CHAPTER 4

SIX SIGMA METHODOLOGY

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CHAPTER 4

SIX SIGMA METHODOLOGY

4.1 EVOLUTION OF QUALITY AND QUALITY IMPROVEMENT CONCEPTS

Introduction

The quality improvement process has been started long back and can be traced late 13th century. The quality movement can trace its roots back to medieval Europe, where craftsmen began organizing into unions called guilds in the late 13th century. Until the early 19th century, manufacturing in the industrialized world tended to follow this craftsmanship model. The factory system, with its emphasis on product inspection, started in Great Britain in the mid-1750s and grew into the Industrial revolution in the early 1800s.

In the early 20th century, manufacturers began to include quality processes in quality practices.[1]

The birth of total quality in the United States came as a direct response to the quality revolution in Japan following World War II. The Japanese welcomed the input of Americans Joseph M. Juran and W. Edwards Deming and rather than concentrating on inspection, focused on improving all organizational processes through the people who used them.[2]

By the 1970s, U.S. industrial sectors such as automobiles and electronics had been broadsided by Japan's high-quality competition. The U.S. response, emphasizing

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[1] http://asq.org/learn-about-quality/history-of-quality/overview/20th-century.html
[2] Pardeshi Prakash Chandrashekhar, "Human Resource Managent", Nirali prakashan, Pune, pg 20.2

not only statistics but approaches that embraced the entire organization, became known as total quality management (TQM). Researcher has gone through the below quality terms;

4.1.1 TOTAL QUALITY MANAGEMENT (TQM)

In TQM, satisfaction of the customer is ensured only through production of quality products at a competitive price.

In the words of John Gilbert, "Total Quality Management is a process designed to focus on customer expectations, preventing problem, building commitment to quality in the workforce and promoting open decision making".[3]

In the few years since the turn of the century, the quality movement seems to have matured beyond Total Quality. New quality systems have evolved from the foundations of Deming, Juran and the early Japanese practitioners of quality, and quality has moved beyond manufacturing into service, healthcare, education and government sectors. During 1980's many quality improving concepts came like six sigma, kaizen ,Quality circle, in 1990's lean production and in 2000 lean six sigma.

[3] Ramsey J and Roberts, "Perception on Total Quality" proceeding of quality forum IV,Nov, 1992, pg 4

Chart no. 4.1

Differentiation between TQM and Six Sigma;

Sr. no	Six Sigma	Total Quality Management (TQM)
1.	Six Sigma is a focused, systematic approach based on two standard methodologies of DMAIC and DMADV.	Total Quality Management is a holistic approach encompassing a no. of tools.
2.	Six sigma focuses on impacting the bottomline through breakthrough improvements.	TQM advocates incremental improvements based on kaizen
3.	Six Sigma defines a formal, clearly defined organizational infrastructure consisting of Master Black Belt, Black Belt, Green Belt	Organizational infrastructure are not found in TQM
4.	Six Sigma utilizes project management approach for identifying and implementing improvement projects.	TQM does not specify a formal approach for implementation.

4.1.2 Kaizen

According to Wikipedia (2006), the Japanese usage of Kaizen is "to take it apart and put it back together in a better way." What is taken apart is usually a process, system, product or service. Importantly, kaizen must operate with three principles in place:

process and results (not results-only); systemic thinking (i.e. big picture, not solely the narrow view); and non-judgmental, non-blaming (because blaming is wasteful). Everyone participates in kaizen; people of all levels in an organization. The format for kaizen can be individual, suggestion system, small group or large group. Kaizen is a daily activity whose purpose goes beyond improvement. It is also a process that when done correctly humanizes the workplace, eliminates hard work (both mental and physical), teaches people how to do rapid experiments using the scientific method, and how to learn to see and eliminate waste in business processes.

4.1.3 Lean manufacturing

Lean is simply about creating more value for customers by eliminating activities that are considered waste. Lean works to create process speed by reducing cycle time and improving efficiency by reducing costs. Any activity or process that consumes resources, adds cost or time without creating value becomes the target for elimination. Unnecessary complexity adds costs, time, and waste. One of the important aspects of Lean is the focus on 'system-level' improvements (versus 'point improvements'). It's the system-level work that can dramatically improve a company's bottom line results. This knowledge, combined with the understanding of how to remove waste properly, is critical for any successful Lean implementation.

- Focuses on maximizing process velocity
- Provides tools for analyzing process flow and delay times at each activity in a process
- Centers on the separation of “value-added” from “non-value-added” work with tools to eliminate the root causes of non-value-added activities and their cost
- Provides a means for quantifying and eliminating the cost of complexity

Most often Lean and Six Sigma are implemented together in service organizations because you can't separate quality and speed when improving processes. Both are necessary when working to improve and streamline the way service tasks are completed just as in manufacturing. Six Sigma focuses more on quality, while Lean focuses on speed by streamlining and reducing complexity.

There are certain aspects where these two differ from each other. They are as follows;

Chart no. 4.2

Differentiation between Lean Manufacturing and Six Sigma;

Sr. no	Lean Manufacturing	Six Sigma
1.	Lean Manufacturing has Japanese origin, which can be traced to the Toyota Production System (TPS), developed by the Japanese engineer Taiichi Ohno and Shigeo Shingo	Six Sigma has a US origin, developed based on the Crosby's philosophy of "Zero Defect". Six sigma is a business strategy first conceptualized by Motorola company in the early 1990's. Bill Smith was the first who formulated the particulars of the methodology at Motorola.
2.	Lean Manufacturing focuses on effective use of resources and elimination of waste.	Six sigma aims for quality improvement by eliminating variations in processes.

