# ‘Six Sigma’: The Essence of Modern Manufacturing and Service MNCS

MR. SHARAD CHOUDHARY
Academic Counselor, IGNOU

MS. REENA YADAV
Assistant Professor,
DDU College, University of Delhi

MR. ANIL KUMAR
Assistant Professor,
Shri Ram College of Commerce, University of Delhi
Delhi (India)

**Abstract:**
*Today, Quality control is just as important in the service sector as it is in the manufacturing industry. Quality control measures can be used effectively in the service sector by applying the lessons learned in manufacturing industries. Six-sigma is a quality control approach that can and should be applied to all interaction: with customers, vendors, other employees, between management and departments etc. Six-sigma is more than a quality control program for reorganizing the entire approach to work in every respect; productivity, communication, involvement at every level and external service. Six-sigma (6σ) simply means a measure of quality that strives for near perfection. Six-sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving towards six standard deviations between the mean and the nearest specification limit) in processes which are Critical to Quality -- from manufacturing to transactional and from product to service.*

**Keywords:** *Quality Control. Six-sigma, Total Quality Management*

## 1. Introduction

### The Meaning of Sigma (σ)

Sigma represents standard deviation – a measure of variability.

What is standard deviation? The standard deviation is the most frequently calculated measure of variability. The standard deviation value represents the average distance of a set of scores from the mean.

## 2. Standard deviation and the normal curve

Knowing the standard deviation helps create a more accurate picture of the distribution along the normal curve. A smaller standard deviation represents a data set where scores are very close in value to the mean; a smaller range. A data set with a larger standard deviation has scores with more variance; a larger range. For example, if the average score on a test was 80 and the standard deviation was 2, the scores would be more clustered around the mean than if the standard deviation was 10.

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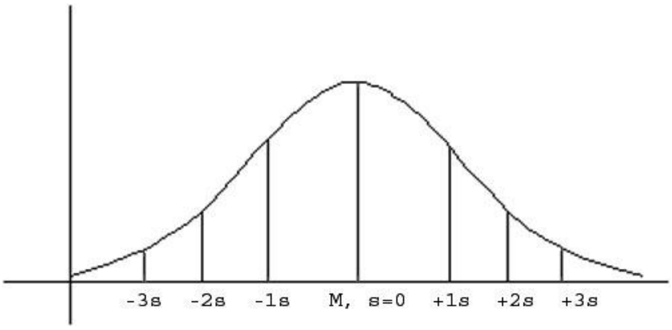



- Approximately 68% of all the values in a normally distributed population lie within ± 1 standard deviation from the mean.
- Approximately 95.5% of all the values in a normally distributed population lie within ± 2 standard deviation from the mean.
- Approximately 99.7% of all the values in a normally distributed population lie within ± 3 standard deviation from the mean.

## 3. The Meaning of Six-Sigma

Perfection – impossible to achieve completely and all of the time – is a goal worth keeping in mind. If we set our sights any lower, we deserve what we get. If we settle for 80 percent or 70 percent, we can never expect to reach 95 percent or 98 percent. There goes a saying that; “it only takes one small tear in the net for all the fish to escape”. A small tear in the net becomes a bigger tear and the fish escape as the net is pulled in. the corporate world also works in the same way. What might seem a minor imperfection or a flaw in a remote department affects the products and the services of the organization. The solution is to find all the tears and repair them, methodically and completely. Yes, new tears will appear in the net, but we can’t shrug and explain, “We found most of them” We also cannot just shrug and say, “It’s not my job,” Perfection is not a requirement, but it is a goal worth setting. We can then compare our outcomes to the goal, seeing improvement and measuring it against that goal.

Sigma is the letter in the Greek alphabet used to denote standard deviation, a statistical measurement of variation. Standard deviation can be thought of as a comparison between expected results or outcomes in a group of operations, versus those that fail. Sigma ($\sigma$) has become the statistical symbol and metric of process variation. The Sigma Scale of measure is perfectly correlated to such characteristics as defects-per-unit, parts per million defectives, and the probability of failure. Six is the number of sigma measured in a process, when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations.

Six-sigma may be defined in several ways. Tomkins (1997) defines Six-sigma to be “a program aimed at the near-elimination of defects from every product, process and transaction.” Harry (1998) defines Six-sigma to be “a strategic initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools that can lead to breakthrough quantum gains in quality.
The measurement of standard deviation shows us that rates of defects are measurable. Six-sigma is the definition of the outcomes as close as possible to perfection or the target value. With six standard deviations, we arrive at 3.4 defects per million opportunities (DPMO), or 99.9997 percent. This would mean that at Six-sigma, an airline would lose only 3 pieces of luggage for every one million that it handles, or that the phone company would have only three unhappy customers out of every million who use the phone that day i.e. Six-sigma can be a performance goal, see fig 6.1. The purpose in evaluating defects is not to eliminate them entirely, but to strive for improvement to the highest possible level that the organization can achieve.

