The Pros and Cons of Six Sigma Quality Management

S. J. Jerome Teng (鄧樹楨)
Department of Information Management
Kainan University, Taoyuan, Taiwan.
jerometeng@yahoo.com

摘要

六標準差品質改善方法論最初是在 1980 年代中期由美國「摩托羅拉公司」所發展命名，近年來六標準差方法論受到很多的注意，由於美國一些公司成功採行此方法使其受到全球性的興趣，它是一種專案管理方法，藉由排除偏差而改善生產過程與顧客滿意度，其管理目標是減少製造業與商業過程中的變化，其聲稱目標是在長期過程中每一百萬個產品根據規格只存在有 3.4 個缺陷品，六標準差是運用統計學方法及「定義、量測、分析、改善、管制」等過程，後者是類似於「愛德華茲・戴明」(Edwards Deming)的「計劃-實施-檢驗-行動」管理循環。本論文之目的是探討六標準差品質管理方法論的來源、統計學概念、優點利益、批評與缺點。

關鍵詞：六標準差，品質改善，專案管理。

ABSTRACT

Six Sigma quality methodology was originally developed and coined by Motorola in the mid-1980's. Six Sigma has received considerable attention in recent years. Successful implementations in some US corporations have attracted growing worldwide interest. It was used to improve manufacturing processes and customer satisfaction by eliminating defects. Six Sigma is a project-driven management approach that aims to reduce the variation of manufacturing and business processes. It is both a philosophy and a methodology. The proclaimed goal is to achieve long-term processes that have six sigma capability, or produce only 3.4 defects per million opportunities (DPMO) in relation to product specifications. Six Sigma utilizes a statistical approach along with the Define, Measure, Analyze, Improve, and Control (DMAIC) process cycle that was similar to Edwards Deming's Plan-Do-Check-Act cycle. This objective of this paper is to reviews the origins, statistical concept, benefits, criticisms and downsides of Six Sigma methodology.

Keywords: Six Sigma, Quality Improvement, Project Management.

1. Introduction

Companies and businesses are constantly under pressure to provide quality products or services to remain competitive and profitable. Quality in business, engineering and manufacturing has a pragmatic interpretation as non-inferiority, superiority or usefulness. Various methods for quality improvements have been introduced in the past. They have played a crucial role in better business management. Many different concepts and techniques have evolved through the years to enhance quality management, including well-known methods such as Statistical Process Control (SPC), kaizen, Zero Defects, quality circles, Total Quality Management (TQM), Six Sigma, Malcolm Baldrige National Quality Award, Theory of Constraints (TOC), Quality Management Systems (ISO 9000, etc.) and continuous improvement [1].

The Six Sigma methodology is a more recent quality improvement approach. It has received considerable attention in recent years. Today, Six Sigma is one of the hottest contemporary subjects in quality management. The seeming claim of able to reduce defects or non-compliance to nearly non-existent levels is certainly a very attractive proposition to any business. Six Sigma is a set of practices. It is both a metric, a philosophy and a methodology. Although the particulars of the Six Sigma methodology were originated by Bill Smith at Motorola in 1986 [2], Six Sigma was heavily inspired by five preceding decades of quality improvement methods. They include techniques such as quality control, TQM, and Zero Defects. Similar to its predecessors, Six Sigma asserts the following themes:

1. Continuous efforts to reduce variation in process outputs is key to business success.

2. Manufacturing and business processes can be measured, analyzed, improved and controlled.

3. Succeeding at achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Six Sigma was originally started at Motorola to improve manufacturing processes and customer satisfaction by eliminating defects. Its proclaimed quality goal is to achieve six sigma capability, or produce only 3.4 defects per million opportunities (DPMO) in relation to product specifications. This enabled Motorola to become one of the first winners of the prestigious “Baldrige Quality Award” and was claimed to be responsible for impressive improvements in all aspects of business management. Other US companies such as General Electric (GE), Allied Signal, Navistar, Polaroid, Bombardier, 3M, etc., also embarked on Six Sigma programs.

