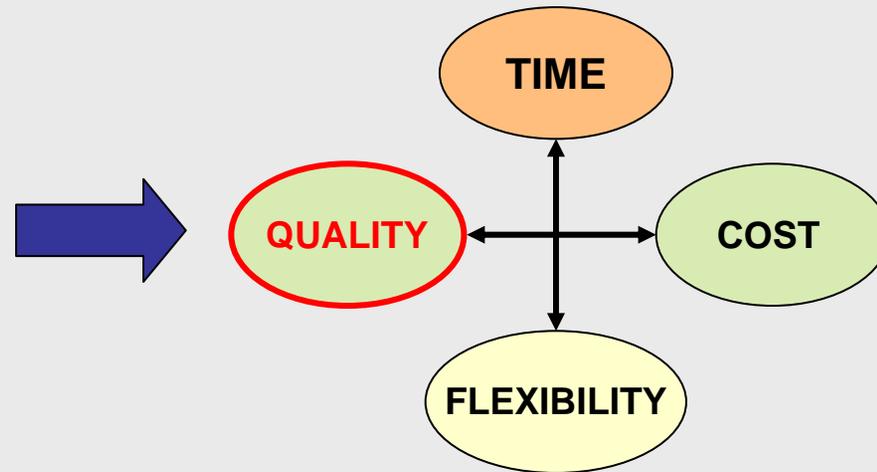


Class 12: Quality Lecture



1. **What are the causes of quality problems on the Greasex line?**
2. **What should Hank Kolb do?**
3. **Overview of Total Quality Management (TQM)**

