Statistical Process Control

User Agreement and Copyright Information

air academy ASSOCIATES © 2020

Statistical Process Control

- In this session, we will discuss:

    - What a control chart is and how it can help us

    - 7 Out-of-Control symptoms

    - 4 different types of control charts
        - IMR Chart
        - Xbar-R Chart
        - p-Chart
        - c-Chart

    - Using SPC XL to generate and interpret control charts

    - Various examples of the use of control charts

- A list of supplemental material and additional practice/review questions for this session are provided at the end of this presentation

- You can download the pdf of this presentation, along with any supporting data files, on the site where you are accessing this course

Control Chart

… represents the "Voice of the Process"

… identifies outliers, shifts, and trends
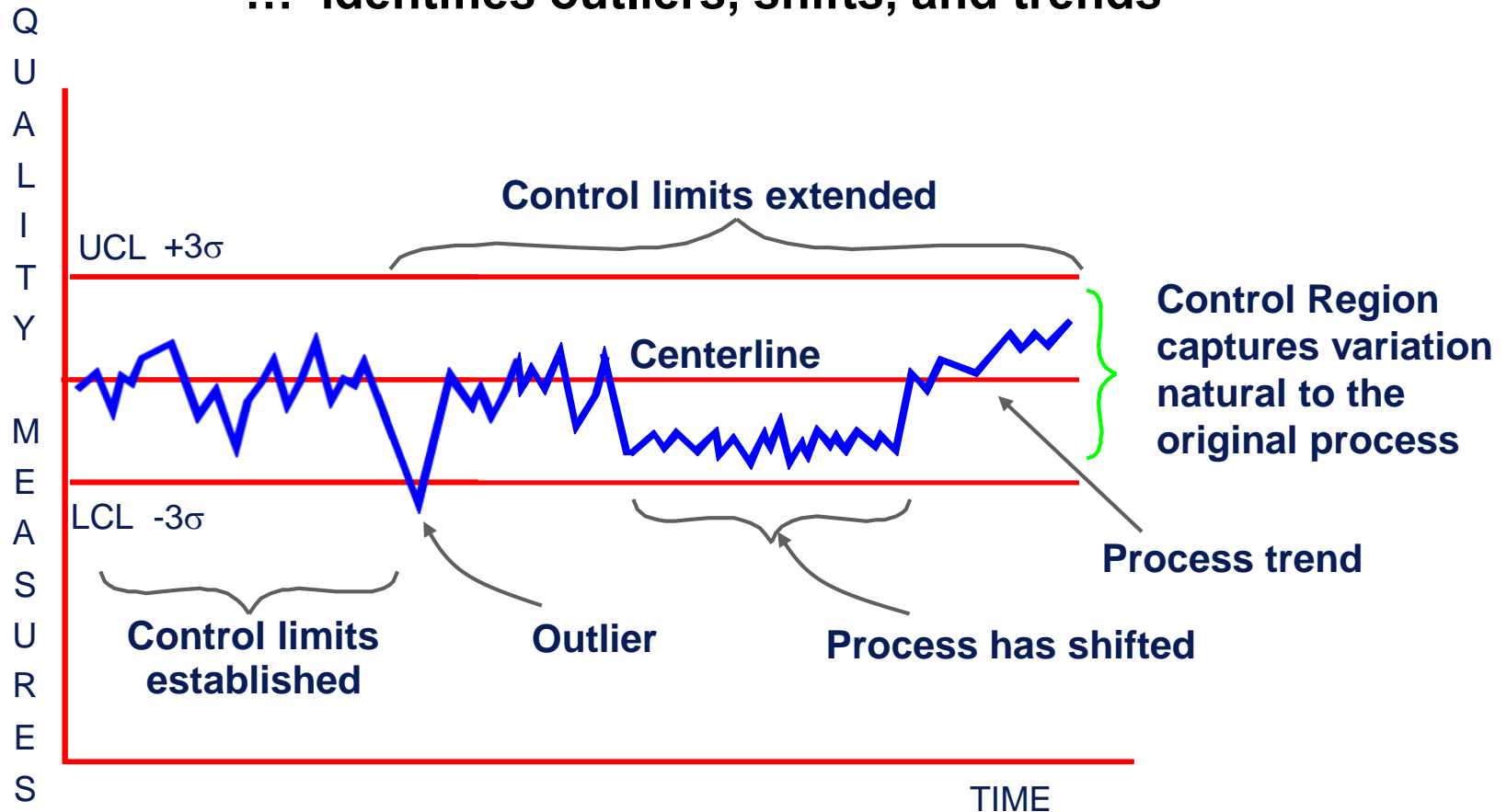
Remember the 68/95/99 Rule
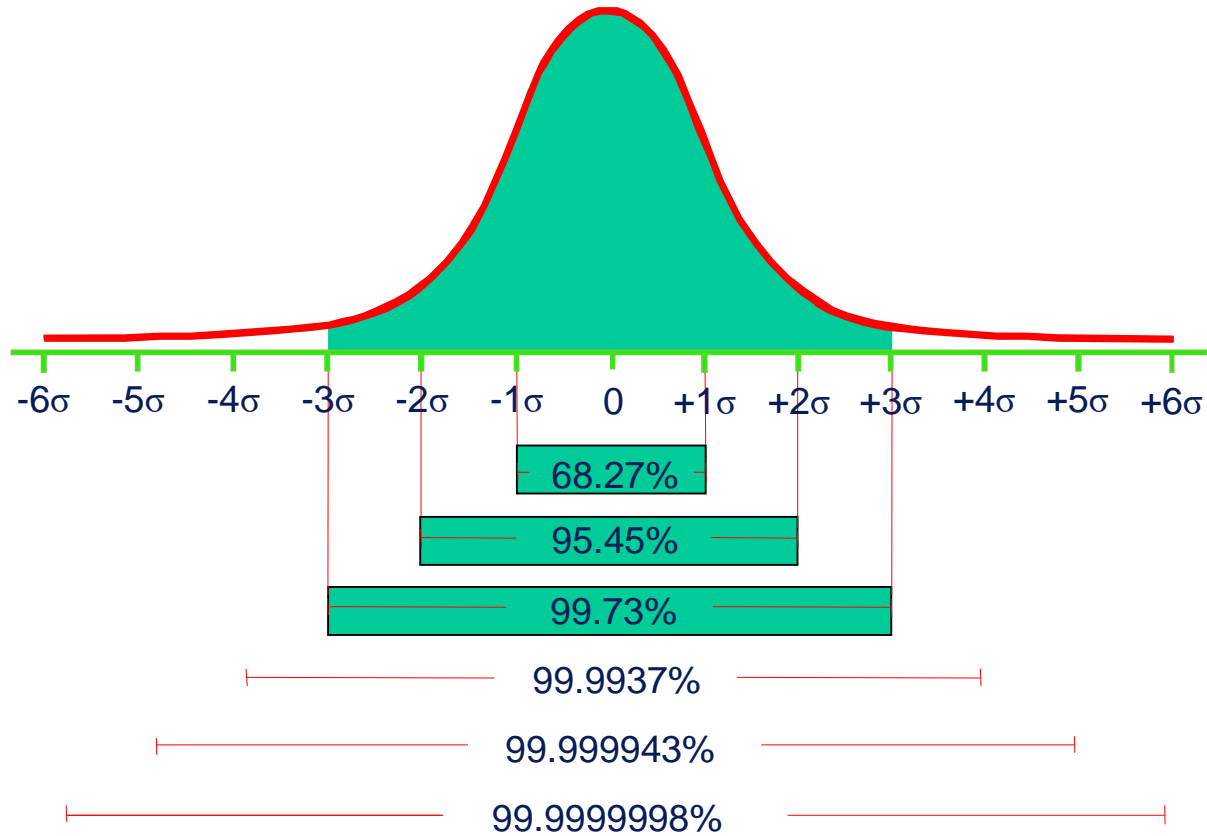
Areas under the Normal Curve

Control Chart with Zones

UCL **+3σ** ....