3.	Lean Manufacturing makes use of Japanese manufacturing practices such as JIT, pull system, etc.	Six Sigma uses a systematic DMAIC methodology for improvement in processes.
4.	Lean Manufacturing employs Japanese quality tools such as Kaizen, Poka Yoke, 5S etc.	Six Sigma is a data based approach and makes extensive use of basic and advances statistical tools and techniques.
5.	Lean Manufacturing architecture compromises multifunctional teams.	The organizational architecture for six sigma includes Champion, Master Blac Belt, Black Belt, Green Belt each one having a specific role to play in six sigma projects
6.	Lean manufacturing is more applicable on the manufacturing organizations	Six sigma is being implemented by both manufacturing as well as service industries/ organizations.

Thus these methodologies have made great impact on six sigma.

4.2 SIX SIGMA

An historical overview

Motorola receives the credit for creating Six Sigma,[4] but the methodology and concepts are clearly rooted in the quality improvement tradition promoted by Deming's TQM principles and the works of Juran[5]. Since then, thousands of companies that have embraced this philosophy and have achieved immense success by adopting specific training and project management practices[6] are;-

Chart no. 4.3

Companies using six sigma methodology

General Electric	GE Capital	Motorola
Bank One	Lockheed Martin	Dow Chemical
Black & Decker	Federal Express	DuPont
Johnson & Johnson	Microsoft	National Semiconductor
Texas Instruments	Toshiba	United Technologies
Apple Computers	General Dynamics	Allied Signal
American Express	Intel	IBM
Bank of America	Bank of New York	Capital One Financial
Citigroup	Deutsche Bank	Fidelity
Fleet Bank	J.P. Morgan Chase	Merrill Lynch
Morgan Stanley	Tower Group	Wells Fargo
Hewlett Packard	Honeywell	

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4 Chassin MR**:** Is health care ready for Six Sigma quality**?** *The Milbank Quarterly* 1998, **pg:**565-591.

5 Barry R, Murcko A, Brubaker C: *The Six Sigma Book for Healthcare:Improving Outcomes by Reducing Errors* Chicago, Il: Health Administration Press; 2002

6 Brady JE, Allen Theoder T: Six Sigma literature: a review and agenda for future research. *Quailty and Reliability engineering International*
6th april, 2006,pg:335-367.

Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi.

Like its predecessor, Six Sigma doctrine asserts that:

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

4.2.1 Origin of Six Sigma:

Six Sigma was born in the 1980's at Motorola. Bill Smith, an engineer at Motorola's Communications sector, was quietly working behind the scenes studying the correlation between product's reliability and how often that product had been repaired during the manufacturing process. He presented a paper, which concluded that if a product was found defective and correlated during the production process, other defects were bound to be missed and found later by the customer during early use of the product. However, when the product was manufactured error free, it **rarely** failed during early use by the customer. They also found that the foreign competitors were making more reliable products. As a result, Motorola began to improve the quality and simultaneously reduce the cost by focusing on product design and manufacturing. The Six Sigma architects of Motorola focused on making improvements in all operations within a process. This led to quantum leap in manufacturing technology in Motorola. The company saved $2.2 billion in 4 years.

In the year 1988, Motorola received the first Malcolm Baldrige National Quality Award from the US government for its improvement record based on Six Sigma program.

4.2.2 Features of Six Sigma:

It has the following important features:

1. Six sigma shifts the paradigm quality as the cause of good business performance and not the effect. Before 1980's all process and product improvement techniques were aimed at continuous improvement of quality. Six Sigma propagates that all-round quality performance(error free performance excellence with continuous improvement) is bound to result in the attainment of the desired business excellence in terms of reduction in the cost of production, Maximizing of customer satisfaction and return on Investment.
2. The philosophy of Six Sigma is to make fewer mistakes in all the organizational activities and keep on reducing the mistakes.
3. It is a business strategy to reduce the cost by attaining good quality.
4. It is a statistical process control technique aimed at achieving total confidence in the company's products and service performances for the customers as well as the management.
5. It is a philosophy of achieving the ultimate goal of 'Do it right the first time every time'.
6. It is a performance measure. The sigma and Part Per Million(ppm) are correlated as indicated under;

Chart no. 4.4

The sigma levels/ Six Sigma value chart

Sigma	Defect Per Million
2	308537
3	66807
4	6210
5	233
6	3.4

Source: www.sixsigmaspc.com

This implies that as compare to the 3 σ performance level, the 4 σ is ten times improvement in performance and as compare to 4 σ performance level; the 6 σ is 1800 times improvement in performance.

7. Sigma in statistics is used to indicate the standard deviation. A sigma value indicates the ability of a process to perform defect free work. The higher the sigma value, the better the process is performing and the lower the probability that a defect will occur.
8. The Six Sigma reduces the defect and variation in the product by improving the process that produces and delivers the product.
9. The Six Sigma is not delegable. The involvement of the top management is a must.
10. The Six Sigma principles and philosophy are equally applicable to the manufacturing and the services industry.
11. Six Sigma's main objectives are reduction of variation, defects, costs and cycle time, aimed towards maximization of customer satisfaction.
12. The focus of Six Sigma is on the following areas:
    i. Independent variable to the process
    ii. Root cause of any problem and its elimination
    iii. Focus is on the inputs to the process and not on the output.

iv. Focus is on the problem and not on the symptom.

v. Focus is in controlling the problem and not on monitoring.

4.2.3 Objectives of Six Sigma

1. **Strategic level**: at the strategic level, the goal of six sigma is to align an organization to its market place and deliver real improvements(in terms of rupees) to the bottom line.
2. **Operational level:** at the operational level, the six sigma goal is to move the business product or service attributes within the zone of customer specifications and to significantly shrink process variation.

