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Review Article

Six Sigma - A Statistical Methodology

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Abstract

In the present state of affairs, data is collected and analyzed for any change. Data is, in fact, analysed and experience is stored. This data with statistical analysis gives results about performance of a process. The main attempt of the top management is to decide on the benchmark for improvement and to devise a methodology for change in work ethics and process improvement. This is done by what is called 'six-sigma', which is about precision and accuracy leading to data driven strategy and decisions. The current practice of six sigma is an extension of the previous work of Brandy and Allen [2].

The paper outlines the basic essentials of six-sigma theory, its main characteristics and the powerful methodology (DMAIC) consisting of 5 steps: Define, Measuring, Analyze, Improvement and Control. Interestingly, Mumbai's 'Dabbawala' case study is a case of six-sigma rating.

Keywords: Nature; Six-Sigma; Methodology

Introduction

Any society is dynamic by nature ever changing in many ways seeking improvement and perfection. In the present times, the dominant work culture may be called 'corporate culture'. This is reflected in

- Innovative leadership at the top,
- Planning with care,
- Implementing with preparation,
- Keeping efficient human resources,
- Process improvement based on project-after-project,
- Constant efforts to increase productivity and quality of products,
- Setting benchmarks in the competitive world.

The support for above action plan, in the contemporary times is being increasingly provided by mathematics.

Six-Sigma, a mathematics based strategy for near perfection originated at Motorola in 80's and is employed by Pfizer, Merck, JP Morgan, Quest Diagnostics, Siemens and many other corporations who are saving millions and in some cases billions of dollars. This mythology was used in 1988 by Motorola who won the first Malcolm Baldridge Quality Award. Essentially, it is a management philosophy translated into statistical methodology for disciplined quality improvement. One of Six Sigma's applications is to eliminate the defects from any process, product or service. The numerical goal is 3.4 defective items per million.

Measure of variation

Companies and governments, as we all know, keep various types of data for their system. Data serves the purpose which is otherwise normally termed as 'experience.' Data can perhaps be called as objective (rather than subjective) and measurable experience. Six Sigma prepares the managers to think about their business in a structured way. This means that they

- Pinpoint the causes of variations
- Identify impact of variation

- Bring assumptions to the surface so that variations can be evaluated, and
- Step beyond the mental biases which are faced by every person.

Keeping the right data on performance is that way an important and rather simple matter. Commonly, from the data performance measures such as averages are reported and variation is ignored. However, the variation is the key for improvement and can also be easily calculated.

Six-sigma essentially is the practical approach with a focus on reducing variation. For this it employs statistical analysis based on bell shaped normal distribution which depends on two parameters, namely:

- Mean;
- Standard deviation, identified by the Greek character sigma (σ), the most common and useful of the measures of variation, for n observations in the data, $x_1, x_2, \ldots, x_n$, given by

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

Causes of variation

In general, there can be two types of variations, namely special cause and common cause as defined below:

- Special cause variation – These are accidental in nature, e.g. delay because of transportation, lack of proper support, etc.
- Common cause variation – These are caused by known factors. This reflects that the choices management has made in terms of people, processes, technology, training, etc.

First of all special cause variation is removed by the Management. This will bring the system 'under control.' Once a process is 'under control,' the only way to improve performance is to reduce common cause variation.

The cost of poor quality

There are two main categories of costs of quality which are described as given below:

- Failure costs and prevention/appraisal costs. External failure costs occur when products fail in front of the customer and examples include warranties, returns, litigation, lost goodwill, etc. Internal failure costs occur when products fail before leaving the firm and examples include scrap and rework.
- Prevention and appraisal costs are generally spent to avoid a defect or to find the defect after it happens. Employee training, supplier certification, and process improvement initiatives are included in prevention costs and the hiring inspectors, designing sampling plans, etc. are included in appraisal costs.

In this regard following table showing 'cost of quality at various levels of sigma', developed may give a novel idea.

Sigma	Defect rate (per million)	Cost of quality	Competitive level
6	3.4	<10%	World Class, No 1
5	233	10 - 15%	World Class, No. 2
4	6,210	15 - 20%	Industry Average
3	66,807	20 - 30%	Low Industry Average
2	3,08,537	30 - 40%	Non Competitive
1	6,90,000	> 40%	Going Down

Table 1

Standard deviation and its important property

In every instance with the normal distribution

- 68.26% of all occurrences take place between the mean and ± 1σ
- Hence, setting a performance standard of ± 1σ means that 32% of service encounters will not meet the standard
- A performance standard of ± 2 σ indicates a 95% success rate and a 5% failure rate.
- What happens at ± 3σ, 4σ, … or … 6σ?.