Six Sigma as a quality improvement methodology has gained a great publicity. It may have changed the paradigm of how statistics is applied in business management and industry. With its high-profile adoption by large US companies such as GE in the mid-1990s, Six Sigma gained more popularity toward the end of the 20th century. According to GE, Six Sigma is a "disciplined methodology of defining, measuring, analyzing, improving and controlling the quality in every one of the company's products, processes and transactions, with the ultimate goal of virtually eliminating all defects." Six Sigma advocates continue to emphasize this methodology for purposes of project management and business performance.

However, as with any ‘hot’ management topic, the hyperbole that often accompanied the achievement of Six Sigma in industry could lead to unrealistic expectations on the goals it is capable of achieving. Many great promises of massive savings and formidable success in the end may fail to materialize. Six Sigma is not a cure-all for project management. It comes with a price tag of expenses, efforts, and other distractions. The Six Sigma methodology has its potential and possible limitations, especially in a knowledge-based or innovation-oriented business environment.

This paper intends to provide an overview of the Six Sigma framework and its application for business and project management. This paper reviews the pros and cons of the Six Sigma methodology, including its origins, statistical concept, implementation strategy, benefits, criticisms, downsides, and challenges. The objective is to become better informed about the arguments for and against Six Sigma and be able to take advantage of the quality initiative wherever applicable.

2. Historical Background of Quality Initiatives

In Japan, after World War II, American brought in experts in statistical control methods and those who were familiar with the US War Department’s training programs to restore a war-torn nation. The training programs include Job Instruction and Job Methods. In conjunction with the “plan-do-check-act” (PDCA) cycle taught by W. Edwards Deming, and other statistics-based methods taught by Joseph M. Juran, these programs became the foundation of the “kaizen” revolution in Japan that took place in the 1950s. The word “kaizen” means "change for the better", “improve”, or “continuous improvement.” The cycle of kaizen activity was also known as the Shewhert cycle, or Deming cycle.

In 1962, the Japanese introduced the concept of “Quality Circles” as another method to improve quality in their manufacturing business. A Quality Circle is typically a volunteer group composed of workers who meet together to discuss workplace improvement subjects, and present their ideas to the management, especially relating to quality issues. The ideal size of a quality circle is about 8 to 10 people. Topics may include improvement ideas on product design, safety issue, and manufacturing process. The Quality Circle method enhances the creative potential of workers and thereby gives the Japanese industry an extra edge in creativity and competition.

The term Total Quality Management (TQM) was originated from "Total Quality Control"(TQC). The TQC was the key concept of a book ***“Quality Control: Principles, Practice, and Administration”***, published in 1951. Its author was Armand Feigenbaum, an American quality control expert. This book was subsequently released in 1961 with a new title of ***“Total Quality Control.”*** Other quality experts such as W. Edwards Deming, Joseph Juran, Philip B. Crosby, and Kaoru Ishikawa also had contributed to the management knowledge now known as TQM. However, the philosophy of TQM is not equivalent to that of TQC. Since the 1960s, the term TQM was frequently used as a quality control tool both in the US and Japan. For example, the former CEO of NEC in Japan, Koji Kobavashi, mentioned the term TQM during a speech when he received the Deming Prize award in 1974.

In response to the fierce product competition coming from Japan, the American manufacturing industries started to initiate several quality control and improvement methods in the 1980s. The quality initiatives were used to help making the US domestic production of goods and services more competitive. For instance, “Quality Circles” was implemented in companies, such as Honeywell and Fairchild Electronics, to make employees aware of what was required to produce quality products to satisfy the customers’ need. Other quality improvement systems were also introduced, such as “Zero Defects” at Ford Motors Company, “Total Quality Management” (TQM) at Boeing and Bell Telephone Companies. It looked as if quality control methodologies would certainly offer good solutions to many of the manufacturing problems. The Japanese industry had demonstrated some significant results to that effect and they were beating the US in the market place.

