Advanced Control Charts: When and Why to Use Them

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Types of Data

- **Discrete Data**
  - Finite data that has defined boundaries
    - Shoe size
    - Bowling ball size
    - Coffee cup size
    - Pages in a book
    - People in a class
    - Seats on an airline

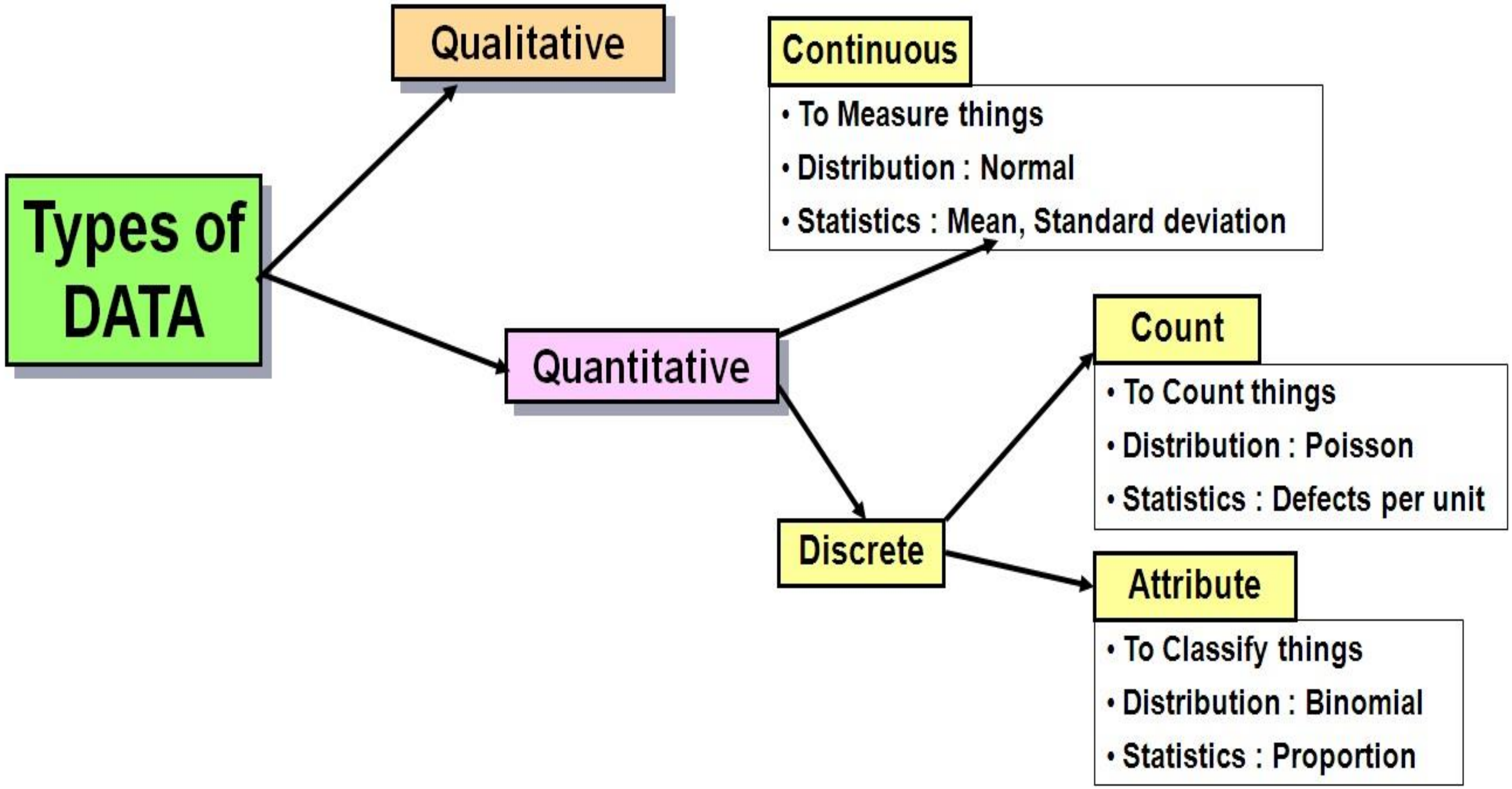
Two Types:

Attribute Data- Examples include, "Good/Bad", "Pass/Fail", "Yes/No".

