Statistical Quality Control

Semester IV **STAT CC410**

Unit 2

A. A Run of Length 8 or More Points
B. Cyclic Behavior of Points
C. Presence of Trend
D. Gradual Shifts in the Process Level
E. Mixture Patterns (or The Effect of Two or More Distributions)
F. Stratification Patterns

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Analysis of Patterns on Control Chart

A. A run of length 8 or more points:

- A control chart may indicate an out of control condition when one or more points fall beyond the control limits or when the plotted points exhibit some nonrandom pattern of behaviour.
- Let us take the example of $\bar{X}$ chart shown in Figure 1. Here, we see that all the 25 points fall within the control limits, the points do not indicate statistical control because their pattern is very nonrandom in appearance. Specifically, we note that 19 of 25 points plot below the central line, only 6 of them plot above.
- If the points truly are random, we should expect a more even distribution above and below the central line.
- From the Figure 1, we also observe that after the 4^{th} point, 5 points in a row increase in magnitude. This arrangement of points are called a ***run***.
- Since the observations are increasing, we could call them a ***run up***.

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- Similarly, a sequence of decreasing points is called a ***run down***.
- This control chart has an unusually long run up beginning with the 4^{th} point and an unusually long run down beginning with the 18^{th} point.
- Now, we define a run as a sequence of observations of the same type. For example, if 2 points in a row above the central line is called a run of length 2.
- A run of length 8 or more has a very low probability of occurrence in a random sample of points. Thus, any type of run of length 8 or more is often taken as a signal of an out of control condition. For example, 8 consecutive on one side of the central line may indicate that the process is out of control.
- Although runs are an important measure of nonrandom behavior of a control chart.

