SIX SIGMA (6σ)

Category: Approach

ABSTRACT

Six Sigma(G) is an approach originally developed by Motorola in 1980s to systematically improve processes by eliminating defects(G) which will result to reduction of process variation.

At Motorola, they think Six Sigma as a metric, a methodology and a management system at the same time[i].

The term "Six Sigma" refers to the ability of highly capable processes to produce output at defect levels below 3.4 defects per (one) million opportunities (DPMO)[i].

KEYWORDS

Six Sigma, 6σ, process improvement, process capability, DMAIC, DMADV, DFSS

OBJECTIVE

Six Sigma's goal is to improve processes by reducing levels of output defects at levels below 3.4 defects per (one) million opportunities (DPMO)[ii].

FIELD OF APPLICATION

To improve production processes, service delivery processes, administration processes etc.

RELATED TOOLS

FMEA, QFD, Paretto Diagram, Fishbone Diagram, Control Chart, Process Maps, Histograms, Check Sheets, Gannt Chart

DESCRIPTION

At Motorola, Six Sigma has been and still is defined as a quality improvement program with a goal of reducing the number of defects to as low as 3.4 parts per million opportunities. In fact, there is a difference in the true value of Six Sigma and Motorola's value of Six Sigma[iii]. The explanation of this difference is beyond the scope of this tool. However the reader can refer to reference no iv for further reading.

SIX SIGMA EVOLUTION

Motorola is the creator of the formal Six Sigma methodology. The first proponents of Six Sigma after Motorola were GE Aircraft Engines, Texas Instruments, Allied Signal, Eastman Kodak, Borg-Warner Automotive, GenCorp, Navistar International and Siebe plc[iv].

Although six sigma has been developed in industry, in recent years started to apply in the service sector, and in healthcare more specific, although the big challenge in services is the identification of the appropriate metrics, and gathering and exploitation of credible data which are not produced from a manufacturing process which is in statistical control, rather than responses produced from human behaviour.

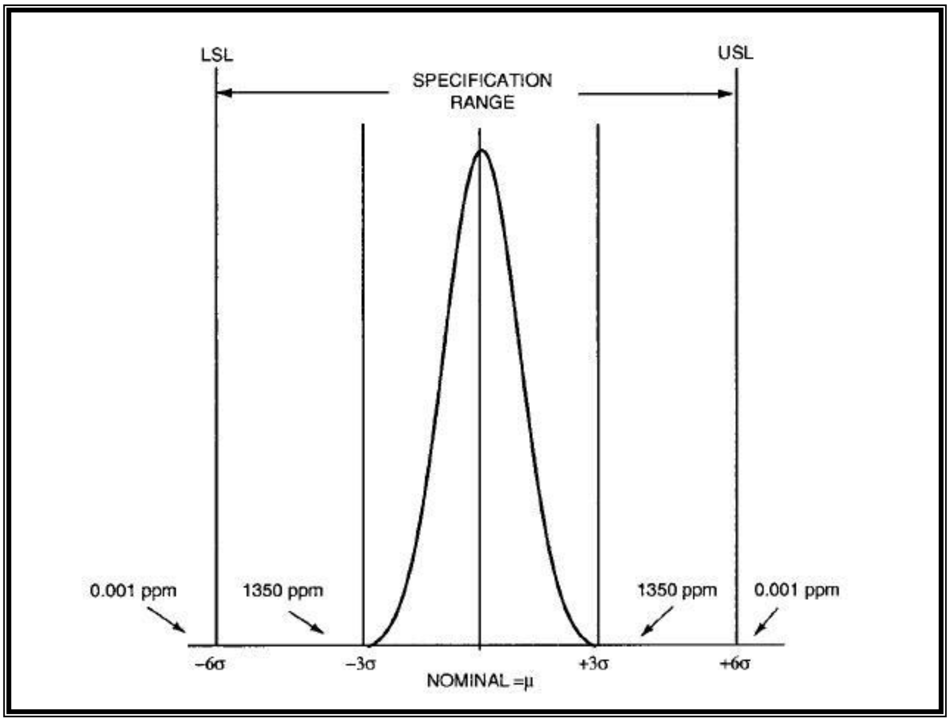
On the other hand, the basic six sigma objective for eliminating errors is more than appropriate as a target especially in the very sensitive for human life healthcare sector.

The first healthcare organisation that implemented fully six-sigma was Commonwealth Health Corp (CHC) with partnership with General Electric[v].

SIX SIGMA EXPLANATION[IX]

Six Sigma is, basically, a process quality goal, where sigma is a statistical measure of variability in a process.