3. The Initiation of Six Sigma

Motorola was facing the same problems as other US manufacturing industries during the 1980s. They found that they were losing a large portion of their business and productivity through the cost of non-quality in manufacturing. Motorola’s chairman, Bob Galvin, decided that a much more stringent strategy was needed to solve their problems. Motorola set their goal on total customer satisfaction and defect-free performance in all products and services. The Six Sigma quality improvement initiative was launched in January 1987. The concept was formulated by a Motorola engineer named Bill Smith in 1986 [2, 3]. He found that the quality level associated with a measure of Six Sigma corresponds to a failure rate of about two parts per billion and adopted this as a standard. The program to achieve this lofty goal was developed at Motorola and coined “Six Sigma”, which included many of the systematic tools associated with Six Sigma programs of today. The program was launched at Motorola in 1987. Since then, "Six Sigma" has become a federally registered trademark of Motorola company. Six Sigma utilizes two key methodologies, namely, DMAIC and DMADV, both were inspired by Edward Deming’s Plan-Do-Check-Act Cycle. Figure 1 shows a schematic diagram of the DMAIC and DMADV cycle.

Figure 1. The DMAIC quality loop/cycle.

In statistical term, sigma is a measure of process variation known as the standard deviation, σ. Six Sigma at Motorola implies the occurrence of defects at a rate of 3.4 defects per million opportunities (DPMO) or lower. The standard deviation σ is a measure of dispersion of a set of data around the mean value, μ. Quality or performance variation can be characterized as a number of standard deviations from the mean value of performance. A normal distribution diagram is shown in Fig. 2. The areas under the normal distribution in Fig. 2 associated with each σ-level relate directly to the probability of performance falling in that particular range. For example, the area within ±1σ is equivalent to a probability of 0.683 or 68.3%. These probabilities as σ varies are displayed in Table 1. It also shows the percent variation versus the number of DPMO.

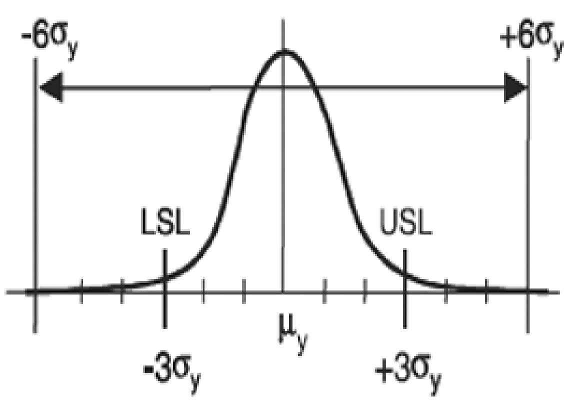

Figure 2. Design based on ±3 standard deviation.

(LSL, USL: Lower- Upper Specification Limits)

Table 1. Sigma level vs. percent variation and defects per million.

Sigma Level	**Percent Variation**	**Defects per Million (Short Term)**	**Defects per Million (Long Term, 1.5 sigma shift)**
±1σ	**68.26**	**317,400**	**697,700**
±2σ	**95.46**	**45,400**	**308,733**
±3σ	**99.73**	**2,700**	**66,803**
±4σ	**99.9937**	**63**	**6,200**
±5σ	**99.999943**	**0.57**	**233**
±6σ	**99.9999998**	**0.001**	**3.4**

Quality results can be measured using any of the variability metrics in Table 1. "Sigma level" is the percent variation or probability, or number of defects per million parts. Quality is indicated by comparing the associated performance specification limits and the measured performance variation. In Fig. 2, the lower and upper specification limits (LSL, USL) that define the desired performance range are shown to coincide with ±3σ from the mean. The design associated with this level of performance variance is considered a "six-sigma" design. Traditionally, if ±3σ performance variation was identified inside the set specifications, then it was considered an acceptable variation. In the ±3σ case, 99.73% of the variation is within specification limits, or the probability of meeting the specified requirements is 99.73%. The ±3σ limit would correspond to 2700 ppm defective. In engineering terms, this probability level was usually deemed acceptable. But the ±3σ limit may not be good enough for other quality specifications, such as electronic components or high-tech products.