2 Sigma = 69.15% error free
3 Sigma = 93.32% error free
4 Sigma = 99.38% error free
6 Sigma = 99.9997% error free

Phone out/month
2σ = 9.25days out
3σ = 48.1 hours
4σ = 4.5 hours
6σ = 2 seconds

Phone out/month
2σ = 9.25days out
3σ = 48.1 hours
4σ = 4.5 hours
6σ = 2 seconds

100,000 invoices
2σ = 30,854 wrong
3σ = 6,681 wrong
4σ = 621 wrong
6σ = 0.3 wrong

Six-sigma as a Performance Goal

The goal of Six-sigma is not only to achieve Six-sigma levels of quality, but to improve profitability too. Prior to Six-sigma, improvements brought about by quality programs, such as Total Quality Management (TQM) and ISO 9000 usually had no visible impact on a company's net income. In general, the consequences of immeasurable improvement and invisible impact caused these quality programs gradually to become the fad of the moment.

In 1891, British physicist Lord Kelvin wrote, "When you can measure what you are speaking about, and express it in numbers, you know something about it." Mikel Harry, a noted Six-sigma authority, extends the thought as, "we don't know what we don't know; we can't act on what we don't know; we won't know until we search; we won't search for what we don't question; we don't question what we don't measure." Both imply that if you failed to quantify the results of what you were doing, in a way, it means that you might not understand what you were really doing.

Hence, organizations that are unable to track the impact of quality improvements on profitability cannot know what changes need to be made to improve their profit margins. And most importantly, profitability is the natural concern of management in organizations. If a quality initiative failed to present its quantitative bottom-line value to the management, it will lose the management's commitment to it and, eventually, fade away. In contrast with other quality initiatives, Six-sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction. In the short term, Six-sigma is a method to eliminate defects and the opportunity for defects. It utilizes a statistical unit of measurement to measure the capability of the process, then achieve defect free performance, and ultimately increase the bottom-line and customer satisfaction.

Six-sigma is a system for achieving and sustaining business success. It is based upon customer focus, process understanding, and the wise use of facts and data.

Six-sigma can also be defined as "a new strategic paradigm of management innovation for company survival in the 21st century, which implies three things:

- Statistical measurement
- Management strategy &
- Quality culture.

Six-sigma depicts how good the products, services and processes of an organization really are through statistical measurement of quality level. It is a new management strategy under the leadership of top-level management to create quality innovation and total customer satisfaction. It is also a quality culture. It provides a means of doing things right the first time and to work smarter by using data information. It also provides an atmosphere for solving many CTQ (critical-to-quality) problems through team efforts. CTQ could be a critical process/product result characteristic to quality.

## 4. Evolution of Six-Sigma (6σ)

Before, January 15, 1987, Six-sigma was solely a statistical term. Since then, the Six-sigma crusade, which began at Motorola, has spread to other companies who are continually striving for excellence. While it is progressing, it has extended and evolved from a problem-solving technique to a quality strategy and ultimately into a sophisticated quality philosophy. Within a few years, the same idea had taken root at General Electric and Allied Signal. GE decided in 1995 to implement Six-sigma throughout the entire organization. CEO Jack Welch led the company through this implementation, and many divisions of GE experienced impressive improvements in quality during those years. Estimates are that cost savings from Six-sigma application exceeded $320 million within the first two years, and more than $1 billion by 1999. Today, Six-sigma is the fastest growing business management system in industry.

To elaborate the evolution of Six-sigma, one Six-sigma authority has to be introduced: **Mikel Harry**, who is called the "**Godfather" of Six-sigma** and is acknowledged as the leading authority on theory and practice. Even though he did not invent the concept, the way that it is currently practiced bears the unmistakable marks of Harry's personality and personal history. Harry's history path is followed here to reveal the evolution of Six-sigma.

The evolution began in the late 1970s, when a Japanese firm took over a Motorola factory that manufactured television sets in the United States and the Japanese promptly set about making drastic changes to the way the factory operated. Under Japanese management, the factory was soon producing TV sets with 1/20th the number of defects they had produced under Motorola management. Finally, Motorola recognized its quality was awful. Since then Motorola management decided to take quality seriously. When Bob Galvin became Motorola's CEO in 1981, he challenged his company to achieve a tenfold improvement in performance over a five-year period.

In 1984, after Harry was awarded a doctorate from Arizona State University, he joined Motorola where he worked with **Bill Smith**, a veteran engineer who was in Mikel Harry's words, "the father of Six-sigma". During 1985, Smith wrote an internal quality research report which caught the attention of Bob Galvin. Smith discovered the correlation between how well products did in its field life and how much rework had been required during the manufacturing process. He also found that products that were built with less nonconformity were the ones that performed the best after delivery to the customer. Although Motorola executives agreed with Smith's supposition, the challenge then became how to create practical ways to eliminate the defects. With the concept of "logic filter", one of Harry's papers at Arizona State University, together with Smith, Harry developed a four-stage problem-solving approach: Measure, Analyze, Improve, and Control (MAIC). Later, the MAIC discipline became the road map for achieving Six-sigma quality.

