

## Six Sigma

- Our objectives for this section are to introduce the concepts of Six Sigma, including the historical roots. Six Sigma is a relatively new approach to improve processes and we can use it as a framework for much of what we do in our class. I also think that it provides a structured approach that you can use for your project.
- Six Sigma originated at Motorola and was popularized by a handful of other organizations, including GE.
- As the name implies, it has statistical underpinnings. “Sigma” is the Greek letter typically used to denote the standard deviation, a measure of variability. The term is rooted in an area of study called process capability, and has to do with creating and improving processes that are easily capable of meeting customer specifications. The improvement almost always comes by reducing the variability.
- Dr. Edward Popovich, Boca Raton Community Hospital, Boca Raton, FL has defined Six Sigma as follows. “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 ... of the organization and increase customer satisfaction.”
- Although originally developed for manufacturing in the context of tolerance-based specifications, the Six Sigma concept has been operationalized to any process and has come to signify a generic quality level of at most 3.4 defects per million opportunities.

## Benefits of Six Sigma

- Organizations have reported many benefits from implementing Six Sigma, including the following.
  - Improved process flows
  - Reduced total defects
  - Improved communication
  - Enhanced knowledge
  - Higher levels of employee and customer satisfaction
  - Decreased inventory
  - Decreased time to market
  - Better financials
  
- Honeywell Black Belts have achieved \$4.0 Billion in benefits through 4th Quarter '04. Similar financial returns have been claimed by other organizations as well.

## Six Sigma Metrics

- One of the purported benefits of Six Sigma is that it provides a common language to talk about the quality of processes. It allows organizations to measure variation in diverse processes with a common understanding of what the “Sigma measurement” means, regardless of what is measured. It allows comparison of quality achievement across diverse products and processes. It also enables practitioners to know how effective they are in eliminating variation and defects from their processes.
- As a measurement, Six Sigma is becoming a standard of excellence that is understood and practiced widely through much of the business world.
- There are several metrics in Six Sigma. They all are based on the number of defects that are produced. Below are a few of the most common metrics (and definitions). We will concentrate our efforts on dpmo and sigma score.
  - Defect – any mistake or error that is passed on to an internal or external customer
  - Defects per unit (DPU) = number of defects discovered ÷ number of units produced
  - Defects per million opportunities (dpmo) = number of defects discovered ÷ total opportunities for error.

$$\text{dpmo} = \frac{\text{Number of Defects}}{\text{Number of Opportunities}} \times 1,000,000$$

- A sigma score tells us how far away the mean of the processes is from the customer’s specification, measured in standard deviations.

- Example dpmo Computation

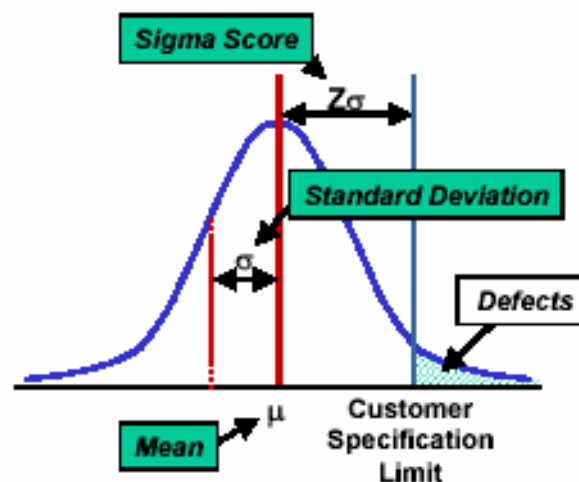
Over the last year 1,054 injections were administered at a clinic. Quality is measured by the proper amount of dosage as well as the correct drug (so for each injection, there are two possible “defects”). In two instances, the incorrect amount was given, and in one case, the wrong drug was given. How many defects per million opportunities (dpmo) did the clinic have for this process over the last year?

- Sigma Score

A sigma score is a calculation that compares the output of a process (“voice of the process”) to customer requirements (“voice of the customer”). The roots for the calculation of sigma score comes from the analysis of continuous process data compared to customer specifications.

- A sigma score is computed as a *z-score* that is calculated based on a specification. For example, consider a process with only an upper specification. The sigma score is the number of standard deviations that the mean  $\mu$  is away from the upper specification limit (USL), which is calculated as one of the following:

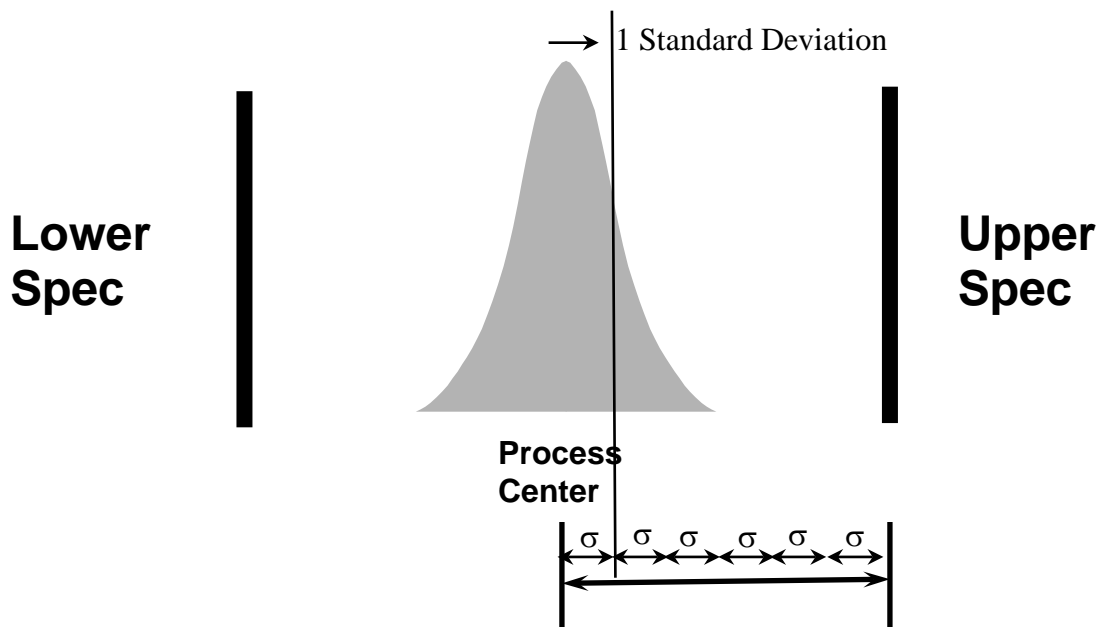
$$Z = \frac{USL - \mu}{\sigma} \quad \text{or} \quad Z = \frac{\mu - LSL}{\sigma} \quad \text{or} \quad Z = \min\left(\frac{USL - \mu}{\sigma}, \frac{\mu - LSL}{\sigma}\right)$$



- Consider an example where in a standardized braking test employed by World Adventures Bicycles, a stopping distance test found a mean of 23.6 ft. and a standard deviation of 2.41 ft. The customer specifies that the maximum stopping distance be 30 ft. What is the sigma score?

## Statistical Definition of Six Sigma

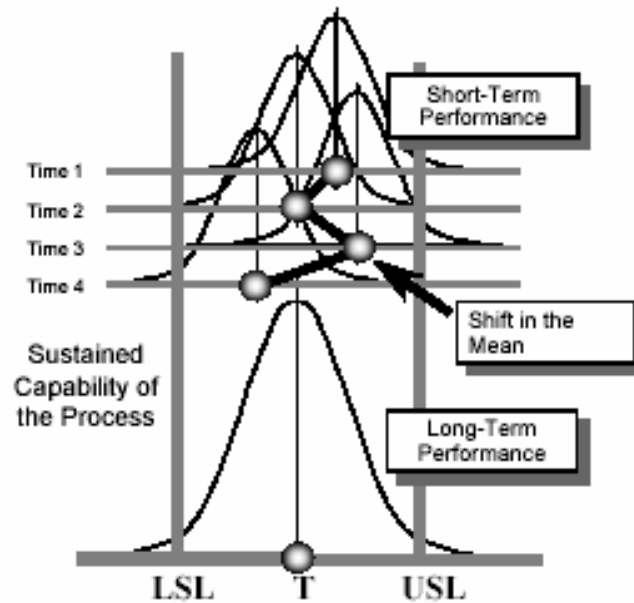
- Six Sigma refers to a process having 6 standard deviations between the process center and the nearest specification limit. In other words, the process has a sigma score of 6.



## Sigma Scores and dpmo

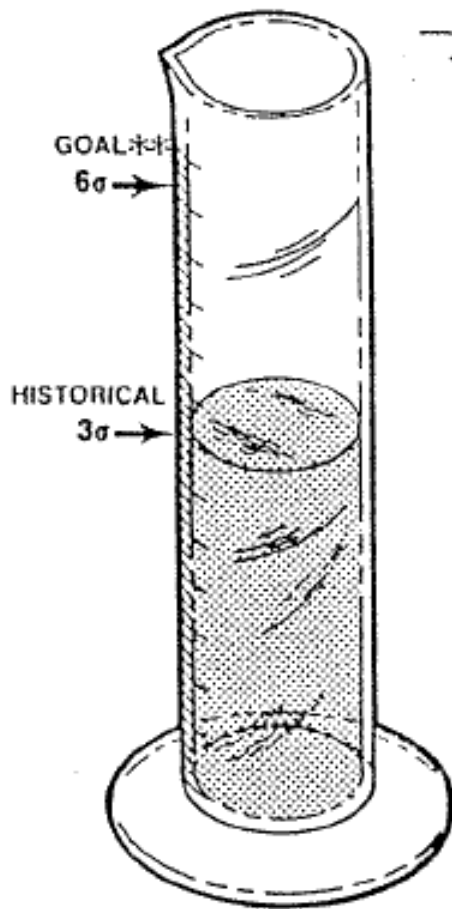
- Some studies of early Six Sigma practitioners found that long-term variation was greater than short-term variation. They concluded that averaged over a number of processes, sigma scores calculated from short-term data were about 1.5 more than those calculated from long-term data.