Zone A 0.02

+2σ

Zone B 0.14

+1σ

Zone C 0.34

$\overline{\overline{X}}$

68% **95%** **99%**

Zone C 0.34

-1σ

Zone B 0.14

-2σ

Zone A 0.02

LCL **-3σ** ....
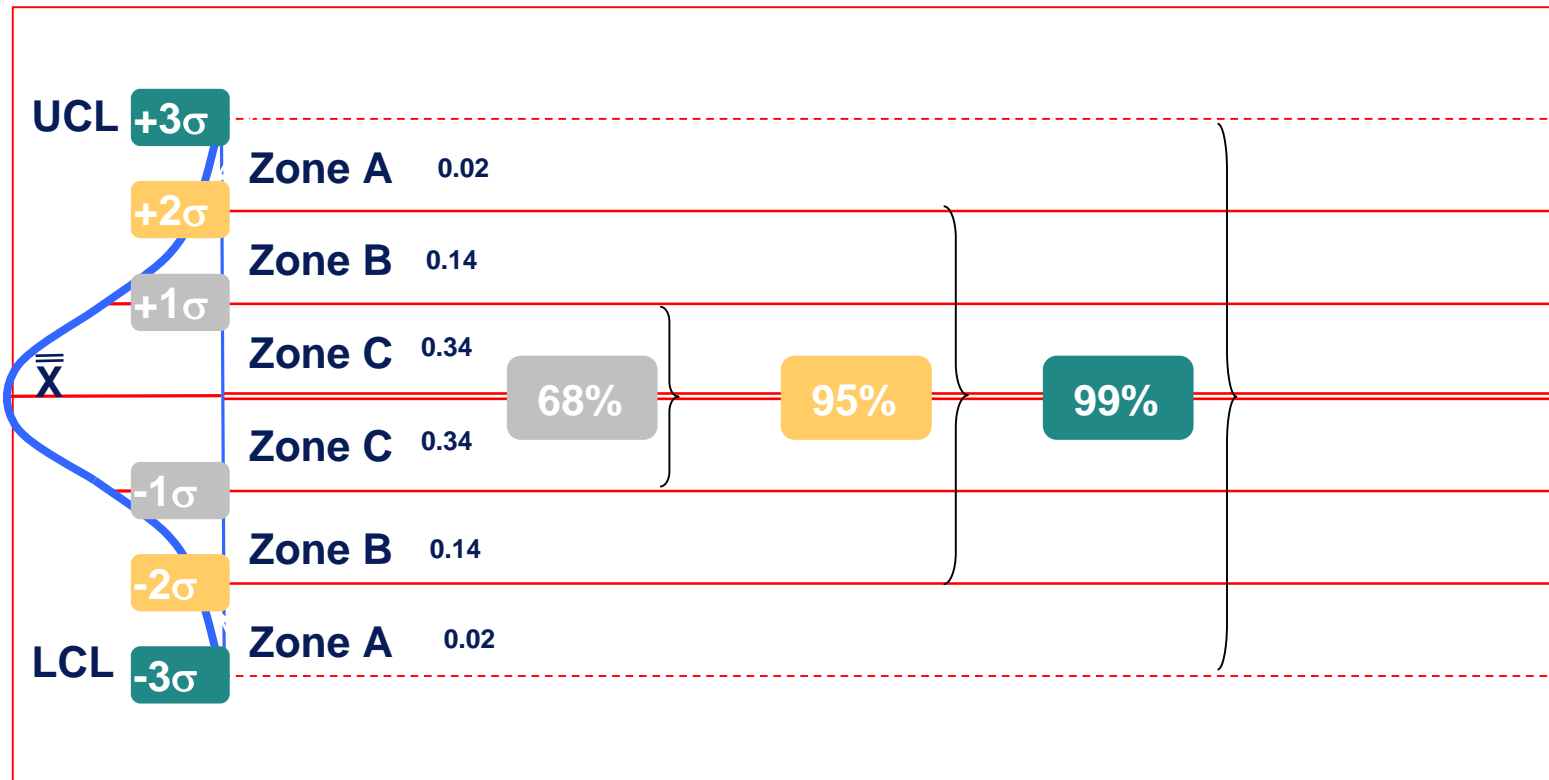
The 68/95/99 Rule

SPC XL will Detect These Symptoms

Symptoms of Out-of-Control

- One or more points are outside the control limits

- 7 or more consecutive points are on the same side of the centerline

- 7 or more consecutive intervals are either entirely increasing or entirely decreasing

- 2 out of 3 consecutive points are in the same Zone A or beyond

- 4 out of 5 consecutive points are in the same Zone B or beyond

- 14 consecutive points alternate up and down repeatedly

- 14 consecutive points in either Zone C (i.e., in center third)