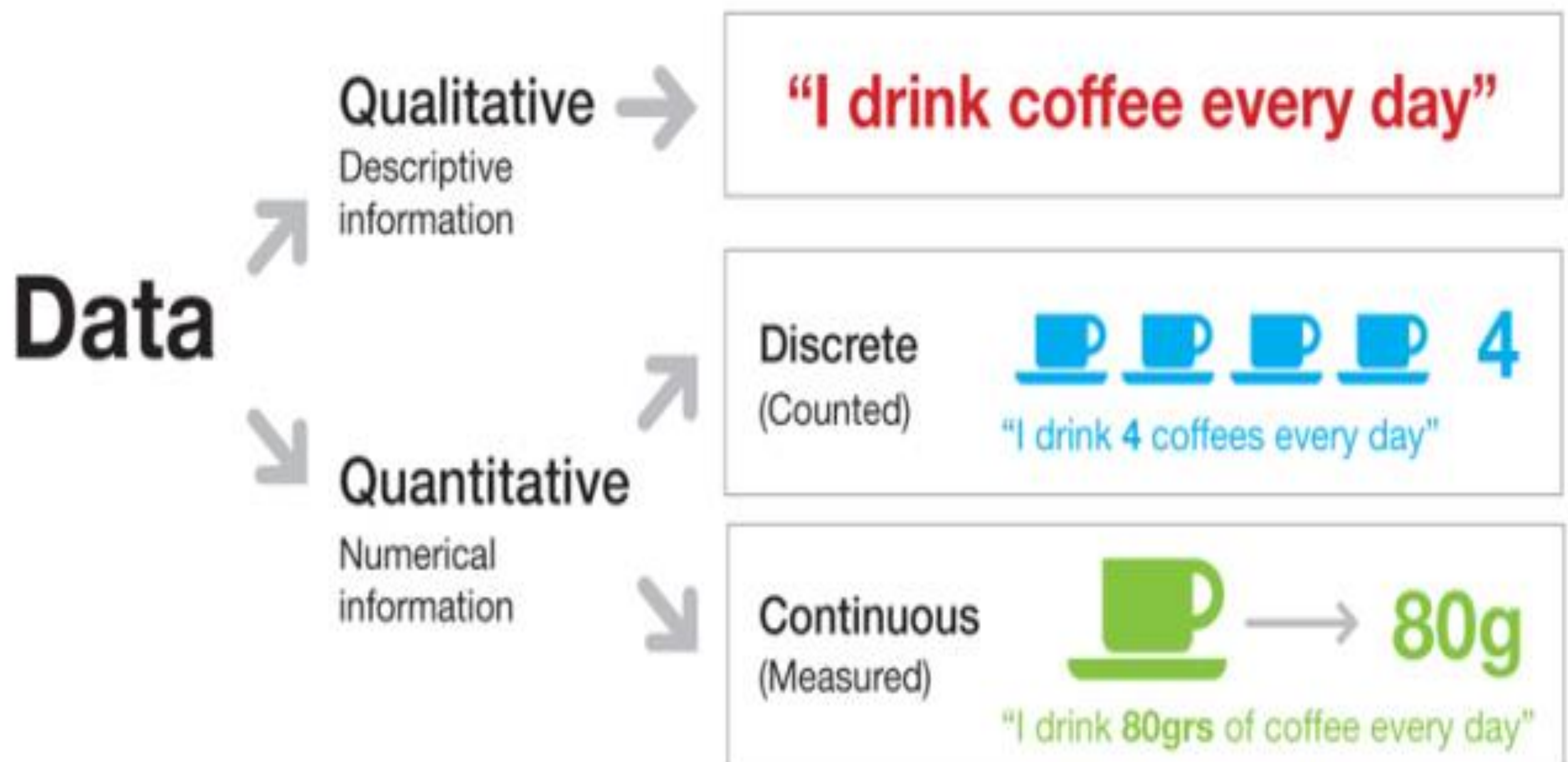
Count Data- Non-negative integer valued random variable. Things such as passengers on airplanes, patients in a clinic, admits to hospital.