On January 15, 1987, Galvin launched a long term quality program, called "The Six-sigma Quality Program". The program was a corporate program which established Six-sigma as the required capability level to approach the standard of 3.4 DPMO. This new standard was to be used in everything, that is, in products, processes, services and administration. The Corporate Policy Committee of Motorola then updated their quality goal as follows:

"Improve product and service quality ten times by 1989, and at least one hundred fold by 1991. Achieve Six-sigma capability by 1992. With a deep sense of urgency, Galvin spread dedication to quality to every facet of the corporation, and achieve a culture of continual improvement to assure Total Customer Satisfaction. There is only one ultimate goal: zero defects in everything we do."

In 1988, at Unisys Corp. Harry discussed with Cliff Ames, one of Unisys' plant managers, about how to leverage the Six-sigma technique throughout an organization and how to recognize the people who were equipped with Six-sigma tools. Since Ames was a lover of karate and Harry himself was a martial arts enthusiast, in some respects, they shared the same eastern martial arts philosophy. People in martial arts are incredibly skilled, have a precise command of tools, are very dedicated, and are very humble to learn. Based on this insight, Harry decided to designate those with Six-sigma skills as "**Black Belt**".

In 1993, at Asea Brown Boveri (ABB), Harry teamed with Richard Schroeder who later joined him to found Six-sigma Academy. Inspired by Kjell Magnuson, one of ABB's business unit presidents, Harry realized that high level executives only focused on clear and quantifiable gains. Further, Harry recognized that it should not be quality first, but business first which will lead to the realization of quality. In addition, from his Marine Corps experience, he understood the importance of tactics. To exploit the full power of Six-sigma by focusing on bottom-line results, Harry refined Six-sigma deployment tactics which included: **Champion, Master Black Belt, Black Belt, and Green Belt.**

There are many success stories of Six-sigma application in well-known world-class companies. As mentioned earlier, Six-sigma was pioneered by Motorola. Since then, and particularly from 1995, and exponentially growing number of prestigious global firms have launched a Six-sigma program.

It has been noted that many globally leading companies run Six-sigma programs and it has been well known that Motorola, GE, Allied Signal, IBM, DEC, Texas Instruments, Sony, Kodak, Nokia, and Philips Electronics among others have been quite successful in Six-sigma.

## 5. Six-Sigma (6σ) Table

Table represents an abbreviated summary of Sigma level, defects per million opportunities (DPMO), and the yield, or success rate of the outcomes. Organizations following Six-sigma programs identify their level of Sigma performance and then compare it to the chart. This is where the benefits of Six-sigma are realized. By comparing the outcomes to the ideal outcome of Six-sigma, organizations can quantify quality itself.

**Sigma Table**

| Sigma | Defects Per million Opportunities | Yield |
|---|---|---|
| 6.0 | 3.4 | 99.9997% |
| 5.0 | 233.0 | 99.977 |
| 4.0 | 6,210.0 | 99.379 |
| 3.0 | 66,807.0 | 93.32 |
| 2.5 | 158,655.0 | 84.1 |
| 2.0 | 308,538.0 | 69.1 |
| 1.5 | 500,000.0 | 50.0 |
| 1.4 | 539,828.0 | 46.0 |
| 1.3 | 579,260.0 | 42.1 |
| 1.2 | 617,911.0 | 38.2 |
| 1.1 | 655,422.0 | 34.5 |
| 1.0 | 691,462.0 | 30.9 |
| 0.5 | 841,345.0 | 15.9 |
| 0.0 | 933,193.0 | 6.7 |

**Example**: A department performed 535 specific operations last month. Of these, 43 were defective (they fell outside the acceptable range of outcomes). This means that 492 of the operations were successful.

The yield was:
492 ÷ 535 = 91.9%
Referring to the table above, we discover that this outcome represents Sigma Somewhere between 2.5 and 3. If the department is able to reduce the number of defects by half, ending up with 21, the acceptable outcome would then grow to 514 out of 535 operations, and the new yield would increase as well.

514 ÷ 535 = 96.1%

Now the Sigma is between 3 and 4, a significant improvement. Of course, if you cut defects in half, you are going to know your outcomes have improved leading to improved quality of products and services.

## 6. Difference between Six-Sigma and TQM

"The difference between Six-sigma and the other quality approaches is that the others measure your abilities to meet some quality. Six-sigma actually measures the output of your processes. So, it's less theoretical and more real world."

Six-sigma introduces a certain rigour and robustness which isn't there in TQM, the harder our targets get, the more difficult it is to use conventional TQM tools to meet them. Six-sigma implementers know what they are chasing, and can measure their progress in objective terms.

