QUALITY ANALYTICS SIMULATION: DATA COLLECTION & CONTROL CHART ANALYSIS

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MEET OUR TEAM

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SIMULATION BACKGROUND

We are quality managers for a new manufacturing plant – Gainsborough Manufacturing Company. As part of our job, we will use the Quality Analytics simulation to simulate the process stability and capability of the plant before handing it over to operations. Our aim is to find out the lowest possible total cost of quality.

Key concepts covered

- Use Minitab to calculate control limits for X-bar and R-charts
- Control and minimize the total cost of quality of a process
- Calculate the capability index of a process
- Minimize the total cost of quality of a process
- Improve the quality of the process by changing the underlying process mean or variance

PURPOSE OF CONTROL CHARTS

Control charts are used to track data over time to determine whether a process is stable and predictable. They help identify variations that are normal (common causes) versus those that signal a problem (special causes).

MONITORING PROCESS STABILITY

Common Cause Variation: Normal, inherent variations in the process that do not require immediate action.
Special Cause Variation: Unusual or unexpected variations that indicate a potential issue. These need to be investigated and corrected to maintain process control.

DISTINGUISHING BETWEEN VARIATION TYPES

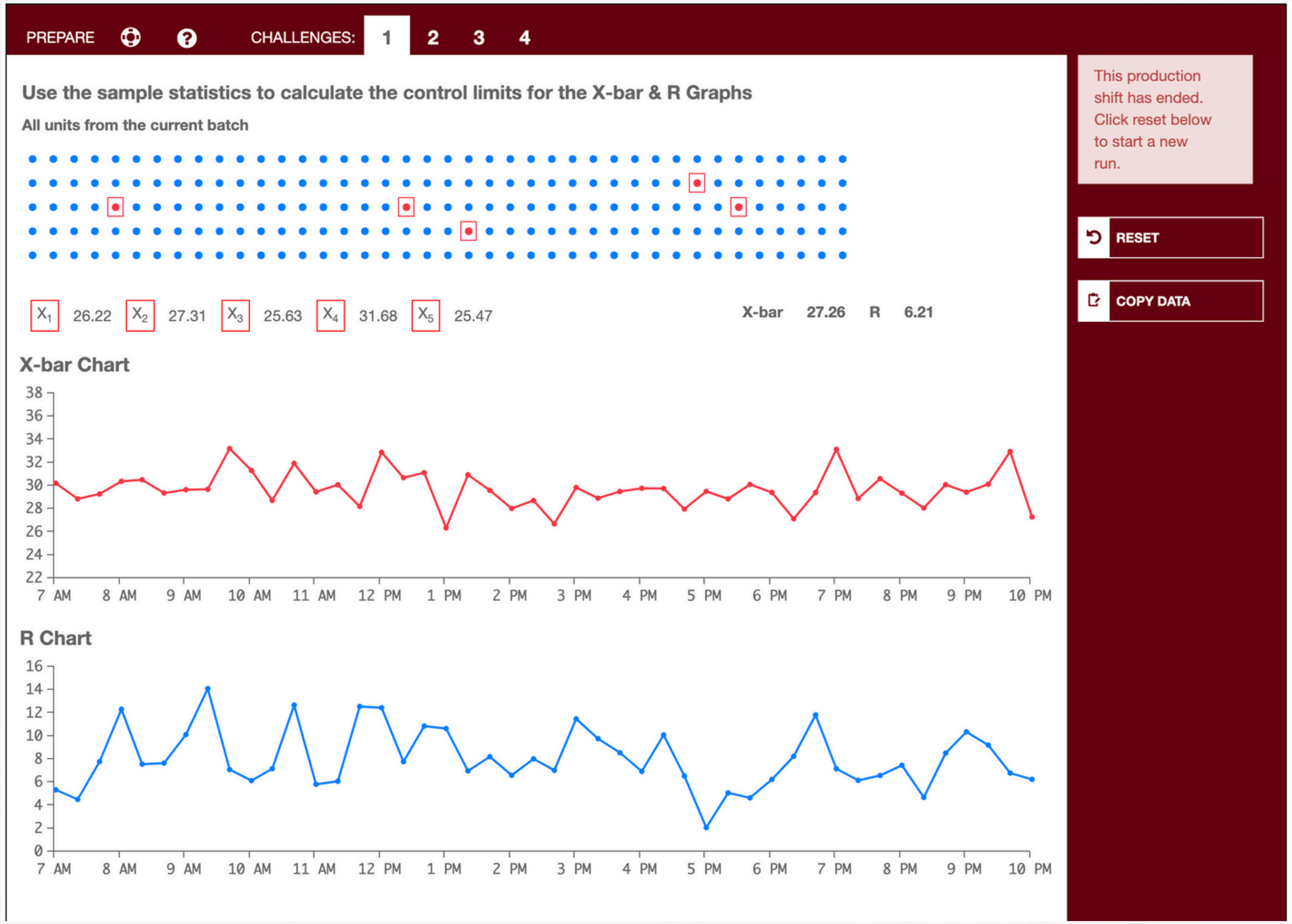
Control charts can reveal trends, shifts, or cycles in the data, providing early warnings of potential issues before they lead to defects.

DETECTING PROCESS TRENDS AND SHIFTS

By visualizing the process performance, control charts help teams make data-driven decisions, ensuring timely adjustments and continuous quality improvement.

