MODERN CONCEPTS OF THE SIX SIGMA METHODOLOGY FOR IMPROVING THE QUALITY

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Abstract

Product quality is generally accepted as being crucial in today's industrial business. The traditional aspects of product quality are connected to product design (translating customer demands into attractive features and technical specifications) and to the design and specification of high performance production processes with low defect rates. Quality management is the general expression for all actions leading to quality.

Quality management is focused on improving customer satisfaction through continuous improvement of processes including the removal of uncertain activities, and continuous improvement of the quality of processes, products and services. The quality management includes four key processes, such as quality planning, quality assurance, quality control and quality costs. The main accent in this paper will be on quality control and the application of one of the quality control tools in order to improve it.

Six Sigma is different from other quality improvement concepts in that its framework is comprised of many principles, tools and techniques, which, together with experience, are all integrated and translated into best practices.

Bearing in mind that the goal of every company is to work effectively and effectively in the long run, this paper focuses on Six Sigma as a way to continuously improve quality. Namely, this paper emphasizes the key features of the quality of products / services, the Need for the application of Six Sigma for quality assurance, and also a detailed list of tools and techniques that can be used during the implementation of Six Sigma.

Key words: quality, six sigma, tools, process improvement.

JEL classification: C10, L15

1. Meaning and key characteristics of quality

Quality is a perceptual, conditional and partly subjective attribute and can be differently understood by different people.

In modern literature in the field of quality there are a number of definitions related to the term quality. The international family of standards ISO 9000: 2000 provides one of the many definitions: "Quality is the degree to which a set of inherent characteristics meets the requirements."[6]

Of the many meanings of the word "quality," two are of critical importance to managing for quality:

- "Quality" means those *characteristics of products* which meet customer needs and thereby provide customer satisfaction. In this sense, the meaning of quality is oriented to income. The purpose of such higher quality is to provide greater customer satisfaction and, one hopes, to increase income. However, providing more and/or better quality characteristics usually requires

an investment and hence usually involves increases in costs. Higher quality in this sense usually "costs more."

- "Quality" means *freedom from deficiencies*—freedom from errors that require doing work over again (rework) or that result in field failures, customer dissatisfaction, customer claims, and so on. In this sense, the meaning of quality is oriented to costs, and higher quality usually "costs less."

Table 1 highlights the basic characteristics of these two definitions.

Table 1. The meanings of quality [9]

Product characteristics that meet customer needs	**Freedom from deficiencies**
Higher quality enables companies to: • Increase customer satisfaction; • Make products salable; • Meet competition; • Increase market share; • Provide sales income; • Secure premium prices. The major effect is on sales.	Higher quality enables companies to: • Reduce error rates; • Improve delivery performance; • Reduce rework, waste; • Reduce field failures,warranty charges; • Reduce customer dissatisfaction; • Reduce inspection, test; • Shorten time to put new products on the market. The major effect is on costs.

When a product or service meets customer needs, it's likely to be said that it have good quality and also when customers are not satisfied is said to be of poor quality. When a product or service exceeds needs, it is likely to be said to have high quality, and if it is below expectations, it is said to be of low quality.

It can be understand that quality measures are subjective. The product does not have to have a malfunction or an error to be considered as a product of poor quality - it may not have the characteristics which are expected. However, the (non) satisfaction of the products and services should be expressed and hence the subjective terms such as good, bad, high and low quality are used. The question arises: "If the product that meets customer requirements has acceptable quality, what is called the one that does not meet the requirements or maybe exceeds the requirements?" In another case, if the acceptable product has defect - will be unacceptable? Maybe not. It can be far superior to other competitive products with its acceptable functions and characteristics.

While not measurable, these subjective terms allow consumers to evaluate products and services in terms of the extent to which they meet their requirements and to what extent they are suitable for their purpose.

Each function or feature of a product or service that is needed to be meet customer needs is *a quality feature*. When it comes to products, the characteristics have almost always a technical dimension, while the service quality characteristics have a human dimension.