The 3 Components of TQM

Goal: Quality

1. Fitness to Standards
2. Fitness to Use
3. Fitness to Market

Tools

1. Measurement Systems
2. Education
3. Incentives
4. Organizational Change

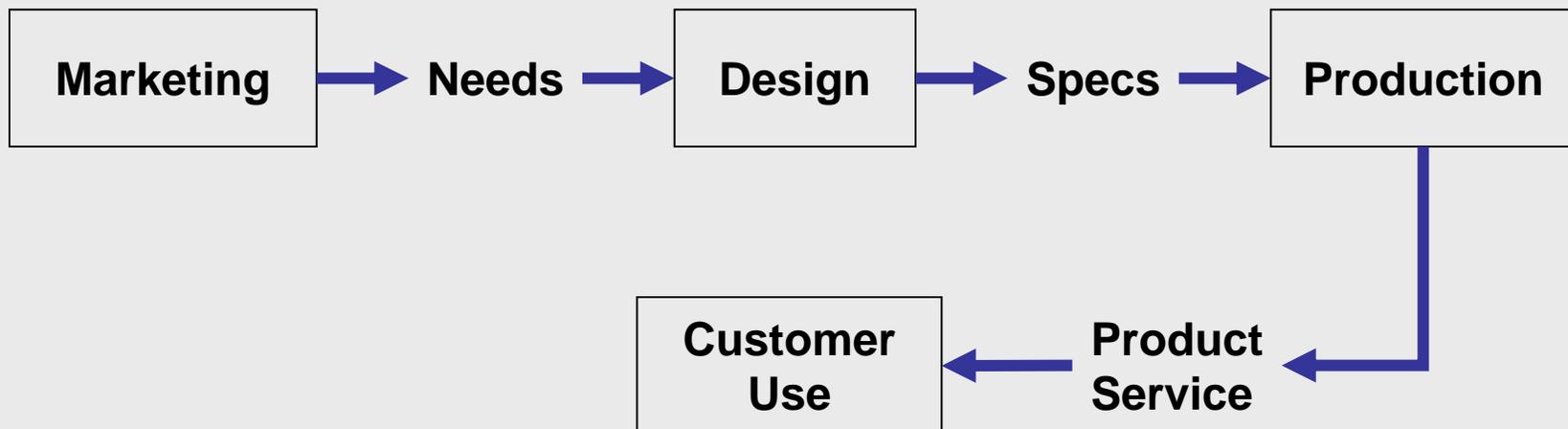
Principles

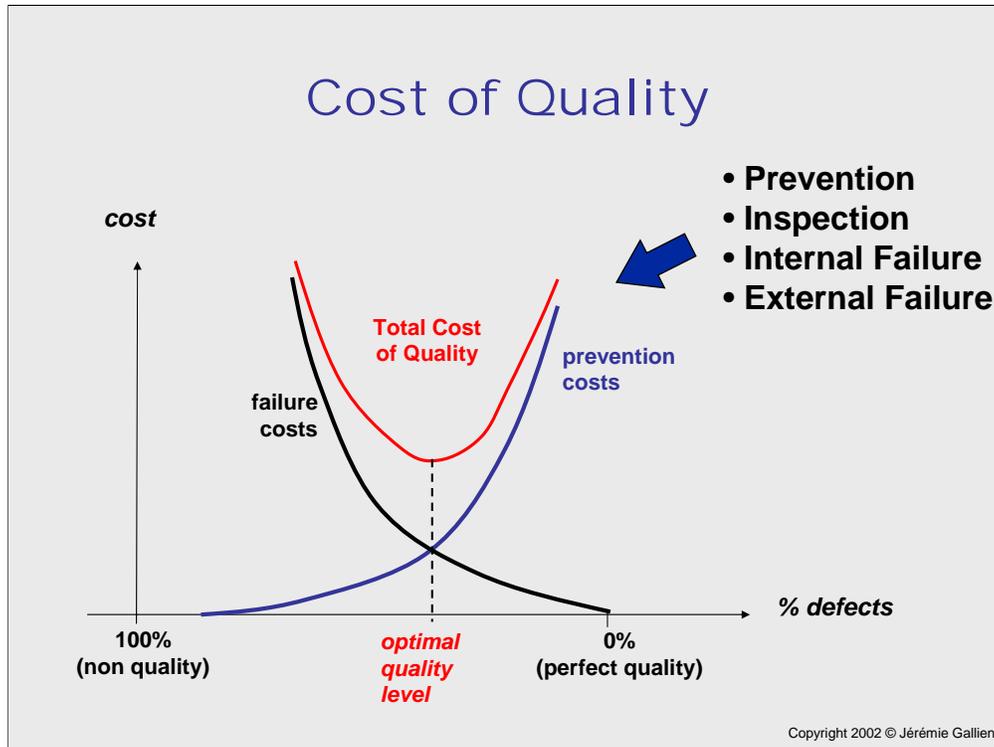
1. Customer First
2. Continuous Improvement
3. Total Participation
4. Societal Learning

What is Quality?

1. Fitness to Standards
2. Fitness to Use
3. Fitness to Market

result from:





•It is important to understand the rationale for this graph, presenting the concept of a (less than perfect) optimal quality level resulting from optimizing the sum of the cost of quality (prevention, inspection, etc.) and the cost of non quality (internal and external failures). It is in particular very relevant in a number of settings where the cost of quality and non-quality is fairly technical in nature (in semiconductor fabs for example, cost components of yield on one hand and atmosphere purity on the other side)

•It is also important to understand the limitations of this reasoning:

- The failure costs are easily underestimated, particularly the external failures (think of brand/reputation, lawsuit settlements...);
- The notion that the cost of quality increases as quality becomes near-perfect is debatable: when quality is very high, there may not be a need for inspection anymore;
- It is also hard to estimate the part of the cost of quality resulting from market response, both positive (impact on brand and desirability of product) and negative (think of the cost for Microsoft of postponing the release of a software product to get some time to work out the bugs: they are clearly making the conscious calculation that this is not worth it);
- This picture is static and for example does not show clearly what the competition's reaction could become (this would drastically increase the cost of non-quality);
- The notion of an accepted level of defects may also have perverse incentive effects and cultural impact on the organization;
- Finally, unlike the EOQ which is a robust model (change in the values of the input data have relatively little effect on the output), this one does not seem to be robust – the cost of non-quality may for example abruptly jump up by several million dollars for a very little reduction in quality level, if that reduction happened to result in a catastrophic external failure (Firestone tires of the Ford explorer, Challenger & Columbia shuttles, etc...).