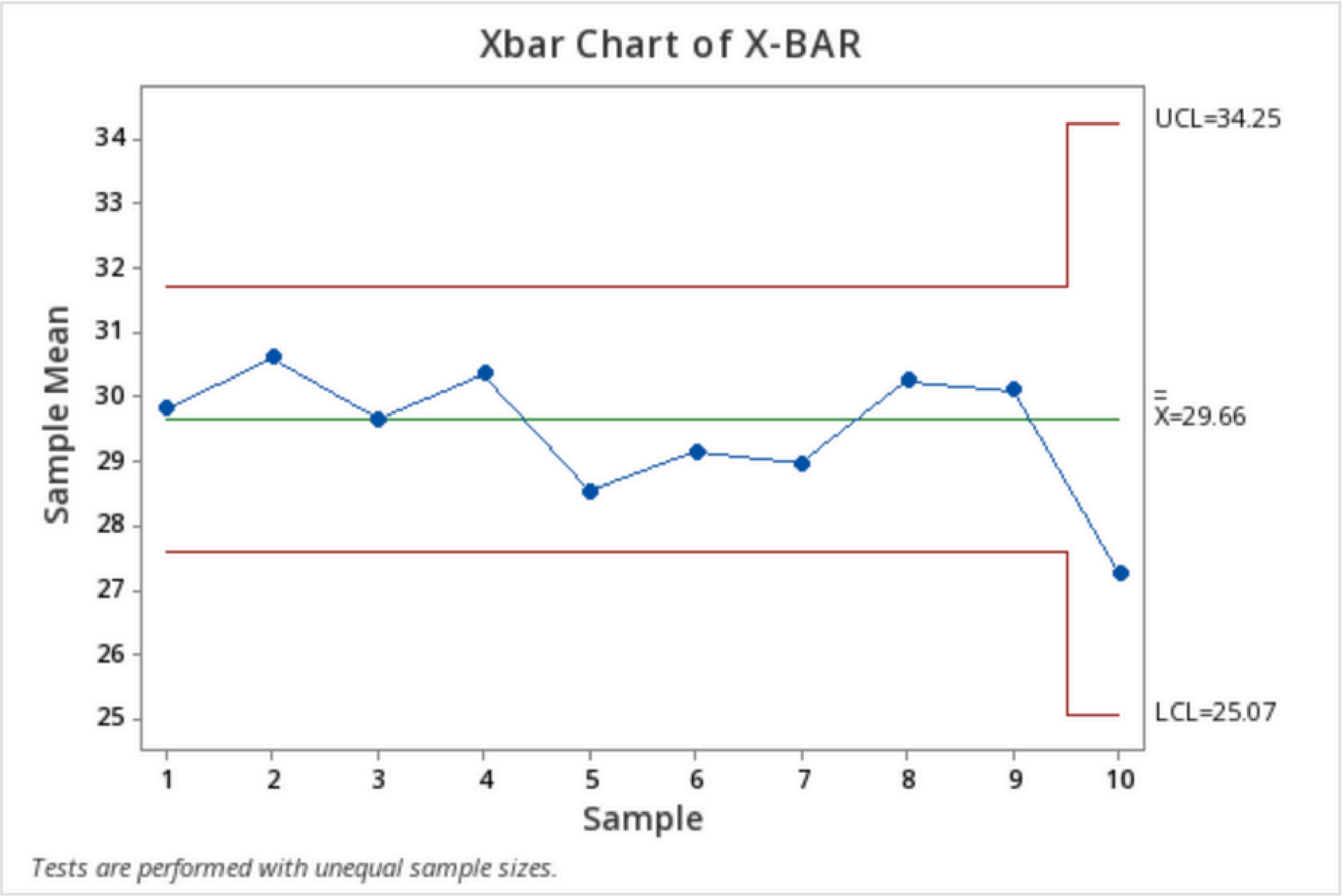
GUIDING QUALITY IMPROVEMENTS

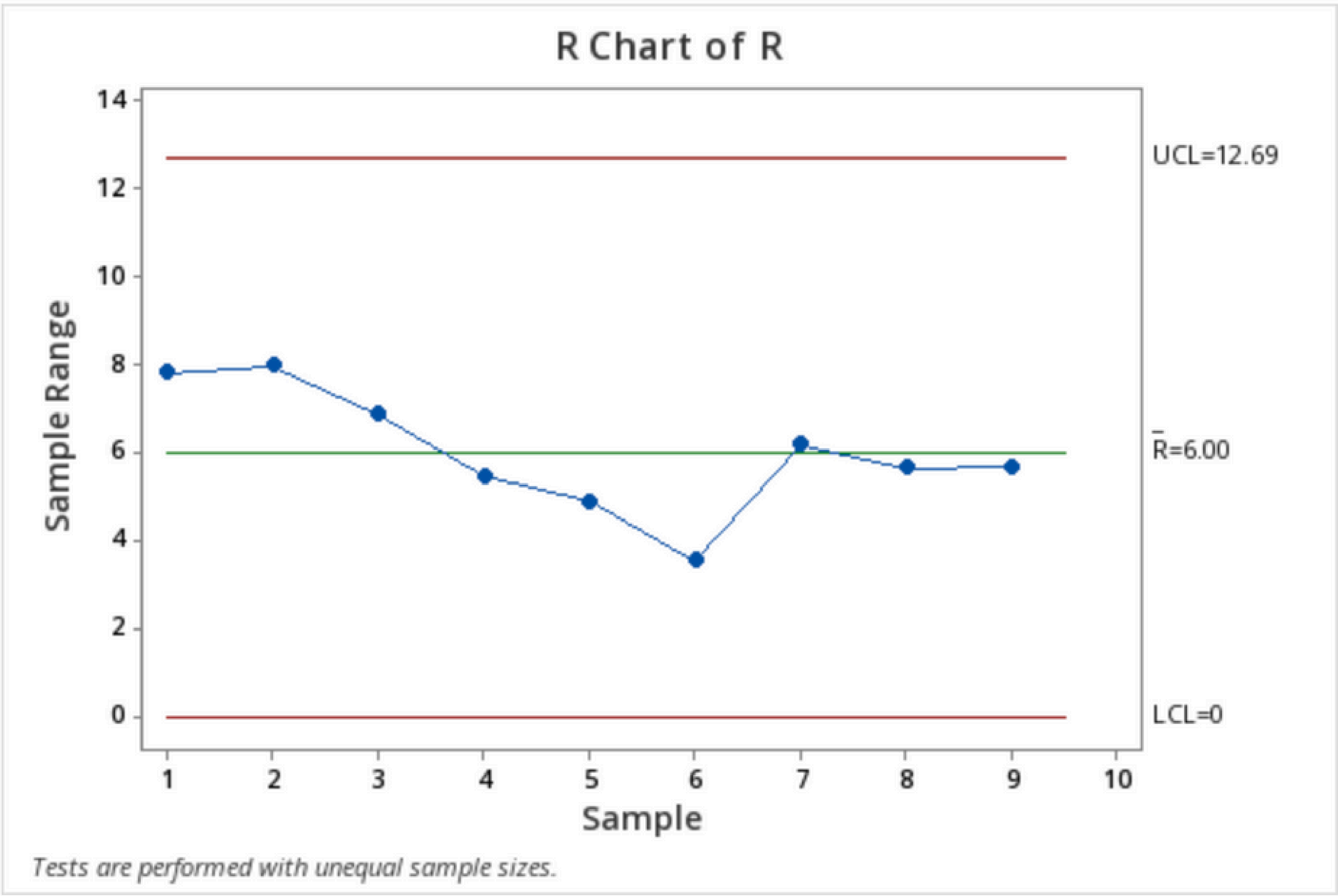
DATA COLLECTION OVERVIEW



DATA WAS COLLECTED OVER A 6TH PRODUCTION SHIFT FROM 7:00 A.M. TO 10:00 P.M.

X-BAR AND R CHARTS





<u>Purpose</u>: The X-bar chart monitors the sample mean over time, helping to detect any shifts or trends in the process average.

<u>Observation</u>:

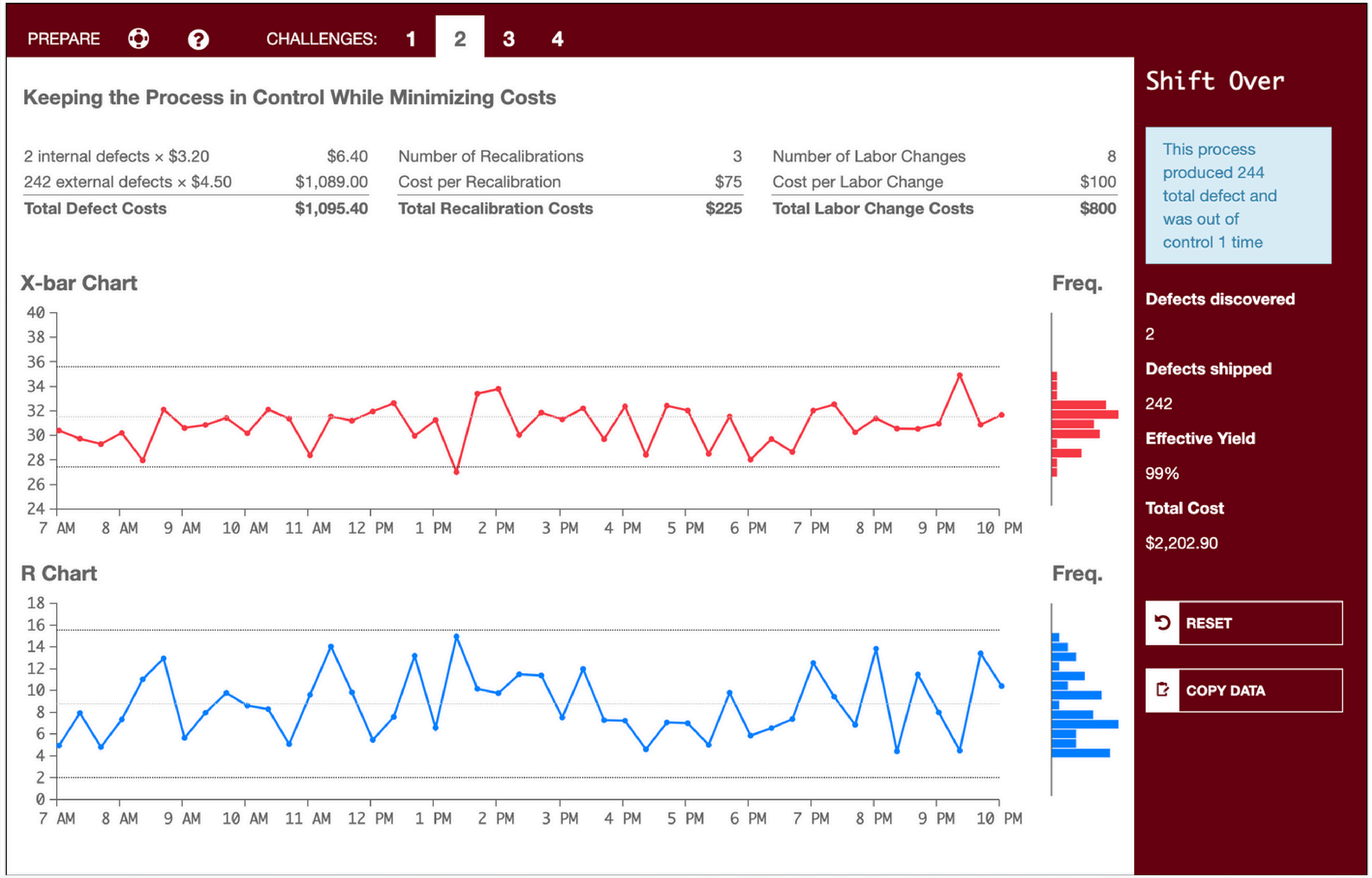
- The chart shows that the sample means generally stay around the average line (X=29.66).
- UCL = 34.25 and LCL = 25.07.
- There are no points outside the control limits, indicating the process is stable and within control.
- Some fluctuations are visible, but they remain within the expected range, showing that there were no significant shifts in the process average during the shift.

<u>Purpose:</u> The R chart measures the variability (range) within each subgroup over time. It helps detect any changes in the process consistency.

<u>Observation:</u>

- The sample ranges are generally around the mean range (R=6.00)
- UCL = 12.69 and LCL = 0
- No points are outside the control limits, suggesting the variability between samples is consistent.
- Although there is a downward trend in the range at the beginning, it stabilizes over time, indicating consistent quality control adjustments or improvements during the production shift.

PROCESS CONTROL & COST MINIMIZATION



Objective

The goal was to monitor the sample means and ranges throughout the production shift and determine if the process remained in control

Intervention

If the process went out of control, adjustments were made through equipment recalibration or labor changes

Minimizing Defects

The aim was to minimize both internal and external defect costs. Internal defects were discovered during production, while external defects represented issues that reached the customer, leading to higher costs

PROCESS ADJUSTMENTS - DECISION-MAKING APPROACH

Throughout the production shift, we continuously monitored the X-bar and R charts to check for any points that fell outside the control limits or showed patterns indicating potential issues.

<u>Out-of-Control Signals:</u> We looked for data points outside the UCL or LCL, as these indicated that the process was out of control and required immediate attention
<u>Unusual Patterns</u>: Trends, cycles, or sudden shifts in the data, even if within control limits

TRIGGERS FOR ADJUSTMENTS

<u>Equipment Recalibration:</u> If we observed shifts in the X-bar chart, we adjusted the equipment to correct any drift in the process mean
<u>Labor Changes:</u> When the R chart indicated increased variability within samples, we considered labor adjustments

TYPES OF ADJUSTMENTS

<u>Cost Consideration</u>: Carefully evaluated the potential cost of external defects against the adjustment cost to ensure that interventions were justified
<u>Preventive vs. Reactive Approach</u>: Where possible, we aimed to act preventively by addressing trends and early signals before they escalated into out-of-control conditions.