Some key quality characteristics are given in Table 2. These are characteristics which need to be specified and their achievement controlled, assured, improved, managed and demonstrated. These are the characteristics which form the subject matter of the specified requirements referred to in ISO 9000[*]. When the value of these characteristics is quantified or qualified, they are termed quality requirements. ISO 8402: 1994[**] defines requirements for quality as an expression of the needs or their translation into a set of quantitatively and qualitatively requirements for the

[*] ISO 9000 is a set of international quality management and quality assurance standards developed to help companies effectively document the quality system elements to be implemented in order to maintain an efficient quality system. They are not specific to any industry and can be applied to organizations of any size.

[**] ISO 8402: 1994 defines the basic terms referring to the quality concepts applied in all areas for the preparation and use of quality-related standards.

characteristics of an entity to enable its realization and examination. While rather verbose, this definition removes the confusion over quality requirements and technical requirements. The technical requirements for a product or service are quality requirements. The requirements of ISO 9000 are quality system requirements.

Table 2. Quality characteristics [1]

Product quality characteristics		
accessibility	functionality	size
availability	interchangeability	susceptibility
appearance	maintainability	storability
adaptability	odor	test
cleanliness	operability	testability
consumption	portability	traceability
durability	producibility	toxity
flammability	reliability	transportability
flexibility	reparability	
weight	safety	
security	vulnerability	
Service quality characteristics		
accessibility	credibility	honesty
accuracy	dependability	promptness
courtesy	efficiency	responsiveness
comfort	effectiveness	reliability
competence	flexibility	security

2. A need for the application of Six Sigma for quality assurance

Six Sigma is a new, developing approach for quality assurance and quality management with an emphasis on continuous improvements of quality. The main goal of this approach is to achieve the level of quality and reliability that will satisfy even exceed the requirements and expectations of today's more sophisticated clients.

The main goal for initiative of Six Sigma is to reduce the cost of quality. The total cost for quality is usually divided into a tangible and intangible part. The material or visible part of the cost of quality, for example inspection and warranty costs, waste, repair and refusal, can be identified with only 10-15% of the total cost for quality. The remaining 85-90% of the cost for quality is usually immaterial and is therefore ignored and neglected in the company's analysis for costs of quality.

Tools and methodologies within Six Sigma are trying to minimize quality costs, while at the same time to increase the overall level of quality that will contribute to business success and profitability of the company.

The three main components of Six Sigma are results-oriented leadership, capability and methodology for problem solving. Six Sigma has five areas of interest that act as a basis for improvements and they are:

- understanding and reducing variations;
- make improvements from customer needs and expectations;
- understanding the basic process;
- identifying and solving chronic problems;
- focus on achieving measurable results.

General Electric (GE) is the main promoter of Six Sigma for about ten years. Ultimately, Six Sigma improves leadership by providing troubleshooting tools. In the core of Six Sigma has an idea which can completely transform a company, with a focus on the organization towards the consumer.

Six Sigma is a highly disciplined process that helps the focus to be put on the development and delivery of almost perfect products. Why "Sigma"? Sigma is a letter in the Greek alphabet used in mathematical statistics to define a standard deviation. The standard deviation indicates the deviation from the mean value (Figure 1). The word is a statistical term that measures how much a given process has deviations that deviate from perfection. When Six Sigma is achieved for a

particular process, and the upper and lower specification limits are six standard deviations from the mean value.

