SIX SIGMA

What is Sigma (σ)?

- The term **'Sigma'** taken from the Greek alphabet, is used to designate the distribution or spread about the mean (average) of any parameter of product, process or procedure.
- **Six Sigma** is a system of practices originally developed by Motorola to systematically improve processes by eliminating defects.
- The process was pioneered by Bill Smith at Motorola in 1986 and was originally defined as a metric for measuring defects and improving quality, and a methodology to reduce defect levels below 3.4 defects per one million opportunities (DPMO).

What is Six Sigma (6σ)

- Level of process performance equivalent to producing only 3.4 parts per million defects or has a yield of 99.9997%.
- Six Sigma has evolved over the last two decades and so has its definition. Six Sigma has literal, conceptual, and practical definitions.
- Six Sigma can be taken at three different levels:
  - As a metric
  - As a methodology
  - As a management system

Essentially, Six Sigma is all three at the same time.

Six Sigma as a Metric

- The term "Sigma" is often used as a scale for levels of "goodness" or quality.
- Using this scale, "Six Sigma" equates to 3.4 defects per one million opportunities (DPMO).
- Therefore, Six Sigma started as a defect reduction effort in manufacturing and was then applied to other business processes for the same purpose.

Six Sigma as a Methodology

- As Six Sigma has evolved, there has been less emphasis on the literal definition of 3.4 DPMO.
- Six Sigma is a business improvement methodology that focuses an organization on:
  - Understanding and managing customer requirements
  - Aligning key business processes to achieve those requirements
  - Utilizing rigorous data analysis to minimize variation in those processes
  - Driving rapid and sustainable improvement to business processes
- Structured problem solving techniques and roadmap
- Two primary sub-methodologies in Six Sigma
  - DMAIC: **D**efine-**M**easure-**A**nalyze-**I**mprove-**C**ontrol-- Tool for incremental process improvement of **existing** processes
  - DMADV: **D**efine-**M**easure-**A**nalyze-**D**esign-**V**erify-- Methodology for producing **new** processes

SUCCESSFUL APPLICATIONS OF SIX SIGMA MANAGEMENT

- Asea-Brown-Boveri
- AT&T
- General Electric
- Motorola
- Seagate
- Texas Instruments
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- Tata Motors
- TVS group
- Godrej
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TIMELINE FOR SIX SIGMA MANAGEMENT

1978 Motorola's TV and Car radio quality were found to be low on quality. Both of these products were later abandoned or sold by Motorola to other corporations. TVs produced were of higher quality than those produced when Motorola ran the facility, even though essentially the same workers were producing the TVs. Apparently, it was management that made a big difference.

1981 Motorola's chairman, Bob Galvin, decided after meeting with customers and studying Motorola's quality effort that the company would now be focused on reducing manufacturing defects by tenfold within a 5-year period. Also, reducing total cycle time was a key component of the effort.

1987 Motorola met its goal of a tenfold reduction in defects. Unfortunately, some major competitors had improved faster in that time period. The goal of tenfold improvement was a good goal but 5 years was not fast enough.

1987 Motorola top management raised the "bar" to a tenfold improvement every 2 years, 100-fold every 4 years, and a target of 3.4 defects per million was set for 5 years. The name *Six Sigma* was given to this target and Sigma became a metric that was equated to defects per million opportunities (DPMO). In addition, the total cycle time reduction goal of 50% was mandated as a synergistic part of Six Sigma.

Late 1980s Motorola top management realized that reducing defects and cycle time in their internal processes would reduce "concept to market cycle time," thus reducing cost and reaction time to changing markets and technology, and would reduce failures in the field, resulting in increased customer satisfaction and decreased warranty costs.

1988 Motorola is awarded the Malcolm Baldrige National Quality Award in its inaugural year. One of the duties of an award recipient is to share its quality story and approach with others throughout the United States.

1989–93 Texas Instruments, ABB, and Kodak join Motorola to support the Six Sigma Institute.

Mid-1990s General Electric and Allied Signal popularized the Six Sigma approach by attributing their increase in market capitalization to the results attained by their drive for Six Sigma quality.