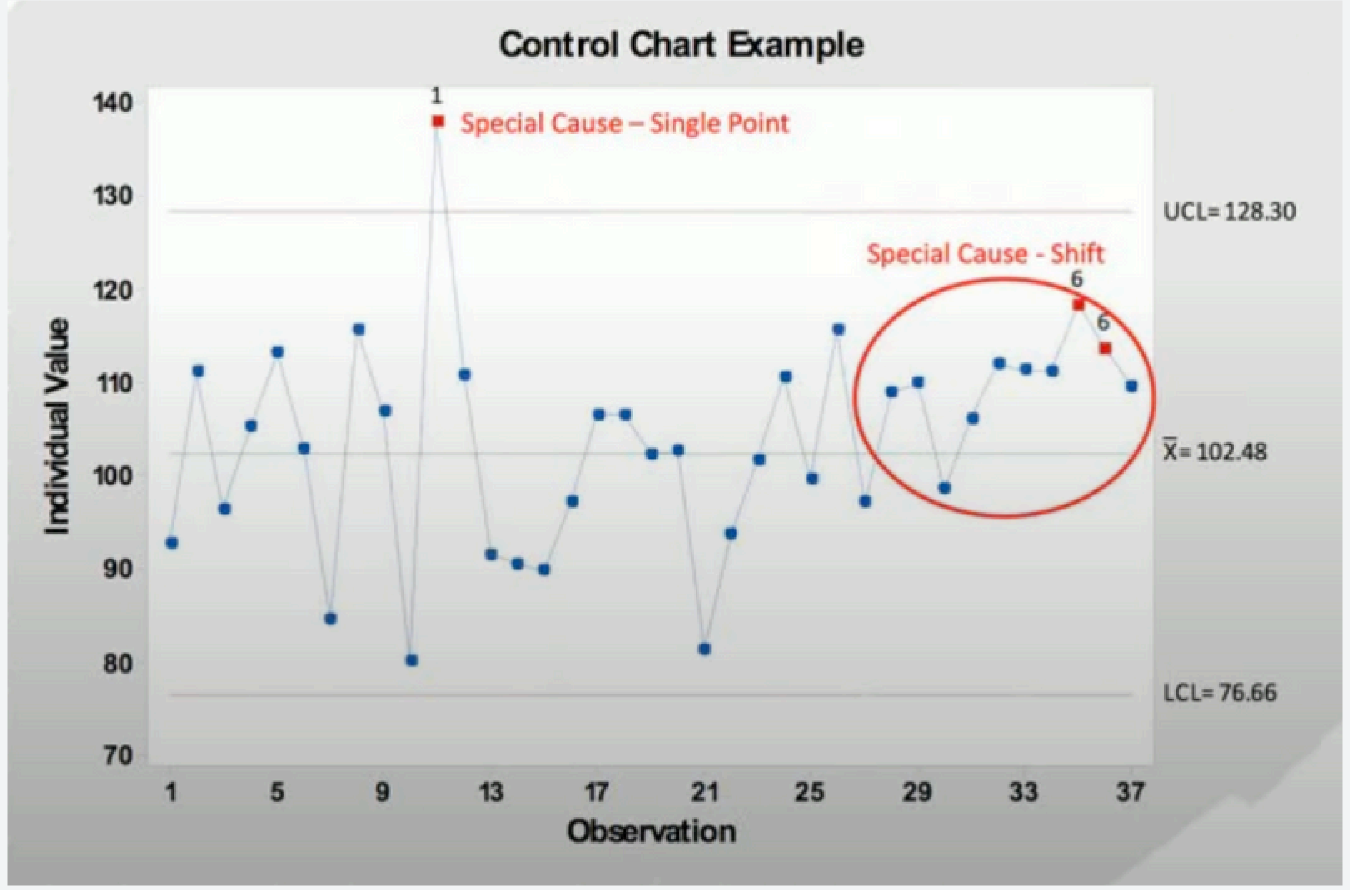
BALANCING COST AND QUALITY

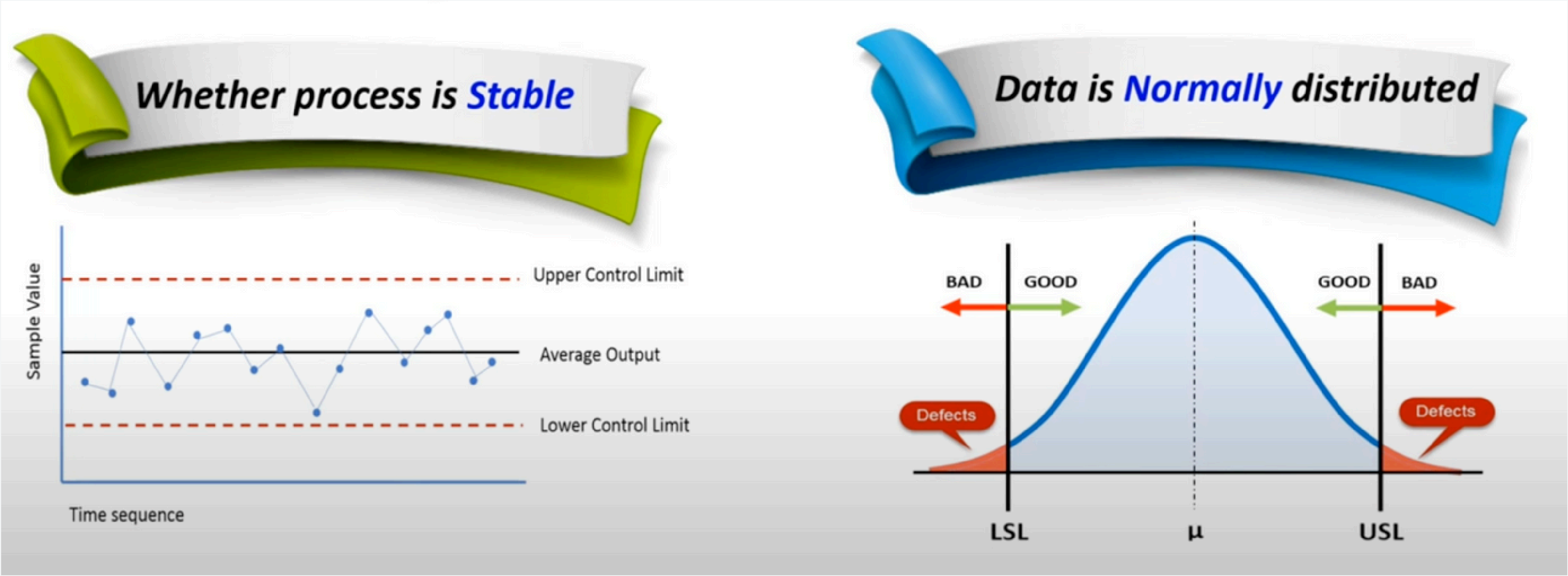
PROCESS CAPABILITY INDEX - DECISION-MAKING APPROACH

Statistical measurement of a process's ability to produce parts within specified limits on a consistent basis
-To determine if your process is capable; that is, meeting specification limits and producing "good" parts

Common cause variation: -The natural or expected variation in a process

Special cause variation: -Unexpected variation that results from unusual occurrences





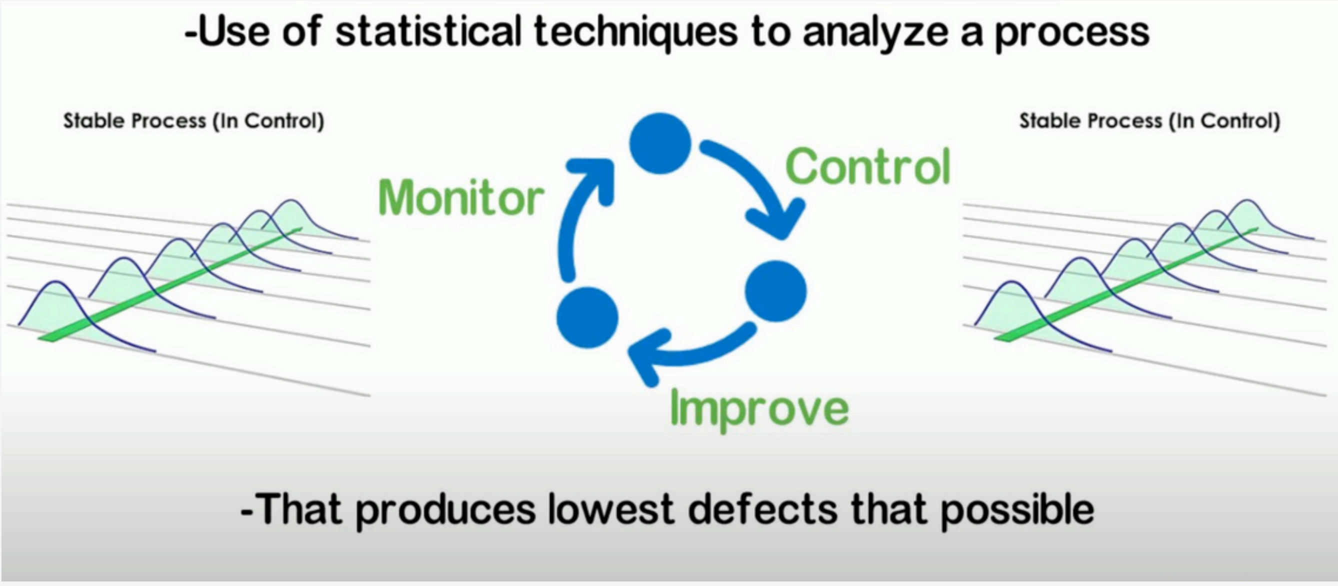
PROCESS CAPABILITY INDEX - FORMULA

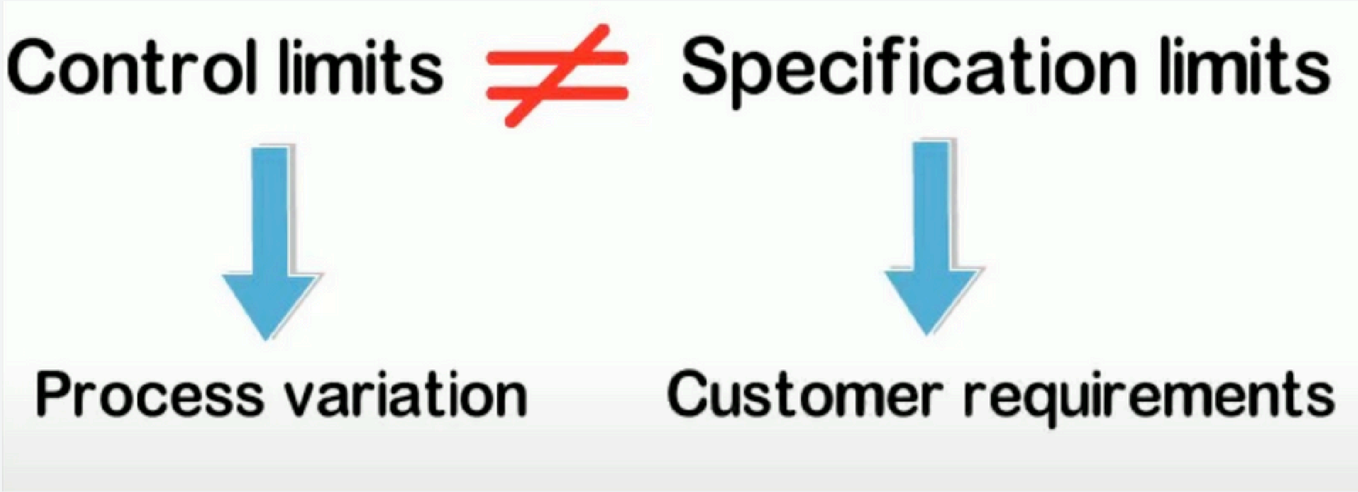
A process can be in control and yet not be capable of meeting specifications

