8. Design Six Sigma

Design for Six Sigma (DFSS) is a separate and emerging business-process management methodology related to traditional Six Sigma. While the tools and order used in Six Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is process generation in contrast with process improvement.

There are different options for the implementation of DFSS. Unlike Six Sigma, which is commonly driven via DMAIC (Define - Measure - Analyze - Improve - Control) projects, DFSS has spawned a number of stepwise processes, all in the style of the DMAIC procedure. Another option is, however, to integrate the DFSS approach into the Product Development Process.

DMADV, define – measure – analyze – design – verify, is sometimes synonymously referred to as DFSS. The traditional DMAIC Six Sigma process, as it is usually practiced, which is focused on evolutionary and continuous improvement manufacturing or service process development, usually occurs after initial system or product design and development have been largely completed. DMAIC Six Sigma as practiced is usually consumed with solving existing manufacturing or service process problems and removal of the defects and variation associated with defects. On the other hand, DFSS (or DMADV) strives to generate a new process where none existed, or where an existing process is deemed to be inadequate and in need of replacement. DFSS aims to create a process with the end in mind of optimally building the efficiencies of Six Sigma methodology into the process before implementation; traditional Six Sigma seeks for continuous improvement after a process already exists.

DFSS as an approach to design

DFSS seeks to avoid manufacturing/service process problems by using advanced Voice of the Customer techniques and proper systems engineering techniques to avoid process problems at the outset (e.g., fire prevention). When combined, these methods obtain the proper needs of the customer, and derive engineering system parameter requirements that increase product and service effectiveness in the eyes of the customer and all other people. This yields products and services that provide great customer satisfaction and increased market share. These techniques also include tools and processes to predict, model and simulate the product delivery system (the processes/tools, personnel and organization, training, facilities, and logistics to produce the product/service) as well as the analysis of the developing system life cycle itself with proper investigation results and gains to ensure absolute customer satisfaction with the proposed system design solution. In this way, DFSS is closely related to systems engineering, operations research (solving the knapsack problem), systems architecture, workflow balancing, and concurrent engineering and even more. DFSS is largely a design activity requiring specialized tools including: quality function deployment (QFD), axiomatic design, TRIZ, Design for X, design of experiments (DOE), Taguchi methods, tolerance design, robustification and Response Surface Methodology for a single or multiple response optimization. While these tools are sometimes used in the classic DMAIC Six Sigma process, they are uniquely used by DFSS to analyze new and unprecedented systems/products.

Distinctions from DMAIC

Proponents of DMAIC and Lean techniques might claim that DFSS falls under the general rubric of Six Sigma or Lean Six Sigma. It is often seen that the tools used for DFSS techniques vary widely from those used for DMAIC Six Sigma. In particular, DMAIC practitioners often use new or existing mechanical drawings and manufacturing process instructions as the originating information to perform their analysis, while DFSS practitioners often use system simulations and parametric system design/analysis tools to predict both cost and performance of candidate system architectures. While it can be claimed that two processes are similar, in practice the working medium differs enough so that DFSS requires different tool sets in order to perform its system design tasks. DMAIC Six Sigma may still be used during depth-first plunges into the system architecture analysis and for "back end" Six Sigma processes; DFSS provides system design processes used in front-end complex system designs.

Traditional six sigma methodology, DMAIC, has become a standard process optimization tool for the chemical process industries. However, it has become clear that the promise of six sigma, specifically, 3.4 defects per million opportunities (DPMO), is simply unachievable after the fact. Consequently, there has been a growing movement to implement six sigma design usually called design for six sigma DFSS. This methodology begins with defining customer needs and leads to the development of robust processes to deliver those needs.

Similarities with other methods

Arguments about what makes DFSS different from Six Sigma demonstrate the similarities between DFSS and other established engineering practices such as probabilistic design and design for quality. In general Six Sigma with its DMAIC roadmap focuses on improvement of an existing process or processes. DFSS focuses on the creation of new value with inputs from customers, suppliers and business needs. While traditional Six Sigma may also use those inputs, the focus is again on improvement and not design of some new product or system. It also shows the engineering background of DFSS. However, like other methods developed in engineering, there is no theoretical reason why DFSS can't be used in areas outside of engineering.