BENEFITS OF SIX SIGMA MANAGEMENT

Benefits to an organization are gained through the continuous reduction of variation and centering of processes on their nominal levels. The benefits are:

- Improved process flows
- Reduced total defects
- Improved communication
- Reduced cycle times
- Enhanced knowledge
- Higher levels of customer and employee satisfaction
- Increased productivity
- Decreased work in progress (WIP)
- Decreased inventory
- Improved capacity and output
- Increased quality and reliability
- Decreased unit costs
- Increased price flexibility
- Decreased time to market
- Faster delivery time
- Conversion of improvements into hard currency

Benefits to stakeholders are a by-product of the organizational benefits. The benefits to stake-holders include:

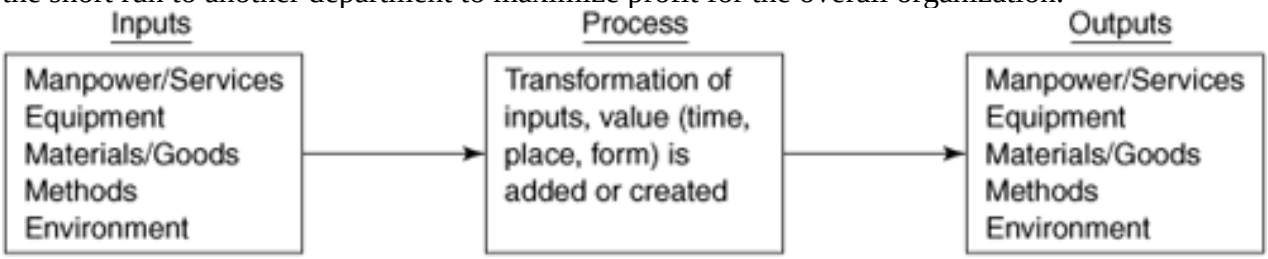
- Stockholders receive more profit due to decreased costs and increased revenues.
- Customers are delighted with products and services.
- Employees experience higher morale and more satisfaction from joy in work.
- Suppliers enjoy a secure source of business.

PROCESS BASICS (VOICE OF THE PROCESS)

Definition of a Process

A **process** is a collection of interacting components that transform inputs into outputs toward a common aim, called a *mission statement*.

It is the job of management to optimize the entire process toward its aim. For example, a particular department in an organization may have to give up resources in the short run to another department to maximize profit for the overall organization.



The transformation, involves the addition or creation of value in one of three aspects: time, place, or form.

An output has "time value" if it is available when needed by a user.

For example, you have food when you are hungry, or material inputs are ready on schedule.

An output has "place value" if it is available where needed by a user.

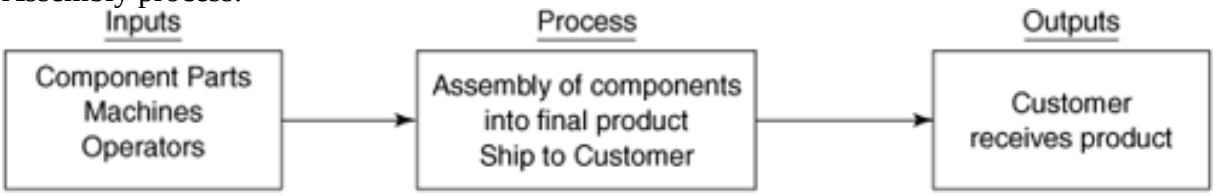
For example, gas is in your tank (not in an oil field), or wood chips are in a paper mill (not in a truck).

An output has "form value" if it is available in the form needed by a user.

For example, bread is sliced so it can fit in a toaster, or paper has three holes so it can be placed in a binder.

Processes include production processes, administration, sales, service, human resources, training, maintenance, paper flows, interdepartmental communication, and vendor relations

Assembly process:



An organization is a multiplicity of micro sub processes.

All processes have customers and suppliers; these customers and suppliers can be internal or external to the organization.

A customer can be an end user or the next operation downstream.

The customer does not even have to be a human; it could be a machine.

A supplier could be another firm supplying subassemblies or services, or the prior operation upstream.

Variation of the Process

The outputs from all processes and their component parts may be measured; the measurements invariably vary over time and create a distribution of measurements.
The distribution of measurements of the outputs from a process over time is called the **Voice of the Process (VoP)**.

Consider a process such as getting ready for class in the morning. Some days you are busier than usual, and on other days you have less to do than usual. Your process varies from day to day to some degree. This is **common variation**.

