Whitepaper Collection

Volume

6

Six Sigma

An Overview

Published by Senior Consulting
Strategical, Conceptual and Technical Consulting

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Abstract
Six Sigma has been a popular management philosophy for years. Its goal is to make an organization more effective and efficient.
Unlike other quality initiatives that focused on tools, Six Sigma is based on the active involvement it generates from the management. A deployment involves strategic assessment and planning, comprehensive training of internal resources, structured and methodical deployment, roll-out of continuous improvement projects, ongoing measurement of newly performance metrics and most importantly communication.

Modification History

Version	Date	Author	Description of Changes
0.1	01.03.2004	Alexander Gola	Initial Release
0.2	23.05.2004	Alexander Gola	Insert of chapters for phases, statistics and benefits
0.3	28.05.2004	Alexander Gola	Enhancements
1.0	29.05.2004	Alexander Gola	First Release
1.1	03.06.2004	Alexander Gola	Enhancements regarding example worksheets
1.2	12.12.2004	Alexander Gola	Enhancements
1.3	17.12.2004	Alexander Gola	Enhancements regarding tool roadmap
1.4	06.01.2005	Alexander Gola	Enhancements
1.5	18.01.2005	Alexander Gola	Enhancements, Chapter "Trademarks"
1.6	25.02.2005	Alexander Gola	Enhancements
1.7	18.10.2005	Alexander Gola	Publishing informations
1.8	26.01.2007	Alexander Gola	Changed company address

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Six Sigma

Six Sigma is a quality philosophy and science of reducing costs and improving customer satisfaction through variation reduction, statistical and lean methods. It uses customer-focused goals and measurements to establish continuous improvement at all levels of an organization.
Today a majority of time organizations are using the DMAIC methodology, because there are existing processes that have wasting resources. The remaining minority of Six Sigma practitioners are using a "Design for Six Sigma" (DFSS) or DMADV methodology approach to design a new product for Six Sigma quality.

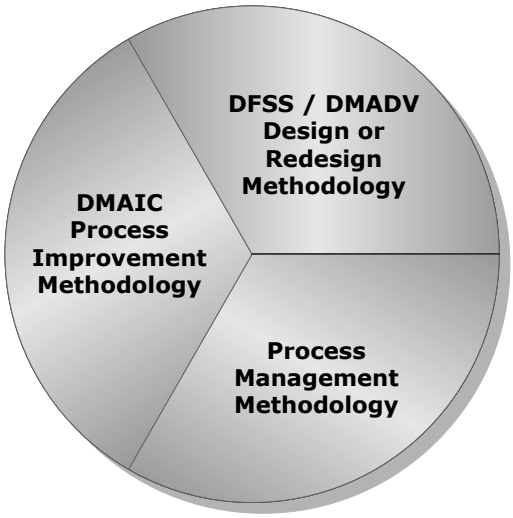

Figure 1 Overview Of Six Sigma

The DMAIC methodology is almost universally recognized and defined as comprising of five phases, DFSS is used to completely design or re-design a product or service.

History

The root of Six Sigma as a quality standard can be traced back to 1920, when Walter Shewart showed, that three sigma in a product variation is the point where a process requires corrections.
In the early and mid-1980s with Chairman Bob Galvin, Motorola decided that the traditional quality levels did not provide enough granularity. As a result of this, a Motorola engineer named Bill Smith began to experiment with problem solving through statistical analysis.
After a small period Motorola initiated its "Six Sigma Quality" initiative. As part of this the company implemented a new standard and created the methodology and needed cultural changes associated with this.
The new standard was conceptualized as a quality goal to reduce the number of opportunities for defects. In 1989 Motorola announced a five-year goal, which defined the company defect rate of not more than 3.4 parts per million.
After the successful introduction, Motorola shared the approach with other companies and is now widely used by major corporations worldwide. Companies such as DEC, IBM and General Electric have successfully implemented Six Sigma and reduced costs literally by billions of dollars.

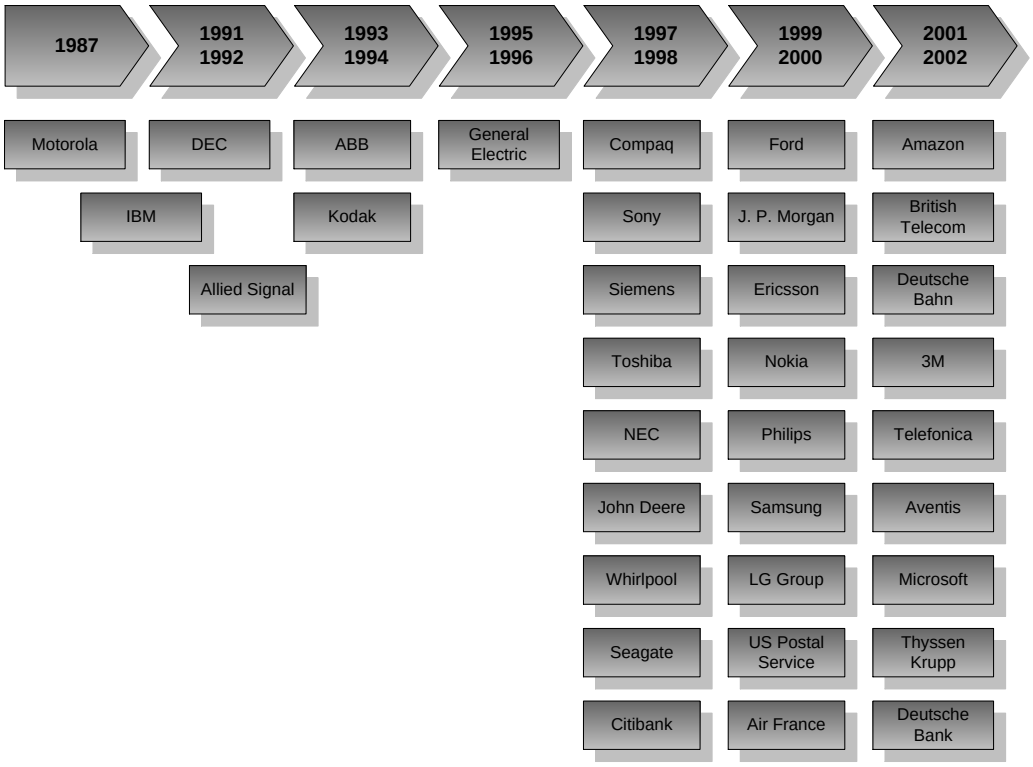

Figure 2 History Of Six Sigma

Today more recently Ford, Dow Chemical, American Express and BMW have started working on instituting the methodology.

Differences To Other Quality Methodologies

While Six Sigma was originally created as a continuous quality improvement technique, today it is significantly different than the "Total Quality Management" (TQM) approach of the 1980s.
The following figure shows the key differences between Six Sigma and TQM.