Industry Benchmark

For this graph of labor hours / vehicle vs. assembly defects for various countries, please see:
"World Assembly Plant Survey 1989" by MIT-IMVP (International Motor Vehicle Program).

Quality and Productivity

$$\text{Productivity} = \frac{\text{Production Output (\$ created)}}{\text{Production Input (\$ consumed)}}$$

Materials + Direct Labor + Indirect Labor + Capital + Service



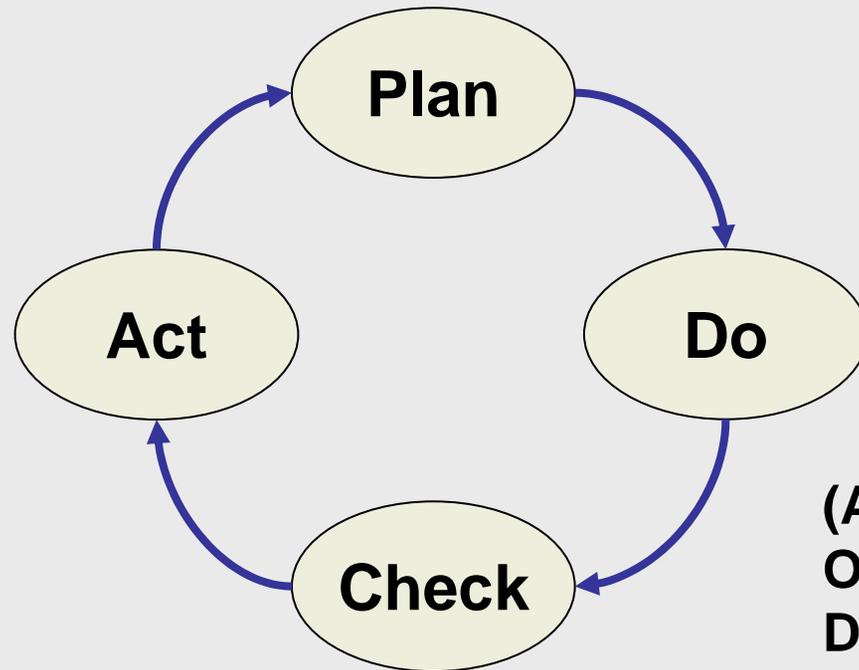
- The point made of this slide (and the previous one with the automotive industry benchmark) is that there is not necessarily an inverse relationship between productivity and quality.
- The numerator of the ratio defining productivity tend to increase with quality, because of positive market response.
- The denominator may actually decrease with higher quality, because all of its terms (materials, direct labobr, etc. as listed above) have a cost component (scrap, rework, etc...) that increases with poor quality.
- This type of reasoning along with the critique of the optimal quality level illustrated in the slide “Cost of Quality” gives rise to the motto “Quality is Free” (the title of a book written by Crosby, one of the recognized american quality “gurus”).

Quote from Dr. W. E. Deming

“The prevailing system of management has destroyed our people.”

Continuous Improvement

Philosophy: “A defect is a treasure”



**(Also known as
Observe - Assess
Design - Intervene)**

→ **“In God We Trust; All Others Bring Data”**

Measurement Systems

W. E. Deming advocated that the SQC tools be known by everybody in the organization:

- 1. Pareto Analysis**
- 2. Process Flow Chart**
- 3. Fishbone Diagrams**
- 4. Histograms**
- 5. Control Charts**
- 6. Scatter Plots**

Statistical Process Control

1. Is the Process ***In Control?***



Control Chart or X bar Chart

2. Is the Process ***Capable?***



SQC Histogram

\bar{X} Charts ("X bar Chart")