Control Charts

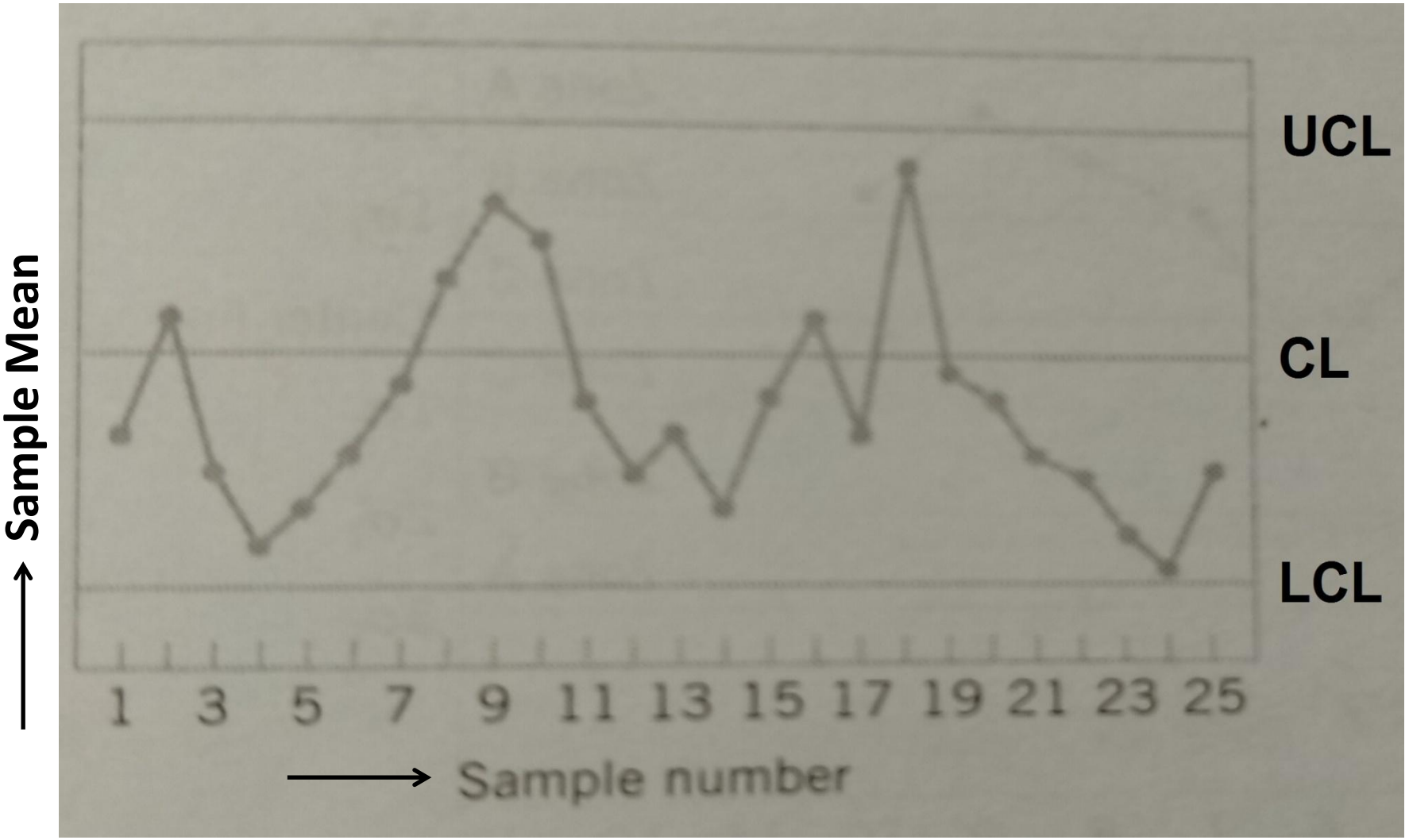

Figure 1

B. Cyclic Behavior of Points:

- Consider the $\bar{x}$ chart in Figure 2, where the plotted sample averages exhibit a cyclic behavior, yet all the points fall within the control limits.
- Such a pattern may indicate a problem with the process operator fatigue, raw material deliveries, heat or stress build up, etc. Although the process is not really out of control, the yield may be improved by elimination or reduction of the sources of variability causing this cyclic behavior.