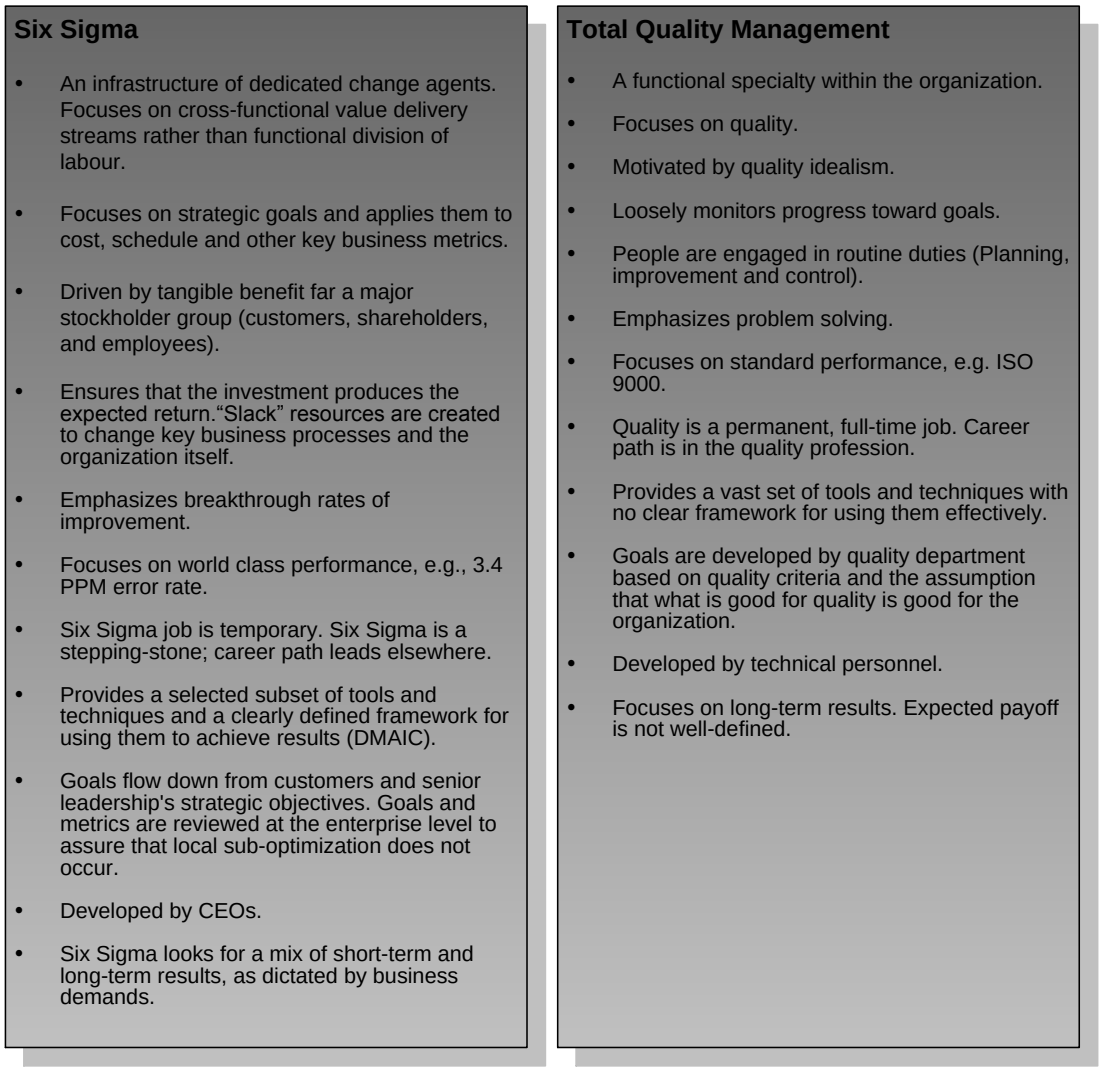

Figure 3 Differences between Six Sigma and TQM

The next generation Six Sigma is an overall high performance system that executes business strategy.

Vision

Each organization must have a vision to communicate its future direction and expectations to its employees, suppliers and customers. The type depends upon the leadership style and used management systems, but every time it requires a good understanding of the methodology, its intent and benefits. Without the understanding for benefits, the organization vision could miss the true objective.
The vision must completely incorporate the philosophy, the methodology, the existing traditional and the expected approach.

Organizational Issue	Traditional Approach	Six Sigma Approach
Problem resolution	Fixing symptoms	Preventing causes
Behavior	Reactive	Proactive
Decision making	Experience-based	Data-based
Process adjustment	Tweaking	Controlling
Supplier selection	Cost (piece price)	Capability
Planning	Short-term	Long-term
Design	Performance	Producibility
Employee training	If time permits	Mandated
Chain-of-command	Hierarchy	Empowered teams
Direction	Seat-of-pants	Benchmarking and metrics
Manpower	Cost	Asset

Table 1 Approaches For A Six Sigma Vision

In summary, the vision must be a set of words and initiatives that relates to a particular corporate culture and a new direction to produce better corporate performance through an improvement in operations.

The following list shows the key initiative areas, which must be involved to realizing a good organization vision.

Resource Management
From identification to assignment, resource management should ensure the effective use of all organization internal resources, with the capability of assignment based on project requirements and scheduling.

Project Tracking and Management
Tracking and management should provide an organization with a view on all of the Six Sigma projects that are in progress as well as completed. Important data, milestones and performance measures are available to be shared with the organization.
Project leaders can leverage project tracking to help them manage their projects more effectively – reminding them of what project tools can be used and when – from project mandate through the project completion.

Knowledge Management
Knowledge Management supports the project leader, their teams as well as organizational leaders and decision makers by providing access to the most recent Six Sigma training materials, improvement tools and templates, project dictionaries, deployment planning informations, case studies and other informations that needs to be shared across the organization.

Executive Reporting
Successful management of the Six Sigma deployment requires a complete view that is available anytime. Executive reporting should provide not only access to all of the continuous improvement activities within a organization, but also enable "management by exception" driven by standard as well as user-defined queries and alerts.

Collaborative Tools
Six Sigma will demand "end-to-end" communication for an organization. To ensure this, a company needs a shared environment available that allows the complete organization to share and collaborate on this voyage.

Philosophy And Concepts

To make Six Sigma a success in an organization, it must affect everyone in the organization. Everyone must be involved and affected, regardless of their position in the organization. Because of this, world class organizations have three major focus areas: being customer focused, process focused and employee focused.
Today most organizations, which had not established Six Sigma, working at a four sigma level. The quality and costs are high.