1. **Periodical Random Samples x_i of n items**

2.
$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n}$$

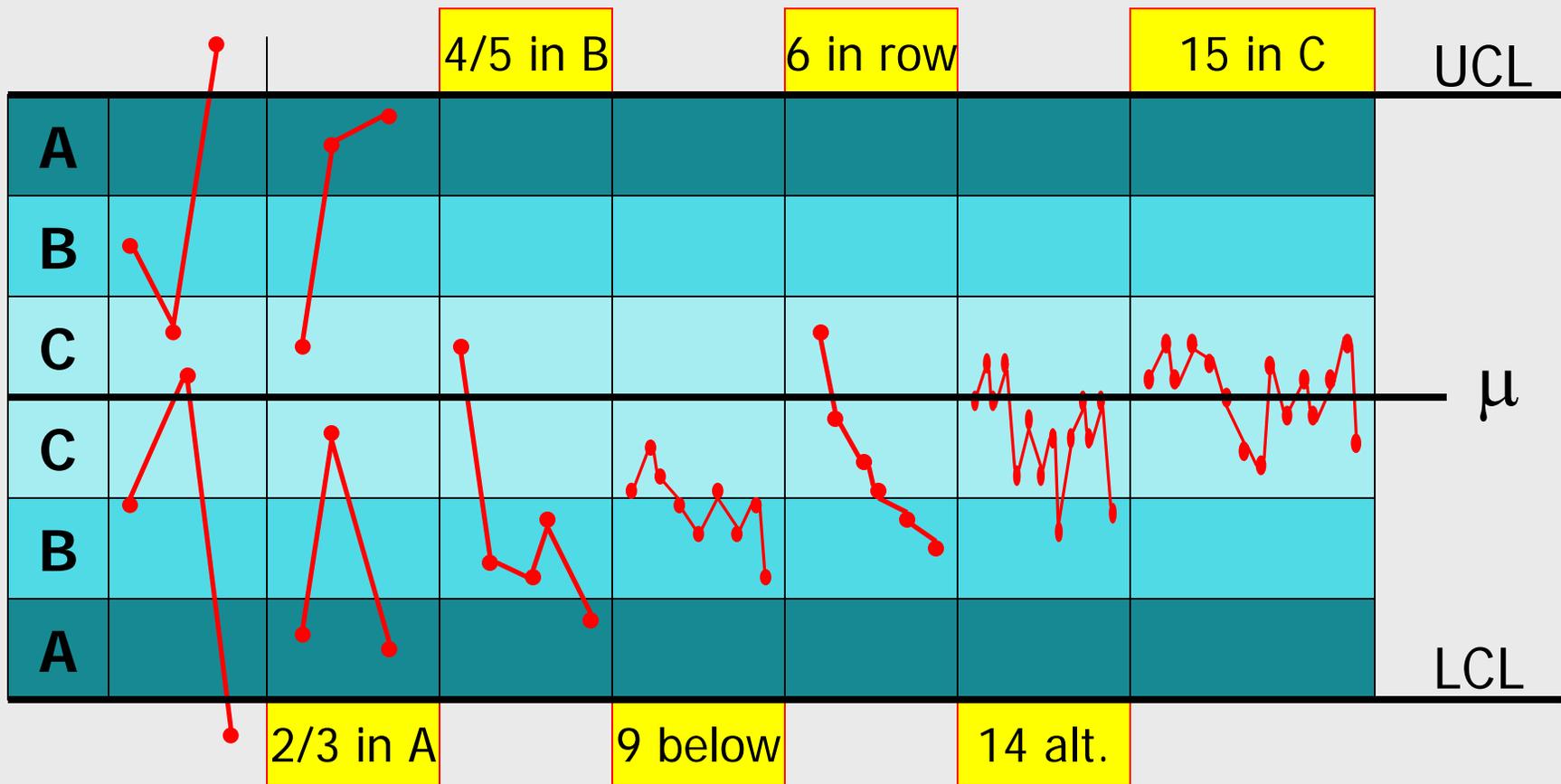
3. **Once μ, σ are known** $\Rightarrow \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$

4. **UCL = $\mu + 3 \cdot \sigma_{\bar{x}}$ LCL = $\mu - 3 \cdot \sigma_{\bar{x}}$**