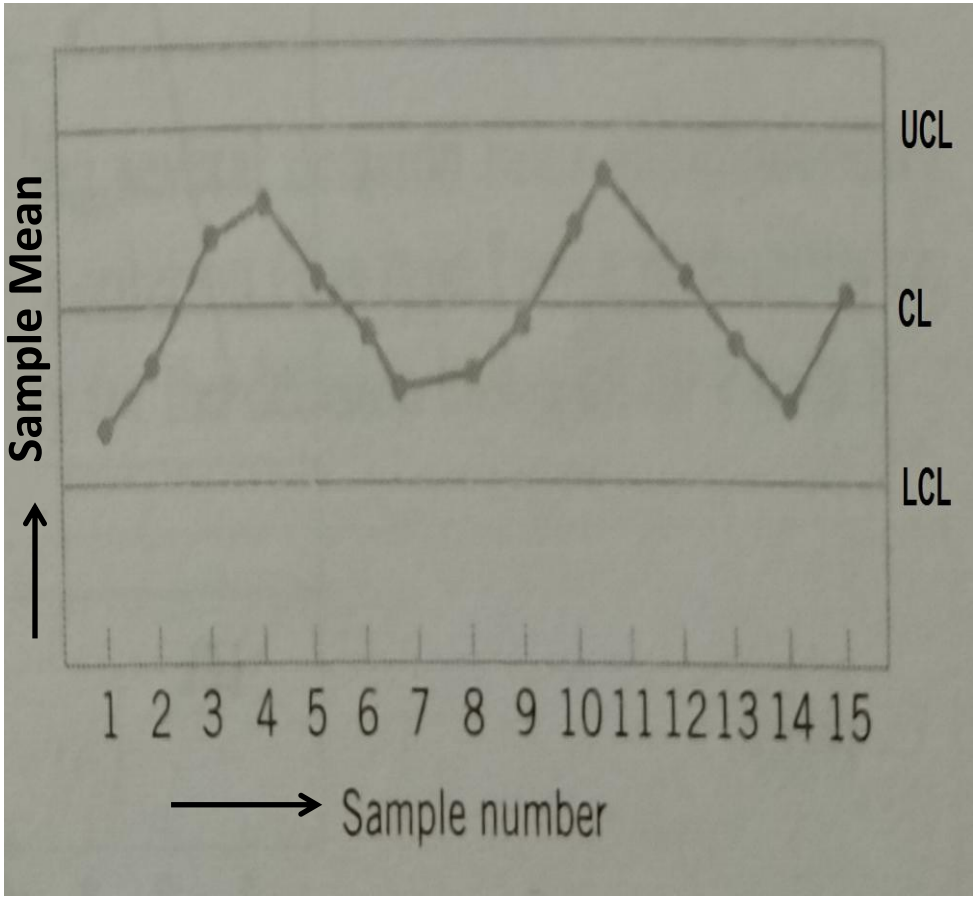

Figure 2

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- The ability to interpret a particular pattern in terms of assignable causes requires experience and knowledge of the process. That is, we must not only know the statistical principles of control charts, but we must also have a good understanding of the process.

C. Presence of Trend:

- A trend or continuous movement in one direction, as shown in the control chart in Figure 3. Trends are usually due to a gradual wearing out or deterioration of a tool or some other critical process component. In chemical process they often occur because of setting or separation of the components of a mixture.
- They can also result from human causes, such as operator fatigue or the presence of supervision.
- Finally trends can result from seasonal influences, such as temperature.
- When trends are due to tool wear or other systematic causes of deterioration, this may be directly incorporated into the control chart model.
- A device useful for monitoring and analyzing processes with trends is the regression control chart.