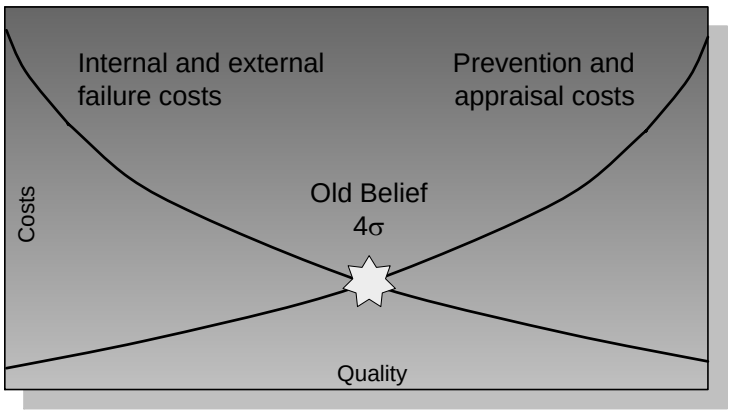

Figure 4 Old Philosophy Belief

A successful implementation will result in improved effectiveness and efficiency, which will bring more profitability and business growth. Basis of this is a better proportion of costs and quality.

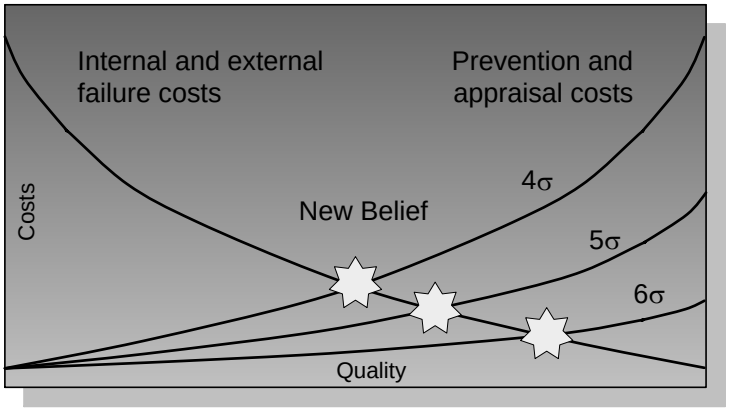

Figure 5 New Philosophy Belief

The path of getting a better sigma level and becoming more effective and efficient contains three parts. The first deals with the strategy, which is called Business Process Management. The second part deals with the tactics of how project teams improve a new or broken process. The last key part is the cultural one.

The processing starts with the management. In the beginning the Six Sigma strategy instructs the behaviour to begin identifying the 20 to 30 most important processes in the organizations business. In that case, processes are defined as series of steps and activities that take inputs provided by the supplier, add value and provide outputs for their customers.
The next step includes the measurement of the current performance and collection of data of each of these processes.
Once the management has identified these processes, they must identify the lowest performing processes that have the biggest impact on the business objectives. When these processes are identified, it is important to assign process ownership. In some cases, the owners will be the current management, in other cases project teams must be formed.
Each process owner is required to calculate the baseline performance and start fixing the processes that constitute the totality of their organization. For these, statistical tools are used to identify the vital few factors, the factors that matter most for improving the quality of processes and generating bottom-line results.
Many of the used components of the Six Sigma model are borrowed from the automotive world, e.g. Advanced Product Quality Planning (APQP), Statistical Process Control (SPC), Lean Manufacturing and Business Operating Systems (BOS).

Strategic Components And Deployment

The mainly used methodology, also called DMAIC, is a project-based approach consisting typically of five phases: Define, Measure, Analyze, Improve and Control. Every of this phase can include substeps, called tollgates. Each of these tollgates indicates the specific work a project team must complete.
The summary of these phases and tollgates is a systematic, closed-loop process for continued improvement, which eliminates unproductive steps, focuses on new measurements and applies technology for improvement.

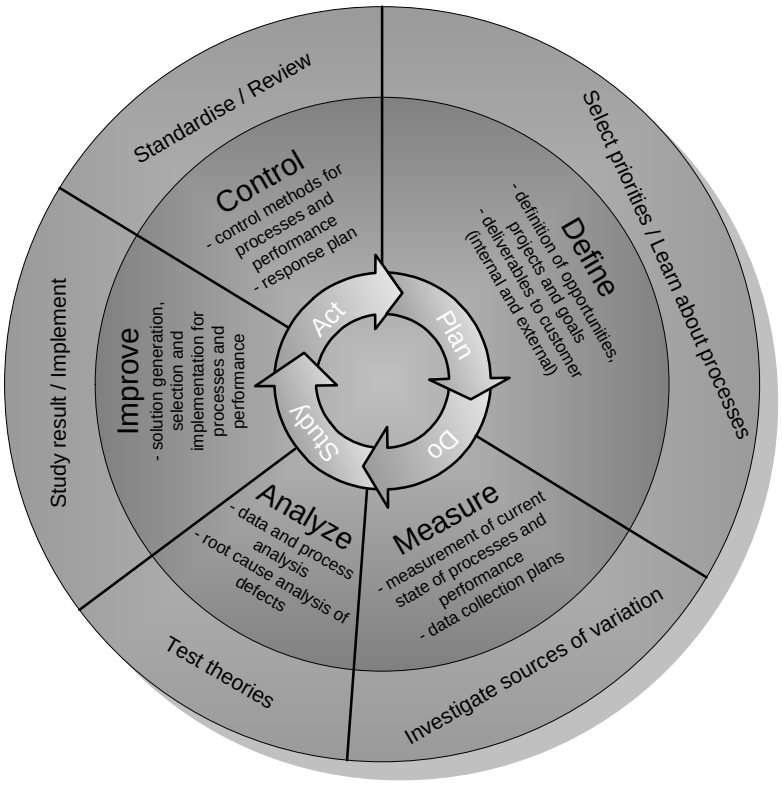

Figure 6 Methodology Of Six Sigma

- In the Define Phase, projects are selected from business, operational and customer needs, based on their connection to executive strategies. Customer needs are stated and the processes and products to be improved are identified.
- In the Measure Phase, tools are applied to validate the measurement system and to characterize the process. The baseline and target performances of the process are determined and the input and output variables of the process are identified.
- In the Analyze Phase, sources of variation are identified. Data is analyzed to establish a statistical relationship between the process input and output.
- In the Improve Phase the process performance is optimized. The improvements are identified that optimize the outputs and reduce defects and variation. The new process operating conditions are statistically validated.

- In the Control Phase tools are applied to sustain the gains made by the process improvements. The key process inputs are controlled to achieve the key process outputs consistently.

Each project must complete all five phases and must use predetermined methods and analysis.