5. **Plot \bar{x} 's**

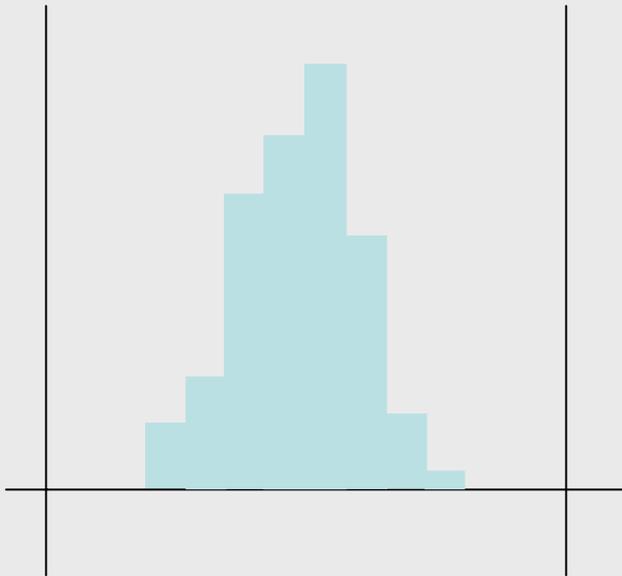
6. **Is Process out of Control ?**

Tests For Control



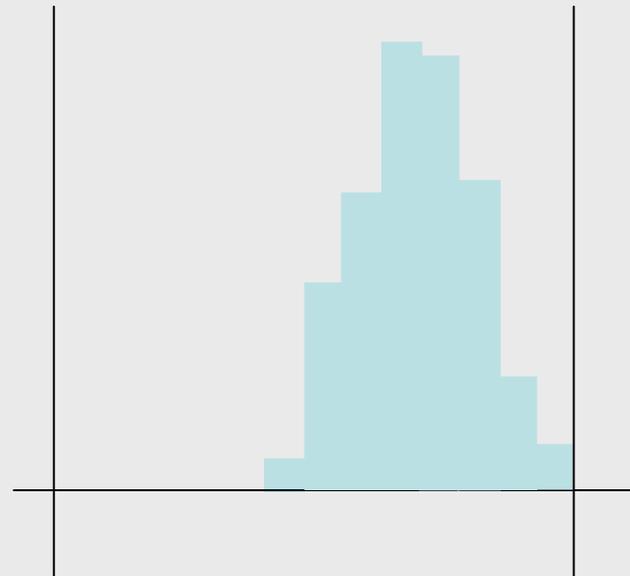
SQC Histograms

LSL



USL

LSL

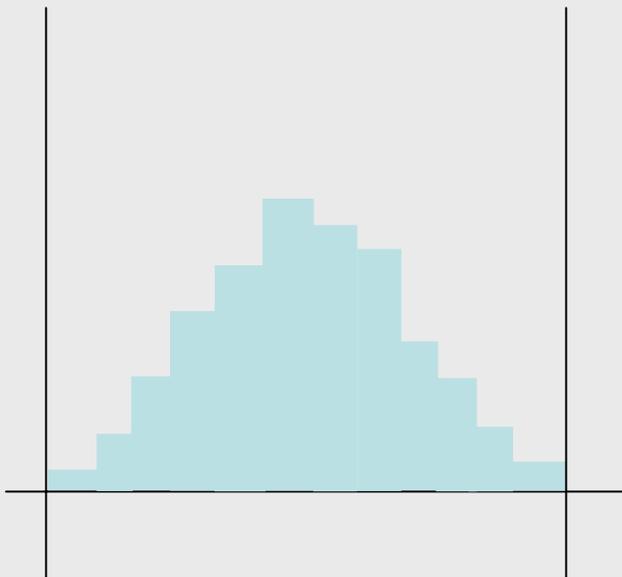