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Control Charts

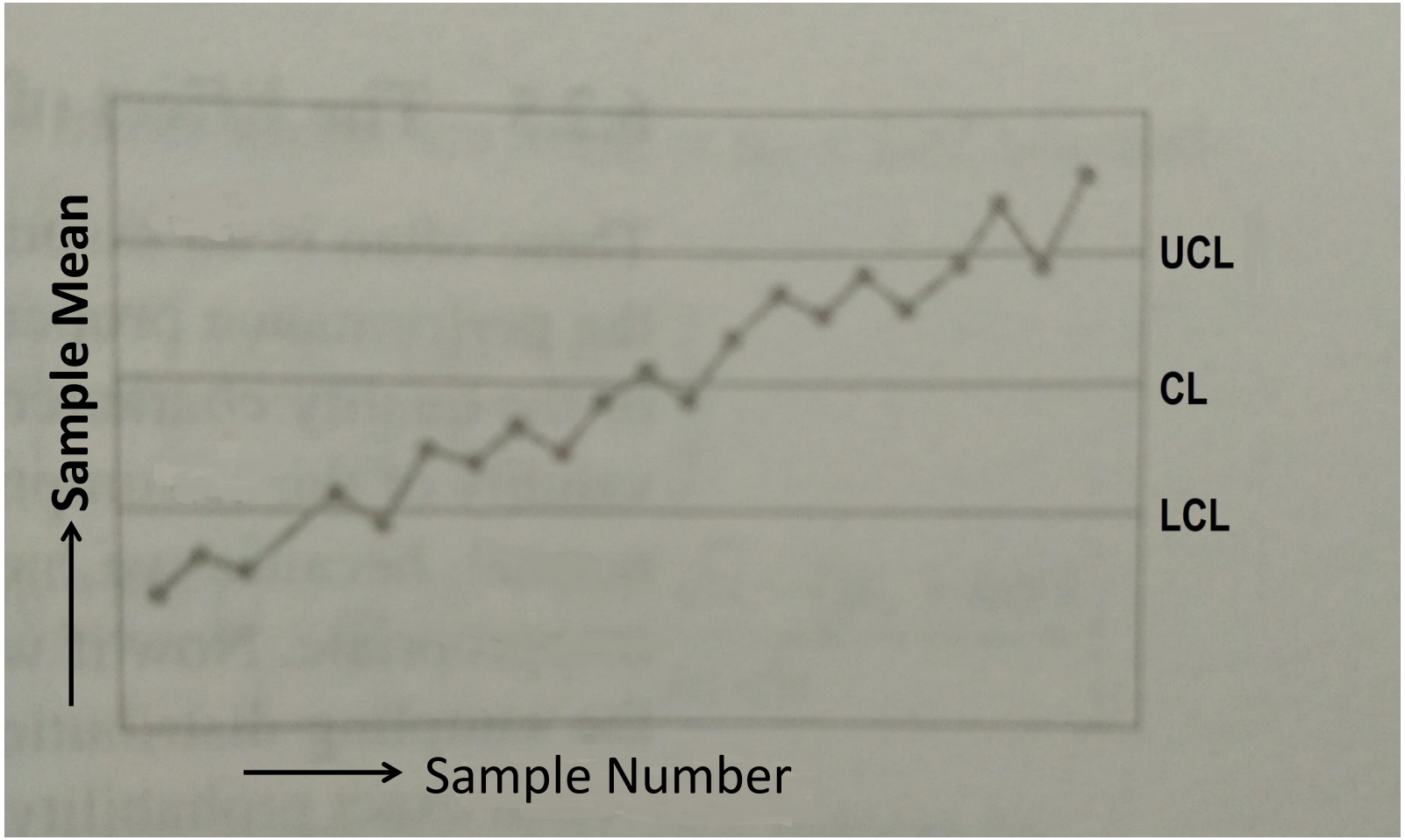

Figure 3

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D. Gradual Shifts in the Process Level :

- The gradual shifts in level may result from the introduction of new workers, change in methods, raw materials, or machines, a change in the inspection method or standards, or a change in either skill, attentiveness, or motivation of the operators.
- Sometimes an improvement in process performance is noted following introduction of a control chart program, because of motivational factors influencing the workers.
- Gradual shifts occur when a process parameter changes gradually over a period of time. Afterward, the process stabilizes.
- An $\bar{X}$ chart might exhibit such a shift because the incoming quality of raw materials or components changed over time, the maintenance program changed, or the style of supervision changed.
- An *R* chart might exhibit such a shift because of a new operator, a decrease in worker skill due to fatigue or monotony, or a gradual improvement in the incoming quality of raw materials because a vendor has implemented a statistical process control system.
- Figure 4 shows an $\bar{X}$ chart exhibiting a gradual shift in the level.

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Gradual Shift in Process Level on $\bar{X}$ Chart