One puzzling aspect of the ‘‘official’’ Six Sigma literature is that it states that a process operating at Six Sigma will produce 3.4 parts-per-million (PPM) nonconformances. However, if a special normal distribution table is consulted, one finds that the expected non-conformances are 0.002 PPM (2 parts-per-billion, or PPB). The difference occurs because Motorola presumes that the process mean can drift 1.5 sigma in either direction. The area of a normal distribution beyond 4.5 sigma from the mean is indeed 3.4 PPM. Since control charts will easily detect any process shift of this magnitude in a single sample, the 3.4 PPM represents a very conservative upper bound on the non-conformance rate.



In contrast to Six Sigma quality, the old three sigma quality standard of 99.73% translates to 2,700 PPM failures, even if we assume zero drift.

SIX SIGMA METHODOLOGY

The basic approach is to measure performance on an existing process, compare it with a statistically valid ideal and figure out how to eliminate any variation[vi].

It starts with a detailed analysis to quantify and measure factors that are critical to our customers' success, and to find ways to remove obstacles (defects) to that success[vii].

Customer requirements, both external and internal, are paramount in choosing which Six Sigma projects to undertake[vi].

When Six Sigma was first launched at GE Aircraft Engines, a four-step methodology (MAIC) was followed. Recently, the Define phase has been added to recognize the importance of having a well-scoped project and to be in line with the current practices across GE)[vi]. The DMAIC model is consisted of the following descrete phases.

Phase 1: define (D)

Who are the customers and what are their priorities?

A Six Sigma project team identifies a project suitable for Six Sigma efforts based on business objectives as well as customer needs and feedback. As part of the definition phase, the team identifies those attributes, called CTQs (critical to quality characteristics), that the customer considers to have the most impact on quality.

Phase 2: measure (M)

How is the process measured and how is it performing?

The team identifies the key internal processes that influence CTQs and measures the defects currently generated relative to those processes.

Phase 3: analyze (A)

What are the most important causes of defects?

The team discovers why defects are generated by identifying the key variables that are most likely to create process variation.

Phase 4: improve (I)

How do we remove the causes of the defects?

The team confirms the key variables and quantifies their effects on the CTQs. It also identifies the maximum acceptable ranges of the key variables and validates a system for measuring deviations[(G)] of the variables. The team modifies the process to stay within the acceptable range.

Phase 5: control (C)

How can we maintain the improvements?

Tools are put in place to ensure that under the modified process the key variables remain within the maximum acceptable ranges over time.

In some cases, the 5 steps mentioned above, should be supplemented by the "recognise" of the problem prior to "define", and "standardise" and "integrate" as final steps of the process helping to incorporate the solution into the organisation permanently.

ORGANIZATIONAL INFRASTRUCTURE

The implementation of Six Sigma is a very intensive, long lasting, and resource demanding job, and needs many people to get trained and involved. Experience of big organizations that implemented Six Sigma, have shown that the appropriate organizational infrastructure is required in terms of roles and responsibilities of personnel.

A successful model of organisational structure in deploying Six Sigma is to implement various levels of expertise as described below[iv]:

- **champions** are fully trained business leaders who promote and lead the deployment of Six Sigma in a significant area of the business;
- **master black belts** are fully-trained quality leaders responsible for Six Sigma strategy, training, mentoring, deployment, and results;
- **black belts** are fully-trained Six Sigma experts who lead improvement teams, who work projects across the business and mentor green belts;
- **green belts** are full-time teachers with quantitative skills as well as teaching and leadership ability; they are fully-trained quality leaders

responsible for Six Sigma strategy, training, mentoring, deployment, and results; and

- **team members** are individuals who support specific projects in their area.

Phase	Responsibility
Recognise	**Champions**
Define	**Champions / master black belts**
Measure	**Black belts**
Analyze	**Black belts**
Improve	**Black belts**
Control	**Black belts**
Standardise	**Champions**
Integrate	**Champions**

Table 1: Six Sigma responsibility matrix[viii]

OTHER SIX SIGMA RELATED MODELS

The basic model for Six Sigma implementation is the DMAIC already described. However, the success of the model lead to variations or improvements of the initial approach, or even complementary models aim to enhance DMAIC.

Design for Six Sigma (DFSS) is a systematic methodology utilizing tools, training and measurements to design products and processes that meet customer expectations at Six Sigma quality levels. DFSS is deployed via a framework known as DMADV[ix]. Six Sigma DMADV process (define, measure, analyze, design, verify) is an improvement system used to develop new processes or products at Six Sigma quality levels[x].

SIX SIGMA IN HEALTHCARE

Six Sigma principles and the healthcare sector are very well matched because of the healthcare nature of very low or zero tolerance to mistakes and potentials for reducing medical errors[xix].