USL

SQC Histograms

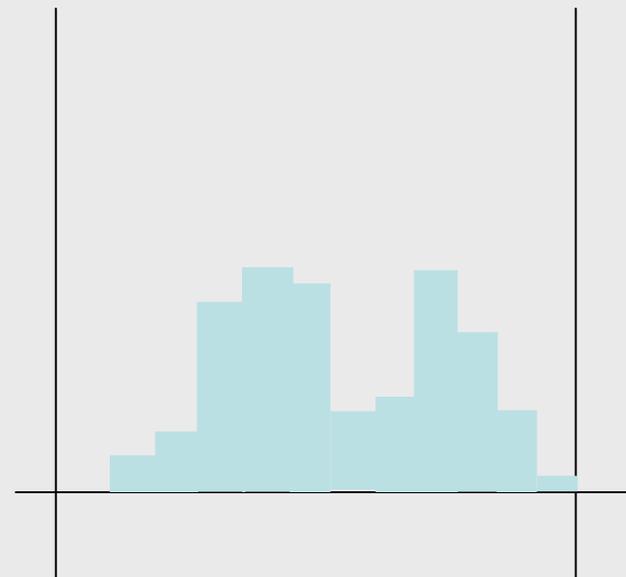
LSL

USL

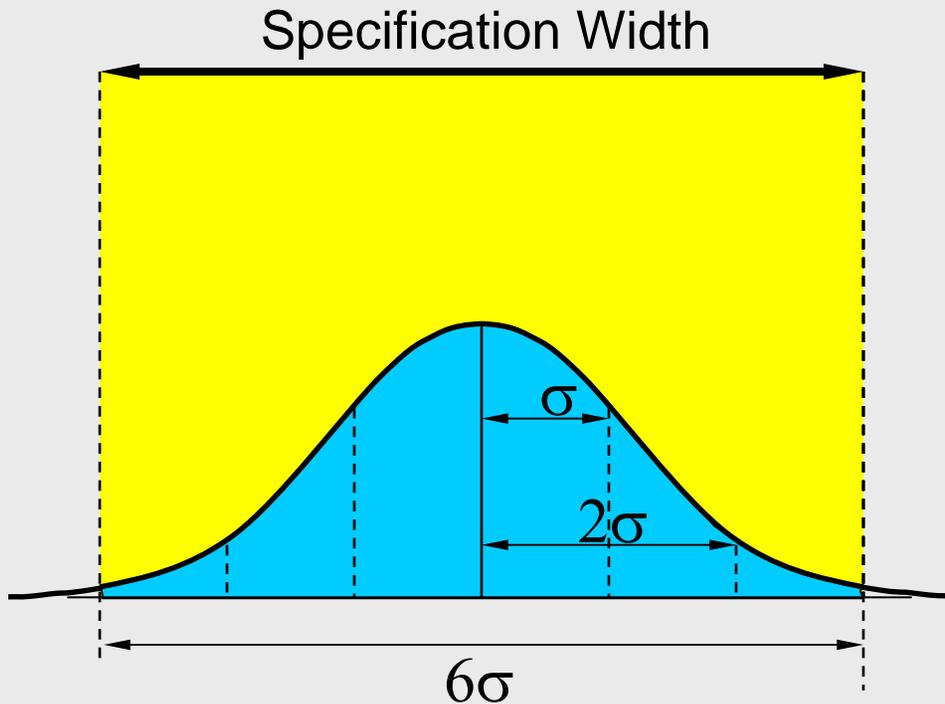


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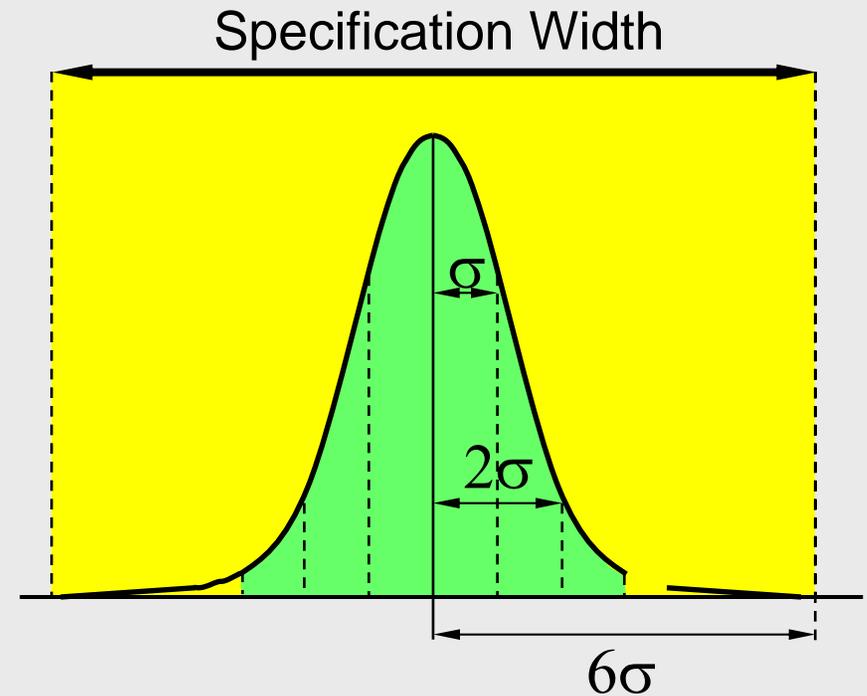
USL