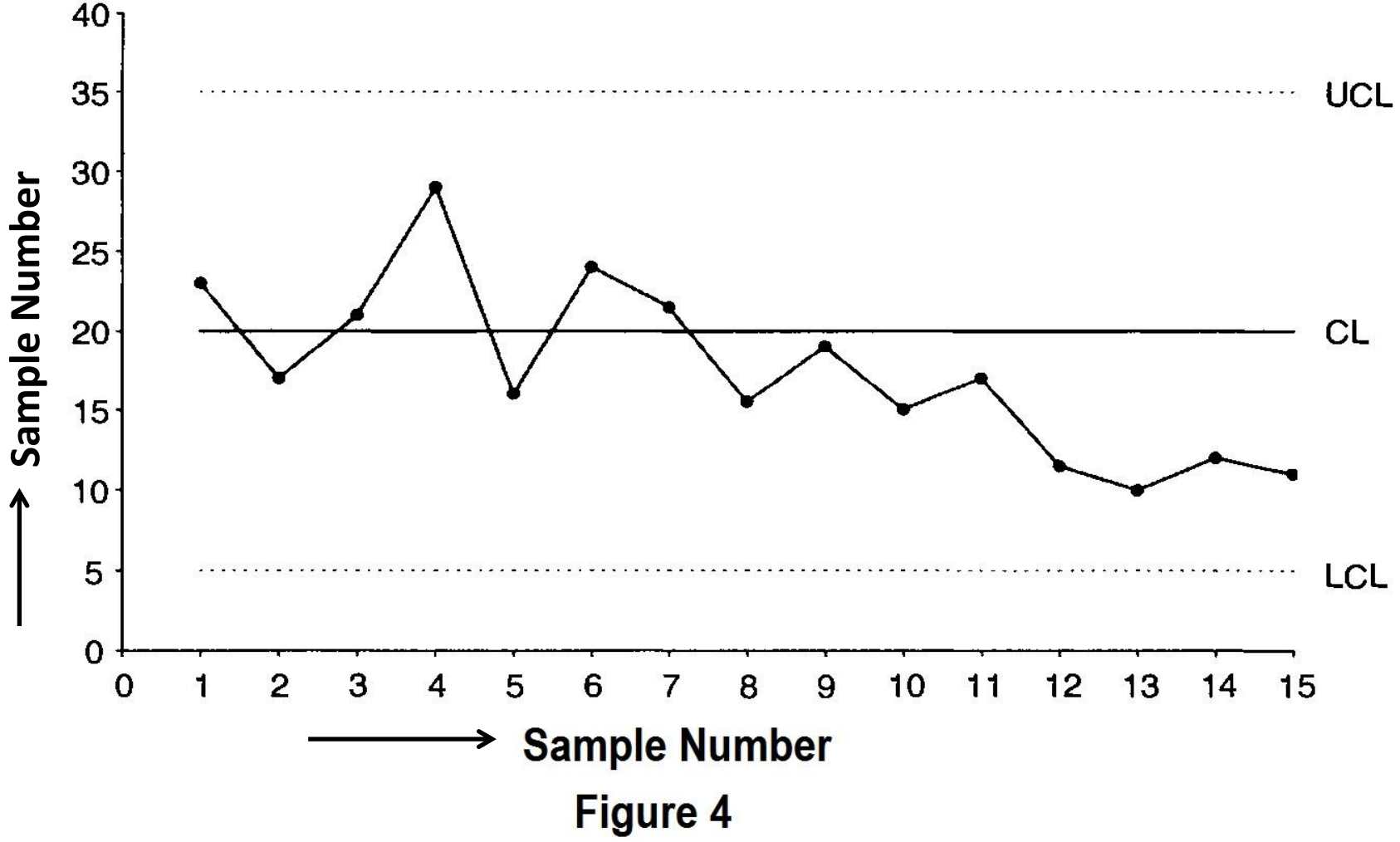

Figure 4

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E. Mixture Patterns (or The Effect of Two or More Distributions):

- A mixture pattern is indicated when the plotted points tend to fall near or slightly outside the control limits, with relatively few points near the central line as shown in Figure 5.
- A mixture pattern is generated by two or more overlapping distributions generating the process output.
- The severity of the mixture pattern depends on the extent to which the distributions overlap.
- Sometimes mixture result from ‘over control’, where the operators make process adjustment too often, responding to random variation in the output rather than systematic causes.
- A mixture pattern can also occur when output product from several sources such as parallel machines is fed into a common stream which is then sampled for process monitoring purposes.

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- A mixture pattern can occur when one set of values is too high and another set too low because of differences in the incoming quality of material from two vendors. A remedial action would be to have a separate control chart for each vendor.
- On an $\bar{x}$ chart, a mixture pattern can also result from over control. If an operator chooses to adjust the machine or process *every* time a point plots near a control limit, the result will be a pattern of large swings.
- Mixture patterns can also occur on both $\bar{x}$ and *R* charts because of two or more machines being represented on the same control chart.
- Other examples include two or more operators being represented on the same chart, differences in two or more pieces of testing or measuring equipment, and differences in production methods of two or more lines.

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Mixture Pattern on an $\bar{X}$ Chart