- **Continuous Data**
  - Infinite data which has no final boundary
    - Length of a ruler (can always break down to smaller and smaller amounts)
    - Length of a road
    - Density of bone
    - Time of a clinic visit
    - Temperature of a freezer
    - Height of a patient
    - Weight of a patient

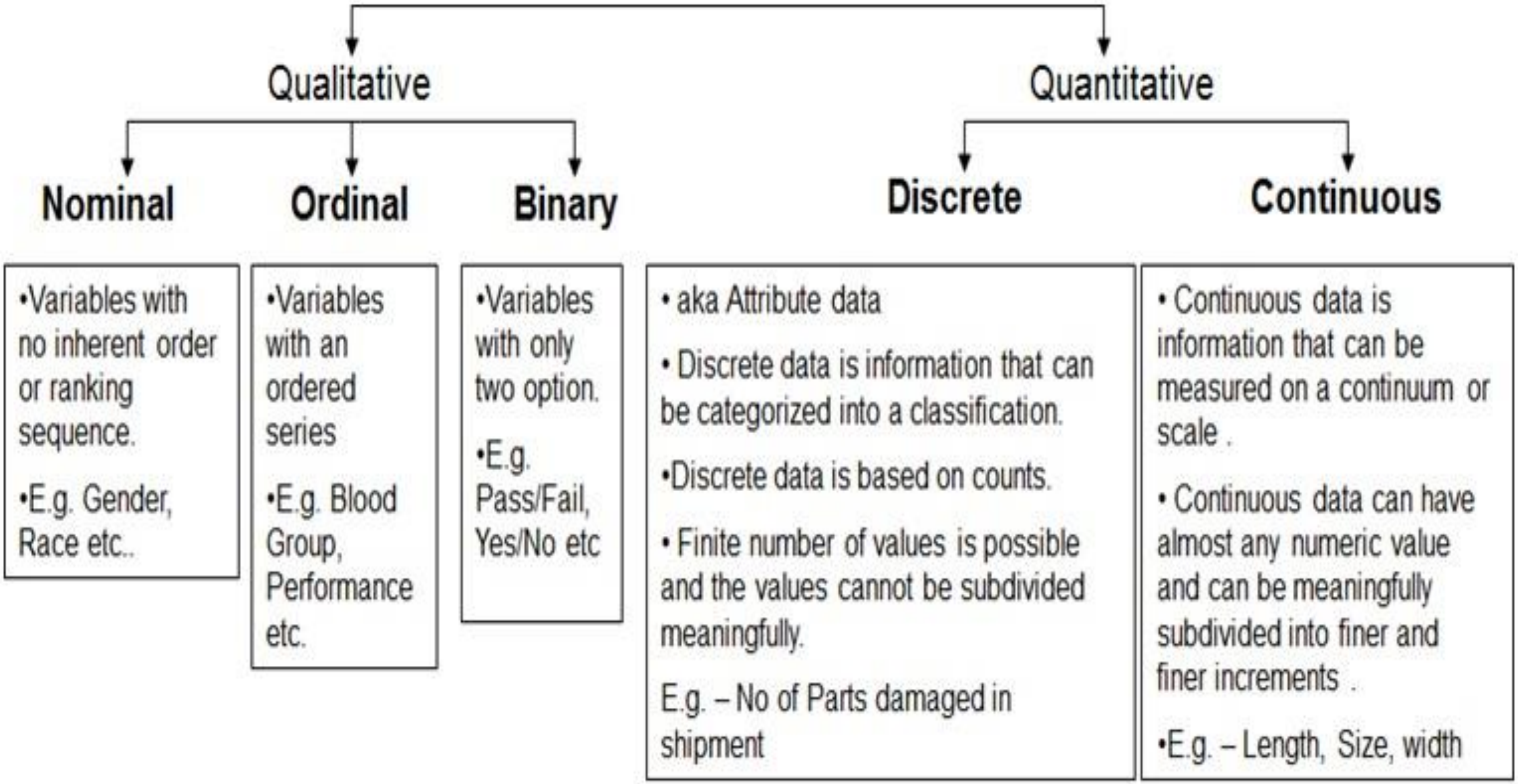
The Type of Data Also Determines Distribution and Statistical Methodology