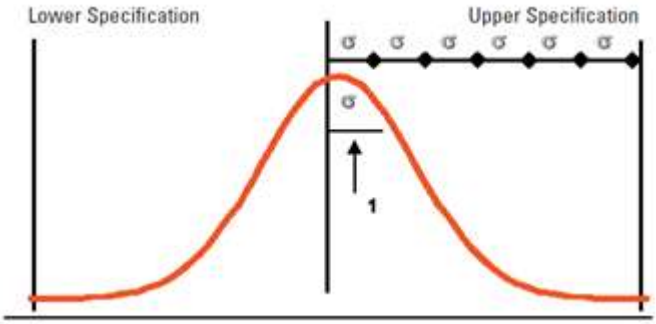

Figure 1. *Six Sigma [adapted by20]*

The central idea behind Six Sigma is if can be measure how many "defects" there are in a process, a solution for their elimination can be systematically found and the process to come nearer то zero-defectiveness as much as possible. A "defect" is define as something that is outside of the client's specifications. Every step or activity in a company is a possibility of occurrence of defects and Six Sigma programs serve to reduce the variation in the processes that lead to these defects. Indeed, those who practice Six Sigma see variations as an enemy of quality and much of the Six Sigma theory is committed to tackling this problem. In order to achieve the Six Sigma quality, the process must produce no more than 3.4 defects per millions of possibilities. One "opportunity" is defined as a chance for non-conformity with the required specifications. This means that there should be almost no errors in the performance of key processes. Six Sigma is based on several key concepts:

Critical aspects of quality: the attributes which are most important to the consumer;
Fault: failure to deliver what the consumer is looking for;
Capacity of the process: what can bring a process;
Variation: what the consumer sees and feels;
Design for Six Sigma: designing to be meet consumer needs and process capacity.

The basic goal of the Six Sigma methodology is implementing of a strategy based on measurement that focuses on improving processes and reducing variations through the application of Six Sigma tools. As a way of doing business, Six Sigma is a detailed and focused process that helps both companies and individuals to develop and deliver almost perfect products and services. It is an entrepreneurial strategy that effectively develops ability and desire of individuals to improve decision-making, solve business problems and improve overall performance of the enterprise.

Namely, Six Sigma is applied for improving financial performance and profitability in working. Two concepts are mainly incorporated here:

- Cost of poor quality. Perhaps the most obvious tangible benefit of quality improvement is the reduction of costs associated with non-quality. In doing so, the disadvantage is that business accounting systems are not set up to cover these costs. Traditional accounting approaches pay little attention on whether the money in the department is spent effectively. It can be perceive from Fiegenbaum's Prevention – Appraisal – Failure model of costs of poor quality [3]. The basic logic is that a relatively small increase in spending on prevention activities will deliver a more than compensating reduction in appraisal and failure costs (Figure 2).

6σ applies prevention activities to reduce failure and appraisal costs on a project by project basis.

Figure 2. *Quality costs during improvement [16]*

- Waste. The concept of waste is fairly generic in nature and has been around for a long time. Many organizations refer to 'non-value added activities' and 'process waste'. The Seven Wastes were identified by Ohno as part of the Toyota Production System (Ohno 1988) and have since been widely applied to process improvement, becoming particularly associated with the principles of lean manufacturing. The following table presents the types of wastes and their potentially associated costs:

Table 3. Types of waste and associated costs [12]

Type of waste	Potential Associated Costs
Waiting	***Labour cost associated with idle time.*** ***Value of lost production (if units are lost) or cost of overtime if this has to be worked to catch up.*** Cost of late delivery if overall process time affected.
Correction	Rework cost (direct and overhead if applicable). Cost of delays (as above). Inspection costs. Disposal costs if correction is not possible. Paperwork system costs.
Over-Production	***Storage costs (including handling costs).*** ***Extra material costs if excess cannot be sold.*** Deterioration/depreciation costs (if appropriate). Cost of delays (as above).
Processing	Additional processing costs (direct and overhead if applicable). Transportation costs.
Conveyance	Additional cost of unnecessary conveyance system. Cost of late delivery if overall process time affected. Deterioration/damage costs.
Inventory	***Storage costs (including handling costs).*** ***Deterioration/depreciation costs (if appropriate).*** ***Obsolescence costs (if appropriate).***
Motion	Additional labour costs (including absenteeism).

It can readily be seen that some of the costs associated with these activities would fit neatly into the Cost of quality models, but that some would be transparent to that system. Table 3 indicates the kind of financial impacts that might be caused by the types of waste.

- ***increasing responsibility and focusing toward client.*** Often a man considers himself an "expert" for client requests. The same, the longer it is in business, there is much more experience than a typical customer, who can buy only a few of the products.