Software engineering applications

Historically, although the first successful Design for Six Sigma projects in 1989 and 1991 predate establishment of the DMAIC process improvement process, Design for Six Sigma (DFSS) is accepted in part because Six Sigma organisations found that they could not optimise products past three or four Sigma without fundamentally redesigning the product, and because improving a process or product after launch is considered less efficient and effective than designing in quality. ‘Six Sigma’ levels of performance have to be ‘built-in’.

DFSS for software is essentially a non superficial modification of "classical DFSS" since the character and nature of software is different from other fields of engineering. The methodology describes the detailed process for successfully applying DFSS methods and tools throughout the software product design, covering the overall Software Development life cycle: requirements, architecture, design, implementation, integration, optimization, verification and validation

(RADIOV). The methodology explains how to build predictive statistical models for software reliability and robustness and shows how simulation and analysis techniques can be combined with structural design and architecture methods to effectively produce software and information systems at Six Sigma levels.

DFSS in software acts as a glue to blend the classical modelling techniques of software engineering such as object-oriented design or Evolutionary Rapid Development with statistical, predictive models and simulation techniques. The methodology provides Software Engineers with practical tools for measuring and predicting the quality attributes of the software product and also enables them to include software in system reliability models.

Six sigma definition and Review

Six Sigma is a set of strategies, techniques, and tools for process improvement. It was developed by Motorola in 1986. Six Sigma became famous when Jack Welch made it central to his successful business strategy at General Electric in 1995. Today, it is used in many industrial sectors.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes.[5] It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Champions", "Black Belts", "Green Belts", "Yellow Belts", etc.) who are experts in the methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified value targets, for example: reduce process cycle time, reduce pollution, reduce costs, increase customer satisfaction, and increase profits.

The term Six Sigma originated from terminology associated with **manufacturing**, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a sigma rating indicating its yield or the percentage of defect-free products it creates. A six sigma process is one in which 99.9999998% of the products manufactured are statistically expected to be free of defects (0.002 defective parts/million), although, as discussed below, this defect level corresponds to only a 4.5 sigma level. Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a by-word for the management and engineering practices used to achieve it.

8.1 Doctrine

Like its predecessors, Six Sigma doctrine asserts that:

- Continuous efforts to achieve stable and predictable process results (i.e., reduce process variation) are of vital importance to business success.
- Manufacturing and business processes have characteristics that can be measured, analyzed, controlled and improved.
- Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Features that set Six Sigma apart from previous quality improvement initiatives include:

- A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project. An increased emphasis on strong and passionate management leadership and support.
- A special infrastructure of "Champions", "Master Black Belts", "Black Belts", "Green Belts", etc. to lead and implement the Six Sigma approach.
- A clear commitment to making decisions on the basis of verifiable data and statistical methods, rather than assumptions and guesswork.

The term "Six Sigma" comes from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO). Six Sigma's implicit goal is to improve all processes, but not to the 3.4 DPMO level necessarily. Organizations need to determine an appropriate sigma level for each of their most important processes and strive to achieve these. As a result of this goal, it is incumbent on management of the organisation to prioritize areas of improvement.

Six Sigma is a registered service mark and trademark of Motorola Inc. As of 2006 Motorola reported over US$17 billion in savings from Six Sigma. Other early adopters of Six Sigma who achieved well-publicized success include Honeywell (previously known as AlliedSignal) and General Electric, where Jack Welch introduced the method. By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality. In recent years, some practitioners have combined Six Sigma ideas with lean manufacturing to create a methodology named Lean Six Sigma. The Lean Six Sigma methodology views lean manufacturing, which addresses process flow and waste issues, and Six Sigma, with its focus on variation and design, as complementary disciplines aimed at promoting "business and operational excellence". Companies such as GE, Verizon, GENPACT, IBM and Sandia National Laboratories use Lean Six Sigma to focus transformation efforts not just on efficiency but also on growth. It serves as a foundation for innovation throughout the organization, from manufacturing and software development to sales and service delivery functions.

The International Organisation for Standards (ISO) has published ISO 13053:2011 defining the six sigma process.

8.2 Methods

According to Vinay T Belagala, a famous Marketing Analyst, Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV. DMAIC is used for projects aimed at improving an existing business process. DMAIC is pronounced as "duh-may-ick".