Reasons for Out-of-Control

- NOISE (uncontrolled) variables

- Inadequate SOPs

- Failure to follow SOPs

- True Process Improvement

Examples of Out-of-Control Symptoms

Rule 1 ("outlier")
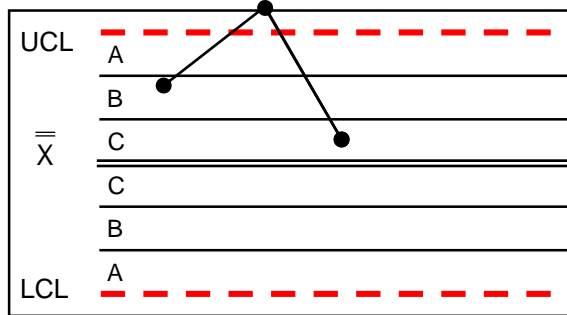
one or more pts are **outside the control limits**

Rule 2 ("shift")
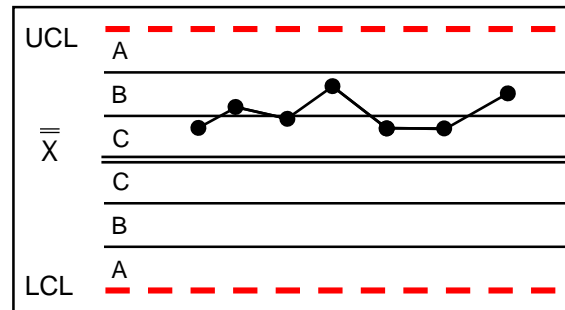
7 cons. pts are on **same side of the centerline**

Rule 3 ("trend")
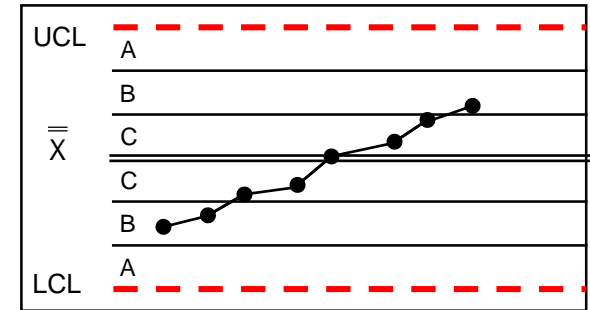
7 cons. **increasing or decreasing intervals**

Rule 4
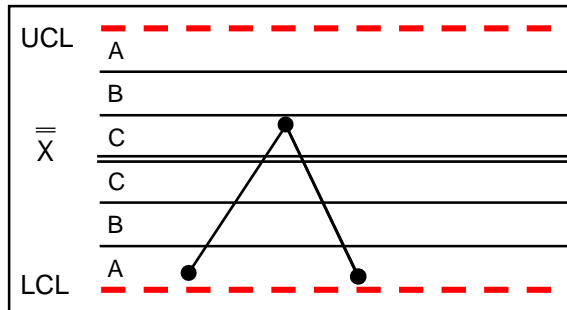
2 out of 3 cons. pts are in **same Zone A or beyond**

Rule 5
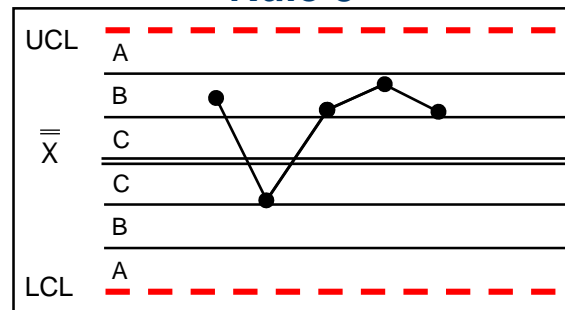
4 out of 5 cons. pts are in **same Zone B or beyond**

Rule 6
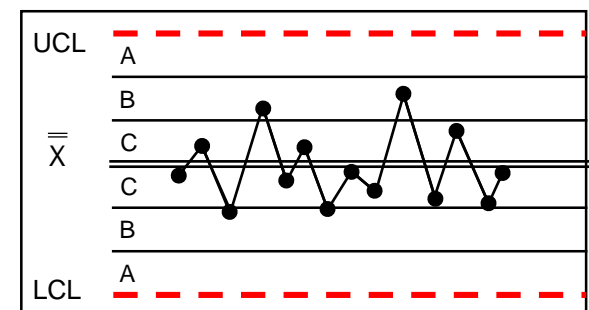
14 cons. pts that **alternate up and down1**

