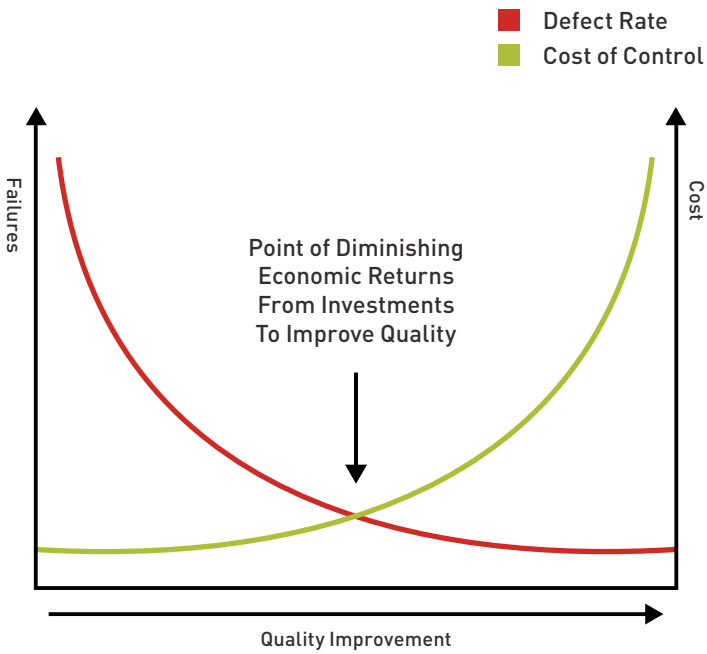


FIGURE II. SIX SIGMA COST OF QUALITY MODEL

at higher quality levels there is not necessarily a point of diminishing economic returns from investments targeted at improving quality. *See Figure II below.* [1] This is because the quality improvements are not based on inspection and detection of the defects, but on eliminating the possibility of the defect ever occurring in the first place. This Six Sigma view demonstrates that the highest quality producer can, in effect, be the lowest cost producer. More simply stated it costs less to do things right the first time.

Six Sigma capitalizes on the new cost of quality model to identify, bring out into the open and address some of the lost opportunity from less than ideal process performance. This opportunity, sometimes called the hidden factory in Six Sigma, includes tangible quality costs of rejects, scrap, concessions, inspection, rework and disposition. This opportunity can also include some intangible costs such as more setups, expediting costs, lost sales, lost customer loyalty, quality audits, improvement program costs, excess inventory, long cycle times, engineering change orders and other abstract or difficult to measure items. Each time a process defect must be detected, repaired and placed back into the process, there is an opportunity from the wasted time, money, resources and floor space. As previously stated and depicted, in *Figure III* Six Sigma refers to this as the hidden factory. Six Sigma is about identifying, quantifying and eliminating the hidden factory in operational and transactional processes.

E: Six Sigma Metrics

In addition to the Sigma Level and DPMO metrics previously mentioned, Six Sigma has also introduced new metrics that are extensions from traditional process metrics. These additional new metrics are Rolled Throughput Yield (Yrt) and Defect per Unit (DPU). In order to explain Six Sigma metrics, one must first grasp an understanding of opportunities. An opportunity is characterized as every chance for a defect to occur. Typically, an opportunity is defined by each process step. However, they can also be defined by each failure mode, transaction, transition, movement or entry. Each process and product may have many opportunities for defects. [2]

Defect per Unit (DPU) is the total number of defects that occurs in a particular process divided by the number of units processed. It is important to realize that, based on the number of opportunities, there may be more than one defect per unit. The traditional approach to analyzing defects is to consider only the first defect detected on a unit. Since the Six Sigma notion of defects is based on the Poisson distribution, each defect that occurs must be noted and accounted for. Since Defect per Unit (DPU) compares processes for performance, it is a method for driving organization-wide improvement focus through the analysis of defects and attacking the processes with the highest DPU.

Rolled Throughput Yield is a derivative of throughput yield and first time throughput. The difference is that Rolled Throughput Yield is a cumulative indicator of first time throughput. Many organizations only focus on yield at the end of the process, which may cause them to lose sight of the rework that occurs within the process. Rolled Throughput Yield calculates the first time throughput at each process step, and then multiplies them together to get an

overall indication of the process capability. Rolled Throughput Yield can also be calculated directly from the DPU (Yrt=e-DPU) based on the Poisson distribution assumption. Rolled Throughput Yield then becomes the probability of a unit passing through the process defect free. This is a departure from the traditional yield metrics that views yield as a ratio of good product over total product processed. Rolled Throughput Yield drives organization-wide improvement focus through as a productivity measure.

Defects per Million Opportunities or DPMO are the number of defects that occur in a given process multiplied by one million, then divided by the total number of opportunities. The total number of opportunities is equal to the number of opportunities for a defect multiplied by the total number of units. This metric is a derivative of the traditional parts per million (PPM) metric, however it is calculated at each process step and cumulated as in the case of Rolled Throughput Yield. DPMO is also different from PPM in that it is based on the number of opportunities. Calculating the DPMO at each step and cumulating the results provides a method for capturing the true total process capability. Calculating the DPMO based on the number of opportunities provides a method for comparing dissimilar processes and taking complexity into consideration when determining process capability. [2]

The Sigma Level is the ultimate Six Sigma process capability measurement, and is calculated directly from DPMO through the normal distribution, or can be located in a conversion chart. The Sigma Level can be determined as an overall group or organization capability measurement and allows for benchmarking within and across companies. Most available literature regarding process performance is based on the Sigma Level scale.