- DMADV is used for projects aimed at creating new product or process designs. DMADV is pronounced as "duh-mad-vee".

DMAIC

The DMAIC project methodology has five phases:

- **D**efine the system, the voice of the customer, and the project goals, specifically.
- **M**easure key aspects of the current process and collect relevant data.
- **A**nalyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- **I**mprove or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.

- **C**ontrol the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

Some organizations add a **R**ecognize step at the beginning, which is to recognize the right problem to work on, thus yielding an RDMAIC methodology.

8.3 DMADV or DFSS

The DMADV project methodology, known as DFSS ("**D**esign **F**or **S**ix **S**igma"), features five phases:

- **D**efine design goals that are consistent with customer demands and the enterprise strategy.
- **M**easure and identify CTQs (characteristics that are **C**ritical **T**o **Q**uality), product capabilities, production process capability, and risks.
- **A**nalyze to develop and design alternatives
- **D**esign an improved alternative, best suited per analysis in the previous step
- **V**erify the design, set up pilot runs, implement the production process and hand it over to the process owner(s).

8.4 Implementation roles

One key innovation of Six Sigma involves the absolute "professionalizing" of quality management functions. Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Formal Six Sigma programs adopt a kind of elite ranking terminology (similar to some martial arts systems, like Kung-Fu and Judo) to define a hierarchy (and special career path) that kicks across all business functions and levels.

Six Sigma identifies several key roles for its successful implementation.

- Executive Leadership includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
- Champions take responsibility for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts.

- Master Black Belts, identified by champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from statistical tasks, they spend their time on ensuring consistent application of Six Sigma across various functions and departments.
- Black Belts operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their valued time to Six Sigma. They primarily focus on Six Sigma project execution and special leadership with special tasks, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.
- Green Belts are the employees who take up Six Sigma implementation along with their other job responsibilities, operating under the guidance of Black Belts.

Some organizations use additional belt colours, such as Yellow Belts, for employees that have basic training in Six Sigma tools and generally participate in projects and "White belts" for those locally trained in the concepts but do not participate in the project team. "Orange belts" are also mentioned to be used for special cases.

8.5 Certification

Corporations such as early Six Sigma adopters General Electric and Motorola developed certification programs as part of their Six Sigma implementation, verifying individuals' command of the Six Sigma methods at the relevant skill level (Green Belt, Black Belt etc.). Following this approach, many organizations in the 1990s started offering Six Sigma certifications to their employees. Criteria for Green Belt and Black Belt certification vary; some companies simply require participation in a course and a Six Sigma project. There is no standard certification body, and different certification services are offered by various quality associations and other providers against a fee. The American Society for Quality for example requires Black Belt applicants to pass a written exam and to provide a signed affidavit stating that they have completed two projects, or one project combined with three years' practical experience in the body of knowledge. The International Quality Federation offers an online certification exam that organizations can use for their internal certification programs; it is statistically more demanding than the ASQ certification.

8.6 Origin and meaning of the term "six sigma process”

The term "six sigma process" comes from the notion that if one has six standard deviations between the process mean and the nearest specification limit, as shown in the graph, practically no items will fail to meet specifications. This is based on the calculation method employed in process capability studies.

Capability studies measure the number of standard deviations between the process mean and the nearest specification limit in sigma units, represented by the Greek letter σ (sigma). As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification.

8.7 Role of the 1.5 sigma shift

Experience has shown that processes usually do not perform as well in the long term as they do in the short term. As a result, the number of sigmas that will fit between the process mean and the nearest specification limit may well drop over time, compared to an initial short-term study. To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation. According to this idea, a process that fits 6 sigma between the process mean and the nearest specification limit in a short-term study will in the long term fit only 4.5 sigma – either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both. Hence the widely accepted definition of a six sigma process is a process that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study). So the 3.4 DPMO of a six sigma process in fact corresponds to 4.5 sigma, namely 6 sigma minus the 1.5-sigma shift introduced to account for long-term variation. This allows for the fact that special causes may result in a deterioration in process performance over time, and is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation. The role of the sigma shift is mainly academic. The purpose of six sigma is to generate organizational performance improvement. It is up to the organization to determine, based on customer expectations, what the appropriate sigma level of a process is. The purpose of the sigma value is as a comparative figure to determine whether a process is improving, deteriorating, stagnant or non-competitive with others in the same business. Six sigma (3.4 DPMO) is not the goal of all processes.