It is easy to see how this logic leads to take a rather patronizing attitude to customers who either don't really know what they want, or don't understand the complexities of the product. This is known as the 'Product Out' concept where the focus is on working to specification or instruction and the product is 'pushed' from the company to the customer (see Figure 3)[13]. The problem

with this concept is that it is slow to respond to changing markets and customer requirements (an ever more significant aspect of the world today). The 'Market-In' approach allows for a much more responsive system and places a requirement on the organization to go and find out the customer requirements (figure 4).

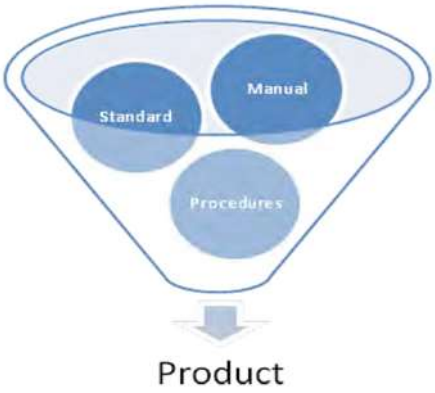

Figure 3. Product out Concept [12]

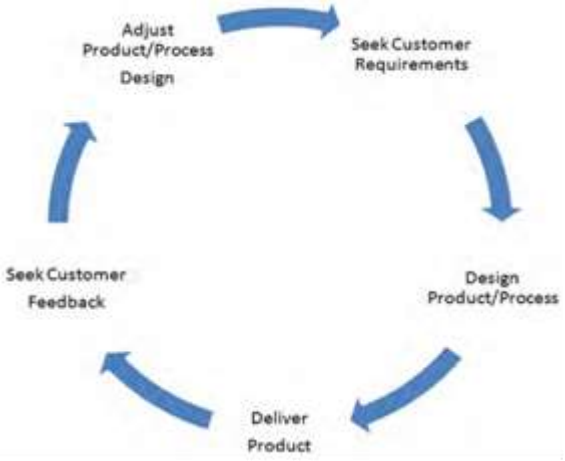

Figure 4. Market In Concept [13]

- **improving product and service performance.** It is clear that reducing defects will be beneficial for customers. However, in looking to reduce variation in product and service outcomes Six Sigma takes a step beyond the out-moded goalpost approach to quality and uses the Taguchi Loss Function. The Taguchi Loss Function shows how increasing capability (i.e. reducing product variation in relation to the tolerance band) can improve customer satisfaction even if all products already meet specification. The Loss Function as defined by Taguchi is basically a challenge to the traditional ideas on what constitutes acceptable quality for manufactured products. Figure 5 contrasts Taguchi's Loss Function and the traditional tolerance (also known as specification)-based approach to product quality.

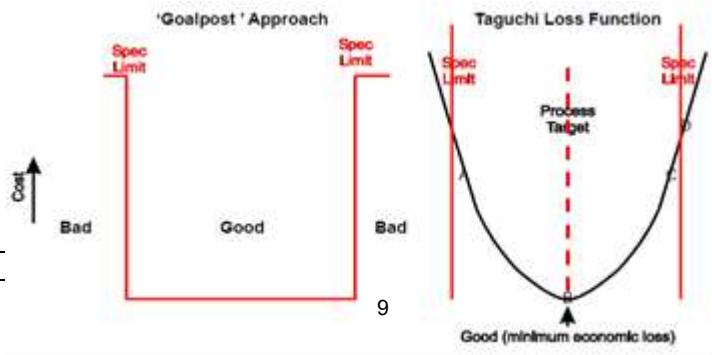

Figure 5. Loss function vs. Tolerancing[13]

- **increasing the contribution to organizational learning.** Six Sigma is inherently a learning process and, as such, has the potential to contribute to organizational learning. This can be seen in the organizational learning cycle shown in the following figure:

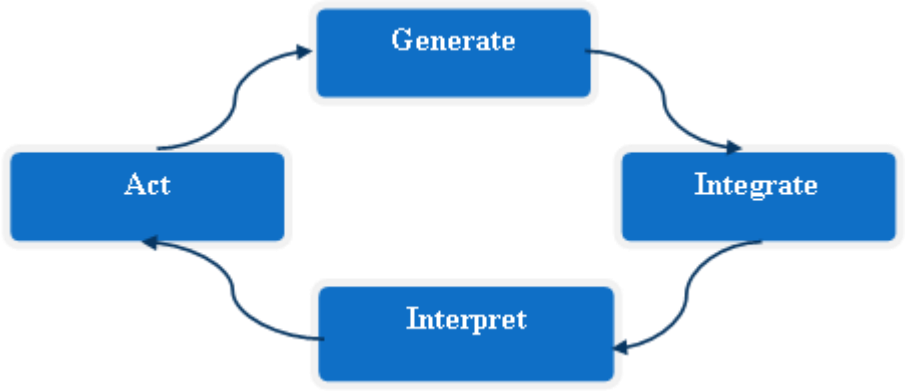

Figure 6. The Organizational Learning Cycle[11]

It is clear that a Six Sigma improvement project generates learning through investigation of a process, integrates that with organizational goals and specific knowledgde of statitsics, etc. and interprets this to generate improvements through action. As a meta-capability (one which spans all domains) this cycle offers much more potential for long-term competitive advantage than the specific project-based improvements in operational efficiency.

The impact of learning on an organization is to increase organizational capability with a better understanding of processes and outcomes and to allow for the generation of new knowledge and innovation which improves the capability of the organization to respond to change and new challenges. This is, in fact, a higher order effect than simply imrpoving processes and generates benefits including[10]:

- maintaing levels of innovation and remaining competitive;
- being better placed to respond to external pressures;
- having the knowledge to better link resources to customer needs;
- improving quality of outputs at all levels;
- improving corporate image by becoming more people oriented;
- increasing the pace of change within the organization.

3. Tools and techniques included in Six Sigma

Six Sigma is the logical extension of the statistical process control (SPC). The concept behind the SPC is simple enough, but really powerful. The variation is present in every production process and such variation is due either to the usual or special reasons. Epochal discovery made by Shewart was a statistical definition and measurement of variation, where the variation within three sigma limits was considered to be random and caused by common causes, and the variation beyond the three sigma limits was caused by special reasons, suggesting a problem in process (Shewart, 1931).

± 3σ process limits means a defect rate of 2.7 / 1000 or 2,700 / 1,000,000 capabilities, if ignore the side shift in the process, and thus the ability of the process is define as the range of normal variation, that is, ± 3σ, or Cpk = 6σ. Six Sigma doubles the range of normal variation to ± 6σ and allows 1.5σ lateral displacement in the middle of the process. The result is a dramatic narrowing of the acceptable target for the defect rate to 3.4 / 1,000,000 opportunities.

The basic elements of Six Sigma are not new. SPC, failure mode effect analysis, gage repeatability and reproducibility studies, and other tools and techniques, have been in use for some time. Six Sigma offers a frameworks that unites these basic quality tools and techniques with high-level management support.

The discussion of Six Sigma tools and techniques in literature is mainly focused on their use in the different phases of the DMAIC methodology. De Koning and De Mast (2006) used seven different literature sources and provided a summary of Six Sigma tools and techniques used in DMAIC phases. Some other literature provide classification scheme for tools and techniques used. Henderson and Evans (2000) discussed about tool sets in three groups; team tools, process tools, and statistical tools. As for Six Sigma tools and techniques specific to service organizations, Antony (2006) provides a grid as a guideline for services.

A number of classification schemes for Six Sigma tools and techniques exists, the majority of which are based on the DMAIC methodology. **The classification schemes** by the American Society for Quality (ASQ) and by Nancy Tague (1995) called **the Tool Matrix** provide an exhaustive list of tools and techniques which can be used during Six Sigma implementation. The ASQ classification scheme and the tool matrix have almost similar categories. The only difference being in the number of tools and techniques each category.