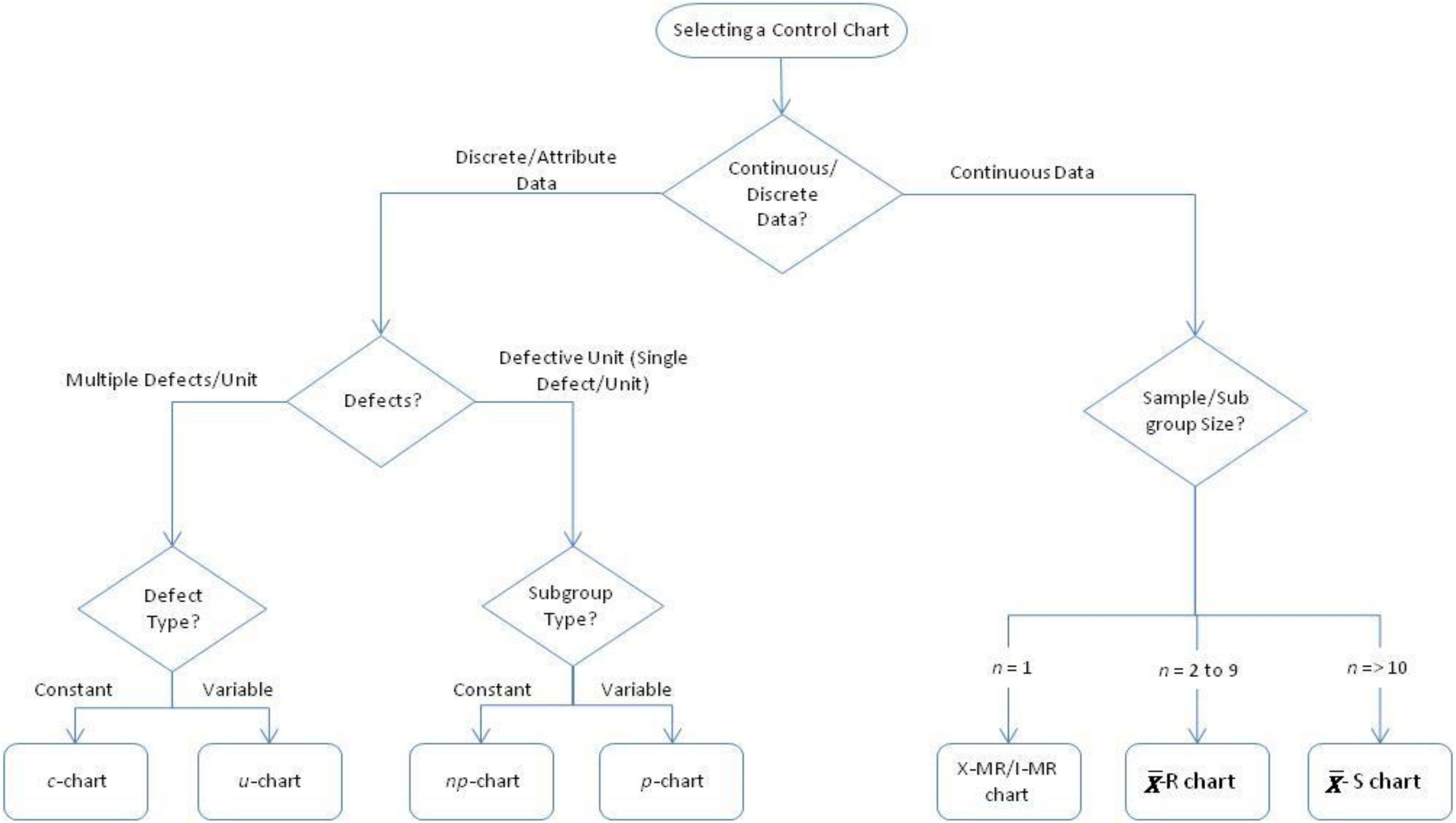
A Way to Think About Qualitative and Quantitative Data