Rule 7
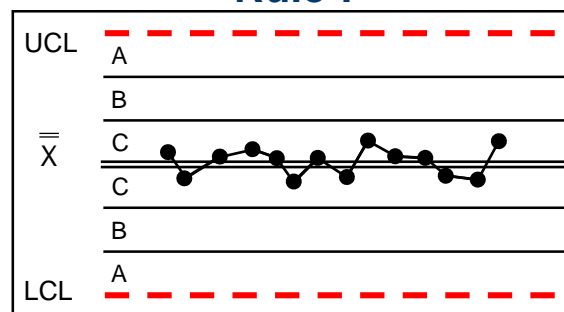
14 cons. pts **in either Zone C (i.e., in center third)**

The Control Chart Wizard in SPC XL

What type of data do you have?

Variables (continuous)

Attribute (discrete)

Defectives: 2 outcomes (pass/fail) (right/wrong)

Defects: items can have more than 1 defect; all defects are counted

Subgroup size (n) fixed and n < 10?

no → Xbar S chart

yes n = 1 → IMR chart

yes 2 ≤ n ≤ 9 → Xbar R chart

Defects or Defectives?

Defectives

Defects

Constant sample size?

yes → np chart

no → p chart

Constant area of opportunity?

yes → c chart

no → u chart

(a p-chart could also be used)

(proportions)

(counts)

(defects per unit)

What is an IMR chart

- IMR stands for Individuals with Moving Range. We really get two charts for the price of one.

- The Individuals (I) chart plots a single value for each time period. This will happen very often in such cases as:
  - Continuous flow processes such as recording one pH reading every hour
  - Closing price of a particular stock
  - Miles per gallon (mpg), when the data point is generated after every fill which may not be on a regular basis or under homogeneous conditions

- The Moving Range (MR) chart plots the difference between successive points on the Individuals chart. The MR chart will have one less point on it than the I chart has and it shows the point-to-point variability

- Always generate a histogram when doing an IMR chart because individual values may not follow a normal distribution. Why?

- Remember the zone rules are dependent on the normal distribution, and if the data does not follow a normal distribution, the zone rules do not apply even though the software may point out zone rule infractions

Go to SPC XL Software and Demo an IMR Chart

⏸

USB **Control Chart Data Files.xlsx**

The Control Chart Wizard in SPC XL
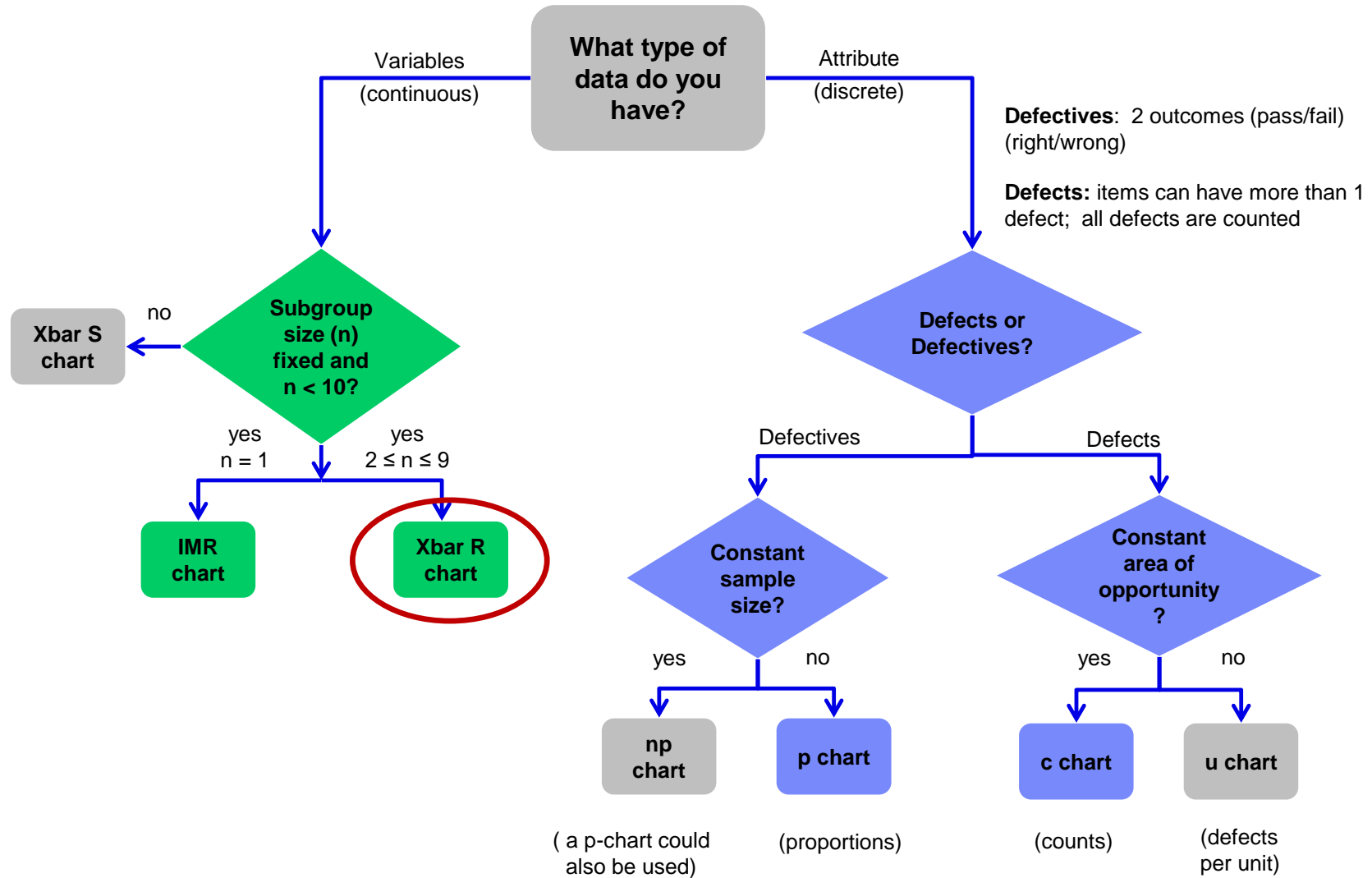
What is a Rational Subgroup