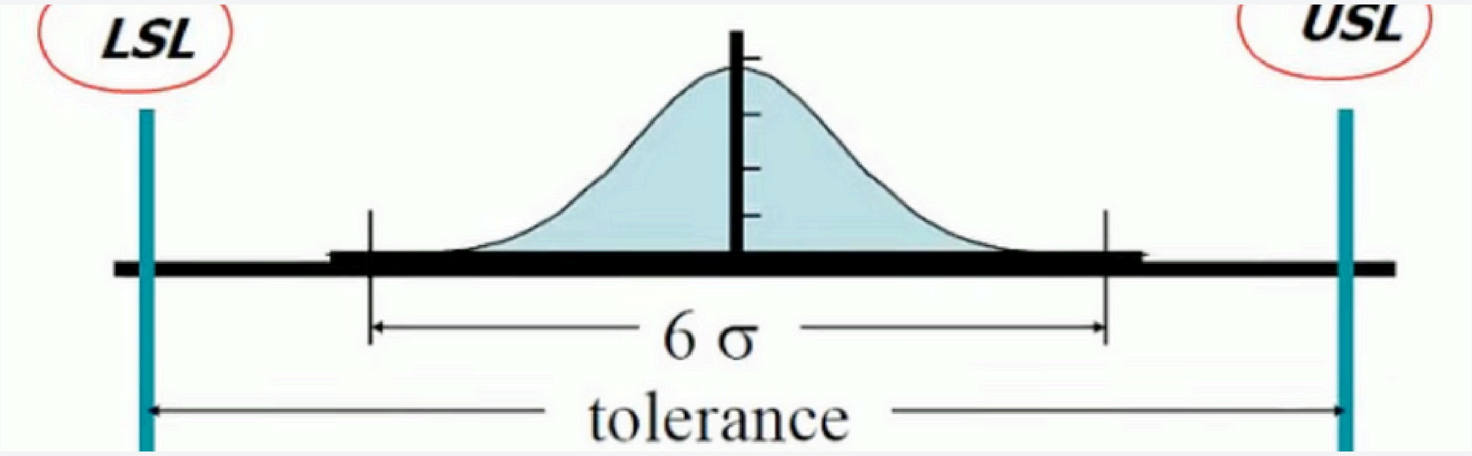
Cp measures "spread" of the process variation

- USL and LSL - Upper and Lower Specification Limits
- u - Target for the process

Cpk (Process Capability Index):
-is used to summarize how a process is running relative to its specification limits

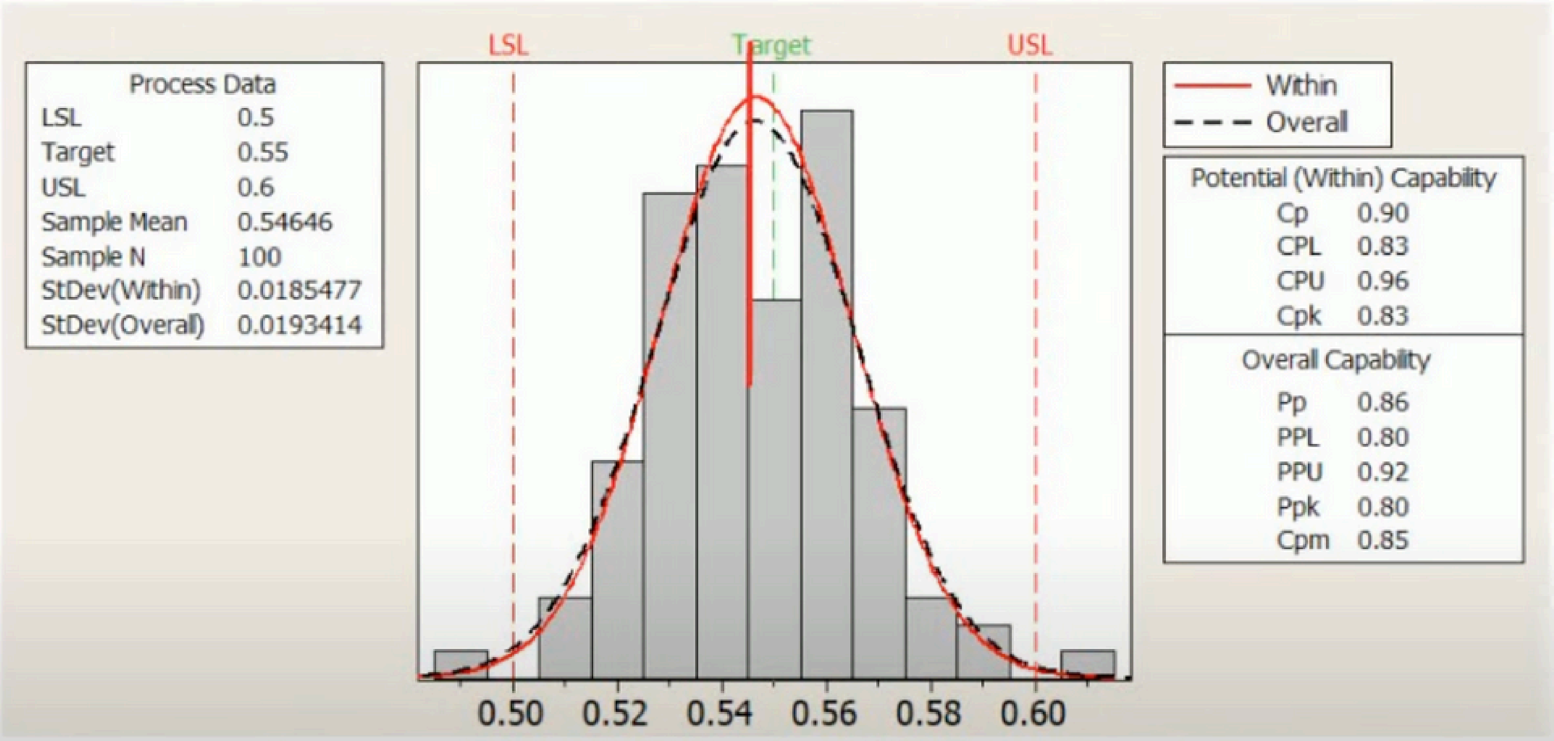






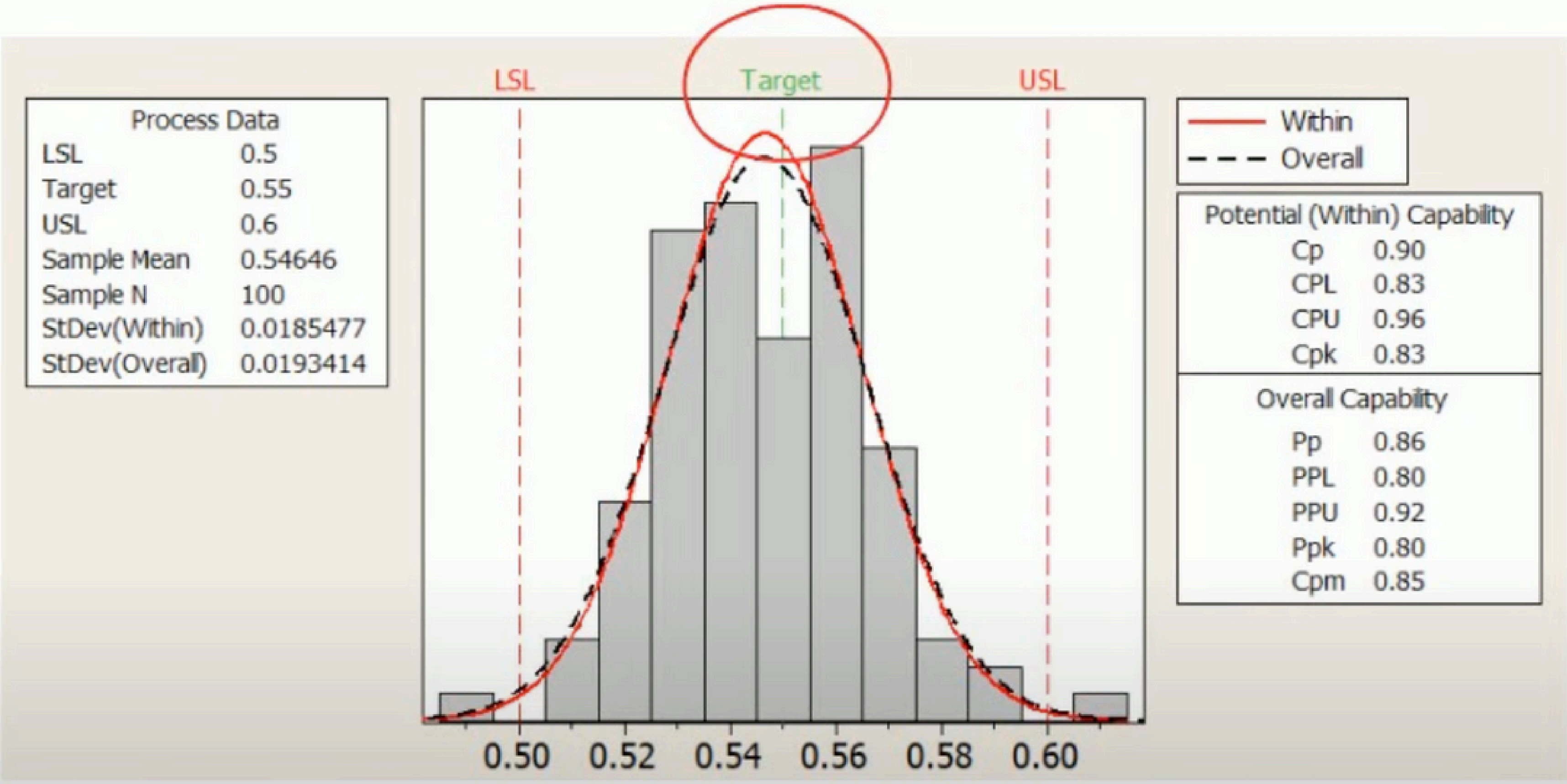
Cpk

-Conformance to Specs



Cpm

-Run to Target



PROCESS CAPABILITY INDEX - FORMULA

Process Capability

1. Use visual inspection to determine whether the process mean is centered between the specification limits.

2. Calculate the process capability index.

   a. Use $\hat{C}_p$ if the process mean is centered between the specification limits.