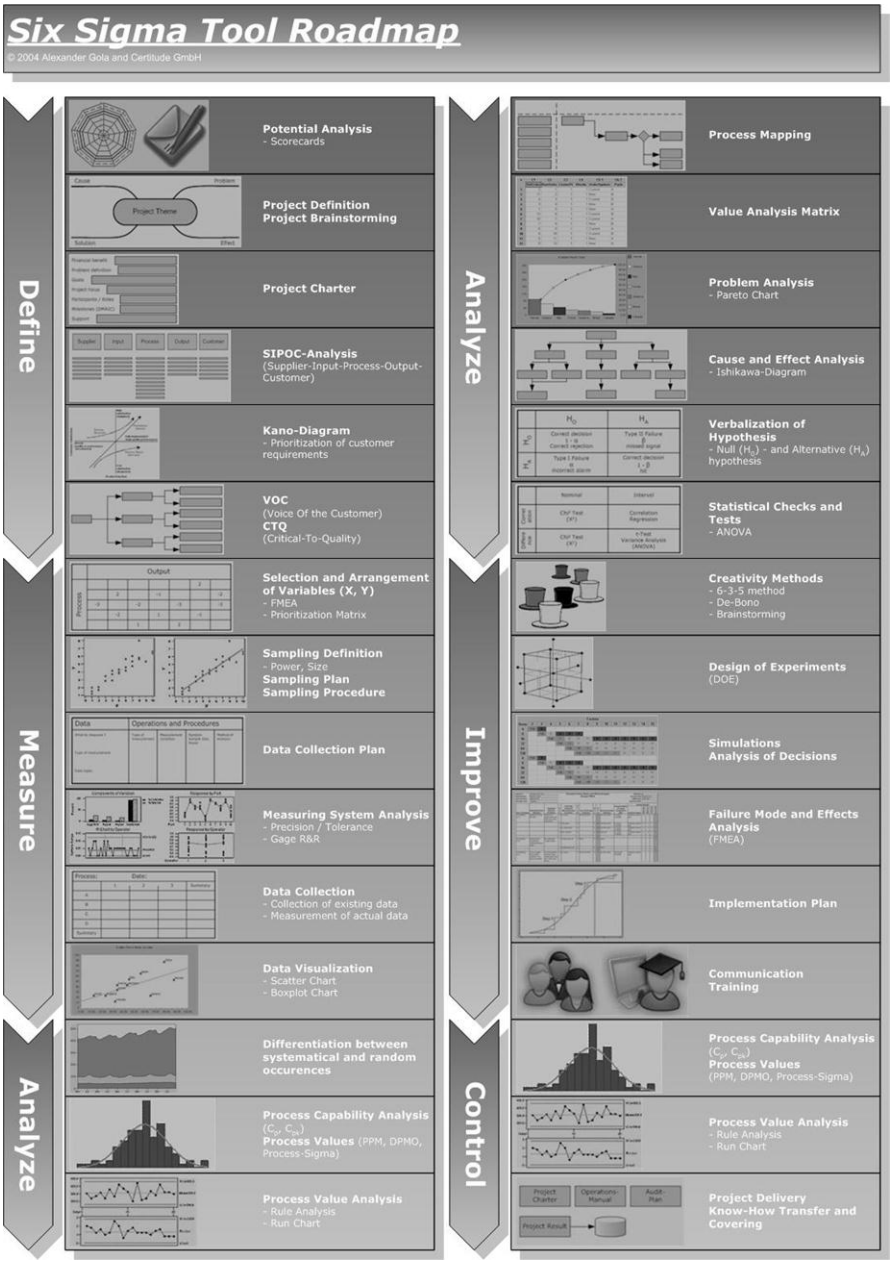

Figure 7 Six Sigma Tool Roadmap

For a detailed overview see the graphic chart Six Sigma Tool Roadmap.

Define Phase

The purpose of the Define Phase is to clearly identify the problem, the requirements of the project and the objectives of the project. The objectives of the project should focus on critical issues which are aligned with the company business strategy and customer requirements.

Steps / Tollgates

- define customer requirements as they relate to this project
- develop defect definitions as precisely as possible
- perform a baseline study (a general measure of the level of performance before the improvement project commences)
- create a team charter and champion
- estimate the financial impact of the problem
- obtain senior management approval of the project

Checkpoints

- Team Readiness
    - team is sponsored by a champion or business leader
    - team formed and team leaders (Master Black Belt/Coaches and Black Belt/Project Leads) assigned
    - improvement team members trained on Six Sigma and DMAIC
    - full participation by members in regularly held team meetings
    - team members perform project work when assigned and in a timely fashion
    - team members regularly document their project work
    - team is equipped with available and reliable resources

- Critical-To-Quality (CTQ)
    - customer identified and segmented according to their different needs and requirements
    - data collected and displayed to better understand customer critical needs and requirements

- Project Charter
    - project management charter, including business case, problem and goal statements, project scope, milestones, roles and responsibilities and communication plan

- Business Process Mapping
    - completed, verified and validated high-level "as is" (not "should be" or "could be") business process map
    - completed SIPOC representation, describing the suppliers, inputs, processes, outputs and customers

Tools

- Project Charter, Pareto Chart, Process Flow Chart, Critical-To-Quality (CTQ), House of Quality, SIPOC Diagram, Stakeholder Analysis (for examples see the spreadsheet "Six Sigma Define Phase Worksheet")

Measure Phase

The purpose of the Measure Phase is to fully understand the current performance by identifying how to best measure current performance and to start measuring it. The measurements used should be useful and relevant to identifying and measuring the source of variation.

Steps / Tollgates

- identify the specific performance requirements of relevant "Critical-To-Quality" characteristics
- map relevant processes with identified inputs and outputs so that at each process step, the relevant outputs and all the potential inputs that might impact each output are connected to each other
- generate list of potential measurements
- analyze measurement system capability and establish process capability baseline
- identify where errors in measurements can occur
- start measuring the inputs, processes and outputs and collecting the data
- validate that the problem exists based on the measurements
- refine the problem or objective (from the Analysis Phase)

Checkpoints

- Key Measures Identified
    - key measures identified and agreed upon
    - high impact defects defined and identified in the business process

- Data Collection Planned and Executed
    - solid data collection plan established that includes measurement systems analysis
    - data collected on key measures that were identified

- Process Variation Displayed/Communicated
    - process variation components displayed/communicated using suitable charts, graphs and plots
    - long term and short term variability

- Performance Baseline/Sigma Calculation
    - measure baseline process performance (capability, yield, sigma level)

Tools

- Pareto Chart, Fishbone Diagram, Process Mapping, Cause and Effect Matrix, preliminary Failure Mode and Effect Analysis (FMEA), Gauge Repeatability and Reproducibility (GR&R), Statistical Process Control (for examples see the spreadsheet "Six Sigma Measure Phase Worksheet")

Analyze Phase

In the Analyze Phase, the measurements collected in the Measure Phase are analyzed so that hypotheses about the root causes of variations in the measurements can be generated and the hypothesis subsequently validated. It is at this stage that practical business problems are turned into statistical problems and analyzed as statistical problems.