4.2.4 Goals /Purpose of Six Sigma:

1. **To reduce variation:-** the main objective of six sigma practice is to ensure consistency in performance so that the users and the customers can develop confidence in the quality and reliability in the products and services offered by the organization. Six sigma practice is oriented towards developing a manufacturing and/or service set up which has zero variation in both the product and the process.

2. **To reduce defects/rework:** the principle objective of the six sigma project is to eliminate or reduce the defects and rejections to practically zero. It is a process control technique. The Japanese mantra of 'Muda' ensures elimination of all wastage. Any rejection of rework, saved gets straightway added to the bottom line in terms of the profit of the organization.

3. **To Improve Yield/ Productivity:** a single rejection saved is an additional piece produced. Any time saved in reworking is time utilized for effective production of the products and services, which again adds to the productivity. It is also an important objective i.e. to improve the productivity by optimum utilization of the men, machin and material along with the elimination of the seven wastages. Higher productivity leads to more production, lower cost of production and better quality and competitiveness in the marketplace.

4. **To enhance customer satisfaction:** customers satisfaction is achieved by providing the products and service of right quality, in right quantity at the right time, right place and at right cost, fulfilling the customers' level of customers' satisfaction, which is the prime objective of any organization now a days. By providing defect-free products and services of consistent performance and quality, th six sigma project definitely enhances the customer satisfaction.

5. **To improve the bottom Line:** the most important objective/goal of Six Sigma is to improve the profitability and return on investment by reduction in the cost of production and processing by continuous process improvement. The Six Sigma activity improves substantially the bottom line, without any investment, just by training and changing the employees' mindset and garnering their greater involvement in their work and the organization.
6. **To improve the Top Line**: **the other** immediate purpose or objective of six sigma is improvement of the organizational reputation in the market and society at large by providing products and service of good quality without any deviation in terms of

performance and reliability. This creates a strong brand image in the market in the market, leading to an increase in the sales and attainment of the market leadership position. Six Sigma projects alos leads to the development of better work culture, better relationships with customers and employees and improves the top line substantially.

4.2.5 Elements of six sigma:

There are three key elements of six sigma process improvement:

1. **Customer: customers** define QUALITY. They expect performance, reliability, competitive prices, on-time delivery, service, clear and correct transaction processing.
2. **Processes:** defining processes and defining metrics and measures for processes is the key element of six sigma.

   Quality requires looking at business from customer’s perspective i.e. one must look at defined processes from the outside-in.

   By understanding the transaction lifecycle freom the customer’s needs and processes, one can discover what they are seeing and feeling. This will give chance to identify week areas within a process and then to improve them as per.
3. **Employees:** The company must involve all employees in six sigma program/project. Company/organization must provide opportunities and incentives for employees to focus their talents and ability to satisfy customers.

   This is important in six sigma that all team members should have well-defined role with measurable objectives

4.2.6 METHODOLOGY/STEPS INVOLVED IN SIX SIGMA:

The methodology of Six Sigma consists of **DMAIC** and **DMADV** cycle. They are as under;

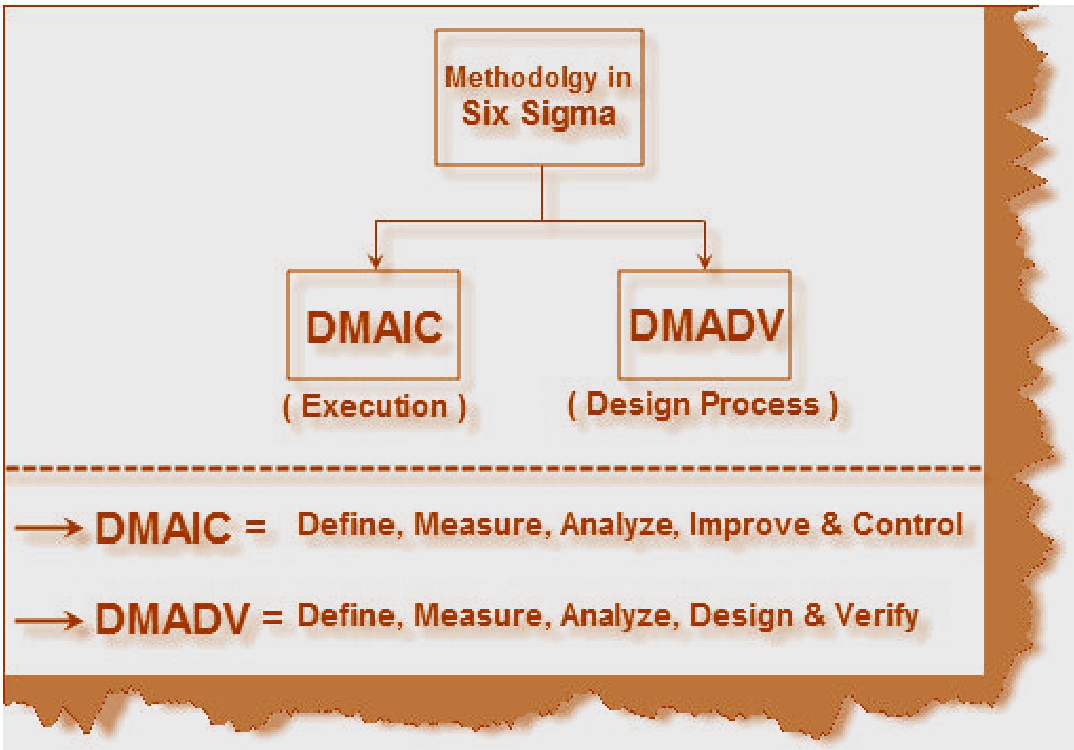


Fig no 4.1 Methodology in Six Sigma

The SIX SIGMA methodologies

At many companies six sigma simply means a measure of quality that strives for near perfection. It is a disciplined, for eliminating defects in any process covering manufacturing and transactions, as well as products and services. The fundamental objective of the six sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of specific projects. This is accomplished through the use of two six sigma sub-methodologies, namely DMAIC and DMADV. The DMAIC, which stands for define, measure, analyze, improve and control, is an improvement system process for existing processes falling below specification and looking for incremental improvement and the DMADV (define- measure- analyze design- verify) apply to the product development and design at Six Sigma quality levels.[7]