## 7. What makes six-sigma so powerful?

The Greek letter, Sigma, is the statistical shorthand for standard deviation--and what the metric really refers to is the extent to which a process is capable of deviating from pre-set specifications without causing errors. The higher the sigma rating, the greater is this capability, with Six-sigma allowing variations of upto 6 times the standard deviation without causing flaws.

The mathematical interpretation of Six-sigma is crucial to implementing the tool. The output of any process in your company--the products rolling off your assembly-lines, the bills created by your accounts people, the pay-cheque delivered-can be analyzed in terms of the number of errors in it. What Six-sigma analysis does is to measure every process on each of the CTQ factors.

Consider, for instance, a process which every hour, produces 100 units of a particular component which should measure 100 mm length. Measurements may show that while 95 out of the 100 units produced are, indeed, 100-mm long, the remaining 5 deviate from that ideal, each to different extent. This data can be used to calculate the standard deviation, or sigma - the likelihood an extent of deviations from the norm - of the process. Assume that the value of sigma for this process turns out to be 0.01.

The question, of course, is whether these deviations will be counter as flaws under the given CTQ. This is determined by the upper and lower specification limits of the product. If they allow those deviations - that is, if the upper and lower control limits of the process fall beyond the upper and lower specification levels - the customer won't have problem. What if they don't? That's when the capability of the process has to be changed.

## 8. Approaches of 6σ

Six-sigma offers 2 approaches. One is to change the design of the product in which this component is used so that it can accordant some of the variations in the length without malfunctioning. Thus, for instance, the so-called design-width could be Three Sigma - accommodating components with 3 times the standard deviation of the process. In other words, components that measure between 99.07 mm and 100.03 mm will also be acceptable. Of course, that still mean eliminating those units whose sigma exceeds 3, but this will, at least, lessen the number defects in every sample.

The second approach is to make improvements in the process itself so that the chances of defects are lowered. That will reduce the value of the standard deviation, or sigma, of the process. If, say, the value of the sigma can be halved through this method to 0.005, the acceptable specification-limits - 99.07 mm and 100.03 mm, respectively - will automatically become 6 times - and not 3 times - the standard deviation. Et voila! A Six-sigma process will be yours. The implication to take a process to Six-sigma level, you must, ideally, adopt both approaches: changing the design to increase the range of acceptability in the CTQ; and improving the process to reduce its chances of variance.

In practical terms, this means that Six-sigma is a tool that must be wielded both at the design stage and at the process stage. As a matter of fact, a Six-sigma rating, in ideal conditions, should produce no errors at all. If it does lead to those 3.40 defects out of every million parts, that's because even the best processes, over a period of time, tend to generate deviations of up to 1.50 sigma. Thus, the effective extent of deviation can go up to 7.50 sigma while the process allows only 6 sigma without defects. That translates into those 3.40 flaws.

## 9. Six-Sigma: An Enabler to a Culture

What makes Six-sigma different from most other quality control programs? It is more than just a way to improve performance; it is a method for changing the corporate culture, from top to bottom. Six-sigma is taken as an enabler to a culture in the entire organization.

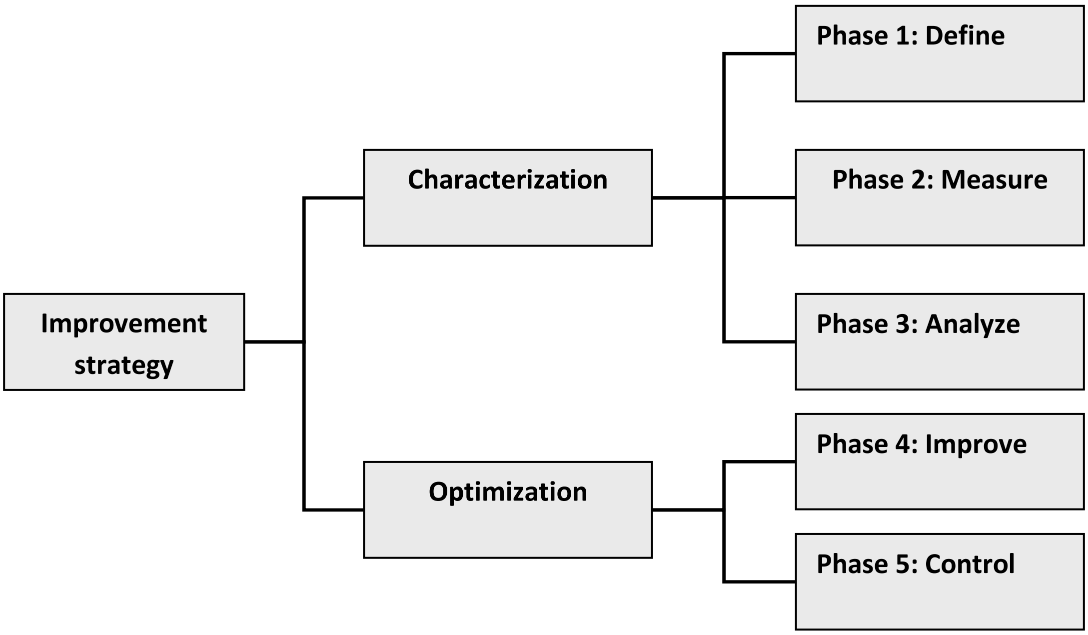
The idea of six-sigma is much more than the latest approach to quality control; it represents a change in philosophy that affects everyone. It is designed to bring everyone into a single team with the same overall goal. So many corporate employees-especially in large organizations-have a sense of isolation or view their relatively small department as a realm unto itself. Six-sigma encompasses the entire corporation as a single corporation and is aimed at removing that sense of isolation.