However, if a construction project begins on the highway you take to college, you might drastically alter your morning routine. This would be **special variation** because it would have been caused by a change external to your driving to college process. If the traffic patterns had remained as they were, your process would have continued on its former path of common variation.

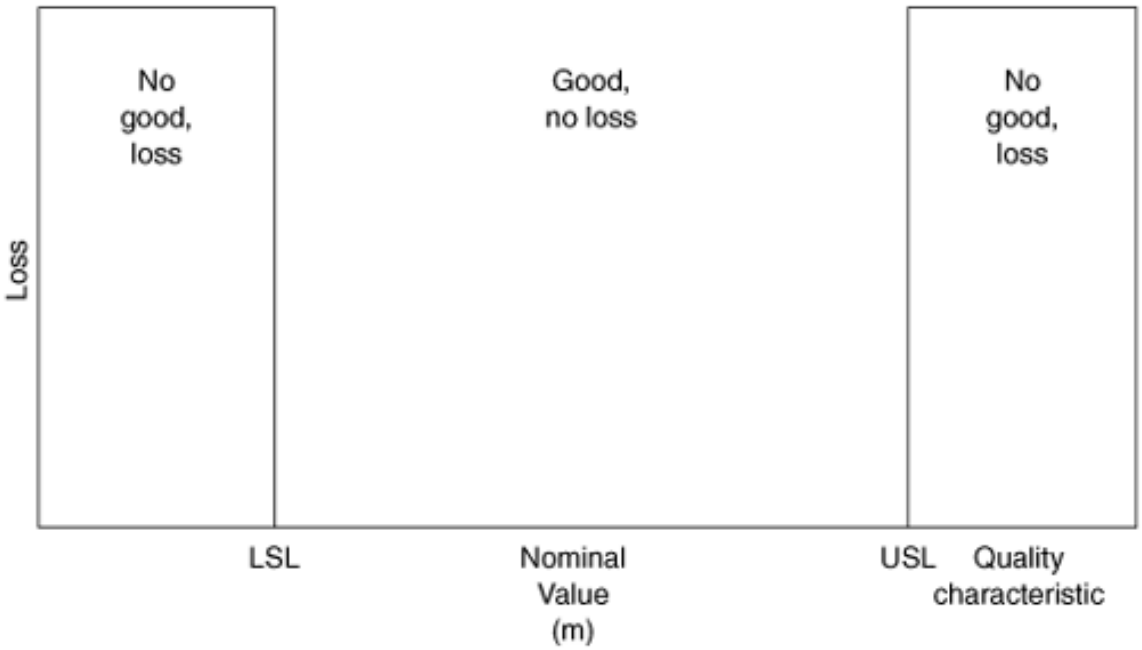
Variation is well understood by **Process Capability**.

DEFINITION OF QUALITY (VOICE OF THE CUSTOMER)

Goalpost View of Quality

Quality meant "conformance to valid customer requirements." That is, as long as an output fell within acceptable limits, called **specification limits**, around a desired value, called the **nominal value** (denoted by *m*), or target value, it was deemed conforming, good, or acceptable. We refer to this as the "goalpost" definition of quality. The nominal value and specification limits are set based on the perceived needs and wants of customers. Specification limits are called the **Voice of the Customer (VoC)**.

Figure shows the goalpost view of losses arising from deviations from the nominal value. That is, losses are minimum until the **lower specification limit (LSL)** or **upper specification limit (USL)** is reached. Then suddenly, they increase and remain constant, regardless of the magnitude of the deviation from the nominal value.



An individual unit of product or service is considered to conform to a specification if it is at or inside the boundary (USL or LSL) or boundaries (USL and LSL).

Individual unit specifications are made up of a nominal value and an acceptable tolerance from nominal. The nominal value is the desired value for process performance mandated by the customer's needs and/or wants. The tolerance is an allowable departure from a nominal value established by designers that is deemed nonharmful to the desired functioning of the product or service.
Specification limits are the boundaries created by adding and/or subtracting tolerances from a nominal value:

USL = upper specification limit = nominal + tolerance and
LSL = lower specification limit = nominal − tolerance.