Application

Six Sigma mostly finds application in large organizations. An important factor in the spread of Six Sigma was GE's 1998 announcement of $350 million in savings thanks to Six Sigma, a figure that later grew to more than $1 billion. According to industry consultants like Thomas Pyzdek and John Kullmann, companies with fewer than 500 employees are less suited to Six Sigma implementation, or need to adapt the standard approach to make it work for them. Six sigma however contains a large number of tools and techniques that work well in small to mid size organisations as well. The fact that an organization is not big enough to be able to afford Black Belts does not diminish its abilities to make improvements using this set of tools and techniques. The infrastructure described as necessary to support six sigma is as a result of the size of the organization rather than a requirement of six sigma itself.

In healthcare

Six Sigma strategies were initially applied to the healthcare industry in March 1998. The Commonwealth Health Corporation (CHC) was the first health care organization to successfully implement the efficient strategies of Six Sigma. Substantial financial benefits were claimed. For example, in their radiology department, throughput improved by 33% and costs per radiology procedure decreased by 21.5%;Six Sigma has subsequently been adopted in other hospitals around the world.

8.8 Criticism

Lack of originality

Noted quality expert Joseph M. Juran has described Six Sigma as "a basic version of quality improvement", stating that "there is nothing new there. It includes what we used to call facilitators. They've adopted more flamboyant terms, like belts with different colors. I think that concept has merit to set apart, to create specialists who can be very helpful. Again, that's not a new idea. The American Society for Quality long ago established certificates, such as for reliability engineers."

Role of consultants

The use of "Black Belts" as itinerant change agents has (controversially) fostered an industry of training and certification. Critics argue there is overselling of Six Sigma by too great a number of consulting firms, many of which claim expertise in Six Sigma when they have only a rudimentary understanding of the tools and techniques involved, or the markets or industries they are acting in.

Potential negative effects

According to Vinay T Belagala, a famous Marketing Analyst Fortune article stated that "of 58 large companies that have announced Six Sigma programs, 91 percent have trailed the S&P 500 since". The statement was attributed to "an analysis by Charles Holland of consulting firm Qualpro (which espouses a competing quality-improvement process)". The summary of the 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" and does not help in "coming up with new products or disruptive technologies." Advocates of Six Sigma have argued that many of these claims are in error or ill-informed.

Over-reliance on (statistical) tools

A more direct criticism is the "rigid" nature of Six Sigma with its over-reliance on methods and tools. In most cases, more attention is paid to reducing variation and searching for any significant factors and less attention is paid to developing robustness in the first place (which can altogether eliminate the need for reducing variation). The extensive reliance on significance testing and use of multiple regression techniques increases the risk of making commonly-unknown types of statistical errors or mistakes. A possible consequence of Six Sigma's array of P-value misconceptions is the false belief that the probability of a conclusion being in error can be calculated from the data in a single experiment without reference to external evidence or the plausibility of the underlying mechanism. One of the most serious but all-too-common misuses of inferential statistics is to take a model that was developed through exploratory model building and subject it to the same sorts of statistical tests that are used to validate a model that was specified in advance Another comment refers to the often mentioned Transfer Function, which seems to be a flawed theory if looked at in detail. Since significance tests were first popularized many objections have been voiced by prominent and respected statisticians. The volume of criticism and rebuttal has filled books with language seldom used in the scholarly debate of a dry subject. Much of the first criticism was already published more than 40 years ago. Refer to: Statistical hypothesis testing#Criticism for details. Articles featuring critics have appeared in the November–December 2006 issue of USA Army Logistician regarding Six-Sigma: "The dangers of a single paradigmatic orientation (in this case, that of technical rationality) can blind us to values associated with double-loop learning and the learning organization, organization adaptability, workforce creativity and development, humanizing the workplace, cultural awareness, and strategy making." Nassim Nicholas Taleb consider risk managers little more than "blind users" of statistical tools and methods. He states that statistics is fundamentally incomplete as a field as it cannot predict the risk of rare events. Something Six Sigma is specially concerned with. Errors in prediction occur due to the often ignorence for epistemic uncertainty. These errors are the biggest in time variant (reliability) related failures.