   $$\hat{C}_p = \frac{USL-LSL}{6\hat{\sigma}}$$

   b. Use $\hat{C}_{pk}$ if the process mean is *not* centered between the specification limits.

   $$\hat{C}_{pk} = \min\left[\frac{USL-\hat{\mu}}{3\hat{\sigma}}, \frac{\hat{\mu}-LSL}{3\hat{\sigma}}\right]$$

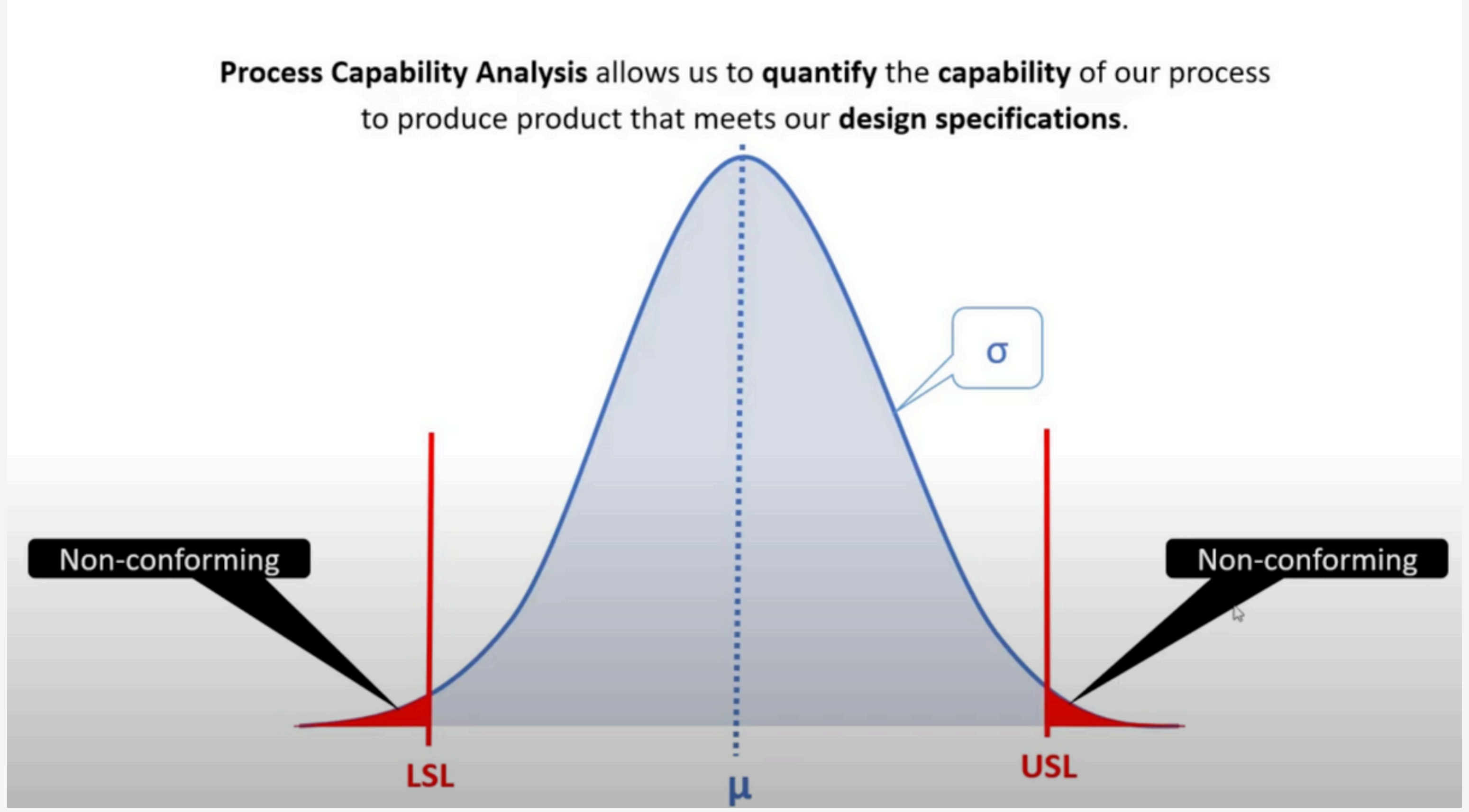
USL = Upper specification limit

LSL = Lower specification limit

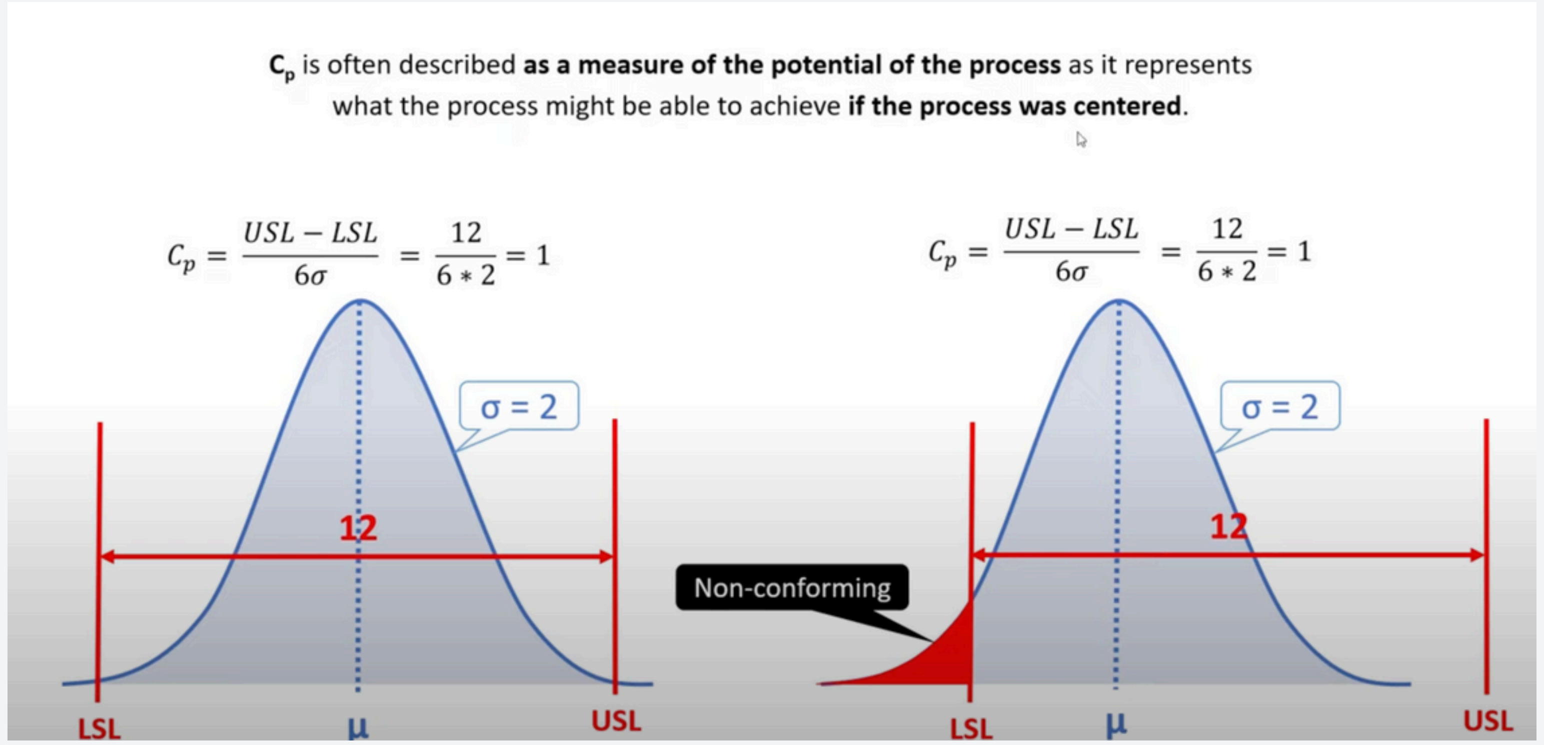
$\hat{\mu}$ = Process mean, which is the centerline between the UCL and LCL. This can be calculated by adding the UCL and LCL, then dividing by 2.