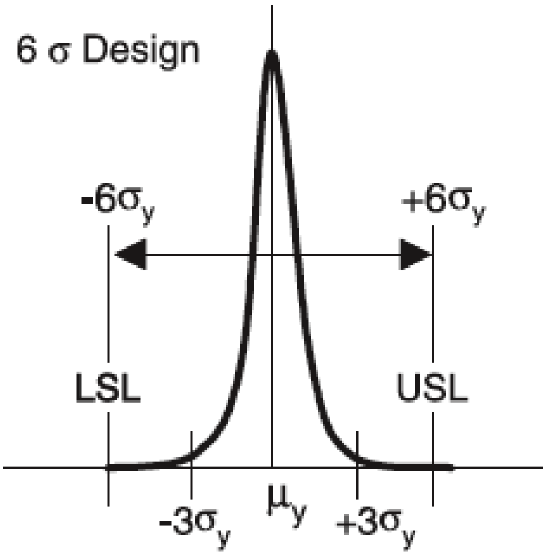

Figure 3. Design based on ±3 standard deviation. (LSL, USL: Lower- Upper Specification Limits)

Figure 3 shows a normal distribution diagram for the 6σ design. In Fig. 3, the lower and upper specification limits (LSL, USL) that define the desired performance range are ±6σ from the mean. This widely used definition of six sigma process indicates that the target performance produces 3.4 DPMO. However, as shown in Table 1, a normally distributed process that have 3.4 DPMO is between ±4σ and ±5σ. To be more precise, the 3.4 DPMO actually corresponds to ±4.5σ, not the ±6σ as the process name would imply. Thus, it can be said that the term Six Sigma is a misnomer. According to statistics, the six sigma should be called 4.5 sigma.

As shown in Table 1, a true 6σ process would reflect a defect rate of only 0.001 DPMO, an almost insignificant number in real life. Practical applications using the upper and lower specification limits of 6σ, or 0.001 DPMO, usually do not exist in our world. Most textbooks or statistics tables end at values of 4σ to 5σ. The perplexing reason is that Motorola first set a goal so that process variability is ±6σ from the mean. To overcome this unrealistic assumption, the ±1.5 sigma shift was introduced by Mikel Harry [4,5]. Harry called this sigma down shift as a long-term overall tolerance error, which is affected by errors in components, such as machine tools. In other words, they further assumed that the process was subject to disturbances that could cause the process mean to shift, no more no less, by as much as 1.5σ. This effectively reduces the specification limit of 6σ down to 4.5σ. It means that there will be a typical 1.5σ long-term shift in most process means, to give room for the tolerance error. The way that the 6σ term was derived and used often is the first criticism imposed on this tool.

To obtain the estimate for the DPMO number depends on knowing something about the shape of the distribution from which the samples are drawn. But it is difficult to prove that the data belong to any particular distribution, normality or otherwise. Normal distribution may be assumed if no contrary evidence was found. But, estimating DPMO number down into the 100s or 10s of parts according to this assumption is next to impossible, because the actual defects are often deviations from normality, which have been assumed, having the long-term drift, not to exist.