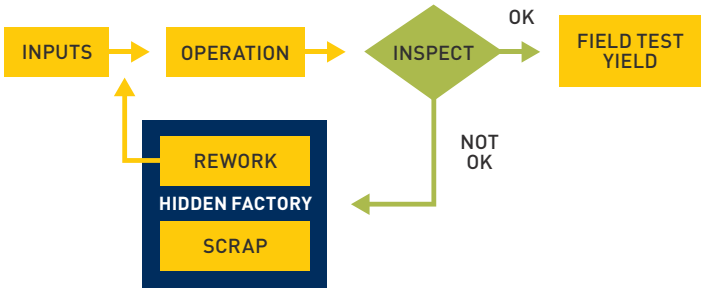
The objective of Six Sigma is to track the trends in these metrics in order to establish a project baseline and ultimately to document the performance after project completion. This difference in metric performance is used to substantiate the claims of improvements related to the project.

F: Roles and Responsibilities

Leadership and support for the Six Sigma structure must flow from the top down, involving Executives, Senior Leadership, Deployment Directors, Deployment Champions, Project Champions, Master Black Belts, Black Belts, Green Belts and Team Members.

Executives and Senior Leadership within a Six Sigma structure will drive the implementation of Six Sigma publicly through their actions and words, and will set meaningful goals and objectives for the corporation with respect to Six Sigma performance. These goals should be aligned with corporate strategic objectives and cascaded throughout the various functional organizations across the company. It is critical that the Executives tie their organizational performance reviews and merit system directly to Six Sigma performance. Often there is an executive charged with the responsibility for the implementation / deployment of Six Sigma. This is usually a Vice President position in an organization independent of any of the functional areas. Some companies have included Six Sigma in the quality area. However, this may send mixed messages regarding Six Sigma as a business improvement process and not just another quality improvement program. The Executive position is often termed Executive Champion or Director of Six Sigma.

FIGURE III. THE SIX SIGMA HIDDEN FACTORY



The role of Six Sigma Corporate Deployment Director is a full time position charged with all aspects associated with the deployment of Six Sigma. The Corporate Deployment Director typically reports directly to the Executive Director and is responsible for developing the balanced scorecard on the Six Sigma process. Six Sigma process metrics will guide the administration of the Six Sigma program from a corporate level. Different companies have different degrees of autonomy and empowerment between the corporate Six Sigma Deployment Director and local deployment. However, some level of administration must occur at the corporate level. Some organizations have local Deployment Directors at a functional level.

Typically, the Deployment Champion is a functional position within the functional areas of the organization. This position is ultimately responsible for the success of Six Sigma within their organization. They regularly monitor and report their organizational balanced scorecard metrics to the corporate level. They are responsible for holding the leaders in their organization accountable for the Six Sigma performance, as well as for developing the reward and recognition systems within their organizations. Companies differ as to whether the Deployment Champions are full-time or part-time in Six Sigma.

The Project Champion is a local project coordinator position. The Project Champions are responsible for selecting Black Belts, identifying projects, scoping projects, assigning Black Belts and monitoring the Black Belts' project process. Typically, the Project Champion will coordinate a tollgate project review process to ensure that projects are progressing. During this process, the Project Champions are responsible for holding the Black Belts accountable, eliminating barriers, providing resources and coaching the Black Belts. Typically there is one Champion for every three Black Belts. This position is normally part time with respect to Six Sigma.

Master Black Belts are trainers, facilitators and coaches in the Six Sigma process. They are full time on Six Sigma. Master Black Belts have a unique blend of strong quantitative, teaching, consulting and leadership skills. They are experts in the tools and in statistical

methods. Some organizations differentiate between deployment Master Black Belts and project Master Black Belts. Deployment responsibilities include organizing, developing and instructing training, working on deployment issues, monitoring the deployment balanced scorecard, sharing best practices, championing deployment related mega projects and helping in the development of other Master Black Belts. Project responsibilities include helping the champion to identify and scope Black Belt projects, assisting in project reviews, sharing best practices, certifying Black Belts and championing local mega projects. A Master Black Belt should spend 10% of their time in training brining back new skills and methods to the organization. Typically there is one Master Black Belt for every ten Black Belts.

The Black Belt is the backbone of the Six Sigma process. They are typically full time on Six Sigma; however, some organizations have part time Black Belts. They are experts in Six Sigma strategy and lead project teams. Black Belts should be selected by Executives, Champions and Master Black Belts from a pool of the company's highest potential employees. A Black Belt should be a visible advocate of the application of statistical methods and be an established leader within the organization.

Black Belts typically attend a rigorous multi-week training process which follows a plan-training-apply-review strategy. In addition to learning the methodology and tools of Six Sigma, they are also working through their first project. Some organizations include a training project and evaluation. For a Black Belt to become certified, they typically have to complete the training, successfully complete two projects and pass a certification examination.

Green Belts are often team members with training in Six Sigma methodology. They can be future Black Belts and are often the process leaders within the project organization. Green Belts understand Six Sigma methodology and are beginning users of the statistical tools. They assist the Black Belt on the project and are almost always part time on Six Sigma. Typically, there is at least one Green Belt per project team.

Team members are the participants on the project team. They work in conjunction with the Black Belt, stepping through the Six Sigma project process. Team members are specific to the project area and are part time in Six Sigma.

III: CONCLUSIONS

Six Sigma is a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while making fewer mistakes in everything they do, eliminating lapses in quality at the earliest possible occurrence. The benefits of Six Sigma are well documented and are demanding the attention of business leaders and Wall Street analysts alike. It is a method that will change an organization's corporate culture to one of continuous business process improvement, through scientific measures leading to improved customer satisfaction, reduced waste and ultimately improved financial performance.

IV: REFERENCES

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