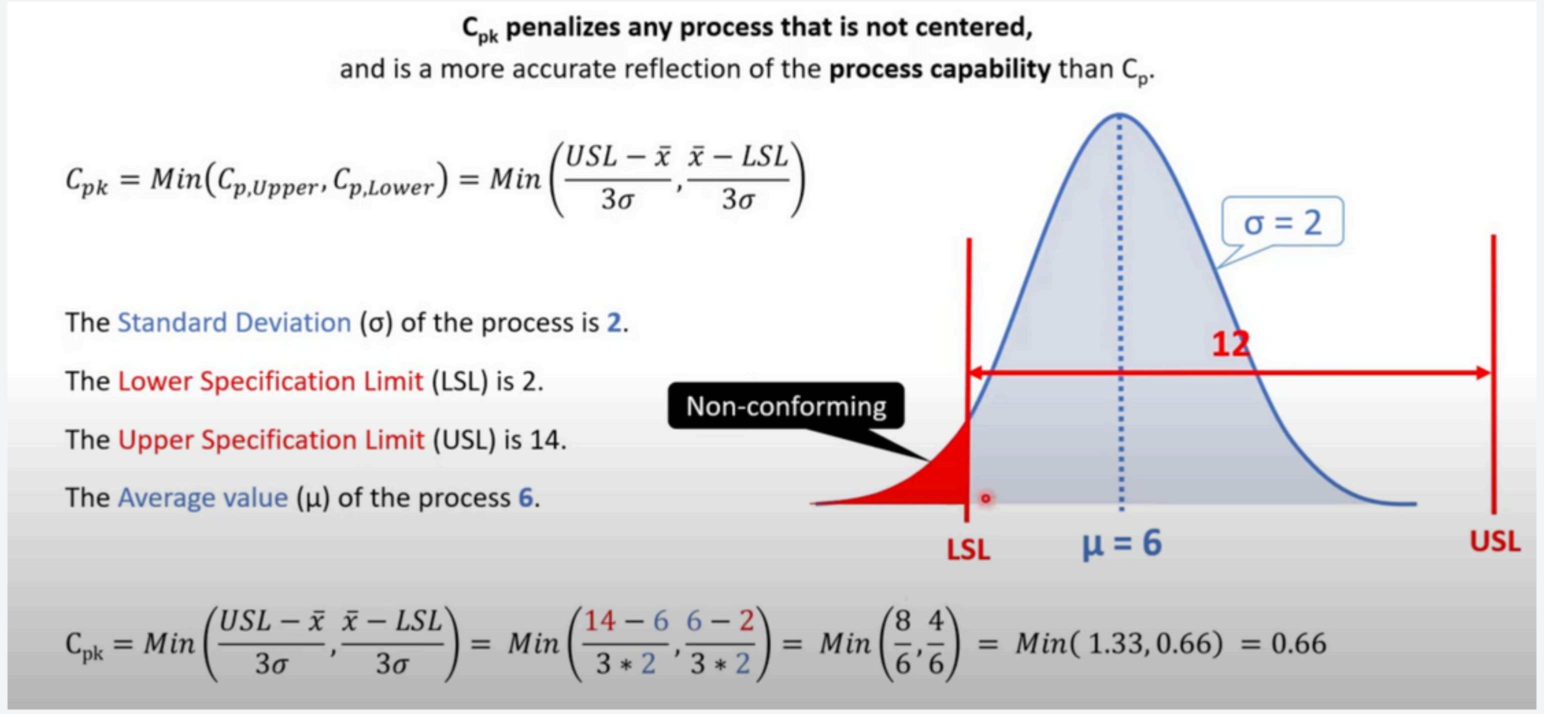
$\hat{\sigma}$ = Process standard deviation, which can be calculated from the control limits, as follows. Calculate the process standard error as the difference between either of the control limits and the process mean, divided by 3. Then, calculate the process standard deviation by multiplying the process standard error by $\sqrt{n}$.

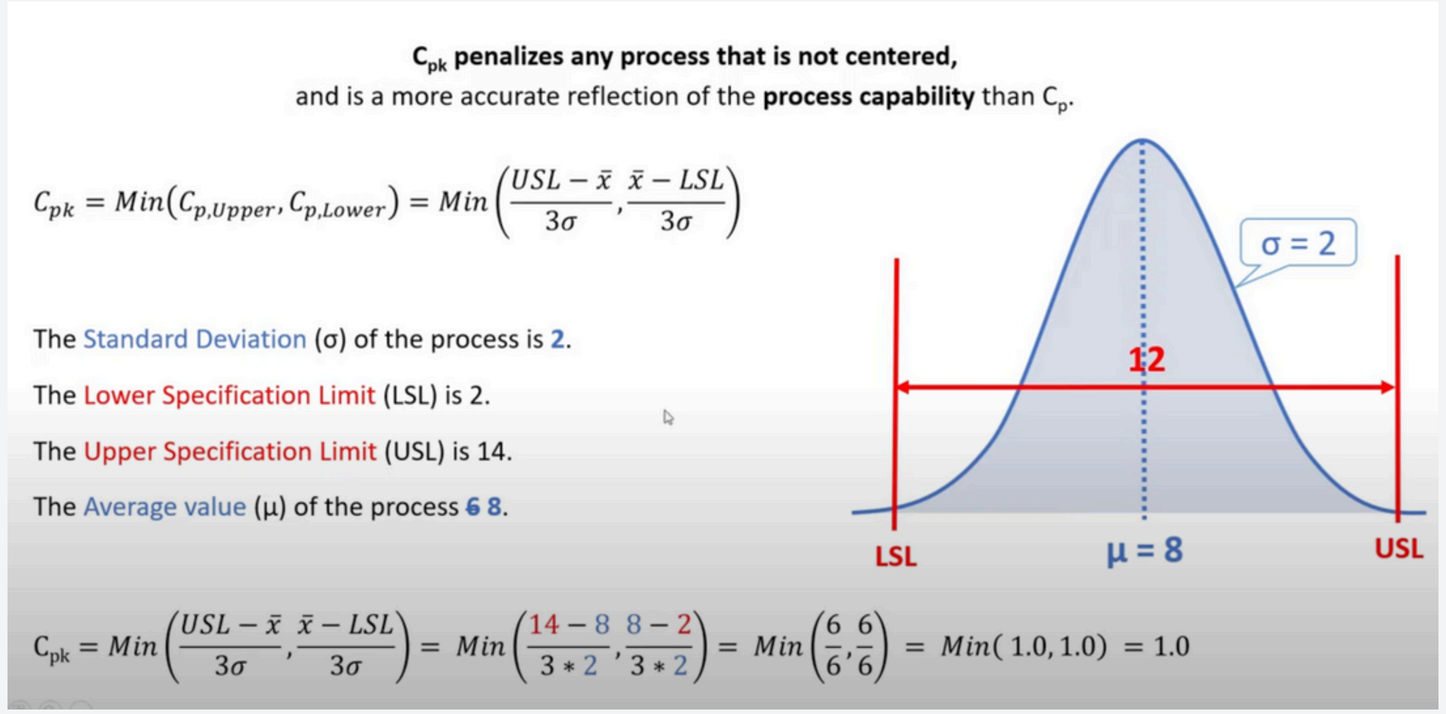
3. Higher values of $\hat{C}_p$ and $\hat{C}_{pk}$ indicate a more capable process. Experts recommend a process capability index of at least 1.33 for a two-sided specification. For a one-sided specification that consists of an upper limit only (for example, concentration) or a lower limit only (for example, for strength), the process is considered capable if the process capability index > 1.25.



PROCESS CAPABILITY INDEX - PROS AND CONS







PROCESS CAPABILITY INDEX - DECISION-MAKING APPROACH

Given Data:

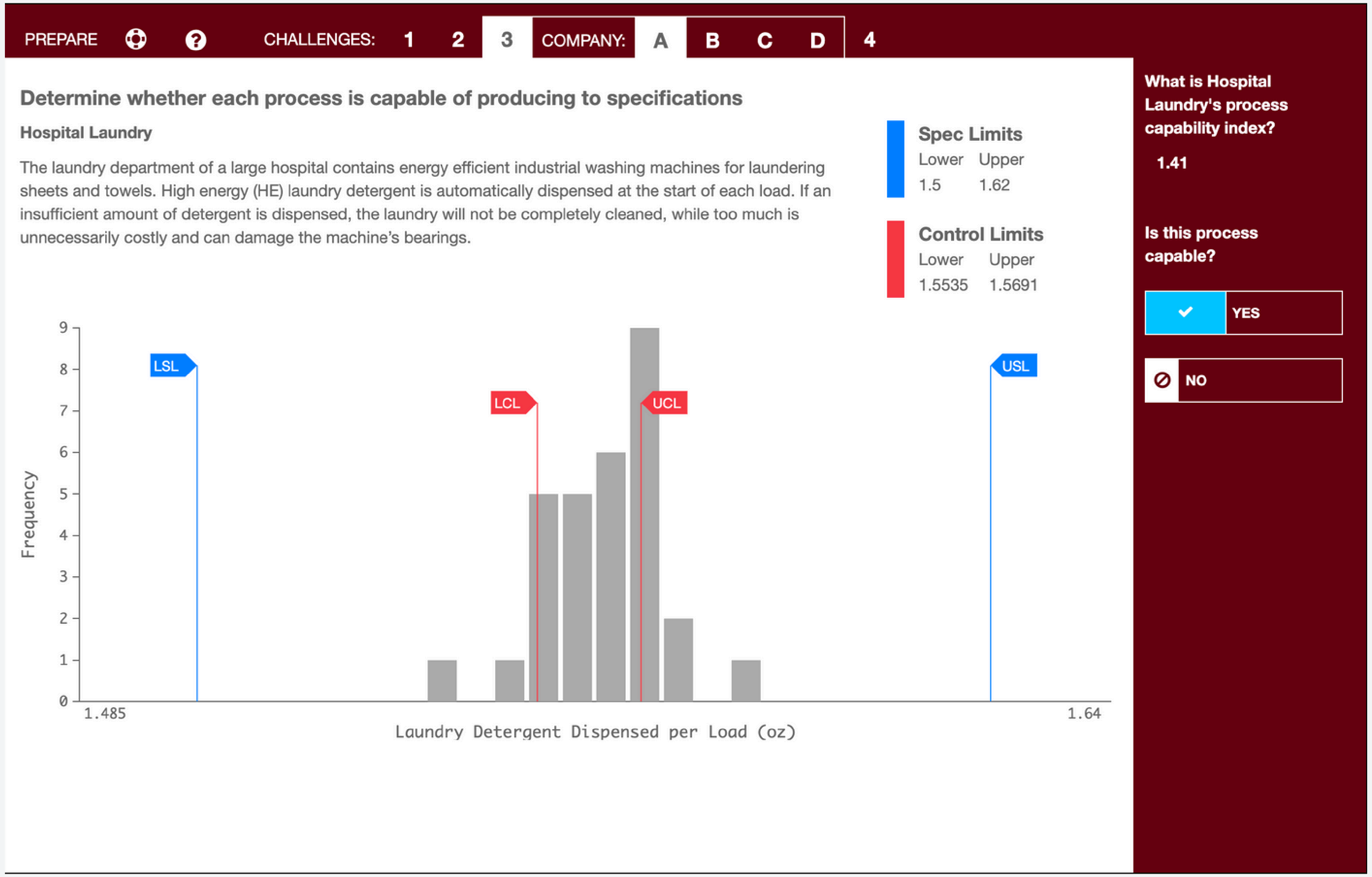
- Upper Specification Limit (USL): 1.62 oz
- Lower Specification Limit (LSL): 1.50 oz
- Upper Control Limit (UCL): 1.5691 oz
- Lower Control Limit (LCL): 1.5535 oz
- Subgroup Size (n): 30

<u>Step 1</u>: Calculate Process Mean
(UCL+LCL)/2 = (1.5691+1.5535)/2 = 1.5613 oz

<u>Step 2</u>: Calculate Process Standard Error
(UCL-Process Mean)/3 = (1.5691-1.5613)/3 = 0.0026 oz

<u>Step 3</u>: Calculate Process Standard Deviation
σ = Standard Error × $\sqrt{n}$ = 0.0026 × $\sqrt{30}$ ≈ 0.0142 oz