Data Classification Decision Tree



An Overview of Your Choices



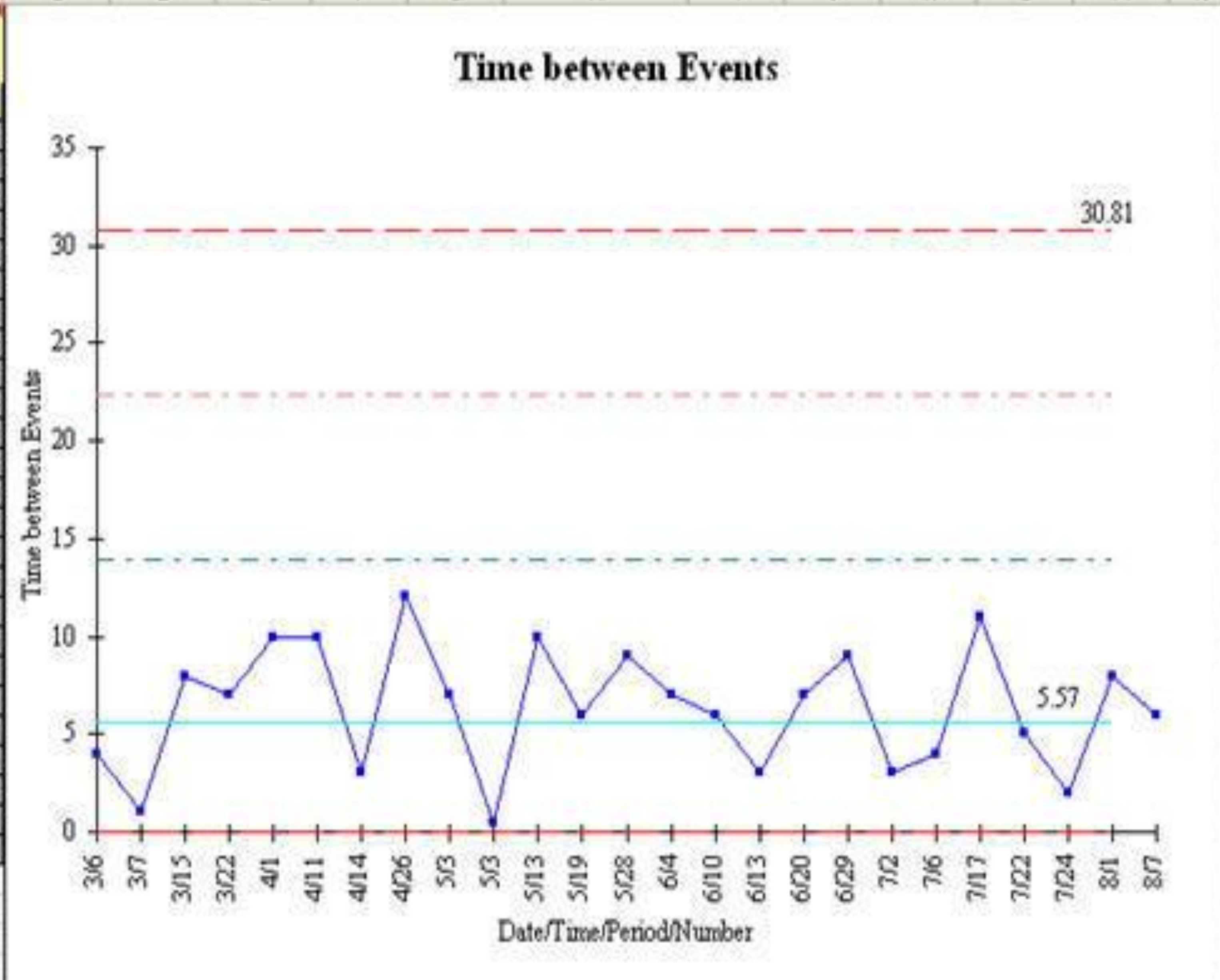
The choice of a control chart depends on the question you are trying to answer!

