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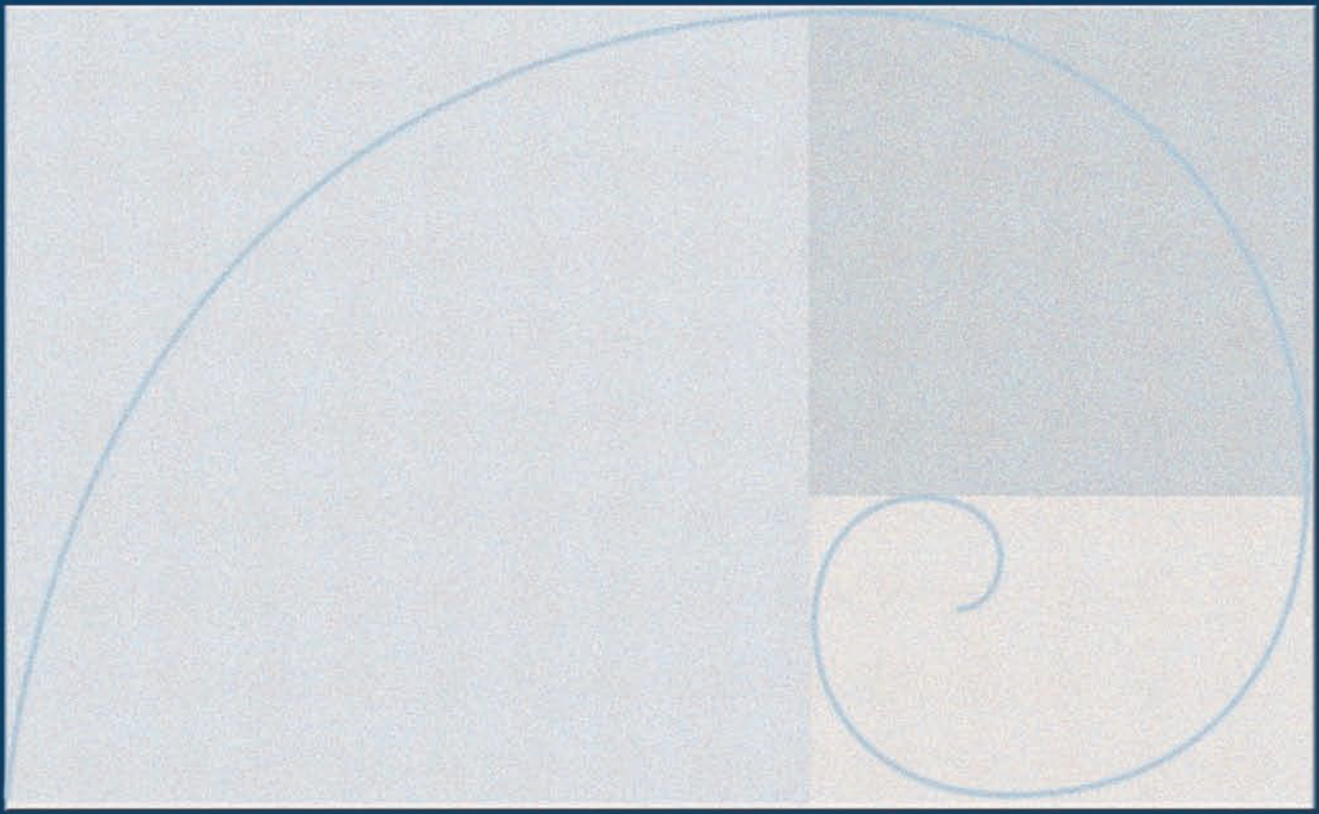
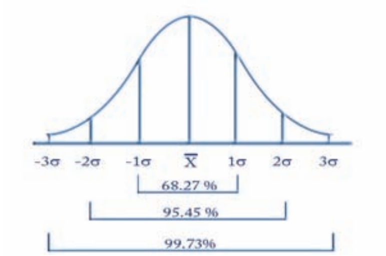
6σ

EG Six Sigma Overview



What Is Six Sigma?