The following are the characteristics of a "Six-sigma Culture"

- More data/fact-based business decisions.
- Willingness to question the status quo.
- To improve, it is important to understand the process.
- A "no-boundaries" approach to business.
- Investment in education and project execution.
- A common language for understanding process and requirements.
- A conviction that everything can be improved.

## 10. DMAIC: The Six-Sigma Methodology

The most important methodology in Six-sigma management is perhaps the formalized improvement methodology characterized by DMAIC (define-measure-analyze-improve-control) process. This DMAIC process works well as a breakthrough strategy. Six-sigma companies everywhere apply this methodology as it enables real improvements and real results. This methodology works well on variation, cycle time, yield, design, and others. It is divided into five phases as shown in figure. In each phase the major activities are as follows:




## 11. DMAIC Process

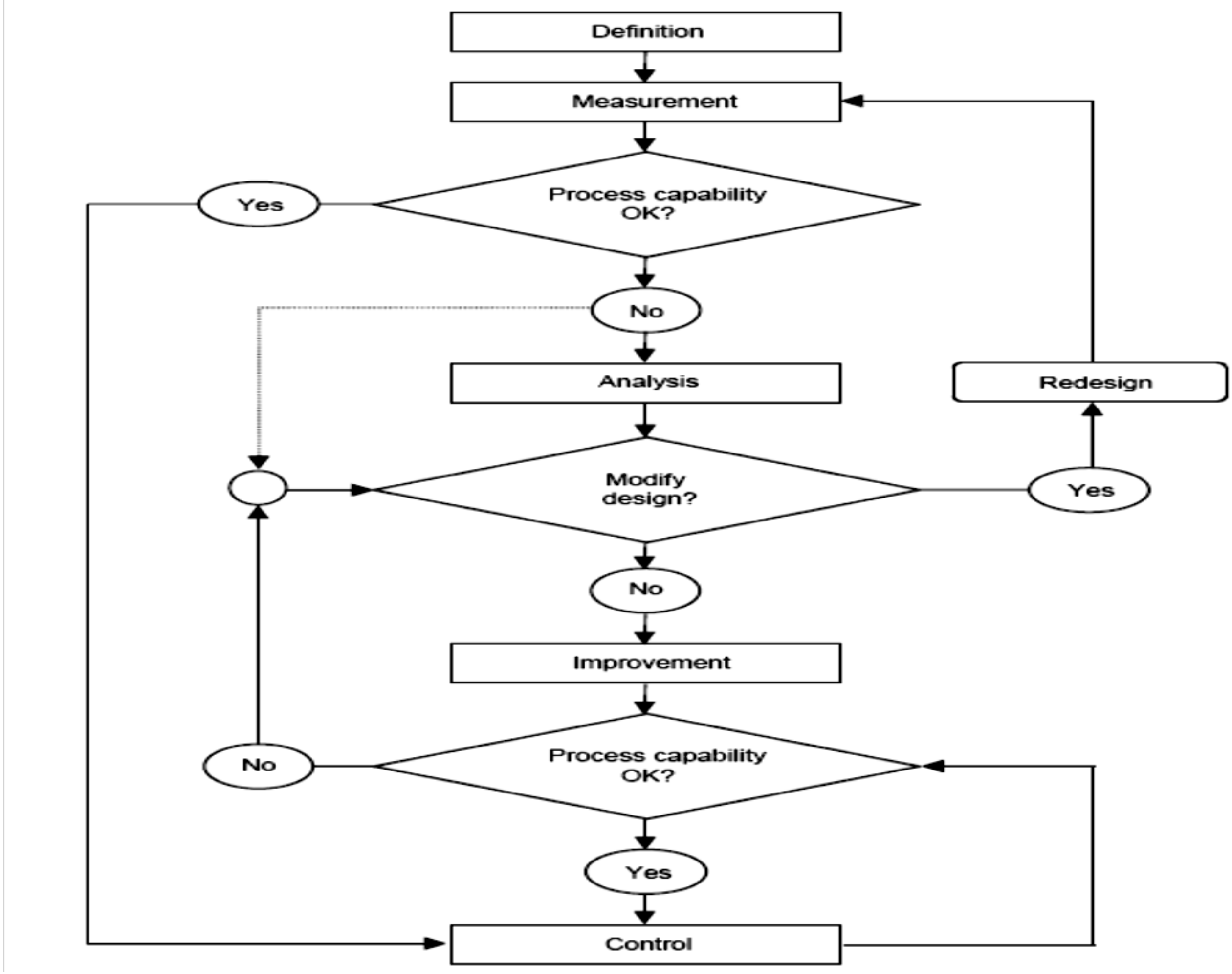
**Phase 1: Define:** This phase is concerned with identification of the process or product that needs improvement. It is also concerned with benchmarking of key product or process characteristics of other world-class companies.