In 1998, the Institute of Medicine released an assessment stating that 98,000 people die each year as a result of medical errors, highlighting the necessity for quality improvements[xi]. Additionally an estimated £400 million is being paid in clinical negligence claims and adverse incidents resulted in approximately £2 billion per annum[xii]. Those are some examples that can easily point out the vital importance of quality in healthcare services, and the significant need for implementation of quality management principles and techniques to improve performance, quality levels, and customer satisfaction.

Six sigma projects in healthcare industry have focused on direct care delivery, administrative support and financial administration[xiii]. From emergency room to boardroom, six-sigma can reduce variability and waste by translating to fewer errors, better processes, improved patient care, greater patient satisfaction rates, and happier, more productive employees. To achieve these goals, the DMAIC must be implemented[xv].

However, applying Six Sigma in healthcare is not always the easiest thing to do. Some of challenges someone has to face, as stated by Mehmet Tolga Taner and Bulent Sezen and Jiju Antony[xv] are the initial investment in six-sigma Belt System training, the absence or difficulty to obtain the baseline data on process performance, the identification of processes which can be measured in terms of defects or errors per million opportunities[xiv], the psychology of the workforce, the extensive use of statistical language.

BENEFITS

Some of the benefits of implementing Six Sigma are[v]:

- Improve responsiveness to and focus on the customer,
- improve product and service performance,
- improve financial performance and profitability by reducing quality costs and defects[(G)],
- achieve and maintain measurable quality standards.

A longer list of improvements could be achieved through six sigma projects in healthcare are listed in the "An overview of six sigma applications in healthcare industry" article[xv].

SUCCESS STORIES.

Some Six Sigma success stories and results are presented here to point out benefits measured in numbers that have been accomplish by implementing Six Sigma.

- Motorola has reported over US$17 billion in savings from Six Sigma as of 2006[xvi]
- In 1997 alone GE invested US$380 million in Six Sigma ± mostly for training. However, there was payback in the same year ± GE received about US$700 million in documented benefits from increased productivity[vi].
- GE Medical Systems alone saved US$40 million in 1997 (Conlin, 1998)[xvii].
- Product development cycles have also improved at GE Harris Energy Control System, LLC. In the past it typically took 12-18 months to develop their Energy Management Systems. After implementing Six Sigma processes, they were able to develop and introduce two new Internet-

based management information products in just three months. The products were identified during a Six Sigma review of critical customer needs[vii].

- AlliedSignal, has shown an incredible upturn since it introduced Six Sigma. In 1992, annual sales were about US$13 billion from a workforce of 102,00. Sales (in February 1998) were estimated around US$14 billion with a workforce of 77,000. Productivity in 2Q1998 rose above the long-term target of 6 percent a year[xviii].

In the following table reported benefits and savings from six sigma in the manufacturing sector are presented (Data compiled from Weiner 2004, De Feo and Bar-El 2002, Anthony and Banuelas 2002, Buss and Ivey 2001, and McClusky 2000)[xix]

Company/Project	**Metric/Measures**	**Benefit/Savings**
Motorola (1992)	In-process defect levels	150 times reduction
Raytheon/Aircraft Integration Systems	Depot maintenance inspection time	Reduced 88% as measured in days
GE/Railcar leasing business	Turnaround time at repair shops	62% reduction
Allied Signal/Laminates plant in South Carolina	Capacity Cycle time Inventory On-time delivery	Up 50% Down 50% Down 50% Increased to near 100%
Allied Signal/Bendix IQ brake pads	Concept-to-shipment cycle time	Reduced from 18 months to 8 months
Hughes Aircraft's Missiles Systems Group/Wave soldering operations	Quality Productivity	Improved 1000% Improved 500%
General Electric	Financial	$2 billion in 1999
Motorola (1999)	Financial	$15 billion over 11 years
Dow Chemical/Rail delivery project	Financial	Savings of $2.45 million in capital expenditures

DuPont/Yerkes Plant in New York (2000)	Financial	Savings of more than $2 million
Telefonica de Espana (2001)	Financial	Savings and increases in revenue 30 million euro in the first 10 months
Texas Instruments	Financial	$ 600 million
Johnson & Johnson	Financial	$ 500 million
Honeywell	Financial	$1.2 billion

PREREQUISITES

- Strong and insisting Management commitment and involvement.
- Strong "Quality Culture".
- Excessive intensive training (GE has implemented a full 13 days of training for every employee!!![xx]).
- Advanced knowledge of statistical techniques, extremely rigorous data collection and statistical analysis.
- Organizational infrastructure, meaning support systems, specific roles and responsibilities, teamworking culture.
- IT infrastructure and data gathering systems.