A **service example** of the goalpost view of quality and specification limits can be seen in a monthly accounting report that must be completed in 7 days (nominal) but no earlier than 4 days (LSL—not all the necessary data will be available) and no later than 10 days (USL—the due date for the report in the board meeting). Therefore, the "Voice of the Customer" is that the report must be completed ideally in 7 days but no sooner than 4 days and no later than 10 days.

A **manufacturing example** of the goalpost view of quality and specification limits is to produce stainless steel ball bearings 25 mm in diameter (the nominal value). A tolerance of 5 mm above or below 25 mm is acceptable to purchasers. Thus, if a ball bearing diameter measures between 20 mm and 30 mm (inclusive), it is deemed conforming to specifications. It does not matter whether the diameter of a ball bearing is 21 mm or 29 mm; they are both conforming units. If a ball bearing diameter measures less than 20 mm or more than 30 mm, it is deemed not conforming to specifications and is scrapped at a cost of Rs.10.00 per ball bearing. Therefore, the "Voice of the Customer" states that the diameters of the ball bearings must be between 20 mm and 30 mm, inclusive, with an ideal diameter of 25 mm.

D*EFINITIONS OF* **S***IX* **S***IGMA* **M***ANAGEMENT* **(R***ELATIONSHIP* **B***ETWEEN* **V***OC AND* **V***OP***)**

Nontechnical Definitions of Six Sigma

Six Sigma management is the relentless and rigorous pursuit of the reduction of variation in all critical processes to achieve continuous and breakthrough improvements that impact the bottom line and/or top line of the organization and increase customer satisfaction.

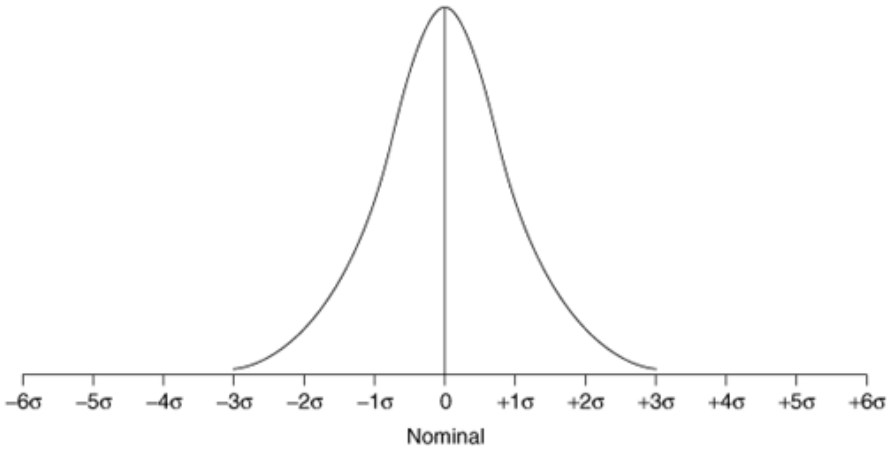
Six Sigma management is that it is an organizational initiative designed to create manufacturing, service, and administrative processes that produce a high rate of sustained improvement in both defect reduction and cycle time

e.g., when Motorola began its effort, the rate chosen was a tenfold reduction in defects in 2 years, along with a 50% reduction in cycle.

For example, a bank takes 60 days on average to process a loan with a 10% rework rate in 2000. In a Six Sigma organization, the bank should take no longer than 30 days on average to process a loan with a 1% error rate in 2002 and no more than 15 days on average to process a loan with a 0.10% error rate by 2004. Clearly, this requires a dramatically improved/innovated loan process.

Technical Definition of Six Sigma Management

The Normal Distribution. The term *Six Sigma* is derived from the normal distribution used in statistics.



Normal Distribution with Mean ($\mu = 0$) and Standard Deviation ($\sigma = 1$)

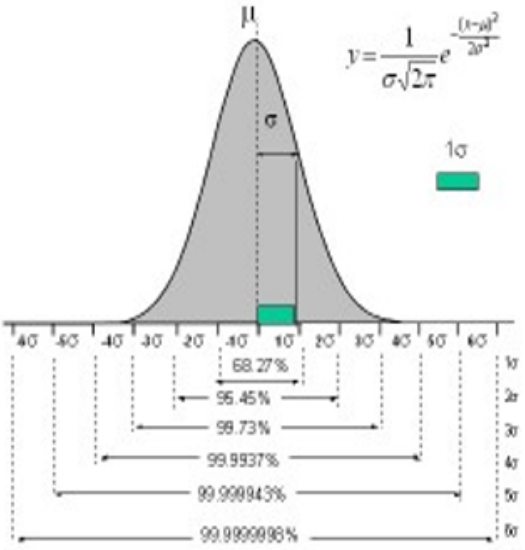
Mean or *average* represents the typical value of the output of a process. *Standard deviation* represents the variability of the output of a process.