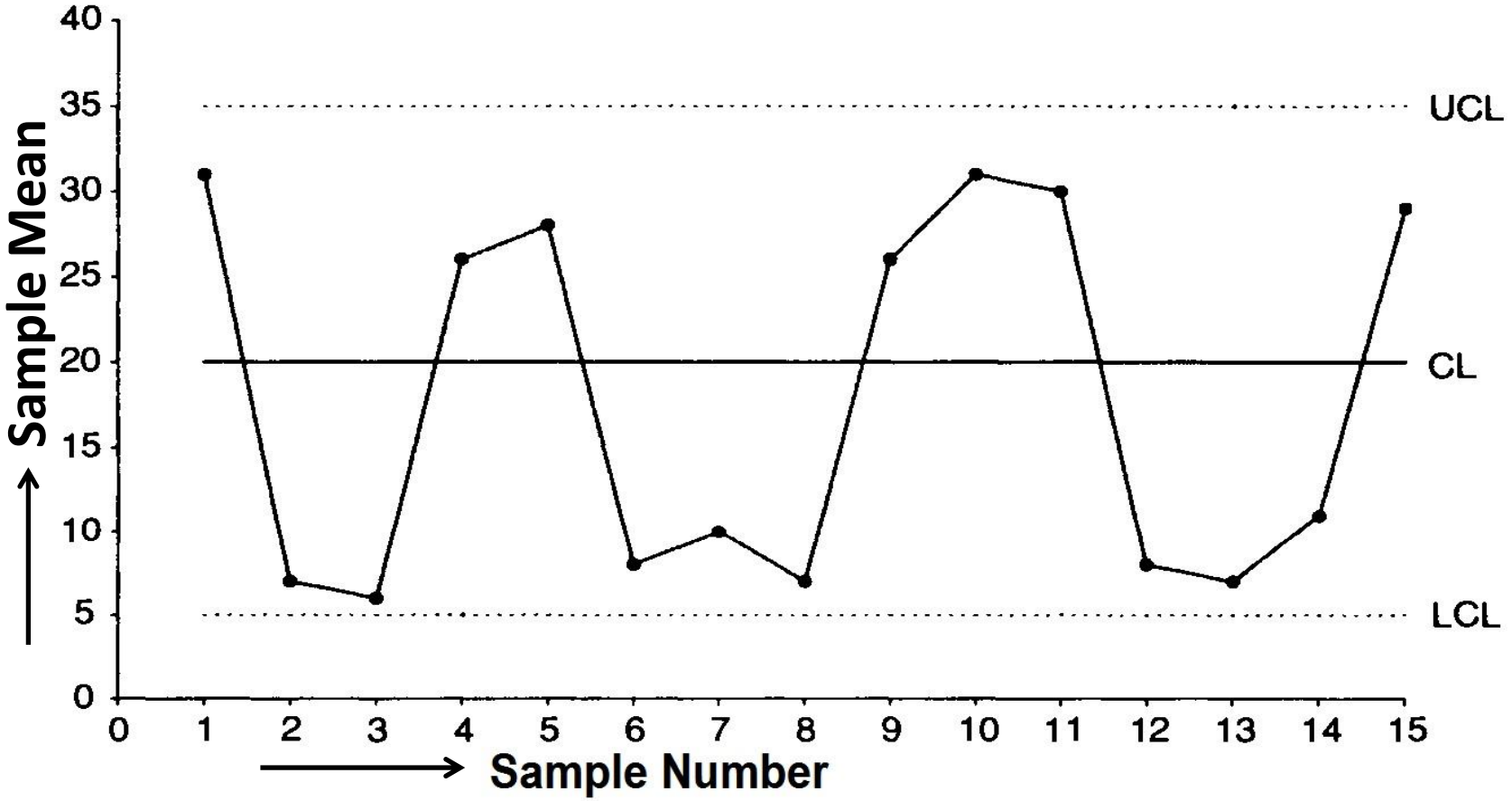

Figure 5

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F. Stratification Patterns:

- Stratification means tendency for the points to cluster artificially around the central line with very few points near the control limits as shown in Figure 6.
- We see that there is a marked lack of natural variability in the observed pattern.
- One potential cause of stratification is incorrect calculation of control limits. This pattern also result when the sampling process collects one or more units from several underlying distributions within each subgroup.

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- For example, suppose that a sample of size 5 is obtained by taking one observation from each of five parallel processes. If the largest and smallest units in each sample are relatively far apart because they come from two different distributions, then *R* will be incorrectly inflated, causing the limits on $\bar{x}$ chart to be too wide.
- In this case, *R* incorrectly measures the variability between the different underlying distributions, in addition to chance causes of variation that is intended to measure.
- Remedial measures in such situations involve having separate control charts for each distribution. The method of choosing rational samples should be carefully analyzed so that component distributions are not mixed when samples are selected.

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- In interpreting pattern on $\bar{x}$ and *R* charts, we should consider the two charts jointly.
- If the underlying distribution is normal, then the random variables $\bar{x}$ and *R* computed from the same sample are statistically independent.
- Therefore, $\bar{x}$ and *R* should behave independently on the control chart.
- If there is correlation between $\bar{x}$ and *R* values – that is, if the points on the two charts follow each other - then this indicates that the underlying distribution is skewed.
- If specifications have been determined assuming normality, then those analyses may be error.