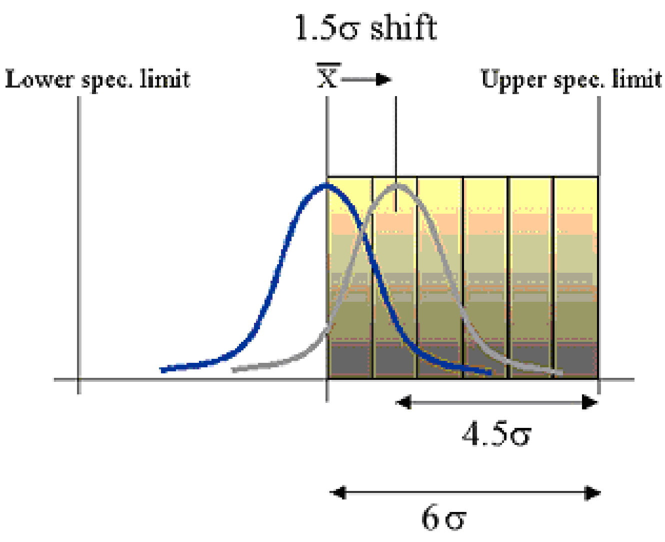

Figure 4. 1.5 sigma shift was added to six sigma.

Figure 4 illustrates the idea of the long-term 1.5σ shift which reduces the specification limit from 6σ to 4.5σ. Their relationships in terms of DPMO are also shown in Table 1. Even for the specification limit of 4.5σ, or a process yield of 99.99966%, this goal is far beyond normal quality capabilities and requires very significant efforts. However, it may be suitable for the specification limit of some electronic devices or components.

Figure 5 illustrates the relationship of the defect rate (DPMO) versus process sigma level assuming normal distribution. The defect rate at 6σ, as Motorola put it, is 3.4 DPMO. In actuality, without the 1.5σ shift, a defect rate of 3.4 DPMO corresponds to 4.5σ. Figure 6 shows the likely meaning of the defect rate (DPMO) versus process sigma level in the real world. For example, the defect rate of 3.4 DPMO usually occurs at situations in airline safety.

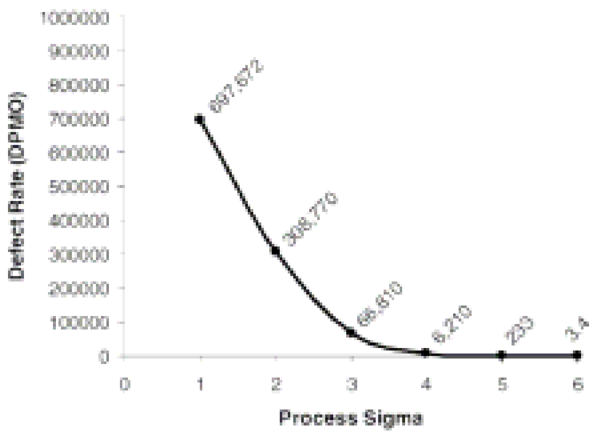

Figure 5. Defect Rate (DPMO) vs. process sigma level (long-term 1.5σshift included) [6]

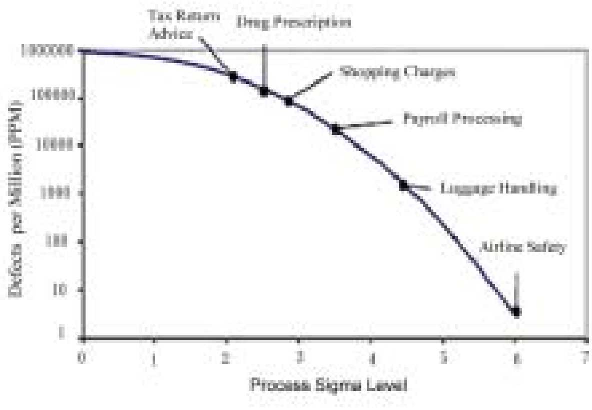

Figure 6. Possible meaning of DPMO vs. process sigma level in real life. (Crompton Corp.)

Mikel Harry introduced ±1.5σ shift in 1986. Harry referred to a paper "Statistical Tolerancing: The State of the Art. Part 3. Shifts and Drifts", written in 1975 by D.H. Evans. Evans referred to a paper written by Arthur Bender in 1962. Harry has not given a scientific explanation for the 1.5σ shift he used. Later, he claimed that the value of 1.5σ was empirically determined and no other empirical information was available at the time. This nearly means that the number of 1.5σ shift was added conveniently to the scheme. In fact, any process where the mean value drifts by a statistically significant amount, such as 1.5σ, can not be said in statistical control.