<u>Step 4</u>: Calculate the Process Capability Index (Cp)
Cp = (USL-LSL)/(6×σ) = (1.62-1.50)/(6×0.0142) ≈ 1.41



PROCESS CAPABILITY INDEX - DECISION-MAKING APPROACH

Given Data:

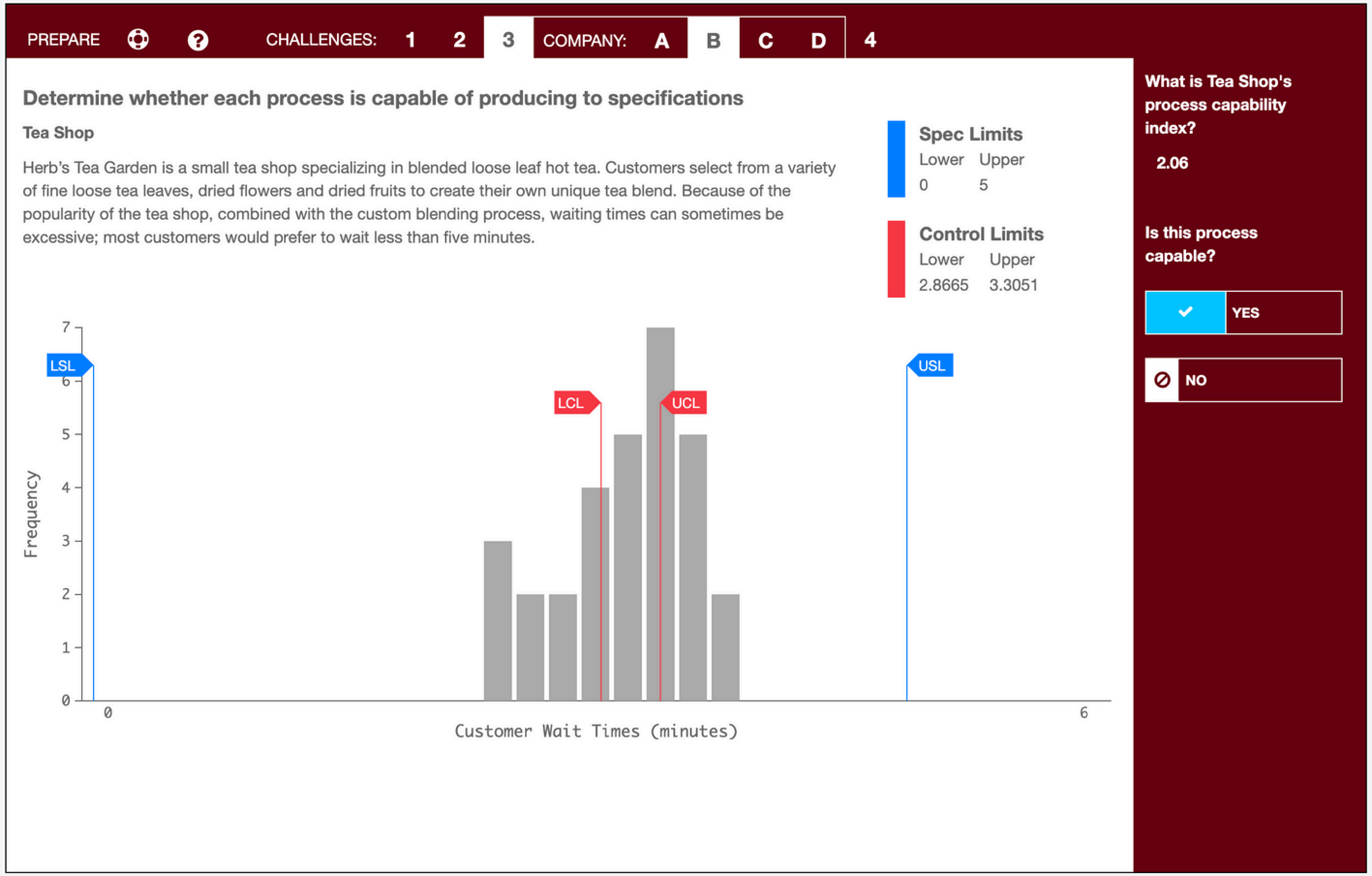
- Upper Specification Limit (USL): 5 minutes
- Lower Specification Limit (LSL): 0 minutes
- Upper Control Limit (UCL): 3.3051 minutes
- Lower Control Limit (LCL): 2.8665 minutes
- Subgroup Size (n): 30

<u>Step 1</u>: Calculate Process Mean
(UCL+LCL)/2 = (3.3051+2.8665)/2 = 3.0858 minutes

<u>Step 2</u>: Calculate Process Standard Error
(UCL-Process Mean)/3 = (3.3051-3.0858)/3 = 0.0731 minutes

<u>Step 3</u>: Calculate Process Standard Deviation
σ = Standard Error × $\sqrt{n}$ = 0.0731 × $\sqrt{30}$ ≈ 0.4005 minutes

<u>Step 4</u>: Calculate the Process Capability Index (Cp)
Cp = (USL-LSL)/(6×σ) = (5-0)/(6×0.4005) ≈ 2.08



PROCESS CAPABILITY INDEX - DECISION-MAKING APPROACH

Given Data:

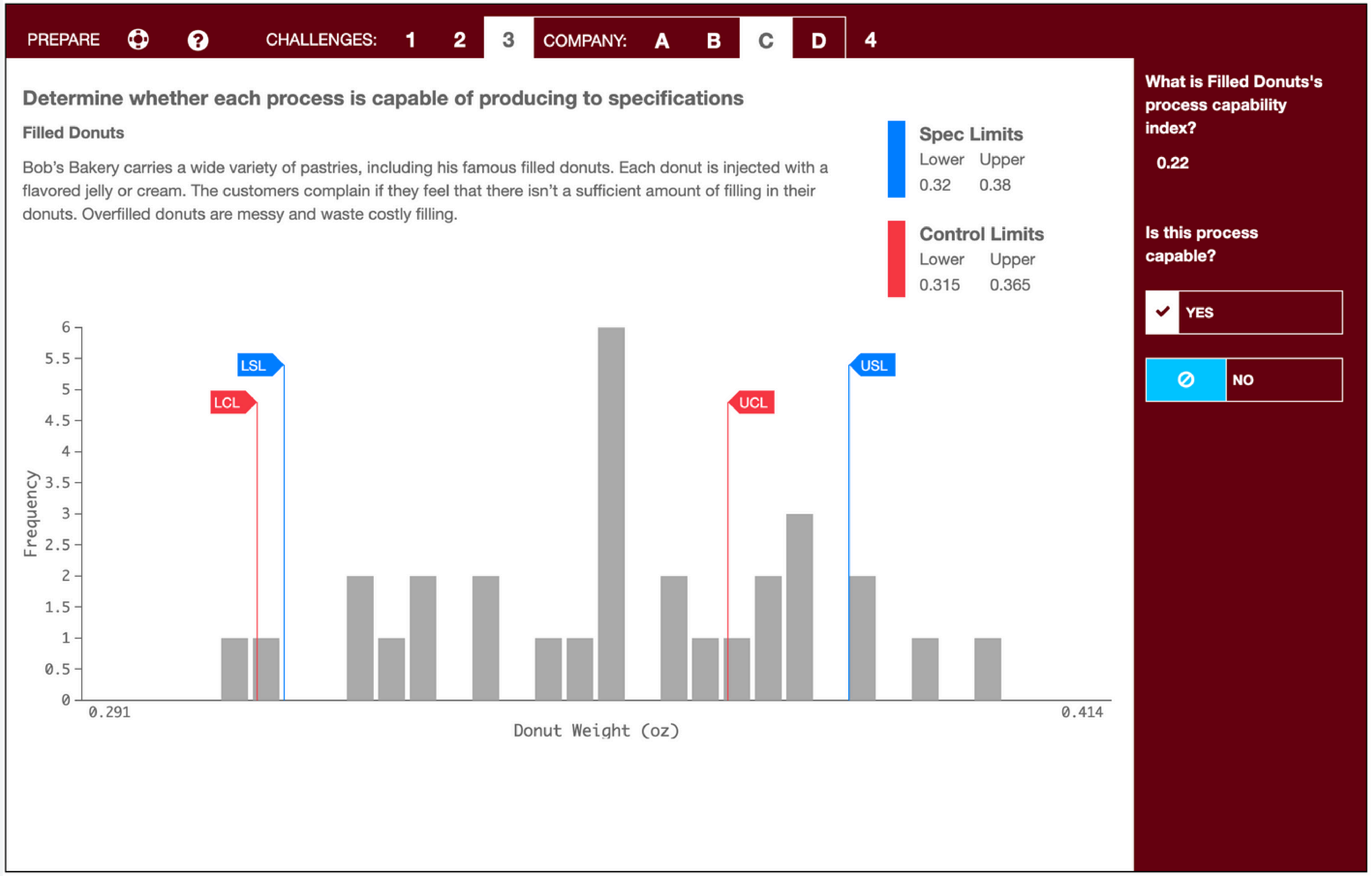
- Upper Specification Limit (USL): 0.38 oz
- Lower Specification Limit (LSL): 0.32 oz
- Upper Control Limit (UCL): 0.365 oz
- Lower Control Limit (LCL): 0.315 oz
- Subgroup Size (n): 30

<u>Step 1</u>: Calculate Process Mean
(UCL+LCL)/2 = (0.315+0.315)/2 = 0.34 oz

<u>Step 2</u>: Calculate Process Standard Error
(UCL-Process Mean)/3 = (0.365-0.34)/3 = 0.0083 oz

<u>Step 3</u>: Calculate Process Standard Deviation
σ = Standard Error × √n = 0.0083 × √30 ≈ 0.0455 oz

<u>Step 4</u>: Calculate the Process Capability Index (Cp)
Cp = (USL-LSL)/(6×σ) = (0.38-0.32)/(6×0.0455) ≈ 0.22



PROCESS CAPABILITY INDEX - DECISION-MAKING APPROACH

Given Data:

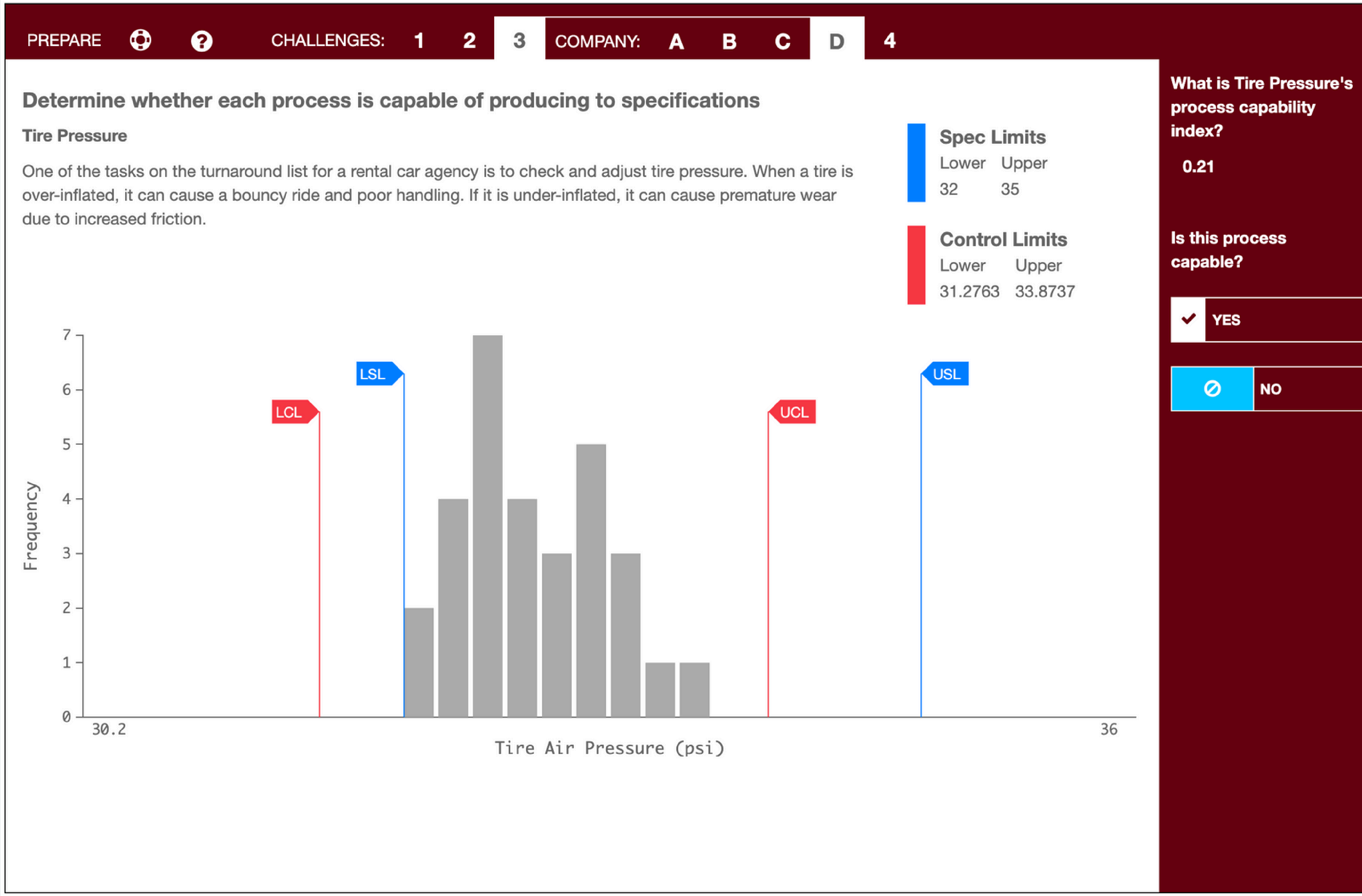
- Upper Specification Limit (USL): 35 psi
- Lower Specification Limit (LSL): 32 psi
- Upper Control Limit (UCL): 33.8737 psi
- Lower Control Limit (LCL): 31.2763 psi
- Subgroup Size (n): 30

Step 1: Calculate Process Mean
(UCL+LCL)/2 = (33.8737+31.2763)/2 = 32.575 psi

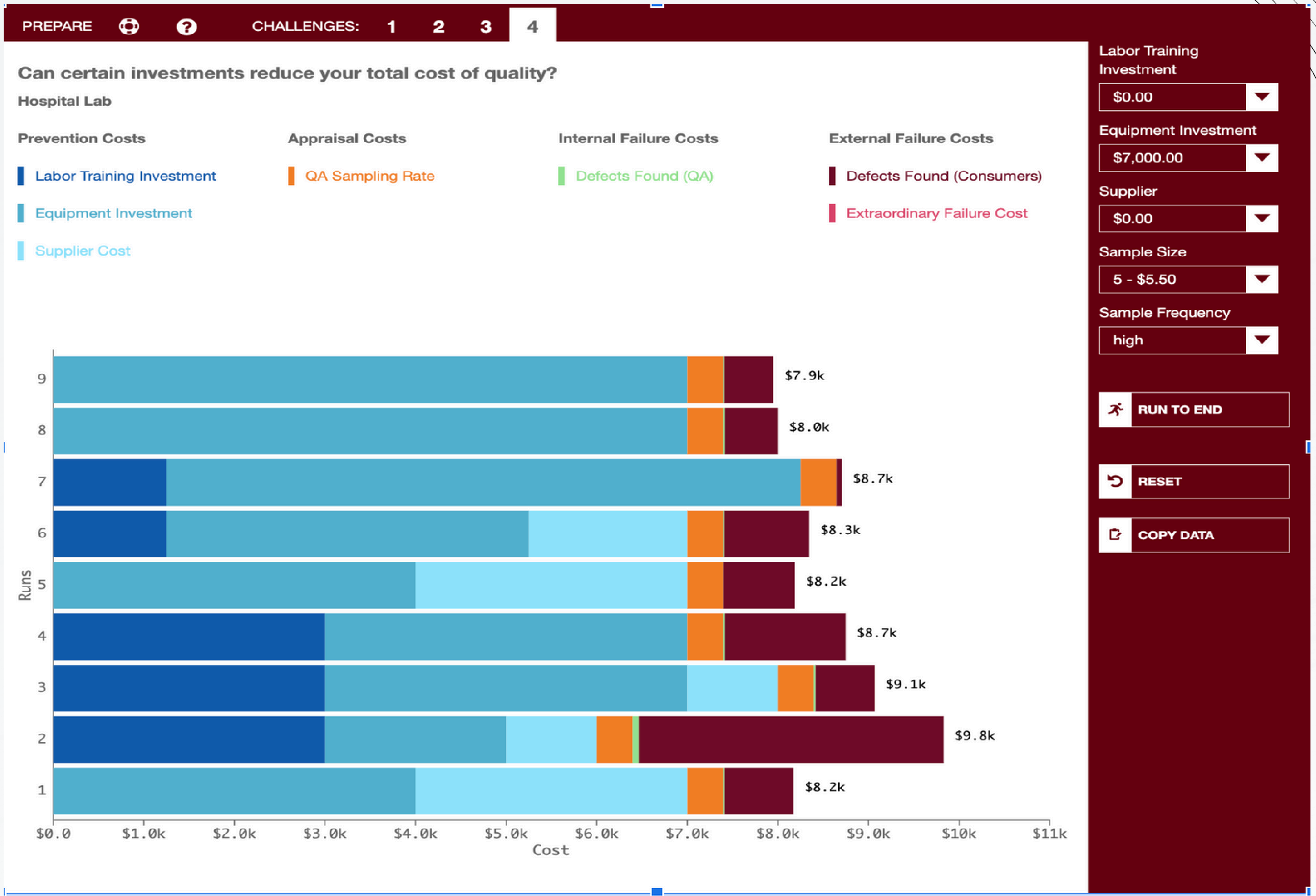
Step 2: Calculate Process Standard Error
(UCL-Process Mean)/3 = (33.8737-32.575)/3 = 0.432 psi

Step 3: Calculate Process Standard Deviation
σ = Standard Error × $\sqrt{n}$ = σ=0.432 × $\sqrt{30}$ ≈ 2.365 psi

Step 4: Calculate the Process Capability Index (Cp)
Cp = (USL-LSL)/(6×σ) = (35-32)/(6×2.365) ≈ 0.212



TOTAL COST = 7.9K



STRATEGIES TO MINIMIZE TOTAL COST OF QUALITY

PREVENTIVE MEASURES

Invest in Equipment Upgrades
Prevents defects at the source and minimizes external failure costs

Labor Training
Ensures that workers can operate equipment effectively and handle process adjustments efficiently, reducing the likelihood of errors

EFFECTIVE PROCESS MONITORING

Use Control Charts for Early Detection:
Detects trends or signals that indicate potential problems and address them before they escalate

Adjust Sample Frequency & Size:
Provides more accurate data, ensuring timely intervention without excessive inspection costs

COST-EFFECTIVE PROCESS ADJUSTMENTS

Timely Recalibration:
Prevents more expensive failures by ensuring the process remains within control limits

Strategic Labor Changes:
Addresses variability issues without disrupting production, helping maintain process consistency

OPTIMIZE QUALITY CONTROL INVESTMENTS

Balance Appraisal & Prevention Costs:
Example: high-quality equipment may reduce the need for extensive final inspections, lowering overall quality costs

Continuous Process Improvement:
Identifies opportunities to reduce internal failure rates and external defect costs, thereby minimizing total quality costs over time

CONTROLLING TOTAL COST OF QUALITY

- Understand the total cost of quality
- Find ways to reduce the number of defects before they become customers' problems
- Need to be aware that many quality control issues are preventable
- Understand how their competitors use quality management practices to stay on top of the competition

Lessons learned

MAINTAIN CONTROL

- Use control limits in real-time
- Analyze control charts
- Calculate the control limits

READ CONTROL CHARTS

- Use control charts to determine whether a process is capable

MINIMIZE TOTAL COST

- Examine quality control investment decisions
- Use data analytics

DEVELOP STRATEGY

- Examine the relationship between internal failure costs, external failure costs, appraisal costs

EXPAND CRITICAL THINKING

- Analyze and compare different outcomes
- Evaluate your ability to improve the quality of the project

SERIOUS GAMES AND SIMULATIONS

- Exciting learning
- Used by everyone
- Educating
- Help retain information
- Engagement

THANK YOU FOR LISTENING

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