Steps / Tollgates

- generate hypotheses about possible root causes of variation and potential critical inputs
- identify the vital few root causes and critical inputs that have the most significant impact

Checkpoints

- Data and Process Analysis
    - identify gaps between current performance and the goal performance

- Root Cause Analysis
    - generate list of possible causes (sources of variation)
    - segment and stratify possible causes (sources of variation)
    - prioritize list of 'vital few' causes (key sources of variation)
    - verify and quantify the root causes of variation

- Quantifying the Gap/Opportunity
    - determine the performance gap
    - display and communicate the gap/opportunity in financial terms

Tools

- Descriptive Statistics, Histograms, Correlation/Regression Analysis, Main Effect Plot, Regression Plot, Scatter Plot, Analysis of Variances (ANOVA), Failure Mode and Effective Analysis (FMEA), 5 Why's (for examples see the spreadsheet "Six Sigma Analyze Phase Worksheet")

Improve Phase

The Improve Phase focuses on developing ideas to remove root causes of variation, testing and standardizing those solutions.

Steps / Tollgates
- identify ways to remove causes of variation
- verify critical inputs
- discover relationships between variables
- establish operating tolerances which are the upper and lower specification limits (the engineering or customer requirement) of a process for judging acceptability of a particular characteristic and if strictly followed will result in defect-free products or services
- optimize critical inputs or reconfigure the relevant process

Checkpoints
- Generating (and Testing) Possible Solutions
    - possible solutions generated and tested

- Selecting The Best Solutions
    - optimal solution selected based on testing and analysis
    - new and improved process ("should be") maps developed
    - cost/benefit analysis of optimal solutions
    - small-scale pilot for proposed improvements
    - pilot data collected and analyzed
    - improved process ("should be") maps modified based on pilot data and analysis
    - project impact on utilizing the best solutions

- Designing Implementation Plan
    - solution implementation plan established, including schedule/work breakdown structure, resources, risk management plan, cost/budget and control plan
    - contingency plan established

Tools
- Hypothesis Testing (Continuous and Discrete), Brainstorming, Evaluation Matrix, Process Capability Analysis (CPK), Design of Experiment (DOE), Design for Six Sigma (DFSS) (for examples see the spreadsheet "Six Sigma Improve Phase Worksheet")

Control Phase

The Control Phase aims to establish standard measures to maintain performance and to correct problems as needed, including problems with the measurement system.

Steps / Tollgates
- validate measurement systems
- verify process long-term capability
- implement process control with control plan to ensure that the same problems don't reoccur by continually monitoring the processes that create the products or services

Checkpoints
- Monitoring Plan
    - control plan in place for sustaining improvements (short and long-term)

- Process Standardization
    - new process steps, standards and documentation are ingrained into normal operations

- Documented Procedures
    - operating procedures are consistent
    - knowledge gained on process is shared and institutionalized

- Response Plan
    - response plans established, understood and deployed

- Transfer of Ownership (Project Closure)
    - transfer ownership and knowledge to process owner and process team tasked with the responsibilities

Tools
- Control Plan Summary, Operating Flow Chart with Control Points, SPC Charts, Run Chart, GANTT Chart, Time Series Plots, Process Sigma Calculation, Cost Savings Calculations (for examples see the spreadsheet "Six Sigma Control Phase Worksheet")

Statistics and Variations

Six Sigma statistically measures and reflects true process capability, correlating to such characteristics as defect per unit and probabilities of success or failure. Its value is in transforming cultural outlooks from complacency to accomplishment across the spectrum of industry.
Six Sigma uses "Defects per Opportunities" (DPO) as a measurement tool. It uses the term "opportunities" rather than "units". This is a better term, because units tend to vary in complexity, e.g. a unit it can be a report, a gadget, a contract, a phone call or anything else that describes your product. "Defects per Opportunities" are a good measure of the quality of a process or product. It correlates to defects, cost and time.
The sigma value indicates how often defects are likely to occur. The higher the sigma value, the lower the likelihood of defects. In this case, a defect is anything that results in customer dissatisfaction. Therefore, as sigma increases, cost and cycle time decrease while customer satisfaction increases.
Sigma levels of performance are expressed as "Defects per Million Opportunities" (DPMO). It indicates how many errors would show up if an activity were to be repeated one million times.
"Defects per Million" (DPM) only describes what percentage of your units will have defects that pass on to the customer. A base of one million is used instead of one hundred, because the numbers are usually small in relation to the systems they are meant to measure.

Elements

Proportion defect (P)
The Proportion defect is defined as the fraction defective in a lot or population.

P = number of defective units / total number of product units

Yield ($Y_{1st\text{-}pass}$ or Y_{final} or RTY)
Yield is the percentage of a process that is free of defects. Another way to put it is that yield is defined as a percentage of met commitments (the total summary of defect free events) over the total number of opportunities for which that defect could appear.

Y = 1 - p

The yield proportion can converted to a sigma value using the Z table.

Defects per Unit (DPU or U in SPC)
DPU is the average number of defects observed when sampling a certain population. It takes a fundamentally different approach to the traditional measurement of yield. It is simply a ratio of the number of defects over the number of units tested.

DPU = number of defects / total number of product units

Defects per Opportunities (DPO)
DPO is the average number of defects per unit observed during an average production run divided by the number of opportunities to make a defect on the product.

DPO = DPU / total number of defect opportunities (see CTQ's)

Defects per Million Opportunities (DPMO or PPM)
DPMO is the average number of defects per unit observed during an average production run divided by the number of opportunities to make a defect on the product under study during that run normalized to one million.
The term is synonymous with "Parts Per Million" (PPM).

DPMO = DPO x 1,000,000

DPMO can be converted to a sigma and equivalent C_p value using the following Sigma table, also called as Z table.

Yield	DPMO	Sigma (σ)	C_p Equiv.	COPQ (Costs Of Poor Quality)
.840	160,000	2.50	0.83	40%
.870	130,000	2.63	0.88	
.900	100,000	2.78	0.93	
.930	70,000	2.97	0.99	
.935	65,000	3.01	1.00	
.940	60,000	3.05	1.02	
.945	55,000	3.10	1.03	30%
.950	50,000	3.14	1.05	
.955	45,000	3.20	1.06	
.960	40,000	3.25	1.08	
.965	35,000	3.31	1.10	
.970	30,000	3.38	1.13	
.975	25,000	3.46	1.15	
.980	20,000	3.55	1.18	20%
.985	15,000	3.67	1.22	
.990	10,000	3.82	1.27	
.995	5,000	4.07	1.36	
.998	2,000	4.37	1.46	
.999	1,000	4.60	1.53	10%
.9995	500	4.79	1.60	
.99975	250	4.98	1.66	5%
.9999	100	5.22	1.74	
.99998	20	5.61	1.87	
.9999966	3.4	6.00	2.00	

Table 2 Sigma Table

Critical-To-Quality (CTQ)

CTQ is the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. They align improvement or design efforts with customer requirements. CTQ represent the product or service characteristics that are defined by the customer (internal or external). They may include the upper and lower specification limits or any other factors related to the product or service. A CTQ usually must be interpreted from a qualitative customer statement to an actionable, quantitative business specification. Putting it simply, CTQ are what the customer expects of a product - the needs of the customer. The customer may often express these needs quite well but it is up to the business to convert those needs to measurable terms.