$$\text{SigmaScore}_{\text{ST}} = \text{SigmaScore}_{\text{LT}} + 1.5$$



- It has become standard practice in the Six Sigma community to report Sigma Score values from short-term data, while reporting dpmo values based on long-term data.
- Hence a process with a sigma score of 6 (i.e., a 6-sigma process) is expected to produce 3.4 dpmo over the long run.

### Picturing Sigma Scores and dpmo\*



PPM	SIGMAS	AREA*	SPELLING*	DISTANCE*
0.000003	7σ	Point of a sewing needle	1 misspelled word in all of the books contained in several large libraries	1/8 of an inch
000.002	6σ	Size of a typical diamond	1 misspelled word in all of the books contained in a small library	4 steps in any direction
0000.57	5σ	Size of the bottom of your telephone	1 misspelled word in a set of encyclopedias	A trip to the local gas station
000,063	4σ	Floor space of a typical living room	1 misspelled word per 30 pages (about one chapter in a book)	45 minutes of freeway driving (in any direction, of course)
002,700	3σ	Floor space of a small hardware store	1.5 misspelled words per page in a book	Coast-to-coast trip**
045,600	2σ	Floor space of a large supermarket	25 misspelled words per page in a book	1 1/2 times around the world
317,400	1σ	Floor space of an average factory	170 misspelled words per page in a book	From here to the moon

\* Generating constants approximated on the basis of known proportions, average and/or best estimates. This particular table does not correct ppm for typical sources of variation. Its sole purpose is to demonstrate "practical quality differences" in relation to "equivalent standard deviation units."

\*\* Unadjusted for typical shifts and drifts in the universal average. Such an adjustment would increase ppm from 0.002 to 3.4

\* From *Production and Inventory Management Journal*, Third Quarter, 1991, p. 24

## Process Improvement through Projects

- Almost universally, structured projects are used to apply Six Sigma.
- All Six Sigma projects have three key characteristics: a problem to be solved, a process in which the problem exists, and one or more measures that quantify the gap to be closed and can be used to monitor progress.
- The key factors in Six Sigma project selection include the following.
  - Financial return, as measured by costs associated with quality and process performance, and impacts on revenues and market share
  - Impact on customers and organizational effectiveness
  - Probability of success
  - Impact on employees
  - Fit to strategy and competitive advantage
- Six Sigma provides a structured problem-solving process that gives all employees a common language and a set of tools to communicate with each other, particularly as members of cross-functional teams. The structured process consists of five phases referred to as DMAIC.
  - Define
  - Measure
  - Analyze
  - Improve
  - Control

## Define

- Describe the problem in operational terms and understand the current state of the process.
- Drill down to a specific problem statement (project scoping).
- Identify customers and critical-to-quality characteristics (CTQs), performance metrics, and cost/revenue implications.

## Measure

- Key data collection questions
  - What questions are we trying to answer?
  - What type of data will we need to answer the question?
  - Where can we find the data?
  - Who can provide the data?
  - How can we collect the data with minimum effort and with minimum chance of error?
- This step requires an evaluation of the measurement system, referred to as MSE.

## Analyze

- Focus on why defects, errors, or excessive variation occur
- Seek the root cause
- 5-Why technique
- Look for relationships between variables
- Test hypotheses about the relationships

## **Improve**

- Idea generation
- Brainstorming
- Evaluation and selection
- Experimentation and verification
- Implementation planning

## **Control**

- Maintain improvements
- Standard operating procedures
- Training
- Checklist or reviews
- Statistical process control charts

## Six Sigma Tools

- Embedded in the DMAIC phases is a set of (mainly statistical) tools. These tools include the following.
  - Elementary statistics
  - Advanced statistics
  - Process Mapping
  - Cause and Effect Diagrams
  - Pareto Charts
  - House of Quality
  - Measurement Systems Analysis
  - Process Capability
  - Multivariate Studies (Correlation and Regression)
  - Hypothesis Testing
  - Failure Mode and Effects Analysis
  - Design of Experiments
  - Control Plans

### Prioritizing Improvement

- An important part of managing the improvement project is to identify the key variables. The phases and tools of Six Sigma help to reduce the potential number of variables down to a manageable set, so that practitioners can focus on what is most important.