**Phase 2: Measure:** This phase entails selecting product characteristics; i.e. dependent variables, mapping the respective processed, making necessary measurement, recording the results and estimating the short and long term process capabilities.

**Phase 3: Analyze:** This Phase is concerned with analyzing and benchmarking the key product/process performance metrics. Following this, a gap analysis is often undertaken to identify the common factors of successful performance; i.e. what factors explain best-in-class performance. In analyzing the product/process performance, various statistical and basic QC tools are used.

**Phase 4: Improve:** This phase is related to selecting those product performance characteristics which must be improved to achieve the goal. Once this is done, the characteristics are diagnosed to reveal the major sources of variation. Next, the key process variables are identified. The improved conditions of key process variables are verified.

**Phase 5: control:** This last phase is initiated by ensuring that new process conditions are documented and monitored via statistical process control (SPC) methods.




The flowchart for DMAIC: The Six-sigma Methodology is sketched in figure below:

## 12. Flow Chart of DMAIC Process

Following are some of the basic tools used at different stages in the DMAIC Process.

### *12.1 Stage 1: Define*

**1. Project Charter:** A project charter is the first step in the Six-sigma Methodology. It takes place in the Define step of DMAIC, and the charter can make or break a successful project. It can make it by specifying necessary resources and boundaries that will in turn ensure success; it can break it by reducing team focus, effectiveness and motivation. The necessary project charter areas are as follows, Project Title: project leader, Mentor/Master Black Belt: Project Start Date: Anticipated Project End Date: Project Goals: Team Members: Project Time-Frame:

**2. SIPOC Diagram:** A SIPOC diagram is a tool used by a team to identify all relevant elements of a process improvement project before work begins. It helps define a complex project that may not be well scoped, and is typically employed at the Measure phase of the Six-sigma DMAIC methodology the tool name prompts the team to consider the Suppliers (the 'S' in SIPOC) of your process, the Inputs (the 'I') to the process, the Process (the 'P') your team is improving, the Outputs (the 'O') of the process, and the Customers (the 'C') that receive the process outputs. In some cases, Requirements of the Customers can be appended to the end of the SIPOC for further detail.

**3. CTQs Definition:** In order for any process capability to accurately be calculated, one must properly define and quantify the process defect, unit and opportunity. Every process should have definitions for defect, unit and opportunity.

***12.2 Start with the Customer***

Before you can define your process defects, units and opportunities, you need to understand the needs of your customers. Voice of the Customer (Customer Needs, eSurveys, Focus Groups, Surveys) is the process of gathering customer comments/quotes and translating them into issues and specifications. From these comments, issues and specifications come the customer CTQ (Critical to Quality) – a product or service characteristic that must be met to satisfy a customer specification or requirement. It should be noted that the term customer refers to both internal and external customers.

***12.3 Define your Product/Service Units***

A unit is something that can be quantified by a customer. It is a measurable and observable output of your business process. It may manifest itself as a physical unit or, if a service, it may have specific start and stop points.

***12.4 Define Your Product/Service opportunities***

Simply stated, opportunities are the total number of chances per unit to have a defect. Each opportunity must be independent of other opportunities and, like a unit, must be measurable and observable. The final requirement of an opportunity is that it directly relates to the customer CTQ. The total count of opportunities indicates the complexity of a product or service.

**4. Stakeholders Analysis:** Stakeholder Analysis is a toll used to identify and enlist support from stakeholders. It provides a visual means of identifying stakeholder support so that you can develop an action plan for your project.

***12.5 Stage 2: Measure***

**1. Process Flowchart:** A process flowchart is a graphical representation of a process, depicting inputs, outputs and units of activity. It represents the entire process at a high or detailed (depending on your use) level of observation, allowing analysis and optimization of workflow.

A flowchart is a graphical representation of a process. It represents the entire process from start to finish, showing inputs, pathways and circuits, action or decision points, and ultimately, completion. It can serve as an instruction manual or a tool for facilitating detailed analysis and optimization of workflow and service delivery.