In a normal distribution, the interval created by the mean plus or minus 2 standard deviations contains 95.44% of the data points, or 45,600 data points per million (sometimes called *parts per million*, denoted ppm) are outside of the area created by the mean plus or minus 2 standard deviations [(1.00 − 0.9544 = 0.0456) × 1,000,000 = 45,600].

In a normal distribution, the interval created by the mean plus or minus 3 standard deviations contains 99.73% of the data, or 2,700 ppm are outside of the area created by the mean plus or minus 3 standard deviations [(1.00 − 0.9973 = 0.0027) × 1,000,000 = 2,700].

In a normal distribution, the interval created by the mean plus or minus 6 standard deviations contains 99.9999998% of the data, or 2 data points per billion data points (ppb) outside of the area created by the mean plus or minus 6 standard deviations.

Sigma levels



Sigma Level	Percent Variation	Defects per million (Short term)	Defects per million (Long term 1.5 Sigma shift)
± 1σ	68.26	317400	697700
± 2σ	95.46	45400	308733
± 3σ	99.73	2700	66803
± 4σ	99.9937	63	6200
± 5σ	99.999943	0.57	233
± 6σ	99.9999998	0.002	3.4

ROLES AND RESPONSIBILITIES IN SIX SIGMA MANAGEMENT

- Senior executive (CEO or president),
- Executive committee member,
- Champion,
- Master black belt,
- Black belt,
- Green belt, and
- Process owner.

Senior Executive

- Provides the impetus, direction, and alignment necessary for Six Sigma's ultimate success.
- Should:
  - Study Six Sigma management.
  - Lead the executive committee in linking objectives to Six Sigma projects.
  - Participate on appropriate Six Sigma project teams.
  - Maintain an overview of the system to avoid suboptimization.
  - Maintain a long-term view.
  - Act as a liaison to Dalal street, explaining the long-term advantages of Six Sigma management, if appropriate.
  - Constantly and consistently, publicly and privately champion Six Sigma management.
  - Conduct presidential tollgate reviews of Six Sigma projects.

Executive Committee Member

- Members are the top management of an organization.
- Should operate at the same level of commitment for Six Sigma management as the senior executive.
- Should:
  - Study Six Sigma management.
  - Deploy Six Sigma throughout the organization.
  - Prioritize and manage the Six Sigma project portfolio.
  - Assign champions, black belts, and green belts to Six Sigma projects.
  - Conduct reviews of Six Sigma projects with the senior executive and within their own areas of control.
  - Improve the Six Sigma process.
  - Remove barriers to Six Sigma management.
  - Provide resources for Six Sigma management.

Champion

- **Champions** take a very active sponsorship and leadership role in conducting and implementing Six Sigma projects.
- A champion should be a member of the executive committee.
- Champions work closely with the executive committee, project leaders (called *black belts*) assigned to their projects, and the master black belts (supervisors of black belts) overseeing their projects.
- A champion has the following responsibilities:
  - Identify the project on the organizational dashboard

• Develop and negotiate the project objective with the executive committee.
• Select a black belt (or a green belt for a simple project) to lead the project team.
• Remove any political barriers or resource constraints to the Six Sigma project (run interference).
• Provide an ongoing communication link between the project team(s) and the executive committee.
• Help team members manage their resources and stay within the budget.
• Review the progress of the project with respect to the project's timetable.
• Keep the team focused on the project by providing direction and guidance.
• Assure that Six Sigma methods and tools are being used in the project.
• Participate in the tollgate review process for their Six Sigma projects.