Process Capability



$$c_p = \frac{\text{Specification Width}}{\text{Process Width } [6\sigma]} = 1$$



$$c_p = \frac{\text{Specification Width}}{\text{Process Width } [6\sigma]} = 2$$

Companies Implementing Six Sigma

- **Motorola**
- **Texas Instruments**
- **ABB**
- **AlliedSignal**
- **GE**
- **Bombardier**
- **Nokia**
- **Toshiba**
- **DuPont**
- **American Express**
- **BBA**
- **Ford**
- **Dow Chemical**
- **Johnson Controls**
- **Noranda**

Why 6σ ?

99% Good (3.8 Sigma)



99.99966% Good (6 Sigma)

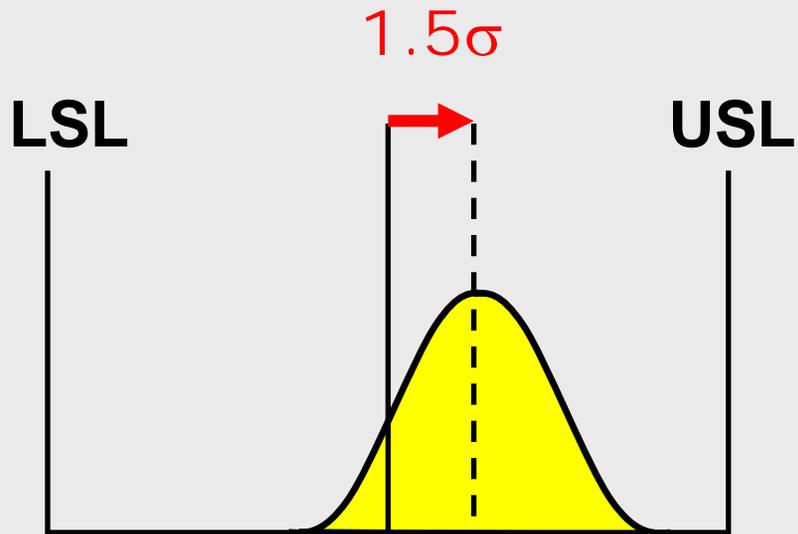
6 σ and Dependent Components

- **Consider a product made of 100 components**
- **Assume a defect rate (AQL) of 1% on each component**
- **The defect rate on the product is:**

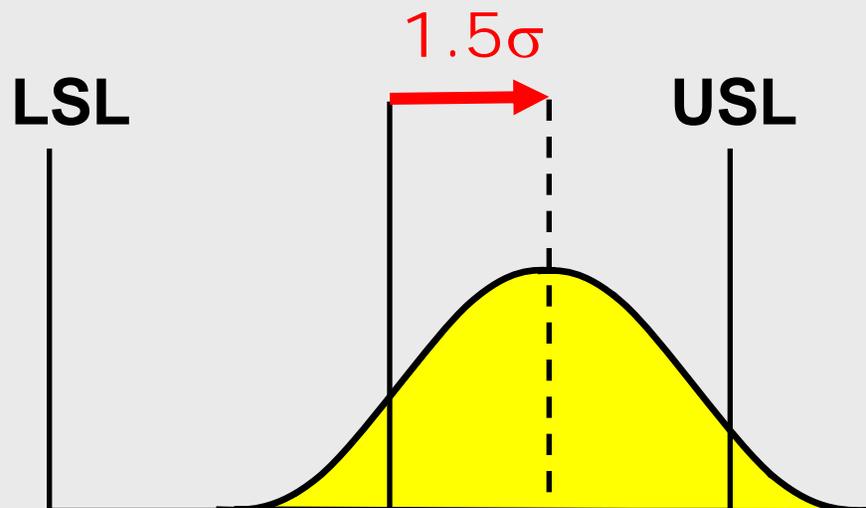
$$(3.8\sigma) \quad \mathbf{P(\text{defect}) = 1 - (0.99)^{100} = 63\% !}$$