Levels

From a business perspective, predictable process performance is a key aspect of process capability.
Today most companies function at four sigma - tolerating 6.210 defects per 1 million opportunities. Operating at the highest level six sigma allows only 3.4 defects per million opportunities and statistically ensures that 99.9997% of all products produced in a process are of acceptable quality.

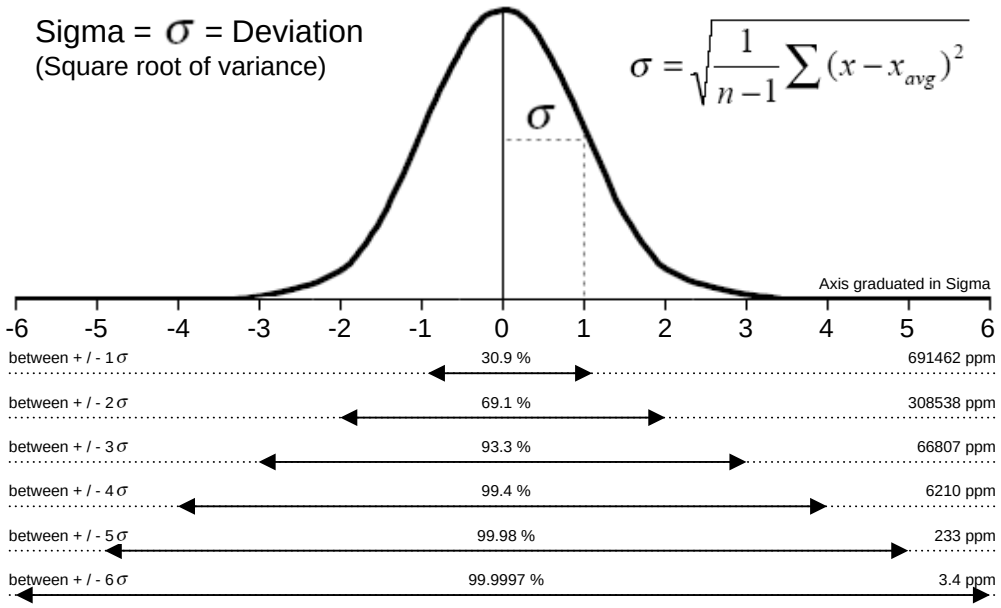

Figure 8 Levels Of Six Sigma

It is very important to understand, that Six Sigma is a performance target that applies to what is referred to in Six Sigma parlance as a single Critical-To-Quality characteristic. It is not a performance target that applies to the total product.
If a given process fails to meet these criteria, it is re-analyzed, altered and tested to find out if there are any improvements. If no improvement is found, the process is re-analyzed, altered and tested again.
This cycle is repeated until the responsibility persons see an improvement. Once an improvement is found, it must documented and the knowledge is spread across other units in the company so they can implement this new process and reduce their "Defects per Million Opportunities".

Responsibilities

For successfully implementing Six Sigma, a complete and well-connected infrastructure, defined responsibilities and process flows are necessary.
To coordinate these informations, daily updated project overviews must be available. (for examples see the spreadsheet "Six Sigma Project Worksheet")

Infrastructure

The infrastructure includes a Core Team, Champion, Master Black Belt, Black Belt, Green Belt, Yellow Belt and an incentive system.

Core Team

The Core Team defines and reviews Six Sigma projects progress and acts as the political leader, removing the barriers for the project teams.
Six Sigma involves changing major business value streams that cut across organizational barriers. It is the means by which the organizations strategic goals are to be achieved. Top management commitment and involvement are critical to Six Sigma implementation.
The Core Team is formed by the management. Its main responsibility is selecting high financial leverage projects, derived from the organization strategic plan. While the projects are progressing, the team regularly reviews the projects.
To understand the Six Sigma approach, a two-day (leadership) training program could use as a foundation selected topics from the list below:

- Six Sigma overview and implementation
- Knowledge-centered activity focus and process improvement
- Overview of descriptive statistics and experimentation
- Understanding the 10 Six Sigma Success Factors and how to deploy them throughout your organization

Sponsor

A Sponsor defines the strategic plan for the organization and is the leader for the whole administrative and financial management. In most cases the sponsor is the commissioner and manager inside the customer organization.

Champion

A Champion is used to provide the program management. They support projects, candidate selections and handle any administrative, reporting related activity. They act as an interface to operational leadership.

Master Black Belt

A Master Black Belt acts as a technical coach and provides the knowledge of quality tools for the project team. He is an in-house expert in Six Sigma tools and methodology.
Roles are:

- coach and support projects for results
- develop and deliver Six Sigma training
- assist in project identification
- partner with Six Sigma Champions
- identify and deploy best practices

Two one-week Master Black Belt training sessions can involve the expansion of topics or addition of other related topics not included in the normal Black Belt training. The training of Master Black Belts can also involve the critique of their training of Black Belts.
There is typically one Master Black Belt for every 1,000 employees.

Black Belt

A Black Belt controls the project and is a change agent for institutionalizing the Six Sigma improvements and methodology.
Roles are:

- lead strategic and high impact process improvement projects
- master basic and advanced quality tools and statistics
- deploy techniques of measurement, analysis, improvement and control

An effective approach to the training of the Six Sigma concepts is the use of four weekly modules spread over four months. Between workshop sessions, attendees apply the concepts previously learned to their projects. During this time they also get one-on-one coaching of the application of the techniques to their project.
There are typically 10 to 20 Black Belts per 1,000 employees.

Green Belt

A Green Belt is the technical process expert and change agent who work in an own functional area.
Roles are:

- lead important process improvement projects
- support strategic Black Belt projects
- drive continuous process improvement

Green Belt training sessions that are two weeks long can include topics and exercises as desired from the Black Belt four-week training sessions. There are typically 3 to 5 Green Belts on the project team with the Black Belt. There are typically 300 Green Belts per 1,000 employees.

Yellow Belt

A Yellow Belt is the balance of a company population. He provide information and support the Six Sigma project teams and is a source for future Green Belts.

Incentive System

The incentive system facilitates Six Sigma projects to generate results.

Phases and Responsibilities

The following table shows the typical tasks and responsibilities for each major phase of a typical Six Sigma project.