Many attributes and processes in the world exhibit a particular kind of variation described as a **normal distribution.** Consider, for example, heights of men. If you plot the heights of a sample group of men on a graph, you will see that your data tend to cluster around the mean. In other words, most men are closer to the average height, and some few men are at the extremes of very tall or very short.



In a normal distribution,

- 68.27 percent of the values lie within 1 standard deviation (1 sigma) from the mean
- 95.45 percent of the values lie within 2 standard deviations from the mean
- 99.73 percent of the values lie within 3 standard deviations from the mean

As you will remember from your elementary statistics studies, **standard deviation** is a measure of variation, calculated as follows:

$$s = \sqrt{s^2} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n - 1}}$$

Where n = the number of items in the sample, x of 1 through x of n are the individual values for the various items in the sample, and x-bar is the mean (average) of the sample.

Six Sigma gets its name from the Greek letter sigma (σ), the symbol for standard deviation. S ix Sigma is a methodology for reducing variations in a process to a point where there are fewer than **3.4 defects per million opportunities (DPMO).** The Six Sigma methodology was originated by a team led by Bill Smith at Motorola in the 1980s. Since that time, the methodology has been very successfully applied at a great many organizations, notably Motorola, General Electric, Allied Signal (Honeywell), Dupont, and the U. S. Air Force., saving these organizations many billions of dollars. Significant new developments are often, of course, simply a novel combination of existing materials ("There is nothing new under the sun," we're told in Ecclesiastes). This is true of Six Sigma, which combines in a particular methodology a great many quality engineering concepts pioneered earlier in the twentieth century by such people as Shewhart, Deming, Juran, Ishikawa, Ohno, Shingo, Taguchi and Shainin.

The goal of a Six Sigma project is to modify a process so that it will operate at a level of 3.4 defects per million opportunities **over the long term.** In such a situation, of course, 99.99966 percent of the values lie within the upper and lower specification limits. If you look

Six Sigma originated in the manufacturing world and grew out of the science of quality engineering. It makes heavy use of **statistical process control** techniques but is not simply a bag of statistical techniques. Rather, it is a methodology for solving quality problems, and it has applicability far beyond the area of manufacturing in which it was developed.

up the numbers in a normal distribution table, you will find that this is actually the case at the 4.5σ level. However, the early developers of Six Sigma set their sights higher—at a Six Sigma level, which corresponds to about 2 defects per billion opportunities (DPBO)—because of their recognition that processes tend to shift over time, often as much as 1.5 standard deviations. So, it is assumed that if you fix a process so that it operates, initially, at a Six Sigma level, then that process will, over time, shift by 1.5 sigma and operate at the 4.5 sigma (3.4 DPMO) level.

Sigma Scale

The Sigma Scale is used to describe the capability of a process. The higher the Sigma Score, or Z-score, the better.

Sigma (Z) Score	Defects per Million Opportunities (DPMO)
0.5	841,345
1.0	691,462
1.5	500,000
2.0	308,538
2.5	158,655
3.0	66,807
3.5	22,750
4.0	6,210
4.5	1,350
5.0	233
5.5	32
6.0	3.4

W. Edward Deming's Quality Equation: Quality = Results of process/Total cost

Six Sigma is but one of many quality control methodologies. Others include **Total Quality Management (TQM), Theory of Constraints (TOC),** and **Lean.** Essentials of the Theory of Constraints: **First-time yield (FTY)** = the number of good units coming out of a process or step/the number of total units going into the process or step. **Rolled throughput yield (RTY)** is the probability that a unit can pass through all the steps in a process free of defects. This probability is calculated by multiplying the percentage yields of each step. TOC posits that every process has one constraint that is limiting. Six Sigma practitioners often borrow this concept and attempt to identify the most significant limiting factor, addressing it, and then turning to the next most significant factor, in keeping with the goal of **continuous quality improvement.**

The Fundamental Equation of Six Sigma—The Transfer Function

The fundamental equation of Six Sigma is known as the **transfer function.** That equation is $Y = f(X) + \varepsilon$, where Y is the outcome or dependent variable; *X's* are the significant inputs, or independent variables; and the Greek letter epsilon (ε) are inputs that have some effect but that are not really significant. The goal of a Six Sigma project is to identify the vital few inputs and modify those to a point where only 3.4 outputs out of a million are outside the **lower specification limit (LSL)** or **upper specification limit (USL).** According to the heuristic, or rule-of-thumb known as the **Pareto Principle,** first articulated by French-Italian sociologist, economist, and philosopher Vilfredo Pareto (1848–1923), for most processes, 80 percent of the variation in the outputs will be accounted for by 20 percent of the inputs.