$$(6\sigma) \quad \mathbf{P(\text{defect}) = 1 - (0.99999996)^{100} = 3.4\text{ppm} !}$$

Robustness To Process Shift

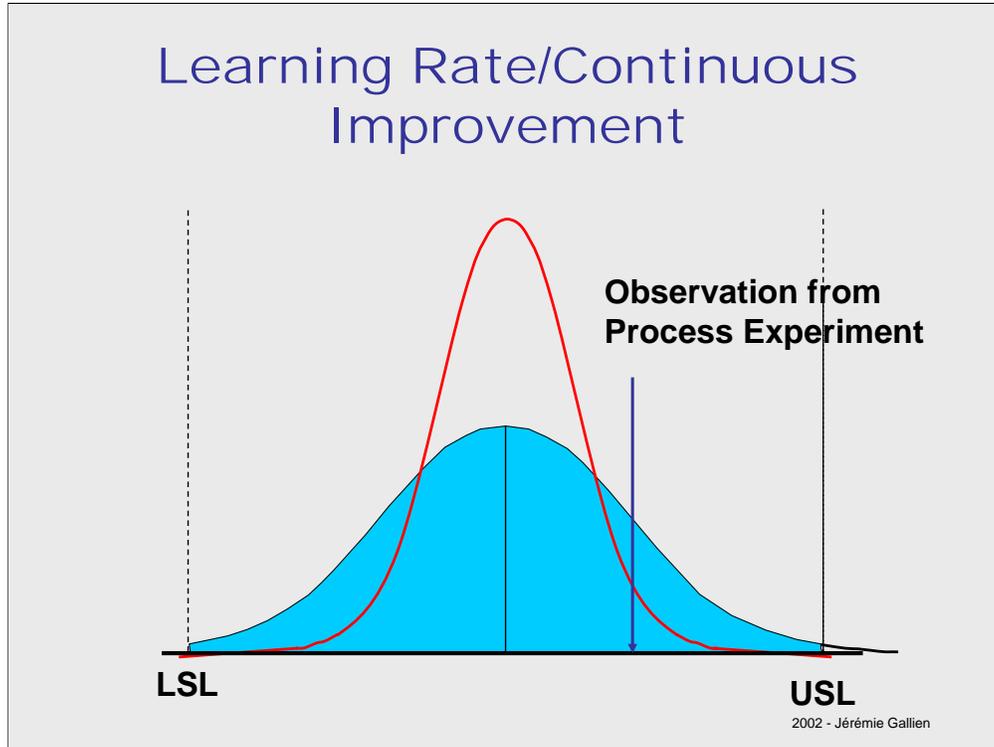


6σ : 3.4ppm defective



3σ : 7% defective

Learning Rate/Continuous Improvement



- This slide illustrates the result obtained when an experiment was performed in order to improve a process, say by varying one of the control levers or input.
- When the process capability is tight, it is much easier to tell apart a special cause (in this case the variation of the input or process control value) from a random fluctuation that could have occurred regardless of the change in the input.
- So performing continuous improvement and process learning is much quicker when the capability is high.

Why 6σ ?

- **Large Volume or Costly Defects**
- **Connected Components**
- **Robustness to Process Shift**
- **Tolerance Buildup**
- **Easier to Learn Process Improvements**

Quality Lecture Wrap-Up

1. **Quality is very systemic in nature –remember Hank!**

2. **Defining Quality, Setting Quality Goals**

3. **Principles of TQM:**

Customer First

Cont. Improvement

Total Participation

4. **Tools of TQM:**

Measurement (SQC, 6 σ)

Education

Incentives

Organizational Change

Process In Control?

Process Capable?