Phase	Responsibility
Plan Project	
• identify opportunities for improvement	Leadership
• identify sponsors	Leadership
• select team members	Sponsor, Black Belt
• complete project charter	Black Belt
• estimate savings	Black Belt
• draft project charter	Black Belt, Sponsor
• review and accept project charter	Sponsor, Process Owner
Define	
• team training	Black Belt, Green Belt
• review existing process documentation	Team Member, Process Expert
• define project objectives and plan	Team
• present objectives and plan to management	Green Belt
• define and map as-is process	Team, Process Expert
• review and redefine problems (if necessary)	Team
• sponsor review	
Measure	
• identify CTQs	Green Belt
• collect data on subtasks and cycle time	Team
• validate measurement system	Black Belt, Process Operator
Analyze	
• prepare baseline graphs on subtasks and cycle time	Black Belt, Green Belt
• analyze impacts, e.g. subtasks, Analysis of Means (ANOM) and charts	Black Belt, Green Belt
• use subteams to analyze time and value, risk management	Black Belt, Green Belt
• benchmark other companies	Team Member
• discuss subteams preliminary findings	Team
• consolidate subteams analyses and findings	Team
Improve	
• present recommendations to process owners and operators	Sponsor, Team
• review recommendations and formulate pilot	Team, Black Belt
• prepare for improved process pilot	Team, Process Owner
• test improved process and run pilot	Process Operator
• analyze pilot and results	Black Belt, Green Belt
• develop implementation plan	Team, Process Owner
• prepare final presentation	Team
• present final recommendations to management team	Green Belt
Control	
• define control metrics	Black Belt, Green Belt, Process Expert
• develop metrics collection tool	Black Belt
• roll out improved process	Process Owner
• roll out control metrics	Process Owner
• monitor process monthly using control metrics	Process Owner, Black Belt

Table 3 Phases And Responsibilities

Project Process Flow and Responsibilities

The following figure shows the flows and responsibilities for a typical Six Sigma project.

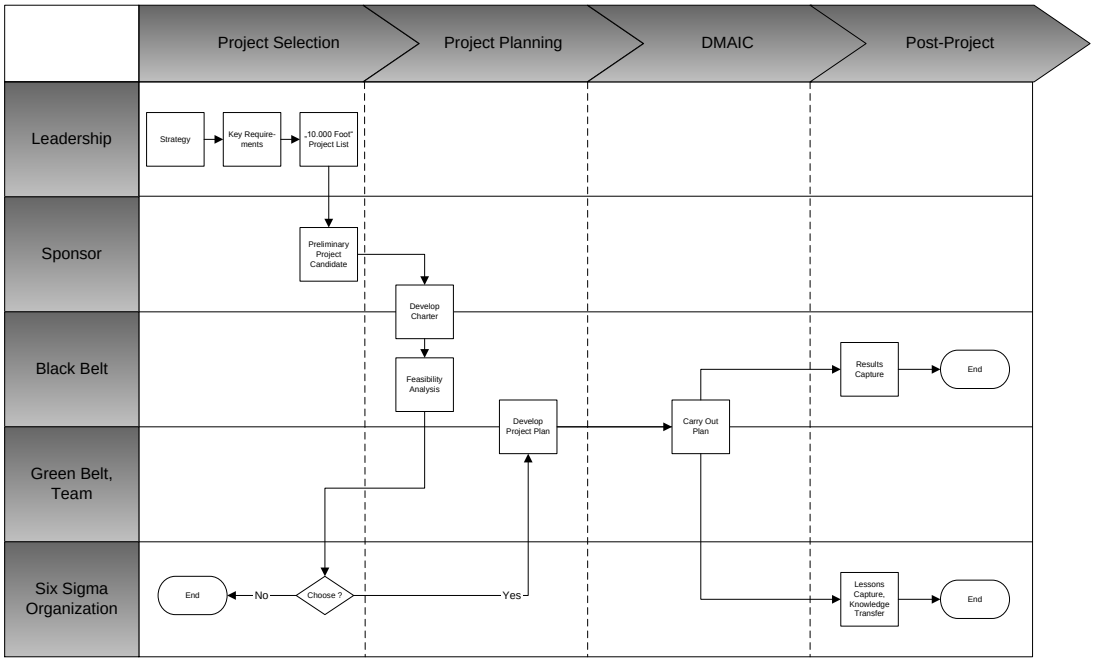

Figure 9 Project Process Flow And Responsibilities

Benefits

Reduced Production Costs
By significantly lowering defect rates, the company can eliminate wastage of materials and inefficient use of labor which is associated with defects. This will reduce the cost of goods sold for each unit of output and therefore add significantly to the companies gross margin or allow the company to sell its products at a lower price in order to generate higher revenues.
In the following table cost examples are shown identified by company, the yearly revenues, the Six Sigma costs (investment) per year and the financial benefits (savings).

Year	Revenue (billion $)	Invested (billion $)	Revenue invested (%)	Savings (billion $)	Revenue savings (%)
Motorola					
1986 - 2001	356.9	not disclosed	-	16	4.5
Allied Signal					
1998	15.1	not disclosed	-	0.5	9.9
General Electric					
1996	79.2	0.2	0.3	0.2	0.2
1997	90.8	0.4	0.4	1.0	1.1
1998	100.5	0.5	0.4	1.3	1.2
1999	111.6	0.6	0.5	2.0	1.8
Honeywell					
1998	23.6	not disclosed	-	0.5	2.2
1999	23.7	not disclosed	-	0.6	2.5
2000	25.0	not disclosed	-	0.7	2.6
Ford					
2000 - 2002	43.9	not disclosed	-	1.0	2.3

Table 4 Production Costs

Reduced Overhead Costs
By significantly lowering defect rates, the company can reduce the amount of time that senior management and middle management spends resolving problems associated with high levels of defects. This also frees up management to focus on more value-added activities.

Improved Customer Satisfaction
By significantly lowering defect rates, the company will be able to consistently ship products to customers which strictly meet the customer specifications and therefore increase customer satisfaction.