The Players in a Six Sigma Project

A Six Sigma project may involve personnel with the following specially designated roles:

Title	Role
Executive leader	C-level individual who throws his or her authority behind Six Sigma implementation in an organization
Process Owner	Manager in charge of the process being fixed, responsible for long-term ownership of new process
Champion	Senior manager who promotes Six Sigma throughout company and in functional groups
Master black belt	Highly experienced Six Sigma practitioner who serves as trainer, mentor, and guide
Black belt	Highly experienced Six Sigma practitioner who works full-time on Six Sigma projects
Green belt	Person who assists black belts part time or who has full responsibility for less complex or essential Six Sigma projects
Yellow belt	Worker from general force given some experience on Six Sigma projects with the aim of creating a Six Sigma culture

A key term used consistently throughout Six Sigma work is **Critical to *X* (or CT*X*)**, where *X* can stand for any element that is critical to the process or to an internal or external customer. A near synonym for CT*X* is **Critical to Quality (CTQ).** In keeping with this mode of description, Six Sigma practioners speak of items that are Critical to Customer Satisfaction or Critical to Cycle Time, and so on.

Title	Role
Designer	Specialist in Design for Six Sigma (DFSS), a methodology employed when a process is so broken that it has to be redesigned from the ground up

In Six Sigma terminology, the meeting that is held at the end of a project phase to present and discuss what was learned and accomplished during the phase is called, variously, a **toll gate,** a **phase review,** a **phase gate review,** or simply a **gate review.**

The Stages in a Six Sigma Project

A Six Sigma project is divided into five stages: **Define, Measure, Analyze, Improve, and Control.** These stages are referred to by the acronym **DMAIC** (pronounced Duh-MAY-ick). Here's what happens at each stage:

Stage	Major Activities
Define. . . the goals of improvement activity.	1. Review/develop the project charter. Use Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Investment (ROI) to make business case. 2. Validate the problem statement and project goals. 3. Validate the financial benefits to be derived from the project. 4. Identify the suppliers, process inputs, process outputs, and internal and external critical-to-quality (CTQ) customer requirements by gathering the voice of the customer (VOC) and the voice of the business (VOB), and create a high-level process map. Use such tools as Affinity Diagrams, CTX Trees, Ishikawa Diagrams, Pareto Analysis graphs, Activity-Based Costing, and SIPOCr charts to gather VOC and VOB. 5. Create a communications plan. 6. Develop a project plan. 7. Complete a gate review.

Stage	Major Activities
Measure. . . current systems; establish valid and reliable metrics to monitor progress toward goal(s).	1. Walk the process. Create more detailed process map or value stream map (VSM). 2. Identify key input, output, and process metrics. 3. Create an XY Matrix to quantify and prioritize the strength of the relationships between the input variables (X's) and the output variables (Y's). 4. Do a Failure Modes and Effects Analysis (FMEA) to study the possible problems in the process and the potential impacts of the problems. 5. Develop data collection plan, including operational definitions. 6. Create a data analysis plan by determining what tools can be used for the types of data that you will collect. 7. Use Measurement System Analysis (MSA)/Gage R&R to validate measurement system. 8. Complete a gate review.