There is another factor which needs to be considered. Performance of system in the long term deteriorates in the long term and that needs to be kept in mind. A table given below can give an idea of these variations at different sigma levels in short and long term.

Sigma	Short Term %	ST per Million	Long Term %	LT parts per Million
1	0.8413	158655.3	0.3085	691462.5
2	0.9772	22750.1	0.6915	308537.5
3	0.9987	1350.0	0.9332	66807.2
4	1.0000	31.7	0.9938	6209.7
5	1.0000	0.3	0.9998	232.7
6	1.0000	0.0	1.0000	3.4

Table 2: Variations at different sigma levels.

Thus, at six-sigma level in the long run, there is chance of only 3.4 defectives out of a million. This is what six-sigma aims at.

Key components of six-sigma

To approach six-sigma following four components are important parts of six-sigma.

Component	Explanation
Management Support	Requiring training of personal and time away from a person's normal job
Project based	Identify problems, select teams to fix each problem and then use a project-based approach to devise solution
Metrics	Appropriately measure what matters for performance and benchmarking
Structured approach	Teams follow 'DMAIC' (explained below) methodology for problem solving
Tools oriented	Teams use statistical descriptions and presentations like histograms, flow charts as needed.

Table 3

Applying a series of linked metrics strategic consistency is ensured

- Top level indicators are those reported to the executive suite.
- Outcomes measures define what matters to an individual process.
- Process measures are things a business monitors while the process is being executed to make sure they are on track to meet their objectives.

The master methodology - D-M-A-I-C

DMAIC is an acronym that stands for Define, Measure, Analyze, Improve, and Control

- Define: Requires that the project team describe in detail about the project considered.
- Measure: Is used to determining how the process used performs on measures of outcome and process.
- Analyze: Involves the work of determining the root cause of the problem
- Improve: Is used to devise the ways for remedial of the root cause
- Control: Is used to devise the control techniques of management which will ensure the continuity of the process.

Using other Statistical tools: In actual operations of the six-sigma tools, there are other advanced statistical tools employed by the experts. In brief some of these are:

- Project management
- Data collection
- Data graphs
- Operational definitions
- Process Capability Assessment
- Hypothesis testing
- Regression analysis
- Designed experiments
- Statistical process control
- Stakeholder analysis
- Implementation planning
- Tollgate reviews

A Case Study

In Mumbai a dabbawala is a person who carries the boxes and his job is to carry and deliver boxes of lunch to office workers containing freshly made food from home.

For the efficiency of their supply chain it has been claimed that this virtually achieves a Six-Sigma performance rating, (i.e. 99.9999% of deliveries are made without error).

Everyone who works within this system is treated as an equal, regardless of a dabbawala's function. Everyone gets paid about four to six thousand rupees per month. More than 175,000 or 200,000 lunches get moved every day by an estimated 4,500 to 5,000 dabbawalas, all with an extremely small nominal fee and with utmost punctuality.

According to a recent survey, there is only one mistake in every 6,000,000 deliveries. The American business magazine Forber gave a six-sigma performance rating for the precision of dabbawalas.

Outside Mumbai **-** Dabbawalla services are popular with the Indian IT developer community in Silicon Valley, CA, USA.

In literature **-** One of the two protagonists in Salman Rushdie's novel 'The Satanic Verses', Gibreel Farishta, was born as Ismail Najmuddin to a dabbawala. In the novel, Farishta joins his father, delivering lunches all over Mumbai at the age of 10, until he is taken off the streets and becomes a movie star.

Concluding Remarks

Six-Sigma is about process capability, cost of poor quality, a hierarchy of metrics to drive strategic consistency, and DMAIC as a way to execute improvement projects.

In other words it has (i) a metric provided by standard deviations in a normal curve, (ii) a goal as low as 3.4 defects per million, and (iii) a rigorous process focused methodology acronym as DMAIC process.

During the last two decades six sigma has found applications in sevice industries (Amheiter and Maleyeff [1], Wei., *et al*. [8]), hospitals (Sewail and Deyong [6], Van den Heuvel., *et al*. [7]), local government (Furterer and Eishennawy [3]), and public sector (Patel S.C. and Zu [5], Kumar and Bauer, K.F. [4]).

Putting all the pieces together provides a very powerful approach to improving performance and functioning which can serve the humanity in a better way.

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