- A rational subgroup is a subset of data collected under relatively homogeneous conditions.

- In order to get homogeneous conditions, subgroups are usually collected within a segment of time (hour, shift, day), space (square yard, square mile), organization (department, division, medical center), or product type.

- The purpose of getting data from a subgroup is twofold:

  - First, to determine the variability **within** each subgroup. This will be shown in the R chart, where the ranges of each subgroup are plotted.

  - Second, to determine the variability **between** the subgroups. This will be shown in the Xbar chart, where the averages of each subgroup are plotted.

- The practitioner should determine the scenario in which the variability **within** and **between** is desired. For example,

  - A hospital wants to determine if the performance measure of LOS (in days) for some particular procedure is stable from a month-to-month perspective.

  - It will then take sample data within each month to form a subgroup for each month.

  - Subgroup sizes of 4-6 are most common.

Go to SPC XL Software and Demo an Xbar-R Chart

Control Chart Data Files.xlsx
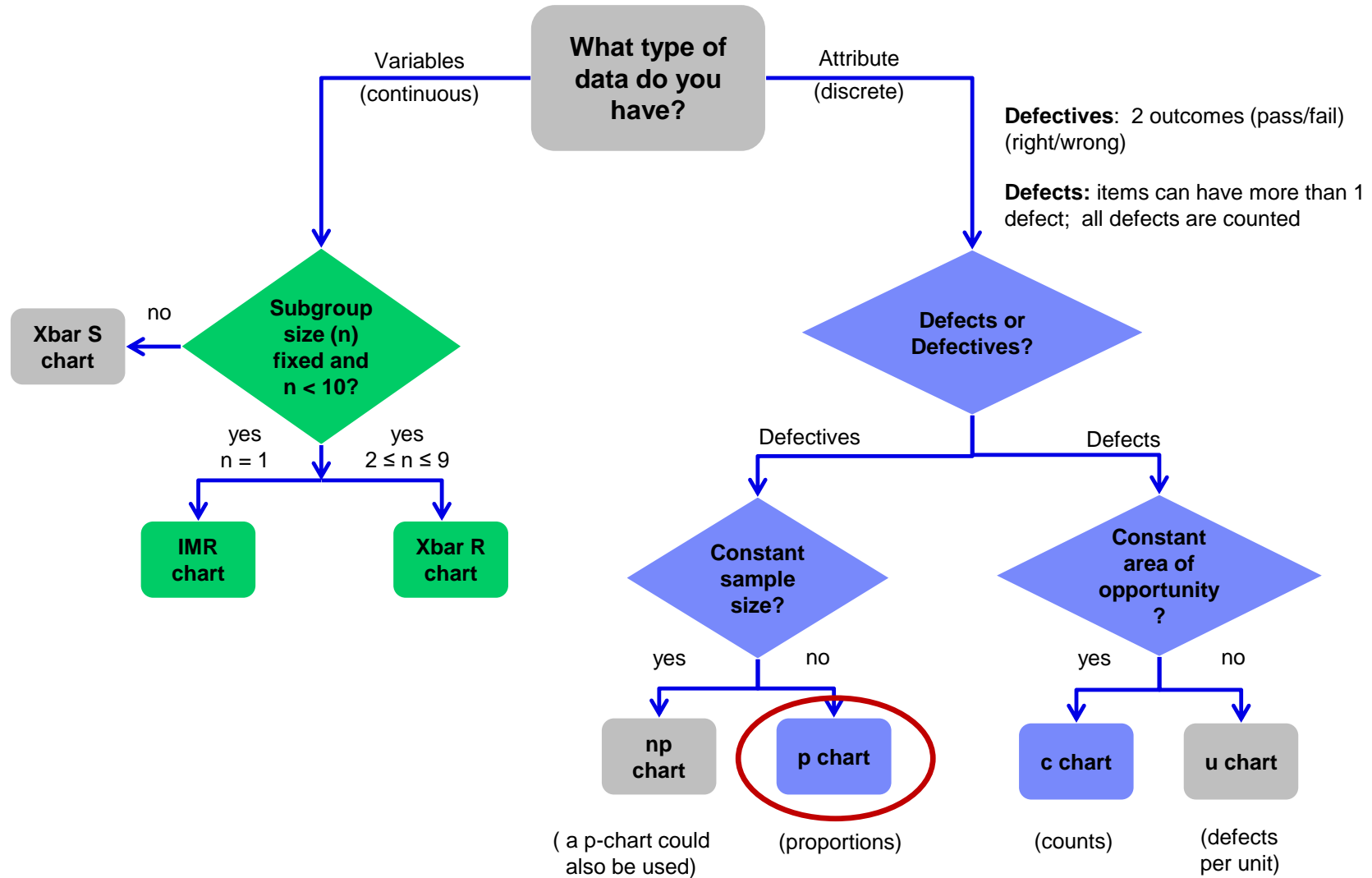
The Control Chart Wizard in SPC XL

What type of data do you have?

- Variables (continuous)
- Attribute (discrete)

Defectives: 2 outcomes (pass/fail) (right/wrong)

Defects: items can have more than 1 defect; all defects are counted