EXAMPLES – CASE STUDY

THE RED CROSS HOSPITAL CASE

Red Cross Hospital in Beverwijk, the Netherlands, is a 384-bed, mediumsized general hospital, with a staff of 930 and a budget of $70 million. In addition to being a general healthcare provider, Red Cross Hospital is the base for a 25-bed national burn care center that provides services to all of the Netherlands. In 2002, it admitted 11,632 patients, performed 8,269 outpatient treatments and received 190,218 visits to its outpatient units. During the past four years, Red Cross Hospital's management and employees invested significant resources in building a quality assurance system, and at the end of 2000, the hospital was awarded an ISO 9002 certification. After that, management began undertaking quality improvement projects on a regular basis, but it was doing so without the benefit of Six Sigma's project management system[xxi].

At the end of 2001, they started the implementation of Six Sigma with one-day training course for the management team. The quality manager and 16 employees continued with an in-company Belt training. More groups have followed up to 2004. Projects were implemented in several areas of interest from patient logistics to medication and the length of stay in the hospital, and all show that Six Sigma, despite its origin from industry, can work equally well in healthcare[xxii].

SAMPLE PROJECT: SHORTENING THE LENGTH OF STAY OF GYNAECOLOGY PATIENTS

Due to the fact that in Netherlands, hospitals receive, as part of their budgets, a fixed amount of money for every admission, reducing the length of stay of patients has a direct impact on the financial results of the hospital because more patients can be admitted.

Define phase

The objective of this project was to shorten the stay of gynaecology patients who had to undergo an abdominal uterus extirpation (AUE) or a vaginal uterus extirpation (VUE). The financial benefits of this project were estimated to be €57 800. An additional benefit was the possible reduction in the waiting lists for these types of gynaecological procedures. The duration of the project was estimated to be six months. The project was carried out by two Green Belts in training. Both Green Belts had one day per week available to spend on the project.

Measure phase

The so-called critical to quality (CTQ) characteristic is the length of stay of patients with AUE or VUE. This CTQ was defined as the length of the stay measured in days. The requirement on the CTQ was to shorten the length of stay as much as possible with no additional discomfort to the patients. The measurement of the length of stay by an information system has been validated.

Analyse phase

Data for the year 2002 were used. There appeared to be a few outliers, which were analysed and excluded from the data by performing a capability analysis. The average stay in the hospital of patients with VUE or AUE was 7 days, and the standard deviation was 2 days. Based on the current performance, the Green Belts decided that the objective of this project was to reduce the length of stay for AUE or VUE patients to 4.5 days with a standard deviation of 0.6 days. This objective should result in a financial benefit of €63 520.

Factors influencing the length of stay were listed by using a cause and effect diagram and a failure mode and effect analysis (FMEA).

Improve phase

The most relevant factors influencing the length of the stay were found to be:

- treatment protocols of patients with AUE or VUE; and

• situation at home, i.e. whether there are relatives who can take care of the patients after discharge.

Changes in the protocols of AUE or VUE patients, such as skipping the pre-surgery day, directly reduced the length of stay of the patient. The other most fruitful improvements were:

• an out-patient clinic to prepare the patient for the operation (this action reduces the length of stay of patients by one day);

• improved protocols;

• check on the situation at home and offer home care if needed; and

• information about the length of the stay given to the patient in advance.

Control phase

All of the above-mentioned improvements were implemented in March 2004. At that time the average length of stay is 5.2 days and the standard deviation is 0.9 days (based on 15 patients). Further reduction in the length of stay is expected after this initial phase.

OTHER CASE STUDIES

Some other success stories of Six Sigma implementation in healthcare can be found in the following articles which are not presented in detail in the current material due to length limitations.

- Grace Esimai, "Lean Six Sigma Reduces Medication Errors", *Quality Progress*, April 2005
- Lee Revere Ken Black and Ahsan Huq, "Integrating Six Sigma and CQI for improving patient care", *The TQM Magazine*, Volume 16 • Number 2 • 2004 • pp. 105-113
- Cherry, Jean; Seshadri, Sridhar, "Six Sigma: Using Statistics to Reduce Process Variability and Costs in Radiology", *Annual Spring Conference Proceedings,* Chicago, IL, Vol. 23, No. 0, March 2001, pp. 1-4
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- Riebling, Nancy B.; Condon, Susan; Gopen, Daniel, "Toward Error Free Lab Work", *Six Sigma Forum Magazine*, Vol. 4, No. 1, November 2004, pp. 23-29
- Walter T. Hayes and Carmine J. Cerra, with Mary Williams, "Pocono Medical Center: Faster Lab Results Using Six Sigma and Lean", *The American Society for Quality* (www.asq.org).
- Patricia Gurney , "Laboratory uses Lean and Six Sigma principles to improve turnaround times, increase staff utilisation and reduce space in five days", *Pathology Service Improvement*, www.pathologyimprovement.nhs.uk

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