Six Sigma methodologies inspired by Deming's Plan-Do-Check-Act Cycle, comprising five phases each, bear the acronyms DMAIC and DMADV.

- DMAIC offers a structured and disciplined process for solving business problems.[8] DMAIC is used for projects aimed at improving an existing business process, especially used in manufacturing industries.
- DMADV is used for projects aimed at creating new product or process designs.

DMAIC

The DMAIC methodology has five phases:

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

[7] Linderman, K., R.G. Schroeder, S. Zaheer and A.S. Choo, "Six Sigma: A goal-theoretic perspective" a journal of Operations management, March 2003, vol 21 edi 2 pg 193-203

[8] Darshak A. Desai, Mulchand B. Patel, " Impact of Six Sigma in a developing economy: analysis on benefits drawn by Indian industries",Journal of Industrial engineering and management, 2009

control, production boards, and visual workplaces and the process is continuously monitored.

DMADV

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

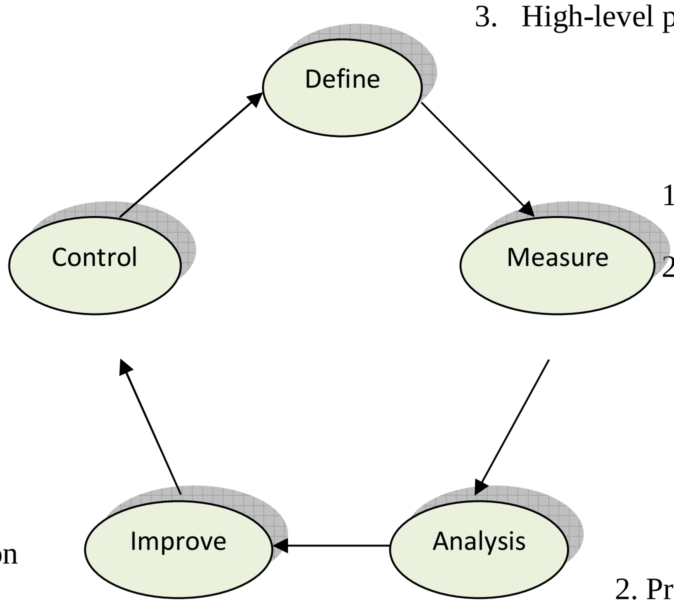
- **D**efine design goals that are consistent with customer demands and the enterprise strategy.
- **M**easure and identify CTQs (characteristics that are **C**ritical **T**o **Q**uality), product capabilities, production process capability, and risks.
- **A**nalyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- **D**esign details, optimize the design, and plan for design verification. This phase may require simulations.
- **V**erify the design, set up pilot runs, implement the production process and hand it over to the process owners.

Fig 4.2

High level DMAIC Improvement methodology

1. Charter

2. Customer needs, requirements
3. High-level process map



1. Control methods plan
2. The response plan Implementation

1. Data collection
2. Plan

1. Solution generation
2. Solution selection
3. Solution implementation

1. Data analysis
2. Process analysis
3. Root cause analysis

The steps are discussed as under;

1. **Define:** in DMAIC methodology, the primary aim is to identify the possibilities for defects or quality problems which can be arrived at through the use of different statistical tools such as regression analysis, chi square testing. The quality problem which requires breakthrough solution has to be defined clearly in measurable terms. The problem selected should consider the requirements of the customer and should have relevance to the company's business.
2. **Measure**: the second most important step is established of the metrics. It is also necessary to identify and rank the improvement opportunities. First the CTQ (critical to quality) characteristics of the process have to be identified in order to focus six sigma on areas that will have the greatest impact on customer satisfaction.

The output of the process, measured as multiples of its six sigma under each CTQ (existing quality level), has to be recorded so that Defect Per Unit (DPU) is estimated in Part Per Million (PPM). This is used as the starting points for setting new targets and proceeding with subsequent steps.

3. **Analyze:** at this stage new goals are set, and the route maps created for closing the gap between current and target performance levels. It begins with benchmarking key product performance against the best-in-class so that the sigma levels attained by comparable processes can be ascertained as the basis for new targets.

   Then the GAP analysis is conducted to identify the factors that distinguish best-in-class processes from those being analyzed so that the areas of change can be identified.

   Statistical tools as well as conventional quality techniques like brainstorming, root cause analysis, fishbone diagram, Pareto analysis may be used for carrying out the analysis.

4. **Improve:** this stages objectives are;

i. To confirm the key process variables and

ii. Quantify their effects on the CTQ;

iii. Identify the maximum acceptable ranges of specifications

iv. If the existing quality level is >3σ, efforts must be directed to improve the processes to achieve at least 3 σ

v. The transition from 3 σ to 6 σ is done on the 2 fronts; first by enlarging the design-width to accommodate greater variability in the output and the second approach is to make improvements in the process itself so that the chances of defects are eliminated.