Stratification Pattern on an $\bar{X}$ Chart

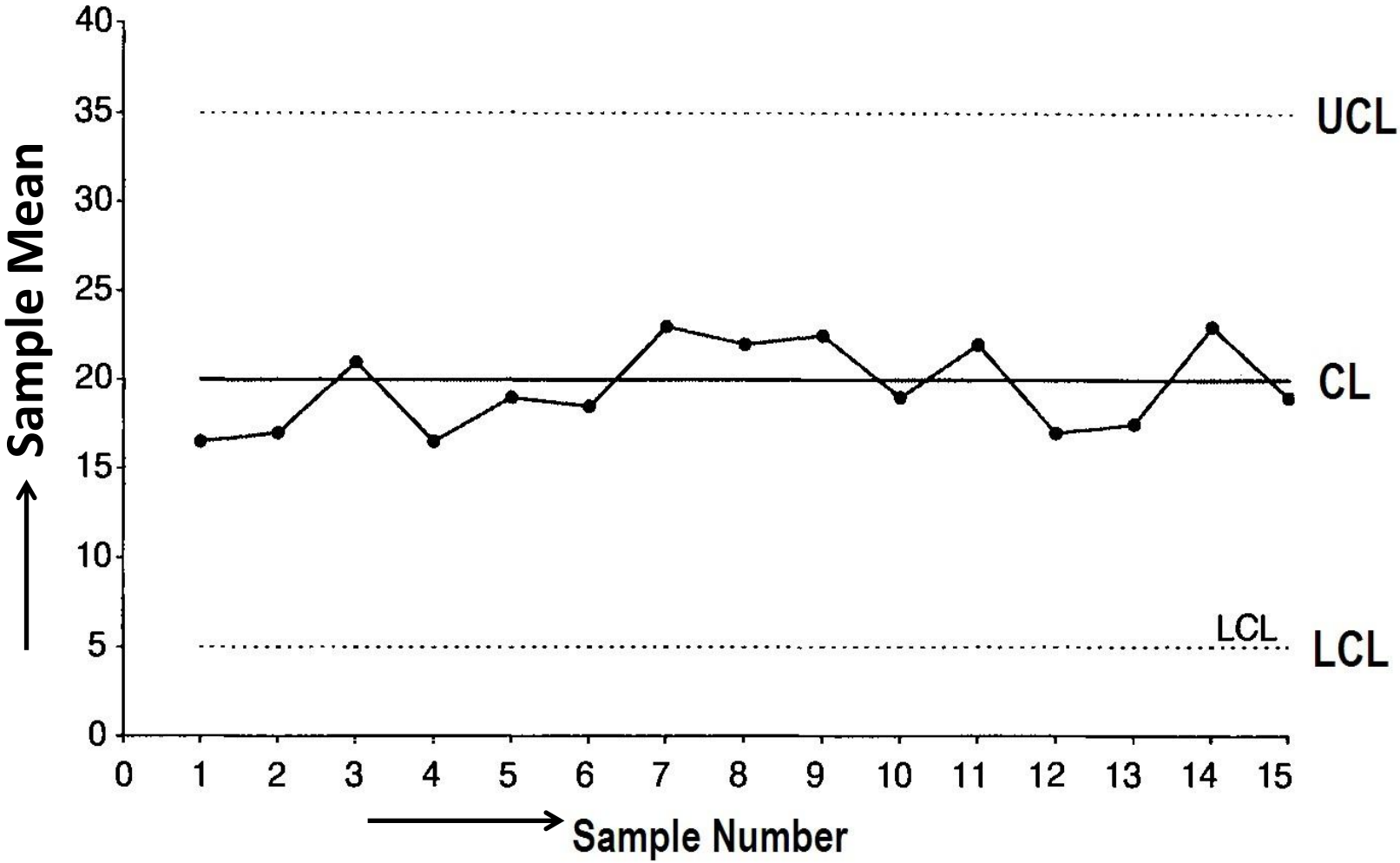

Figure 6

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- Western Electric Handbook (1956) suggests a set of decision rules for detecting nonrandom pattern on control charts. Specifically, it suggests concluding that the process is out of control if either

1. One point plots outside the 3σ control limits,
2. Two out of three consecutive points plots beyond the 2σ warning limits,
3. Four out of five consecutive points plot at a distance of 1σ or beyond from the central line, or
4. Eight consecutive points plot one side of the central line.