Variables (continuous) branch

Subgroup size (n) fixed and n < 10?

- no → **Xbar S chart**
- yes, n = 1 → **IMR chart**
- yes, $2 \leq n \leq 9$ → **Xbar R chart**

Attribute (discrete) branch

Defects or Defectives?

Defectives

Constant sample size?

- yes → **np chart** (a p-chart could also be used)
- no → **p chart** (proportions)

Defects

Constant area of opportunity?

- yes → **c chart** (counts)
- no → **u chart** (defects per unit)

What is a Proportion

- A proportion is a fraction.

- A fraction has a numerator and a denominator.

- The denominator is the sample size or total number of items being looked at for the particular time interval of interest.

- The numerator is the number of items in the sample that are determined to be "defective" (or the "category of interest"). Thus, the numerator will never be larger than the denominator.

- In SPC XL, the numerator and denominator must be in two adjacent columns (or rows), but it doesn't matter which is on the left or on the right (equivalently, top or bottom rows).

- The proportion will always be a number between 0 and 1 inclusive.

- Always remember that a percentage is a proportion multiplied by 100. For example, 4/9 = 44.44%. As a result, many treat percentages as continuous data which they are not. The p-chart should be used.

Go to SPC XL Software and Demo a p-Chart

⏸

Control Chart Data Files.xlsx

The Control Chart Wizard in SPC XL

What type of data do you have?