5. **Control:** the final stage of Six Sigma implementation is to hold the gains that have been obtained from the 'improve' stage. In this stage the new process-conditions are documented, and frozen into systems so that the gains are permanent. The process is

assessed once more after the setting-in period in order to check whether the improvements are being sustained or not.

4.2.7 Similarities and differences between DMAIC and DMADV

Six Sigma is comprised of various methods that helps in increasing the effectiveness and efficiency of business processes. The two most commonly used six sigma methodologies include DMAIC and DMADV.

DMAIC represents Define, Measure, Analyze, Improve and Control. DMADV represents Define Measure, Analyze, Design and Verify. Although both the methodologies have some common characteristics, they are designed for use in different business processes.

Similarities

Although DMAIC and DMADV are designed for different business processes; both the methodologies have some basic similarities. They are;

1. Both the methodologies use facts and statistical tools for finding solutions to common problems, related to quality.
2. Both the methodologies are used for reducing the number of defects to less than 3.4 per million opportunities available for defects occurs.
3. Both methodologies require the service of Green Belts, Black Belts and Master Black Belts during the implementation stage.
4. Both concentrate on achieving the financial and business objectives of an organization.
5. Both the methodologies require support from a champion and Process Owner during the implementation stage.

Differences

Both methodologies have same first initials, but that is where the similarities end. The major differences are listed below;

Chart no.4.5

Methodologies differences

Bases of difference	**DMAIC**	**DMADV**
1. Defining	DMAIC is associated with identifying a business process and its applicability	DMADV helps in defining customer needs in relation to a product or service
2. Measuring	It is used for measuring the current performance of a business process	It is used for measuring the customer needs and specifications
3. Analysis	In DMAIC, a business process is analyzed to find the root cause of a defect or recurring problem	In DMADV, a business process is analyzed for finding options that will help in satisfying the customer needs and specifications
4. Designing	Here, improvements are made in the business process for eliminating defects	In DMADV, an appropriate business model is designed that helps in meeting customer requirements
5. Control systems	In DMAIC, control systems are put in place to keep a check on future performance of a business process	In DMADV, the suggested business model is put through simulation tests for verifying efficacy in meeting customer needs and specifications.

Thus after the similarities and differences, it can be concluded that DMAIC is used on a process or product that already exists and DMADV is used when a new product or process needs to be developed to meet customers' requirements.

4.2. 8 Quality management tools and methods used in Six Sigma

Within the individual phases of a DMAIC or DMADV project, Six Sigma utilizes many established quality-management tools that are also used outside Six Sigma. The following table shows an overview of the main methods used.

Chart no.4.6

Quality management tools and methods used in Six Sigma

➢ 5 Whys	➢ Histograms
➢ Analysis of variance	➢ ANOVA Gauge R&R
➢ Quality Function Deployment (QFD)	➢ Pareto chart
➢ Business Process Mapping	➢ Process capability
➢ Cause & effects diagram (also known as fishbone or Ishikawa diagram)	➢ Regression analysis
➢ SIPOC analysis (**S**uppliers, **I**nputs, **P**rocess, **O**utputs, **C**ustomers)	➢ Root cause analysis
➢ Chi-square test of independence and fits	➢ Control chart
➢ Correlation	➢ Cost-benefit analysis
➢ CTQ tree	➢ Design of

	experiments
➢ Failure mode and effects analysis (FMEA)	➢ General linear model

Source: http://en.wikipedia.org/wiki/List_of_Six_Sigma_software_packages#Software_used_for_Six_Sigma

Six Sigma is a way to measure quality output systematically and to implement improvements. The system relies upon statistics to recognize where improvement in a process is needed. There are three means to evaluate systems and make necessary changes. Six Sigma uses Methods/ methodology, techniques and tools.

A method is simply a way to do anything systematically. The technique is the way to go about a task that may not be apparent. The tools are either mechanical or intellectual ways to complete a task.

As discussed earlier was the methodologies of Six Sigma, the tools for six sigma are discussed as under;-

1. **Process map/mapping:-** the first key tool is process mapping which is used in measure and define stages. It is an integrally important tool that helps to understand every aspect of every input and output. It helps to document the process which maintains control and reduce variation.

Process mappings steps are very simple but extensive. List of all the inputs and outputs i.e. steps, cycle time has to get. With this stage company start identifying the value added and the non-value added factors. Company has to list and classify each step in this context-digging deeper and deeper to ensure that one has documented every factor affecting each step in that process. It is a "living" document ;it helps in document the process that can maintain control over which change and be alert for variations as they start to pop up over time.

Process mapping keep critical team members and resources focused and involved and help them identify the benefits and opportunities of attacking the bottlenecks, capital constrains and other problems.

2. **House of Quality**: this stage/step is the framework of the approach to design management known as Quality Function Deployment (QFD). It is originated in Japan in 1972 at Mitsubishi's Kobe shipyard and has been developed in numerous ways by Toyota and its suppliers and many other organizations.

   The HoQ provides structure to the design and development cycle, often likened to the construction of a house, because of the shape. Here it may increase the initial planning time in a particular development project, but the overall time including design and redesign, taken to bringing a product to the market will be reduced.

3. **Measurement System Analysis**: th goal of this tool is to ensure that the measurement system is statistically confident that its both accurate and precise each and every time it is used. This tool is used in measure phase of DMAIC cycle/methodology. It determines whether or not to take a certain measurement and repeat or reproduce it. Company want to be sure all its measurement systems functions independently and correctly otherwise risk flaws in the data.

   Manager's role here is to involve all team members and to expedite any action necessary to correct measurement systems; as the project cannot move forward.