**2. Building a Data Collection Plan:** This tool has three phases-five steps in total are involved in building a sound data collection plan.

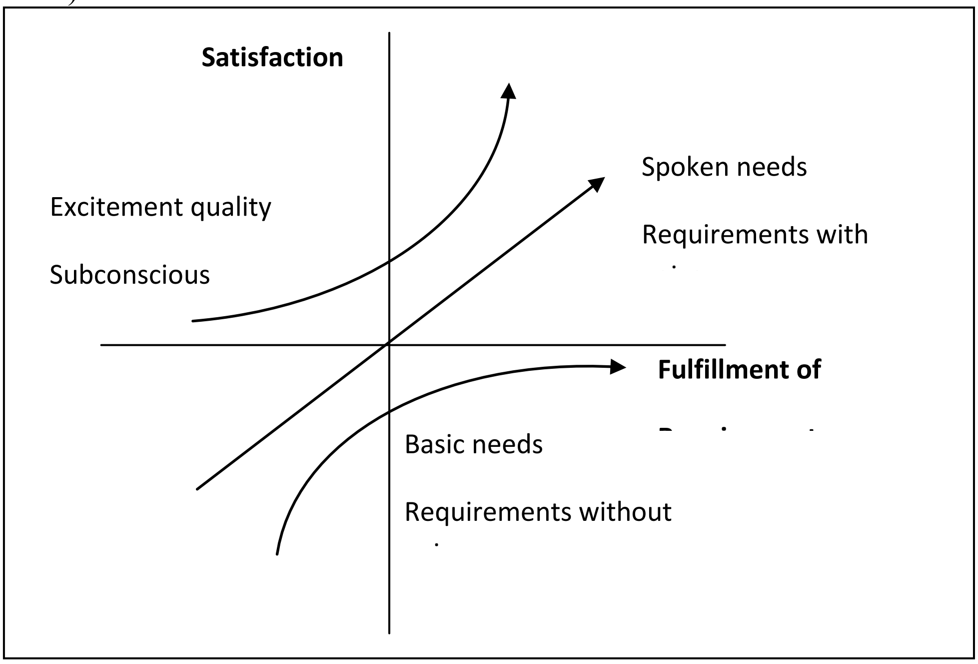
**Phase1: Pre-Data Collection Steps**

1. Clearly define the goals and objectives of the data collection
2. Reach understanding and agreement on operational definitions and methodology for the data collection plan
3. Ensure data collection (and measurement) repeatability, reproducibility, accuracy, and stability

**Phase 2: During Collection Steps**
follow through with the data collection process
**Phase 3: Post-Data Collection Steps**
follow through with the results
A good data collection plan should include the following:

- A brief description of the project,
- The specific data that is needed,
- The rationale for collecting the data,
- What insight the data might provide ( to a process being studies) and how it will help the improvement team, and
- What will be done with the data once it has been collected.

**3. Benchmarking:** Benchmark refers to a measure of best practice performance. Benchmarking refers to the search for the best practices that yields the benchmark performance, with emphasis on how you can apply the process to achieve superior results. American Productivity & Quality center defines Benchmarking as follows, "...benchmarking ... [is] ...'the process of identifying, understanding, and adapting outstanding practices and processes from organizations anywhere in the world to help your organization improve its performance.'"
**4. Voice of Customer:** It is advisable to identify and understand different types of customer requirements before capturing the 'voice of the customer (VOC). One of the commonly used tools for visualizing different types of customer requirements is the Kano analysis. The Kano analysis (see fig.10.3) differentiates three different types of customer requirements and illustrates how customer satisfaction is linked to these requirements. Basic customer needs are the requirements 'without voice'. They are expected to be there (they are regarded as the 'musts'). Spoken customer needs are the requirements 'with voice'. Customers specifically ask for them (they are regarded as the 'wants'). The subconscious requirements are those requirements that customer doesn't think or have no idea that these would be available or would be a part of the deal. They generate customer excitement if they are or become a part of the deal or are offered for small additional charge (they are regarded as the 'nice-to-haves').




*12.6 KANO analysis of customer needs*
The Voice of the Customer (VOC) chart is a useful depiction tool to summarize the results of the Kano analysis. It is a simple Six-sigma tool and typically used to identify the customer requirements. Some of the basic methods and sources used for identification of customer requirements are customer interviews, customer survey questionnaires, customer visits, focus groups etc.

**Stage 3: Analyze**

**1. Histogram:** A histogram is used to graphically summarize and display the distribution of a process data set. It is meaningful to present the data in a form that visually illustrates the frequency of occurrence of values.

**2. Scatter Plot:** A scatter plot reveals relationships or association between two variables. Such relationships manifest themselves by any non-random structure in the plot.