Interestingly, in the 1992 Motorola publication "Six Sigma Producibility Analysis and Process Characterization" written by Mikel Harry and J.R. Lawson, it shows a number of 1.248×10^{-9} for the 6σ. Today, with better computer calculations, the correct 6σ value is at 0.987×10^{-9}, not 1.248×10^{-9} [6]. The error of the calculation difference is 26%.

4. Implementing Six Sigma

Six Sigma works as a goal and as a monitoring statistical process. Six Sigma can help companies improving their business process and bottom-line issue. However, its effectiveness depends on the proper implementation of the metrics and project strategy. A key step in Six Sigma implementation is determining exactly what the customer requirements are and then defining defects in terms of their "critical to quality" parameters. The Six Sigma methodology also can be viewed as a goal-setting quality strategy [7]. From such a perspective, the Six Sigma approach is to establish goals based on customer requirements, but not on company's own considerations. The Six Sigma approach employs tools of unique metrics, such as process sigma measurements, critical-to-quality metrics, defect measures, and 10× improvement measures [8,9,10].

Basic Six Sigma methodology, used to improve an existing process, consists of the following five steps, also called DMAIC loop.[9]

1. Define. Define which process or product that needs improvement. Define the most suitable team members to work with. Define the process improvement goals that are consistent with customer demands and enterprise strategy.

2. Measure. Measure the current process and collect relevant data for future comparison. Identify key factors that have the most influence on the process, and decide how to measure them.

3. Analyze. Analyze the factors that need improvements. To verify relationship of factors. Determine what the relationship is, and attempt to ensure that all factors have been considered.

4. Improve. Design and implement the most effective solution. Optimize the process based upon the analysis using techniques like Design of Experiments. Cost-benefit analyses should be used to identify the best solution.

5. Control. Verify if the implementation was successful and ensure the improvement will last. To ensure any defect-causing variances are corrected. Set up pilot runs to establish process capability, transition to production and thereafter continuously measure the process and institute control mechanisms.

The Six Sigma methodology should be viewed a data-driven, systematic approach to problem solving and meeting customer needs. Statistical tools and analysis are often useful in the process. But it would be a mistake to view the Six Sigma methodology as mainly a statistic effort. An acceptable Six Sigma project can be started with only rudimentary statistical tools. Six Sigma as a problem-solving approach has often been used in fields such as engineering, business, and manufacturing processes.

Another key feature of Six Sigma is specializing of the quality management functions. It uses a variety of improvement specialists to achieve its goals. Prior to Six Sigma, quality management was largely relegated to the production floor and to statisticians in a quality department. The Six Sigma uses Chinese martial arts ranking terms to define a hierarchy system within the business function. A promotion path is sometimes designed within the structure. The Six Sigma designates several key roles for its successful implementation, such as the following:

1. Executive Leadership. They include CEO and other top management members. They are responsible for setting up Six Sigma endeavor. They empower other key members with the freedom and resources to explore new breakthrough ideas. Implementing a Six Sigma program begins at top management level with an evaluation of a company's strategic goals.

2. Champions. They are responsible for Six Sigma implementation across the organization. Executive Leadership selects them from the upper management. Champions also act as mentors to Black Belts.

3. Master Black Belts. They are identified by champions and act as expert coaches for the organization. They devote full time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from the usual rigor of statistics, they work on ensuring integrated deployment of Six Sigma across various functions.

4. Experts. They work across company boundaries, improving services, processes, and products for their suppliers, their entire campuses, and for their customers. Raytheon Incorporated was one of the first companies to introduce Experts to their organizations.

5. Black Belts. They operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma [11].

6. Green Belts. They are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving the overall results.

7. Yellow Belts or Team Members. They are employees who have been trained in Six Sigma techniques as part of a corporate-wide initiative, but have not completed a Six Sigma project and are not expected to actively engage in quality improvement activities.