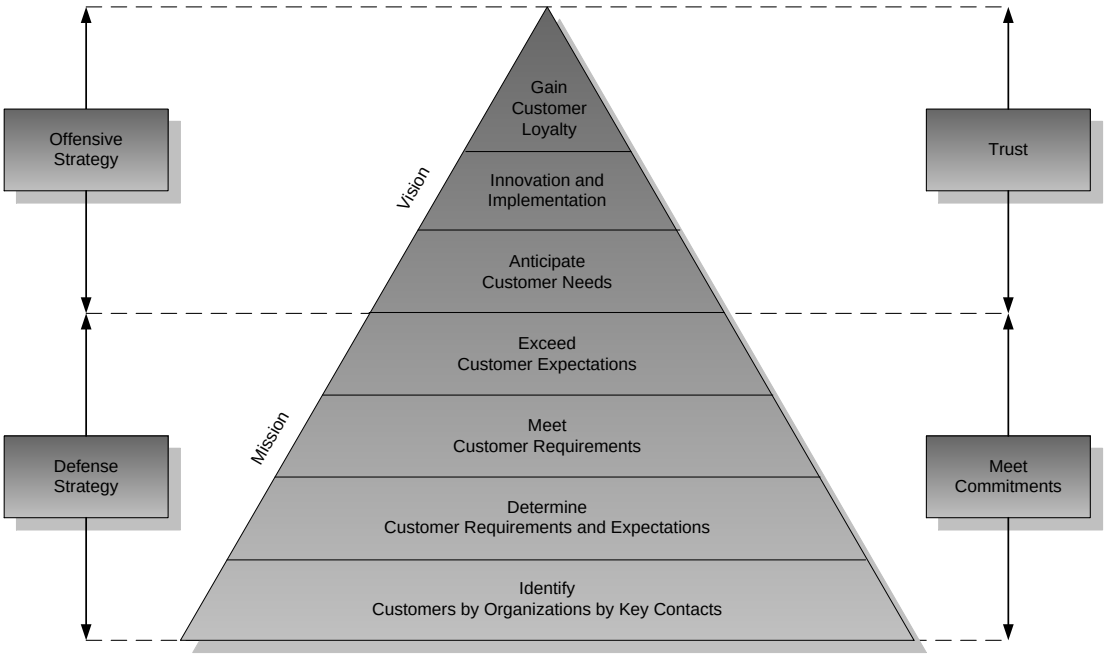

Figure 10 Customer Satisfaction

Increased customer satisfaction reduces the likelihood of losing orders from customers while increasing the likelihood that the customer will place larger orders with the company. This can mean significantly higher revenues for the company.
Furthermore, the cost of acquiring new customers is high so companies that has lower customer turnover will have lower sales and marketing expenses as a percent of total revenue.

Reduced Cycle Times
The longer it takes for inventory to move through the production process, the higher the production costs since slow moving inventory must be moved, stored, counted, retrieved and faces greater risk of becoming damaged or not meeting specifications. However, with Six Sigma, fewer problems arise during a manufacturing process, which means that the process can consistently be completed more quickly and therefore production costs, especially labor costs per unit produced, are lower. In addition to reducing production costs, quicker turnaround times are often a selling point for many customers who want the product delivered as soon as possible.

On-Time-Delivery
A common problem for many companies is a high rate of delayed shipments or deliveries to customers. The variations which can be eliminated in a Six Sigma project can include variations in delivery time. Therefore, Six Sigma can be used to help ensure consistent on-time-delivery.

Greater Ease of Expansion
A company with a significant emphasis on process improvement and elimination of the sources of defects will have a deep understanding of the potential causes of problems in expansion projects, as well as systems in place for measuring and identifying the sources of those problems. Therefore problems are less likely to occur as the company expands its production and if they do occur, they are likely to be resolved more quickly.

Higher Expectations
By aiming the Six Sigma level, it allows the company to set high expectations. Higher expectations themselves can lead to higher performance since they reduce the risk of complacency. Furthermore, Six Sigma programs introduce many new measurements which help to discover and monitor recurring problems and therefore create more of a sense of urgency to get those problems resolved.

Positive Changes to Corporate Culture
Six Sigma is as much about people excellence as it is about technical excellence. Employees often wonder how they are going to solve a difficult problem, but when they are given the tools to ask the right questions, measure the right things, correlate a problem with a solution and plan a course of action, they can find solutions to the problem more easily. Therefore, with Six Sigma, the corporate culture shifts to one that includes a methodical approach to problem solving and a pro-active attitude among employees. Successful Six Sigma programs also contribute to the overall sense of pride of the company's employees.
Six Sigma transforms the way a company thinks and works on major business issues:

- Process design: Designing production processes to have the best and most consistent outcomes from the beginning.
- Variable investigation: conducting studies to identify what the variables cause variation and how they interact with each other.
- Analysis and reasoning: using facts and data to find the root causes of variations, instead of educated guesses or intuition.
- Focus on process improvement: focusing on process improvement as key to excellence in quality.
- Pro-activeness: Encouraging people to be pro-active about preventing potential problems instead of waiting for problems to occur.
- Broad participation in problem solving: getting more people involved in finding causes and solutions for problems.

- Knowledge sharing: learning and sharing new knowledge in terms of best practices to speed up overall improvement.
- Goal setting: aiming at stretch goals, instead of "good enough" targets, so that the company is constantly striving for improvement.
- Suppliers: cost is not the only criteria for vendor evaluation, but relative capability to consistently provide quality materials with the shortest lead time.

Links

As the inventor of the Six Sigma methodology, Motorola can lay claim to the most long-standing and time-tested experiences in the industry. As a part of this company, the Motorola University offers a wide range of Six Sigma services to help organizations of all shapes and sizes meet their objectives for continuous business process improvement.

Homepage: http://mu.motorola.com

The Juran Institute was founded by Dr. Juran in 1979. Today the Institute is the recognized leader in Quality Management and Improvement, Six Sigma deployment and Design for Six Sigma initiatives. Juran Institute provides training, consulting and deployment services. The goal is to make a organization self-sufficient through knowledge transfer in an accelerated approach.

Homepage: http://www.juran.com

Envisioned in January and launched in May 2000, iSixSigma was created to meet the needs of business professionals around the world in search of proven methodologies for improving process efficiency, implementing data driven decision making and focusing on customer needs. iSixSigma LLC is an independent company, privately owned, funded and operated by quality professionals.

Homepage: http://www.isixsigma.com

Microsoft Corporation offers a tool for Six Sigma, which is an integrated set of products and services customized for Six Sigma practitioners. This tool can help a project team manage a large number of projects, more easily track their financial impact, optimize and track resources and electronically share knowledge gathered across the organization.

Homepage: http://www.microsoft.com/solutions/sixsigma
http://www.microsoft.com/technet/itsolutions/techguide/mso/sixsigma/default.mspx

For more than 30 years, Minitab has delivered software and services for quality improvement, education and

research. Thousands of distinguished companies in more than 80 countries around the world have used Minitab products for their quality improvement and Six Sigma projects.

Homepage: http://www.minitab.com/products/minitab/default.aspx

iGrafx is a provider of business process analysis software solutions for flexibly designing, optimizing and implementing more productive processes across the company, e.g. FlowCharter, Process and Process for Six Sigma. The tools can be used to improve deployment and product upgrade capabilities by using a central process knowledge repository.

Homepage: http://www.igrafx.com/solutions

IDS Scheer is a provider of solutions for business process excellence, especially in a Six Sigma environment. The ARIS Business Process Framework offers a complete portfolio for the business lifecycle, including design, implementation, execution and continuous improvement.

Homepage: http://www.aris.com

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