ASQ Classification

According to ASQ, tools and techniques that are utilized in different phases of DMAIC are classified according to their uses. There are 7 broad categories: Cause Analysis Tools, Data Collection and Analysis Tools, Evaluation and Decision Making Tools, Idea Creations Tools, Process Analysis Tools, Project Planning and Implementation Tools, Seven Basic Quality Tools, and Seven New Management and Planning Tools. These tools are presented in the following table:

Table 4. Classification of tools and techniques according to ASQ [17] [19]

Categories	Description	Tools
Cause analysis tools	Used to identify the cause of a problem.	*Fishbone diagram, Pareto chart, Scatter diagram*
Data collection and analysis tools	Used to collect or analysis data.	*Check sheet, Control chart, Design of experiment, Histogram, Scatter diagram, Stratification, Survey*
Evaluation and decision making tools	Used to select the best choices or to evaluate what is performance level of project so far.	*Decision matrix, Multi-voting*
Idea creations tools	Used to create ideas or organize ideas.	*Affinity diagram, Benchmarking, Brainstorming, Nominal group technique*
Process analysis tools	Used when an understanding of process flow is desired.	*Flowchart, Failure mode effect analysis, Mistake-proofing*
Seven basic quality tools	These tools are the most fundamental tools of quality control.	*Cause and effect diagram/ Fishbone diagram, Check sheets, Control charts, Histogram, Pareto chart, Scatter diagram, Stratification*
Seven new management and planning tools	Used to encourage innovation, communicate information and successful planning of key projects.	*Affinity diagram, Relation diagram, Tree diagram, Matrix diagram, Arrow diagram, Process decision program chart*

Tool Matrix

In Nancy R. Tague's The Quality Toolbox (1995), she developed a Tool Matrix that classifies quality tools according to what the tools can offer. It is quite similar to the categorization suggested by ASQ, but differs, as it encompasses more tools. This Tool Matrix is presented in the following table:

Table 5. Tool Matrix [14] [19]

Categories	Tools
Ideas creation	Affinity diagram, Brainstorming. Brain writing Nominal group technique, Relation diagram
Process analysis	Cost of quality analysis, Critical-to-quality analysis, Deployment flowchart, Flowchart Matrix diagram, Relations diagram, Requirements matrix, Requirements-and-measure matrix, Storyboard, Top-down flowchart, Work-flow diagram
Cause analysis	Contingency diagram, Fishbone diagram, Force field diagram, Is-is not matrix, Matrix diagram Pareto chart, Scatter diagram, Stratification, Tree diagram, Why-why diagram
Planning	Activity chart, Arrow diagram, Contingency diagram, Deployment flowchart, Flowchart Force field analysis, Matrix analysis, Mission statement, Operational definitions, Plan-do-check-act cycle, Relations diagram, Storyboard, Top-down flowchart, Tree diagram, Work-flow diagram
Evaluation	ACORN test, Continuum of team goals, Decision matrix, Effectiveachievable matrix, List reduction, Matrix diagram, Mission statement checklist, Multi-voting, Plan-results matrix
Data collection and analysis	Box plot, Check sheet, Control chart, Histograms, Importance-performance analysis, Kologorov-Smirnov test, Normal probability plot, Operational definitions, Pareto chart, Performance index, Process capability, Requirements-and-measures tree, Run chart, Scatter diagram, Stratification, Survey

Conclusion

The purpose of such higher quality is to provide greater customer satisfaction and, one hopes, to increase income. Through analysis and critical review of the different meanings of quality, the paper answers the question "Does higher quality cost more or less?" Six Sigma is a systematic process improvement methodology, which leads to breakthrough in profitability through quantum gains in product/service quality, customer satisfaction, and productivity. Six Sigma is a new, developing approach to quality assurance and quality management with an emphasis on continuous quality improvements. The main goal of this approach is to achieve the level of quality and reliability that will satisfy even to exceed the requirements and expectations of today's more sophisticated clients. Six Sigma concept focuses on removing defects and minimizing the variability. The paper presents tools according to the American Society for Quality (ASQ), tools from Nancy Tag (1995), that is, the Matrix of Tools, and various tools which are effective in describing and analysing service problems in order to make their comparative analysis. By using this qualitative analysis, will can to determine critical success factors, the measurable process parameters, tools and techniques for Six Sigma implementation in product and service organizations.

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