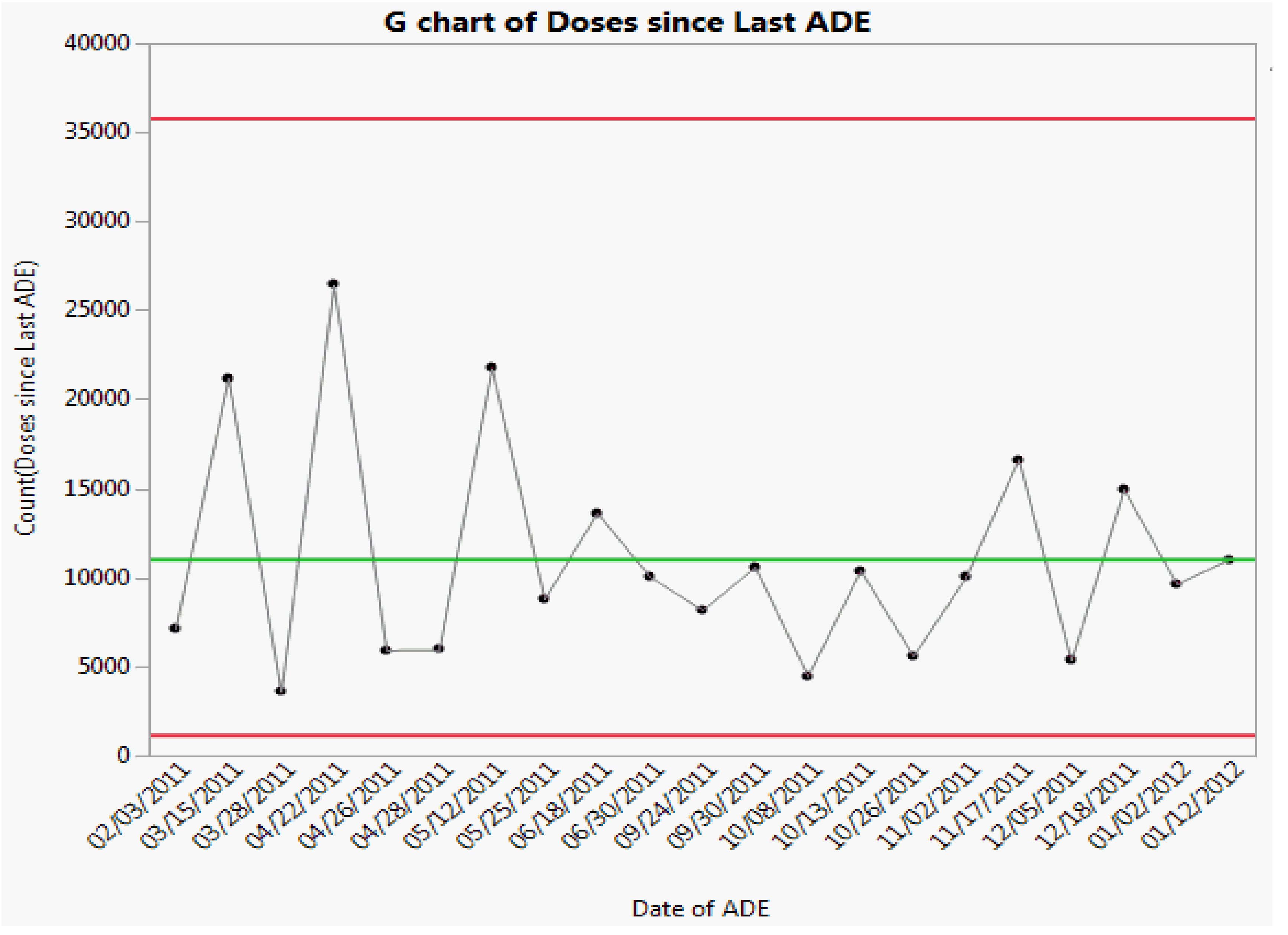
Type of Chart	Medication Production Analysis
X bar & S Chart	What is the TAT for a daily sample of 25 medication orders?
Individuals Chart (XmR)	How many medication orders do we process each week?
C-Chart	Using a sample of 100 medication orders each week, how many errors (defects) are observed?
U-Chart	Out of all medication orders each week, how many errors (defects) are observed?
P-Chart	For all medication orders each week, what percentage have 1 or more errors (i.e., are defective)?