Variables (continuous)

Attribute (discrete)

Defectives: 2 outcomes (pass/fail) (right/wrong)

Defects: items can have more than 1 defect; all defects are counted

Subgroup size (n) fixed and n < 10?

no → **Xbar S chart**

yes n = 1 → **IMR chart**

yes 2 ≤ n ≤ 9 → **Xbar R chart**

Defects or Defectives?

Defectives

Defects

Constant sample size?

yes → **np chart**

no → **p chart**

Constant area of opportunity?

yes → **c chart**

no → **u chart**

(a p-chart could also be used)

(proportions)

(counts)

(defects per unit)

The Conditions for Using a c-chart

- The c-chart is based on the Poisson random variable which is defined as the **number of occurrences per unit interval.** And the interval could be in time or space or equal-sized groupings. But the unit interval must be constant from one interval to the next. For example, we could be counting:

  - The number of speeding tickets issued in a certain county per week. The unit interval is a week, and the number of "defects" is the number of speeding tickets issued that week

  - The number of patients arriving at an emergency room per hour

  - The number of suicides per day

  - The number of hurricanes per month

  - The number of code blues per month

  - The number of falls in a nursing home per week

  - The number of infections per 100 patients. Here the interval is not time but equal-size groupings of 100 patients

  - The number of typos per page in a technical book. Here the interval is spatial, not time

- The beauty of the c-chart is that we are plotting whole numbers and that is sometimes easier to comprehend than plotting proportions. The c-chart is probably the simplest chart of all, but the practitioner must remember that a c-chart is only valid if the "area of opportunity" for a defect, be it in time, space, or groupings of items, is always constant

Go to SPC XL Software and Demo a c-Chart

Control Chart Data Files.xlsx

Key Takeaways

⏸

- As a review, you may want to pause the video at this point and summarize the key learnings from this session, at least from a high-level view. When you are finished, you may resume the video and complete the session.

Key Takeaways

- SPC means listening to the voice of the process over time to see if the process performance measure is changing, and a control chart is the primary means to do this.

- Control charts will separate special cause variation from random variation by identifying outliers, shifts, and trends.

- SPC XL software will automatically detect 7 different symptoms that indicate out-of-control behavior, and it will also allow for the splitting of control limits if a process change has occurred.

- The term "out-of-control" is somewhat of a misnomer in the sense that an out-of-control symptom could indicate process improvement. Other reasons for out-of-control symptoms are noise, inadequate SOPs or failure to follow SOPs.

- We covered 4 different control charts:
    - IMR (Individuals with Moving Range)
    - Xbar-R (Mean and Range of subgroups)
    - p (proportions)
    - c (count)

Are you ready to apply the details of SPC?

Supplemental Material

- Suggested Reading:
  - *Basic Statistics* by Kiemele, Schmidt and Berdine (Chapter 9, Appendix I)
  - *Lean Six Sigma: A Tools Guide* by Adams, Kiemele, Pollock and Quan (pp. 217-222)
  - *Design for Six Sigma: The Tool Guide for Practitioners* by Reagan and Kiemele (pp. 279 -285)
  - Air Academy's app: *Six Sigma Quick Tools*

- SPC XL™ software training tutorials:
  - https://airacad.com/our-insights/training-videos/spc-xl/

- The data files for this session can be downloaded from the site where you are accessing this course.

Additional Practice / Review Questions

1) What is the purpose of a control chart?

2) What are the 3 things that a control chart will identify?

3) What is the difference between an IMR chart and an Xbar-R chart?

4) What is a p-chart?

5) When confronted with percentage data, many practitioners treat this data as variables (continuous) data. Why is this dangerous?

6) Which distribution is the c-chart based on?

7) In the zipped data files that accompany this session, reference the following data file:

us coronavirus data as of 4 May 2020.xlsx

Using the time series data in this file, construct an appropriate control chart to see if the number of new cases has stabilized since April 5. Do the same thing with the number of deaths. Do you see any recurring cycles in the data?

We can help…
Connect With Us

Air Academy Associates
Phone: (719) 531-0777
Email: aaa@airacad.com
https://airacad.com/
https://sixsigmaproductsgroup.com/

Remote Project Coaching

There are times when help outside your organization is needed. When that time comes, benefit from a partner that is experienced, tested, and trusted.

Expert coaching is one of the Top Five Best Practices for generating step change in project execution, as well as enhanced return on investment. We can work remotely with your organization to provide coaching support.

There's an app for that!
Six Sigma Quick Tools