Champions or Sponsors are roles to promote and maintain the Six Sigma principles and strategy within the organization. They are to ensure all the personnel are adequately supported, resourced and funded. They actively participate in project coordination, so that projects are established and monitored appropriately. It is important for the project to have correctly assigned and highly motivated personnel, Green belts, Black belts, etc. A Six Sigma project team typically includes a Champion from management, a Black Belt, Green Belts, Yellow Belts or Process Owners such as engineers and operators who are directly responsible for the process. Full-time Black Belts lead improvement projects and typically receive 4 weeks training. Master Black Belts receive even more training. Green Belts are part-time improvement specialists. They receive less training since they provide supporting roles on the projects.

The focus on achieving Six Sigma quality is commonly referred to as Design for Six Sigma (DFSS). Much of the increased interest in Six Sigma methodology is due to the positive financial impact some companies claim due to the programs. The company admits it is difficult to estimate the savings due to the fact that they do not measure the total savings anymore. Today, they rather see Six Sigma as a business excellence model for specific areas and as an improvement approach to reach business goals. There have been a few retail companies that have attempted to adapt this methodology to their business with mixed success [12,13].

5. Criticisms and Downsides of Six Sigma Methodology

Other than the many praises and testimonies, there have been some criticisms against Six Sigma. One common criticism is that Six Sigma has nothing new to offer [6,14]. It does not belong to a revolutionary concept. Six Sigma has the same common features as the TQM and, in principle, does not contain anything new. Some would consider that Six Sigma approach is in effect a methodology within the larger framework of TQM. Six Sigma resembles an old appraisal approach that focuses on problems after they have already occurred. Therefore, Six Sigma is more like an appraisal tool that does nothing for prevention. According to D.H. Stamatis [15], “that's a shame -- most consultants know it's simply a repackaging of old concepts, but they play along because it's highly marketed, and, for the short-term, there's a great deal of money to be made.”

One criticism is that Six Sigma proponents do not understand that the modern-day quality initiative is a planning-oriented activity rather than an appraisal activity. Product life cycles are getting shorter and shorter in modern society. Another criticism on Six Sigma is that it plays games with the numbers. How to categorize and define defects becomes significant in determining the Six Sigma targets. By simply changing the definition, one can dramatically change the sigma level that meets specification.

Another common criticism on Six Sigma is that it stifles innovation or creativity in an organization [16]. Six Sigma may be an excellent tool set in focusing on issues of quality and cost. But it is not a solution for new products or a breakthrough strategy. In fact, the relevance of Six Sigma to the well-known efficiency program at General Electric has been questioned by one of its creators. Jay Desai, who helped the GE implementing Six Sigma, said in a Reuters news (2004) that when companies must demonstrate change through new products every couple of quarters, companies need to move beyond the 20-year-old method in order to compete. Six Sigma does not create innovation." Another good example is the Polaroid company, a large manufacturer of cameras. Polaroid put their emphasis on quality, but failed to develop new product lines on digital cameras. Despite the good quality, Polaroid paid a deep price and went bankrupt. This is perhaps the most significant drawback or downside of deploying Six Sigma.

The great promises of Six Sigma in business setting may indeed not easily to materialize. As stated in a 2006 Fortune magazine article, “of 58 large companies that have announced Six Sigma programs, 91 percent of them have trailed the S&P 500 companies since.” The point of the Fortune article is that

Six Sigma is effective at what it is intended to do, but that it is narrowly designed to fix an existing process, allowing little room for new ideas or an entirely different approach. All the talents were devoted to reduce defects. Six Sigma does not help in coming up with new products or disruptive technologies. As a result, a cost cutting program, such as Six Sigma, has been shown to suppress new product innovation. For this reason, Six Sigma proponents have infused elements of design and innovation into their practice model.