4. **Process capability tool**: at the end of the measure phase in DMAIC, the last tool deployed is vitally important. Process capability, is the measure of a process being able to

meet specification requirements and fulfill customer CTQ needs on a long term basis. Capability metrics is thus used to find out whether or not the company going to hit the target without variation.

5. **Multivariate study:** at the begin of the Analyze phase, multivariate studies may be use to identify the significant inputs and characterized the process. Here, how the inputs affect the output capabilities of the process is studied. These studies look at sources of variation within a piece or a batch variation from piece to piece and variation related to time to discuss which one contributes the most to that variation. Here the collected data is analyzed to determine the capability, stability and relationship between key inputs and outputs.

6. **Hypothesis testing:** as continued in analysis phase, the next tool at a disposal is the hypothesis testing tool. It is an approach, procedure for making rational decision about possible causes of a given effect.

   It compares things to determine a probability value and isolate the guilty parties through measuring process attributes and capabilities and identifying variables that may affect the CTQ's that have been developed some assumptions or hypothesis about the process. Through a logical sequence of steps, hypothesis testing defines the problem, statistically tests data, selects samples and determines whether or not the probability of defect is caused by random chance. Management keeps the team members involved, removing barriers and knowing what the test results are producing to keep the focus on gathering data in short term to develop term to develop long term solutions.

   One of the ways to test hypotheses is through simulations. Software programs allow managers to plug in data and conduct "what if" the tests to apply the hypotheses.

7. **Failure Modes And Effects Analysis(FMEA):**

A Failure Modes and Effects Analysis is a technique of a very strict methodology to evaluate a system, a design, a process and or a service for possible ways in which failures can occur. For each failure and estimate is made of its effect on the total system and of its seriousness. In addition, a review is made of the action being taken to minimize the probability of failure or to minimize the effect of failure. Customers place increase demands on companies for high quality, reliable products. The increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the quality and reliability. Traditionally, reliability has been achieved through extensive testing and use of techniques such as probabilistic reliability modeling. These are the techniques done in the late stage of development. The challenge is to design in quality and reliability early in the development cycle.

The FMEA is a logical, structured analysis of a system, sub-system, device or process. It is one of the most commonly used reliability and system safety analysis techniques. This simple but straightforward approach can be very technical (quantitative) or very non technical (qualitative) and utilizes three main factors for the identification of the specific failure. The three factors are;

a. Occurrence
b. Severity
c. Detection.

8. Design Of Experiment:

It is a structured, organized method that is used to determine the relationship between the different factors (Xs) affecting a process and the output of that process (Y).

DOE involves designing a set of ten to twenty experiments, in which all relevant factors are varied systematically. When the results of these experiments are analyzed, they help to identify optimal conditions, the factors that most influence the results and those that do not as well as details such as the existence of interactions and synergies between factors.

DOE methods require well structured data matrices. When applied to a well structured matrix, analysis of variance delivers accurate results,even when the matrix that is analyzed is quite small.

DOE is widely used in research and development, where a large proportion of the resources go towards solving optimization problem. The key to minimize optimization costs is to conduct as few experiments as possible. It requires only a small set of experiments and thus helps to reduce costs.

9. Control Plan:

The concluding phase of DMAIC is the control phase. The last tool used is the control plan, which provides a written description of the system to control parts and processes. But a control part is far more than a recitation of facts and steps. It improves quality by doing a thorough evaluation of process characteristics and variation sources. It helps to increase customer satisfaction by focusing resources on process and product characteristics that are important to customers.

A control plan is a detailed assessment and guide for maintaining all positive changes managers, Black Belt and the project team have made. It ensures all the analysis and efforts stay in effect and have the information at the disposal to prevent backsliding to less than optimal performance standards.

Control chart is the fundamental tool os statistical process control. It indicates the range of variability that’s built into a process. It helps determine whether or not a process is operating consistently or if a special cause has occurred to change the process mean or variance.

4.2.9 The Six Sigma Technical Tools:-

The ten (10) most important technical tools which six sigma team members do master as they progress through the DMAIC methodology. They are discussed as under;

Tool 1- The Critical to Quality(CTQ) tree:- the CTQ tree is used during the design phase of DMAIC methodology. It is used to brainstorm and validate the needs and requirements of customers of the process targeted for improvement. The steps in creating a CTQ tree are as under;

a. Identify the need of the customer
b. Identify the first level of requirements of the need, i.e. some characteristics of the need that determines whether the customer is happy with the need.
c. Drill down to more detailed level(s) of the requirement, if necessary.

Tool 2- The Process Map:- during the define phase, the project team creates the first of several process maps. A process map is a picture of the current steps in the process targeted for improvement.

It has five(5) major categories of work from identification of the suppliers, of the process, the inputs the suppliers provide, the name of the process, the output of the process and the customers of the process. Each of these steps is summarized as SIPOC to indicate to the team, the steps that must be conducted to complete a process map.

5 major categories:

- Supplier of the process
- The inputs the suppliers provides
- The name of the process

- The output of the process and
- The customers of the process.

Tool 3- The Histogram:- this tool is used in Analysis stage of DMAIC. The project team member will review data collected during the Measure stage of DMAIC.

It is often suggested that the data be organized into graphs or charts to be more easily understand what the data is saying about the process.

The data is of two types-Discrete data(e.g. fail/pass) and continuous data (time, height etc).

Tool 4-The Pareto Chart:- histogram is useful for continuous data same way when the data is discrete, teams create a pareto chart. Discrete data is counted dat e.g. off/on, yes/no, defect/no defect etc.

When dealing with discrete data, the project team member should create reason codes for why a defect occurs and count and categorize the data into these reasons on codes and Pareto chart is prepared.