Master Black Belt

- A **master black belt** takes a leadership role as keeper of the Six Sigma process and advisor to executives or business unit managers, leveraging his/her skills with projects that are led by black belts and green belts.
- Master black belt reports directly to a senior executive or a business unit manager.
- A master black belt has successfully led many teams through complex Six Sigma projects.
- He or she is a proven change agent, leader, facilitator, and technical expert in Six Sigma management.
- Ideally, master black belts are selected from the black belts within an organization; however, sometimes circumstances require hiring master black belts external to the organization.
- Master black belts have the following responsibilities:
  • Counsel senior executives and business unit managers on Six Sigma management.
  • Identify, prioritize and coordinate Six Sigma projects on a dashboard (see Chapter 3).
  • Continually improve and innovate the organization's Six Sigma process.
  • Apply Six Sigma across both operations and transactions-based processes, such as sales, human resources, information technology, facility management, call centers, finance, etc.
  • Teach black belts and green belts Six Sigma theory, tools, and methods.
  • Mentor black belts and green belts.
  Senior master black belts have 10 years of ongoing leadership experience and have worked extensively with mentoring the organizational leaders on Six Sigma management.

Black Belt

- A **black belt** is a full-time change agent and improvement leader who may not be an expert in the process under study.
- The ideal candidate for a black belt is an individual who possesses the following characteristics:
  • Has technical and managerial process improvement/innovation skills.
  • Has a passion for statistics and systems theory.
  • Understands the psychology of individuals and teams.

- Understands the Plan-Do-Study-Act (PDSA) cycle and learning.
- Has excellent communication and writing skills.
- Works well in a team format.
- Can manage meetings.
- Has a pleasant personality and is fun to work with.
- Communicates in the language of the client and does not use technical jargon.
- Is not intimidated by upper management.
- Has a customer focus.

- The responsibilities of a black belt include:
  - Help to prepare a project objective.
  - Communicate with the champion and process owner about progress of the project.
  - Lead the Six Sigma project team.
  - Schedule meetings and coordinate logistics.
  - Help team members design and analyze experiments.
  - Provide training in tools and team functions to project team members.
  - Help team members prepare for reviews by the champion and executive committee.
  - Recommend additional Six Sigma projects from the dashboard.
  - Coach green belts leading projects limited in scope.

Green Belt

- A **green belt** is an individual who works on projects part time (25%), either as a team member for complex projects or as a project leader for simpler projects.
- Green belts are the "work horses" of Six Sigma projects.
- Green belt certification is a critical prerequisite for advancement into upper management in a Six Sigma organization.
- Green belts leading simpler projects have the following responsibilities:
  - Define the project objective.
  - Review the project objective with the project's champion.
  - Select the team members for the project.
  - Communicate with the champion, master black belt, black belt, and process owner throughout all stages of the project.
  - Facilitate the team through all phases of the project.
  - Schedule meetings and coordinate logistics.
  - Analyze data through all phases of the project.
  - Train team members in the use of Six Sigma tools and methods through all phases of the project.

In complicated Six Sigma projects, green belts work closely with the team leader (black belt) to keep the team functioning and progressing through the various stages of the Six Sigma project.

Supervision Ratios for Six Sigma Belts

Certification level	**Percentage of organization needing certification level**	**Supervision ratios**
Master Black Belt (MBB)	1% of organization	An MBB can mentor about 10 BB at a time, but if the MBB is skilled and several skilled BBs are available, there can be 1 senior MBB managing many BBs.
Black Belt (BB)	6–12% of organization	A BB can mentor about 4–8 GBs at a time
Green Belt (GB)	25–50% of organization (includes executives as GBs)	

Process Owner

- Manager of a process.
- She or he has responsibility for the process and has the authority to change the process on his or her signature.
- A process owner has the following responsibilities:
  • Be accountable for the best practice methods and output of his or her process.
  • Empower his or her employees to follow and improve best practice methods.
  • Focus the project team on the project objectives.
  • Assist the project team in remaining on schedule.
  • Allocate the resources necessary for the project (people, space, etc.).
  • Accept and manage the improved process after completion of the Six Sigma project.
  • Turn the PDSA cycle for the revised process.
  • Ensure that process objectives and indicators are linked to the organization's mission through the dashboard.
  • Understand how the process works, the capability of the process, and the relationship of the process to other processes in the organization.
  • Participate in the tollgate review process for their Six Sigma project.