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New to Six Sigma?

An Introduction to Six Sigma for Students and New Quality Practitioners

By
Qianmei Feng, University of Houston
And
Kailash C. Kapur, University of Washington

Industrial, manufacturing and service organizations are interested in improving their products and processes by decreasing the variation, because the competitive environment leaves little room for error. Variation is the enemy of quality which is defined and evaluated by the customers. We must deliver products and services at the ideal targets demanded by the customers. The traditional evaluation of quality is based on average measures of the process/product and their deviation from the target value. However, customers judge the quality of process/product not only based on the average, but also by the variance in each transaction with the process or use of the product. Customers want consistent, reliable and predictable processes that deliver or exceed the best-in-class level of quality. This is what the Six Sigma process strives to achieve (Kapur and Feng 2005). Over the last twenty years, Six Sigma has been successfully implemented in many industries, from large manufacturing to small businesses, from financial services, insurance industry to healthcare systems.

What is Six Sigma?

In many organizations, Six Sigma means a business management process that provides tangible business results to the bottom line by continuous process improvement and variation reduction. As a data-driven, statistically-based approach, Six Sigma aims to deliver near-zero defects (as defined by the customers) for every product, process, and transaction within an organization.

The objective of a Six Sigma process is to reduce process variation, so that it will result in no more than 3.4 defects per million opportunities (DPMO) in the long term. This defect rate is calculated based on the assumption that many processes are prone to shift of 1.50 standard deviations due to unavoidable assignable causes or degradation mechanisms. To achieve this long-term objective, the process capability has to reach Six Sigma level in a short term, i.e., the range between the target value and the specification limit contains six process standard deviations (six sigma) on both sides of the target. In the short term, the defect rate of a Six Sigma process is only about 0.002 DPMO. However, if the process mean shifts 1.5 process standard deviations over time, the defect rate will change to 3.4 DPMO. For processes that have not reached Six Sigma level, the defect rate will increase significantly when the process shifts (see Figure 1), which can cause serious quality problems over time.

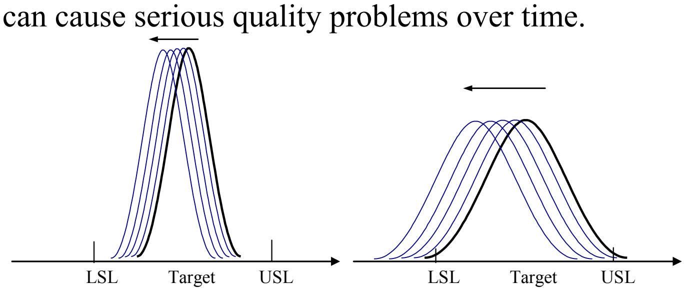

Figure 1: Shifting a Six Sigma process and a Lower Sigma process

A Six Sigma process can also be interpreted in terms of process capability, which is associated with process variation (Kapur and Feng 2006). The typical definition for process capability index, C_{pk}, is $C_{pk} = \min\left\{\frac{USL-\hat{\mu}}{3\hat{\sigma}}, \frac{\hat{\mu}-LSL}{3\hat{\sigma}}\right\}$, where *USL* is the upper specification limit, *LSL* is the lower specification limit, $\hat{\mu}$ is the point estimator of the mean, and $\hat{\sigma}$ is the point estimator of the standard deviation. If the process is centered at the middle of the specifications, which is also interpreted as the target value, then the Six Sigma process means that C_{pk} =2. If want to achieve 3.4 DPMO, it implies that the realized C_{pk} is 1.5 after the process shifts 1.5 standard deviations over time. The requirement of 3.4 DPMO or C_{pk} of 1.5 is not the ultimate goal of Six Sigma; the ideal objective is to establish the right strategy for the never ending continuous process improvement.

Why Six Sigma?

Although the name does not contain the word "quality", Six Sigma is a methodology for structured, process-oriented and systematic quality improvement. As the latest name for a comprehensive set of fundamental concepts, philosophies, tools, and methods for process or quality improvement, Six Sigma continues to show its endurance and return on investment for more than twenty years.

The primary reason for the success of Six Sigma is that it provides a systematic approach for quality and process improvement, and it is not just a collection of tools. During most quality training in academia, industry and government, students and professionals usually are taught a number of individual tools such as DOE, SPC, FMECA, FTA, QFD, etc., and leave the course without a mental big picture about how all these tools fit together. While implementing project by project, Six Sigma provides an overall process of improvement that clearly shows how to link and sequence individual tools. With Six Sigma, students and professionals know what to do when faced with a real problem.

How is Six Sigma implemented?

A typical process for Six Sigma process improvement has five phases: Define, Measure, Analyze, Improve, and Control, denoted by DMAIC. We extend it to a six-phase process, DMAIC(T), in order to emphasis the importance of Technology Transfer (T) of successful experiences. The ideas or experiences can be transferred to similar products, processes, or transactions within an organization via an intranet database of past Six Sigma projects. In this way, the rate of return on the investment from one Six Sigma project can be maximized (Kapur and Feng 2005, 2006).