Tool 5-The Process Summary Worksheet:- The goal of Six Sigma team members while applying the DMAIC methodology is to improve effectiveness and efficiency. Efficiency is measured in terms of cost, time, labor, or value.

The process summary worksheet is a ‘roll-up’ of the sub process map indicating which steps add value in the process and which steps don’t.

Tool 6-The Cause –Effect diagram:- the most important tool/technique to assist the project team in determining root causation is the cause-effect diagram. This tool captures all the ideas of the project team relative to what they feel are the root cause behind the current sigma performance and finally helps in finding a root cause of the problem.

Tool 7-The Scatter Diagram:- once ideas have been prioritized after use of the cause and effect diagram, the most important thing the project team does is validate the remaining ideas with fact and data.

The scatter diagram takes an idea about root causation and tracks corresponding data in the response the team is trying to improve. The team can validate an idea about root causation through a designed experiment, or through the scatter diagram.

Tool 8- The Affinity diagram:- An Affinity diagram is used to help sort and categorize a large number of ideas into major themes or categories. It is especially useful when team is ready to brainstorm solutions in the Improve stage of DMAIC. The steps in creating an Affinity diagram are;

- Have each member write one idea per post-it note and post on a wall randomly.
- As ideas are read off for clarification, sort ideas into similar groups.
- Create a header card for each general category of ideas below it.

Tool 9-The Run Chart:- the run chart is similar to a camcorder, a recording of some process element over time.

Tool 10- The Control Chart:- Similar to the Run chart, a control chart uses the data from a run chart to determine the upper and lower control limits. Control limits are the expected limits of verification above and below the average of the data. These limits are mathematically calculated and indicated by dotted lines.

4.2.10 Implementation of Roles in Six Sigma Methodology

- There are many roles that are used in the Six Sigma Methodology. While most of the roles are used in many organization implementing Six Sigma Methodology but they are not universal. Six sigma creates an infrastructure of champions, master black belts (MBBs), black belts (BBs) and green belts (GBs) that lead, deploy and implement the approach.

  The roles are as under:

Chart no. 4.7

Implementation of Roles in Six Sigma Methodology

No	Title	Roles	Experience and Skills
1	**Executive Leadership**	Top-level executives are responsible for vision and ultimately implementation of the six sigma methodology	
2	**Champion/Sponsor**	Champion initiates and sponsers a Black Belt or team member.this belt is directly accountable for project results. They align project with	Champions or sponser must be executive level or key operational manager. He/she is often a member of organizational's leadership council or

		business goals.	steering committee.
3	**Master Black Belt**	This team is coach, mentor and trainer to Black Belts. People are expert in Six Sigma methodology, tools and processes. This Belt offers hands on help to Black Belts. They devote 100 percent of their time to Six Sigma	Master Black Belt person is generally a proessional six sigma consultant. He must possess substantial experience with all the areas mentioned under Black Belt.
4	**Black Belt**	It is the most critical role. Without a qualified Black Belt, the process may fail. They primarily focus on Six Sigma project execution. People are skilled as well in Six Sigma methodology, tools and processes. This Belt serves generally from 18 months to 2 years, and carries out 4-8 project	This team is usually developed from within the organization, but is re-assisted full time to six sigma. Usually a middle manager or a future manager is developed from this belt. The incumbent must be an expert in the problem solving, data collection and analysis. He/she must be organizational savvy. The focus is on leadership/coaching and understanding of administrative systems and processes.

5	**Green Belt**	This belt is similar to Black Belt, but holds a regular position while participating in or leading a six sigma team. This belt knows basic application of Six Sigma management tools.	Similar to black belt.
6	**Yellow belt**	Trained in basic application of Six Sigma management tools, work with Black Belt throughout the project stages and are often the closest to the work.	Similar to black belt.
7	**Implement--ation Leader**	This people orchestrates entire Six Sigma efforts within an organization	Implementation leader is a corporate VP reporting to CEO. He is often a seasoned professional in quality or organizational improvement hired specifically for six sigma efforts.

Source: www.sixsigma.com

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

1. Six sigma strategy places a clear focus on achieving measurable and quantifiable financial returns to the bottom-line of an organization. No six sigma project is approved unless the bottom-line impact has been clearly identified and defined.
2. Six sigma strategy places an unprecedented importance on strong and passionate leadership and the support required for its successful deployment.

3. Six sigma methodology of problem solving integrates the human elements (culture change, customer focus, belt system infrastructure, etc.) and process elements (process management, statistical analysis of process data, measurement system analysis, etc.) of improvement.
4. Six sigma methodology utilizes the tools and techniques for fixing problems in business processes in a sequential and disciplined fashion. Each tool and technique within the six sigma methodology has a role to play and when, where, why and how these tools or techniques should be applied is the difference between success and failure of a six sigma project.
5. Six sigma creates an infrastructure of champions, master black belts (MBBs), black belts (BBs) and green belts (GBs) that lead, deploy and implement the approach.
6. Six sigma emphasizes the importance of data and decision making based on facts and data rather than assumptions and hunches! Six sigma forces people to put measurements in place. Measurement must be considered as a part of the culture change.
7. Six sigma utilizes the concept of statistical thinking and encourages the application of well-proven statistical tools and techniques for defect reduction through process variability reduction methods (e.g. statistical process control and design of experiments).[9]

4.2.12 Competitive Advantages Of Six Sigma

Six sigma allows becoming competitive-regionally, nationally, or globally. A company that reduces its costs of doing business, meets the expectations of its customers more effectively and efficiently, earns a reputation for quality and fosters a culture of

[9] Jiju Antony, Some pros and cons of six sigma: an academic perspective, Emerald Group Publishing Limited , The TQM Magazine Volume 16 · Number 4 · 2004 , DOI 10.1108, pp. 303-306

dedication and pride will certainly enjoy advantages over its competitors. It can provide higher quality outputs at a lower cost. The advantages are;

1. **Design Better Products**:- six sigma can and does help many companies to design better products with less waste and at a lower cost.