Another example is the Polaroid company, a large manufacturer of cameras. Polaroid put great emphasis on quality improvement, but failed to pay attention to the upcoming digital cameras. Consequently, Polaroid went bankrupt despite the good quality in their products. Over emphasis on cost and quality is likely to cause the companies to become blindsided by other things that impact the future business. In the field of high technology, research development and product innovation are very important to business growth and survival.

A more recent and notable criticism on Six Sigma is the published cover story of the Business Week, June 11, 2007 issue [16]. The article is all about the adverse impact of Six Sigma methodology on the renowned innovative culture at the 3M company. The magazine cover reads: "3M's Innovation Crisis – How Six Sigma Almost Smothered Its Idea Culture." As stated, when measurement and metrics are paramount, they begin to drive behavior focused not on innovation, but to optimize what is being measured. For example, as quoted in the magazine article: "When these types of initiatives become ingrained in a company's culture, as they did at 3M, creativity can easily get squelched. After all, a breakthrough innovation is something that challenges existing procedures and norms." "Six Sigma is plainly a euphemism for cost cutting." "Innovation is by its very nature a disorderly process."

Similar to other major quality initiatives, a potential downside of Six Sigma is that it can receive less than enthusiastic response from workers or employees. When adopted organization wide, it may create an undesirable effect on workplace culture or workers' morale. Employees may complain about the added Six Sigma bureaucracy and performance evaluation. Case in point is the Ford Automobile Company, a Six Sigma participant. The cover story of July 2001 Business Week magazine stated that "Ford: It's Worse Than You Think." The article described that the Six Sigma effort saved the Ford company $52 million dollars last year, but had not improved Ford's quality. One of the reasons is that the performance evaluation system comes with the Six Sigma initiative is divisive to the employees.

Ford's new policy requires the supervisors to rank employees from worst to best: 10% get A's, 89% get B's, 10% get C's. The employees get a C means no bonus. Two C's in a row represents grounds for demotion or dismissal. Shortly after, class action lawsuits filed against Ford caused the C's reduced from 10% to 5%. Nonetheless, workers will try to pay more attention to their own individual performance, while ignoring or pulling down the performance of others. The creation of potentially artificial ranking and reward and punishment system does not make good sense in terms of cooperation among the employees.

For example, a few people are chosen as Black Belts, a larger group is selected as Green Belts, and others may not be included at all. In order for Six Sigma to be truly deployed, every worker should be given an opportunity to become a Green Belt. Employees who have demonstrated strong leadership on improvement issues should be considered for Black Belts. A hierarchical system would exclude people on such a company-wide initiative as Six Sigma. If focuses are not properly placed on bottom-line savings, Six Sigma can easily become a bureaucratic exercise in a company. In addition, the implementation cost of Six Sigma can be a significant investment. The cost feature alone may discourage many small- and medium-sized companies from implementing Six Sigma.

5. Conclusions

The Six Sigma approach was originally

designed as a quality improvement strategy in the mid-1980's. It has incorporated some previous quality control concepts. For example, the Six Sigma approach utilizes the Define, Measure, Analyze, Improve, and Control (DMAIC) process cycle that was similar to the Plan-Do-Check-Act cycle initiated by Edwards Deming. Six Sigma utilizes a statistical approach to tackle the manufacturing and business variability in a rigorous manner. It is now developed as a highly disciplined and statistically based method to remove non-conformities from products, processes, and services [17]. Six Sigma is both a metric, a philosophy and a methodology. The proclaimed goal is to achieve long-term processes that have six sigma capability, or produce only 3.4 defects per million opportunities (DPMO) in relation to product specifications. In recently years, Six Sigma has been adopted as a quality initiative by many large US corporations. Successful implementation and fruitful results have been reported. However, there are reported criticisms against Six Sigma. One common criticism is that Six Sigma is more of a cost cutting tool and it is likely to stifle a company's ability to innovate or create. This paper has presented an overview of the Six Sigma methodology, including its historical background, origins, statistical concept, benefits, criticisms and downsides.

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