One of the great pioneers of scientific management was Herbert Simon, long a professor at Carnegie-Mellon University. Winner of the Nobel Prize for economics and one of the fathers of artificial intelligence, Simon had a life-long interest in heuristics, or rules of thumb, that allowed for satisfactory outcomes in situations of uncertainty or complexity where optimal solutions are not discoverable. He had a profound intuitive understanding of what has come to be a commonplace idea in contemporary systems thinking--that one cannot know or control for all the significant variables, epecially in complex adaptive situations such as economies or markets or large corporate organizations. One heuristic that Simon articulated was means-ends analysis: One specifies the current state as completely as possible. Then one specifies the goal state. Next one does a gap analysis to delineate the differences between the states. Then one takes incremental steps to reduce those differences. This basic idea underlies much of quality work, and there is really very little difference between Simon's means-ends analysis and the Six Sigma process or Lean-school continuous improvement.

The voice of the customer (VOC) and the voice of the business (VOB) lead process engineers to set particular specification limits for given processes. These are the upper specification limit (USL) and the lower specification limit (LSL). Actual run-time studies of a process are used to establish upper control limits (UCL) and lower control limits (UCL) that determine the capability of the process. Another way to look at Six Sigma is to say that it is a methodology for modifying processes so that over the long term their control limits are such that only 3.4 out of a million events lie outside the specification limits.

All entitities and processes in the world exhibit **variation.** Another way to conceptualize Six Sigma is to think of it as a way to identify **the vital few** factors (inputs or independent variables) that influence variation and to develop the most efficient (cost effective) means for controlling those factors in order to come as close as possible to eliminating that variation altogether.

Stage	Major Activities
Analyze. . . the system to identify gaps between the current and the goal state	1. Evaluate and reduce the variables, using graphical analysis, and other means to identify the vital few that are root causes. Tools can include histograms, 5 whys, box plots, dot plots, interval plots, scatter plots, regression, time series plots, multivariate analysis, hypothesis testing, and analysis of variance (ANOVA). 2. Prioritize root causes. 3. Gather benchmarks. 4. Do gap analysis. 6. Do sampling to collect baseline data. Use run charts and control charts to determine whether process is in control (exhibits only common cause variation). 7. If process is in control, do process capability analysis to determine current capability. If not, remove make plan for removing special causes of variation. 8. Create plan for improving capability. 5. Complete a gate review.

Often, these days, you will hear the terms *Lean* and S*ix Sigma* used together. **Lean** is a Six-Sigma-compatible business philosophy originated at Toyota. Its basic principles include completely mapping **the value stream** and eliminating non-value-added processes; ***jidoka***, or stopping processes in progress whenever a problem, defect, or potential for improvement is observed; **just-in-time (JIT); customer pull** rather than business push; modification of processes to move in single piece continuous flow cadence with ***takt time*** (total work time per shift or day divided by customer demand per shift or day); right-sizing of tools to accord with a continuous flow process; ***kaizen***, or **continuous, incremental improvement;** and ***kaikaku***, or **rapid, radical improvement.**

Lean production systems are contrasted favorably with traditional **batch-and-queue mass manufacturing** in which **Materials Requirement Planning (MRP)** systems dictate the pace of production based upon **economic order quantities (EOQs).** Such systems typically create a great deal of waste of materials, waste of waiting, waste of work in progress (WIP), and waste of final inventory.

Stage	Major Activities
Improve. . . the system and pilot solution	1. Develop potential solutions. 2. Evaluate, select, and optimize potential solution(s), improvements to processes, people, technology, environment, materials, etc., to improve process capability. 3. Develop "To Be" Process Map or Value Stream Map. 4. Use experimentation, such as Design of Experiments (DOE), to plan, conduct, and analyze experiments to test possible solution(s). 5. Implement pilot solution(s). 6. Test solution(s) using correlation and regression analysis. 7. Compare results to baselines. 8. Develop an implementation plan. 9. Calculate financial benefits and document improvement metrics. 10. Complete gate review.
Control. . . the system and pilot solution	1. Finalize improvements to be implemented. Attempt to develop a poka-yoke component of your implementation (mistake-proofing). 2. Develop training plan. 3. Implement training plan. 4. Develop documentation plan. 5. Implement documentation plan. 6. Develop monitoring plan. 7. Implement monitoring plan. 8. Develop response (contingency) plans. 9. Develop plan to align implementation with other systems and structures in company. 10. Verify financial impact. 11. Draft project review document. 12. Complete gate review.