2. **Improve Quality**: six sigma methodology at its best produces organization wide synergy, everyone pulling together to improve quality, cut costs and drive profitability.

3. **Top Down Approach**: the top down approach of six sigma means that what is found to be good can be capitalized on and what is found to be bad be removed quickly, because the very top tier of management are involved and expecting change, not running away from it.

4.3 Reported Benefits Of Implementing Six Sigma

4.3.1 Manufacturing sector

Motorola was the first organization to use the term six sigma in the 1980s as part of its quality performance measurement and improvement program. Six sigma has since been successfully applied in other manufacturing organizations such as General Electric, Boeing, DuPont, Toshiba, Seagate, Allied Signal, Kodak, Honeywell, Texas Instruments, Sony, etc.[10] The reported benefits and savings are composed and presented from investigating various literatures in six sigma summarizes the organizations, projects, benefits, improvements, and savings by implementing the six sigma process.[11]

4.3.2 Financial sector

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[10] Weiner, M., Six sigma. Communication World 21 (1),2004,pg 26–29.

[11] Antony, J., Banuelas, R., Key ingredients for the effective implementation of six sigma program. Measuring Business Excellence, 2002 vol 6 ed4,pg 20–27.

In recent years, finance and credit department are pressured to reduce cash collection cycle time and variation in collection performance to remain competitive. Typical six sigma projects in financial institutions include improving accuracy of allocation of cash to reduce bank charges, automatic payments, improving accuracy of reporting, reducing documentary credits defects, reducing check collection defects, and reducing variation in collector performance.[12] Bank of America (BOA) is one of the pioneers in adopting and implementing six sigma concepts to streamline operations, attract and retain customers, and create competitiveness over credit unions. It has hundreds of six sigma projects in areas of cross-selling, deposits, and problem resolution. BOA reported a 10.4 percent increase in customer satisfaction and 24 percent decrease in customer problems after implementing six sigma.[13] American Express applied six sigma principles to improve external vendor processes, and eliminate non-received renewal credit cards. The result showed an improved sigma level of 0.3 in each case.[14] Other financial institutions including, GE Capital Corp., JP Morgan Chase, and SunTrust Banks are using six sigma to focus on and improve customer requirements and satisfaction.[15]

4.3.3 Healthcare sector

Six sigma principles and the healthcare sector are very well matched because of the healthcare nature of zero tolerance for mistakes and potential for reducing medical errors. Some of the successfully implemented six sigma projects include improving

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[12] Doran, C., Using six sigma in the credit department. Credit Management Dec 2003, 32–34

[13] Roberts, C.M., Six sigma signals. Credit Union Magazine 70 (1), 2004, pg 40–43.

[14] Bolt, C., Keim, E., Kim, S., Palser, L., Service Quality Six Sigma Case Studies, ASQ's 54th Annual Quality Congress Proceedings 2000, pp. 225–231.

[15] Roberts, C.M., Six sigma signals. Credit Union Magazine 70 (1), 2004, pg 40–43

timely and accurate claims reimbursement[16], streamlining the process of healthcare delivery and reducing the inventory of surgical equipment and related costs. The radiology film library at the University of Texas MD Anderson Cancer Center also adopted six sigma and improved service activities greatly[17]. Also in the same institution's outpatient CT exam lab, patient preparation times were reduced from 45 min to less than 5 min in many cases and there was a 45 percent increase in examinations with no additional machines or shifts.

4.7.4. Engineering and construction sector

In 2002, Bechtel Corporation, one of the largest engineering and construction companies in the world, reported savings of $200 million with an investment of $30 million in its six sigma program to identify and prevent rework and defects in everything from design to construction to on-time delivery of employee payroll.[18] For example, six sigma was implemented to streamline the process of neutralizing chemical agents, and in a national telecommunications project to help optimize the management of cost and schedules[19]

4.3.5. Research and development sector

The objectives of implementing six sigma in R&D organizations are to reduce cost, increase speed to market, and improve R&D processes. To measure the effectiveness of six sigma, organizations need to focus on data driven reviews, improved

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[16] Lazarus, I.R., Butler, K., The promise of six sigma. Managed Healthcare Executive 2001, 11 (9), 22–26.

[17] Benedetto, A.R., Adapting manufacturing-based six sigma methodology to the service environment of a radiology film library. Journal of Healthcare Management, 2003, 48 (4), 263–280.

[18] Eckhouse, 2003. In Pursuit of Perfection. Bechtel Briefs, August. Available online via !http://www.bechtel.com/sixsigma.htm (accessed March 2, 2004).

[19] Moreton, M., Featured company: bechtel. ASQ Six Sigma Forum Magazine, 2003, 3 (1), 44.

project success rate, and integration of R&D into regular work processes. One survey noted that as of 2003 only 37 percent of the respondents had formally implemented six sigma principles in their R&D organization[20]. Rajagopalan has reported that the development and manufacturing of the new prototype at W.R. Grace (Refining Industry) was cut to 8–9 months from 11–12 months by implementing the DFSS process.[21]

After understanding the six sigma methodology, the fifth chapter deals with the Research design.

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[20] Johnson, A., Swisher, B., How six sigma improves R&D. Research Technology Management, 2003, 46 (2), 12–15.

[21] Rajagopalan, R., Francis, M., Suarez, W., Developing novel catalysts with six sigma. Research Technology Management 2004, 46 (1), 13–16.