Special Charts for Monitoring Rare Events: T charts and G Charts

- Both of these charts provide information about the number of normally occurring events between nonconforming or rarely occurring incidents.
- T charts- Amount of time between defects
    - Time between events
        - Example: Number of days (or hours) since the last defect.
- G charts- Amount of normal events between a defect.
    - Used for attribute data were a defect is rarely encountered.
    - Developed by Jim Benneyan in 1991.
        - Days between events.
            - Example: Days without hospital acquired infections between infections

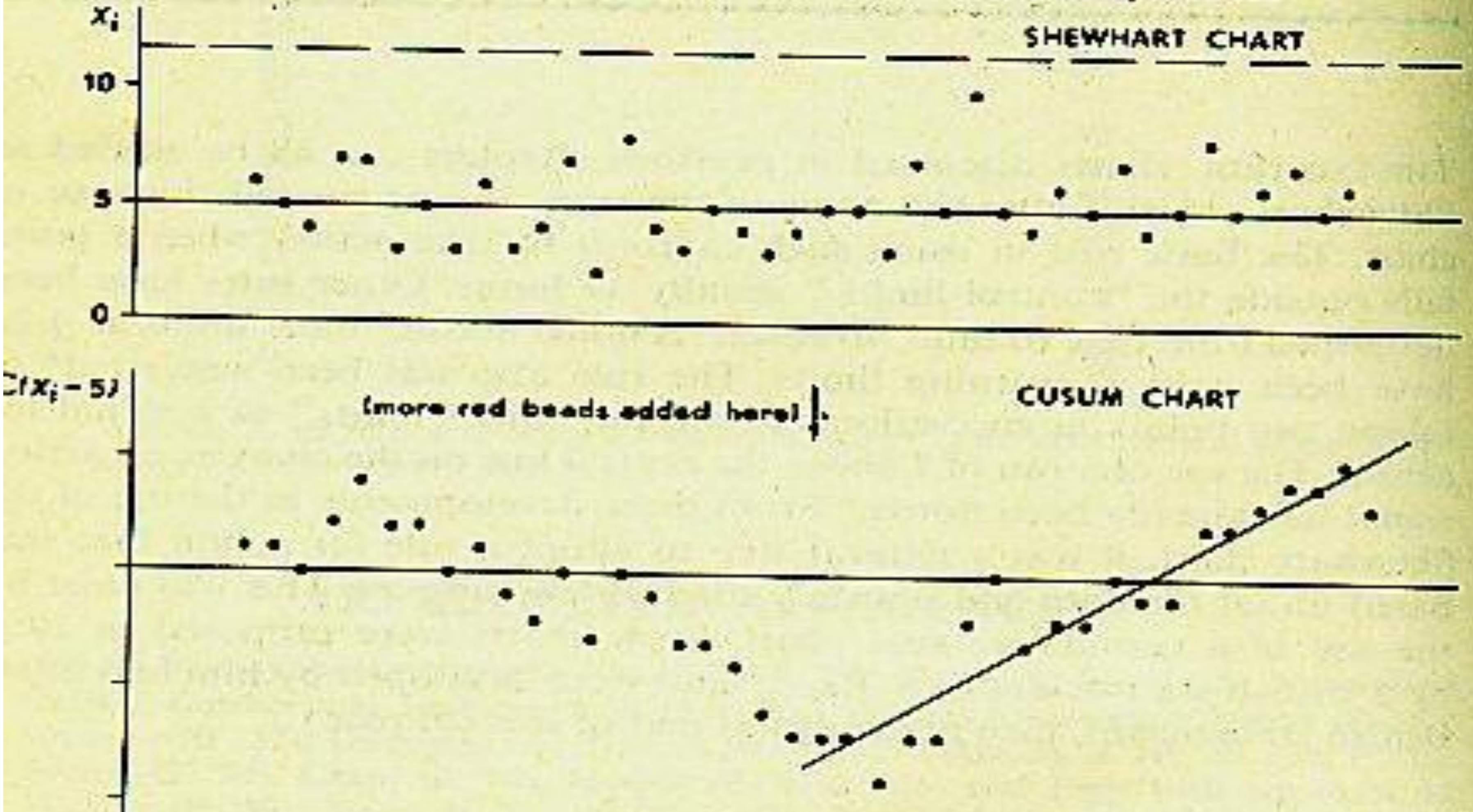
	Rare Event Date/ Time	Time between Event
3	3/6	4
4	3/7	1
5	3/15	8
6	3/22	7
7	4/1	10
8	4/11	10
9	4/14	3
10	4/26	12
11	5/3	7
12	5/3	0.5
13	5/13	10
14	5/19	6
15	5/28	9
16	6/4	7
17	6/10	6
18	6/13	3
19	6/20	7
20	6/29	9
21	7/2	3
22	7/6	4
23	7/17	11
24	7/22	5
25	7/24	2
26	8/1	8
27	8/7	6