The process of DMAIC(T) stays on track by reducing process variations and establishing deliverables at each phase. In each phase, several quality improvement methods, tools and techniques can be used as shown in Table 1.

Table 1. DMAIC(T) Framework

Phase		Tools
D	*Define* the scope and objective of the project, the critical to quality (CTQ) issues, the potential improvement opportunities.	• Project charter • Benchmarking surveys • Spider charts • Flowchart

M	*Measure* the process performance, especially the critical to quality (CTQ), to analyze the operations of the current system.	• Quality Function Deployment (QFD) • Failure Mode, Effect, Criticality Analysis (FMECA) • Gage R&R
A	*Analyze* data collected and use process maps to determine root causes of defects and prioritize opportunities for improvement. Apply statistical tools to guide the analysis.	• Histogram/Pareto chart/Run chart • Scatter plot/Cause and effect diagram • Product capability analysis
I	*Improve* the process by designing creative solutions to fix and prevent problems. Some experiments may be performed in order to find the best solution. Optimization methods are utilized to determine the optimum solution.	• Quality Function Deployment (QFD) • Failure Mode, Effect, Criticality Analysis (FMECA) • Statistical experimental design and analysis • Simulation
C	*Control* the process on the new course. Performance tracking mechanisms and measurements are put in place to assure that the gains are not lost over time. The key to the overall success of Six Sigma methodology is its sustainability.	• Gage R&R • Statistical process control/ Control charts • QS9000/ISO9000
T	*Transfer* ideas and knowledge developed in one project to other sections of the organization. *Transfer* the methods and solutions developed for one product or process to other similar products or processes.	• Project Management • Collaborative team effort and cross functional teams

What is Design for Six Sigma (DFSS)?

While Six Sigma process improvement approach leaves the fundamental structure of a process unchanged, Design for Six Sigma (DFSS) involves changing or redesigning the process at the early stages of product/process life cycle. DFSS becomes necessary when (Yang and El-Haik, 2003)

- The current process has to be replaced, rather than repaired or just improved,
- The required quality level cannot be achieved by just improving an existing process, or
- An opportunity is identified to offer a new process.
- Breakthrough and new disruptive technologies

Although DFSS takes more effort at the beginning, it will benefit an organization in a long run by designing Six Sigma quality into products/processes. There are several methodologies for DFSS, such as DMADV, IDOV or ICOV. DMADV is a popular methodology since it has the same number of letters as the DMAIC acronym. The five phases of DMADV are defined as: Define, Measure, Analyze, Design and Verify. IDOV or ICOV is a well-known design methodology, especially in the manufacturing world. The IDOV (or ICOV) acronym is defined as Identify, Design (Characterize the design), Optimize and Validate. Thus DFSS integrates all or many of the well known methods, tools and philosophies for quality and reliability improvement, research, development and design strategies, and management thinking for teamwork and collaboration from cradle to grave for products and processes in any organization.

Future Trends of Six Sigma

Although Six Sigma originated in manufacturing industry, it has been successfully adopted by many other public or private sectors, from financial services to health care delivery and management, from information technology to knowledge management. The successful implementation over twenty years supports the hypothesis that basic thinking and methods that are used in Six Sigma have lasting values, even though they will be marketed by new names in the future. These ideas can be integrated with other productivity improvement methods, for example the recent focus on Lean Six Sigma. These methods will continue to show their endurance in the global business environment.

References:

1. Kapur, K.C., Feng, Q., Integrated Optimization Models and Strategies for the Improvement of the Six Sigma Process. *International Journal of Six Sigma and Competitive Advantage*, 1(2), 2005.
2. Kapur, K.C., Feng, Q., Statistical Methods for Product and Process Improvement, a chapter in *Springer Handbook of Engineering Statistics*, Pham, Hoang (Ed.), Springer, London, 2006.
3. Yang, K. and El-Haik, B., Design for Six Sigma: A Roadmap for Product Development, McGraw-Hill, New York, 2003.

Six Sigma Resources

Books:

- *The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels*, by Thomas Pyzdek
- *The Six Sigma Way: How GE, Motorola, and Other Top Companies are Honing Their Performance*, by Peter S. Pande et al, Robert P. Neuman, and Roland R. Cavanagh
- *Implementing Six Sigma: Smarter Solutions Using Statistical Methods,* Second Edition, by Forrest W. Breyfogle III
- *Six Sigma Workbook For Dummies*, by Craig Gygi, Bruce Williams, and Terry Gustafson
- *Design for Six Sigma: A Roadmap for Product Development*, by Kai Yang and Basem S. EI-Haik
- *Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions,* by Michael L. George

Journals and Magazines:

- International Journal of Six Sigma and Competitive Advantage
- iSixSigma Magazine
- ASQ Six Sigma Forum Magazine

Web Resources:

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www.isixsigma.com
www.sixsigmafirst.com
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www.sixsigmaspc.com
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