A scatter plot is a plot of the values of Y versus the corresponding values of X:

- Vertical axis: variable Y--usually the response variable
- Horizontal axis: variable X--usually some variable we suspect may be related to the response

**3. Cause and Effect/Fishbone Diagram:** When utilizing a team approach to problem solving, there are often many opinions as to the problem's root cause. One way to capture these different ideas and stimulate the team's brainstorming on root causes is the cause and effect diagram, commonly called a fishbone. The fishbone will help to visually display the many potential causes for a specific problem or effect. It is particularly useful in a group setting and for situations in which little quantitative data is available for analysis.

**4. 5 Whys:** The 5 Whys is a technique used in the Analyze phase of the Six-sigma DMAIC methodology. It's a great Six-sigma tool that doesn't involve data segmentation, hypothesis testing, regression or other advanced statistical tools, and in many cases can be completed without a data collection plan.

**Benefits of the 5 Whys**

- Help identify the root causes of a problem.
- Determine the relationship between different root causes of a problem.
- One of the simplest tools; easy to complete without statistical analysis

**5. Control Charts:** The control chart is a very important tool in the "analyze, improve and control" phases of the Six-sigma improvement methodology. In the "Analyze" phase, control charts are applied to judge if the process is predictable; in the "improve" phase, to identify evidence of special causes of variation so that they can be acted on' in the "control" phase, to verify that the performance of the process is under control.

**Stage 4: Improve**

**1. Brainstorming:** A brainstorming session is a tool for generating as many ideas or solutions as possible to a problem or issue. It is not a tool for determining the best solution to a problem or issue.

**2. Mistake Proofing:** It was a Japanese manufacturing engineer named Shigeo Shingo who developed the concept that revolutionized the quality profession in Japan. Originally called "fool proofing" and later changed to "mistake proofing" and "fail safing" so employees weren't offended, poka yoke (pronounced "poh-kah yoh-kay") translates into English as to avoid (yokeru) inadvertent errors (poka). The result is a business that wastes less energy, time and resources doing things wrong in the future.

**3. Failure Modes and Effect Analysis:** Failure modes and effects (FMEA) is a set of guidelines, a process, and a form of identifying and prioritizing potential failures and problems in order to facilitate process improvement. By basing their activities on FMEA, a manager, improvement team, or process owner can focus the energy and resources of prevention, monitoring, and response plans where they are most likely to pay offs. The FMEA method has many applications in a Six-sigma environment in terms of looking for problems not only in work processes and improvements but also in data collection activities, voice of customer efforts and procedures.

**Stage 5: Control:** The tools used in the control phase of the DMAIC methodology are

- Control charts (variables and attributes) and
- Process Sigma calculations.

## 13. Conclusion

Is the goal of the organization to be perfect in every aspect? Perfection is Elusive, of course, but it can and does represent an enviable goal. More importantly the concept of perfection helps everyone in the organization to develop a working model to maximize excellent service at every level. This is not a theory alone; the suggestion that you can work with other employees and managers to improve service is a crucial requirement in a competitive market. Thus, Six-sigma as an integrated approach to creating effective working models is much more than a tool for improving productivity, creating teamwork or reducing cost. In fact, it serves as a model for corporate attitude that goes beyond the whole team approach that has permeated corporate project work for so many years.

It should be noted that, there are two attributes which need to be present in order for any quality control program to work. First, the program cannot be isolated or defined as a function that occurs in the plant alone, or in the office, department or subsidiary. It has to be a working philosophy that applies from the boardroom to the mail room. The second attribute is that Quality itself cannot be applied only to one portion of the corporate environment. Quality control has its root in designing and manufacturing where it was applied to develop ways to reduce defects, increase productivity and ensure on time delivery of goods.

Today, Quality control is just as important in the service sector and quality control measures can be used effectively by applying the lessons learned in manufacturing industries. Six-sigma is a quality control approach that can and should be applied to all interaction: with customers, vendors, other employees, between management and departments etc. Six-sigma is more than a quality control program for reorganizing the entire approach to work in every respect; productivity, communication, involvement at every level and external service. Six-sigma is an effective approach to a broad based quality control program. It is far more than a traditional approach in which internal teams are created to reduce production defects, solve problems within one department, and address problems in isolation. Six-sigma is more than a quality control program with another name; it is a quality-based system for reorganizing the entire approach to work in every aspect: productivity, communication, involvement at every level, and external service. Because Six-sigma and its guidelines improve performance and communication on many levels, it changes not only the outcome (service, production, etc.) but effects the very way an organization communicates internally and with customers and vendors. Programs may begin with focus on a single problem, such as errors in customer deliveries or the inability to keep products in inventory, but the solutions are not isolated. If a vice president responds to a problem by insisting that it should be fixed at the departmental level, and without examining its broader implication, and opportunity is lost. If that same vice president involves the entire corporation is a study of how and why such problems evolve, they will find more permanent solutions. This does not mean a complex, expensive analysis has to be used; rather, Six-sigma is designed for rapid, simple problem solving that involves all levels and all contacts.

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