G chart of Doses since Last ADE
Count(Doses since Last ADE)
40000
35000
30000
25000
20000
15000
10000
5000
0
02/03/2011
03/15/2011
03/28/2011
04/22/2011
04/26/2011
04/28/2011
05/12/2011
05/25/2011
06/18/2011
06/30/2011
09/24/2011
09/30/2011
10/08/2011
10/13/2011
10/26/2011
11/02/2011
11/17/2011
12/05/2011
12/18/2011
01/02/2012
01/12/2012
Date of ADE

Issues With Shewhart Charts: Missing Special Causes

FIG. 22.1.—Variation in Number of Red Beads in a Sample of 100

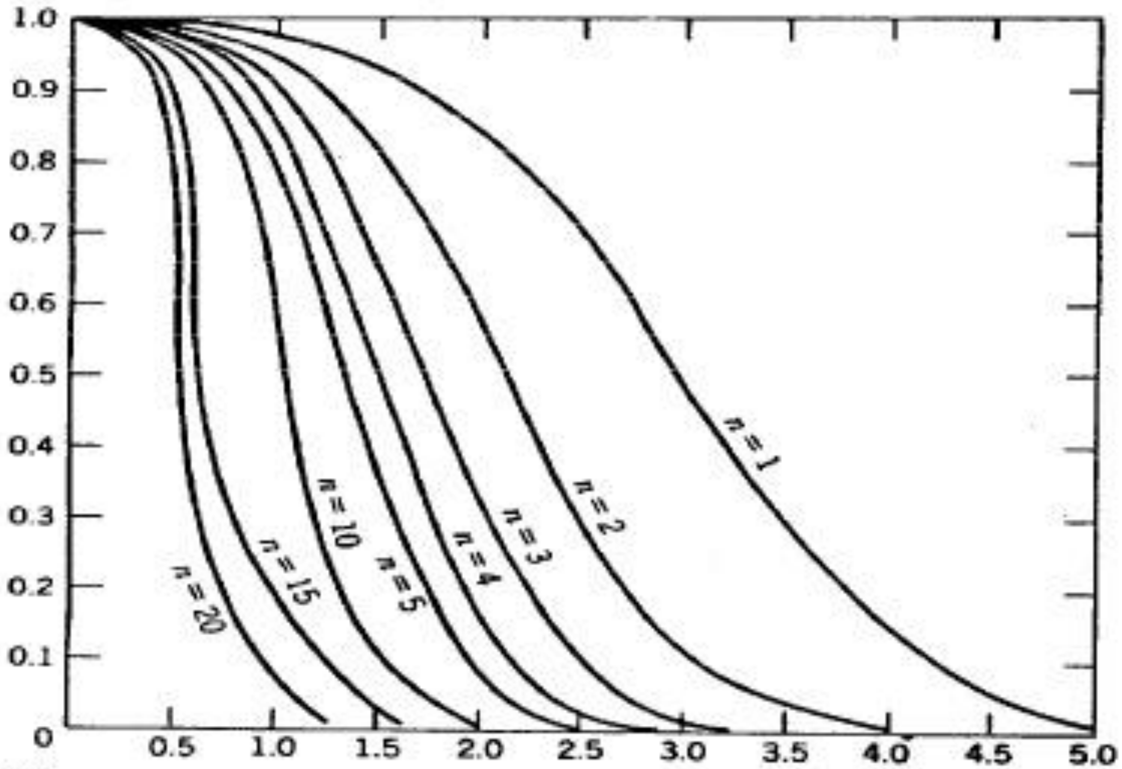


Shewhart Charts cannot detect small shifts

The charts discussed so far are variations of the *Shewhart* chart: each new point depends only on one subgroup.

Shewhart charts are sensitive to large process shifts.

The probability of detecting small shifts fast is rather small:

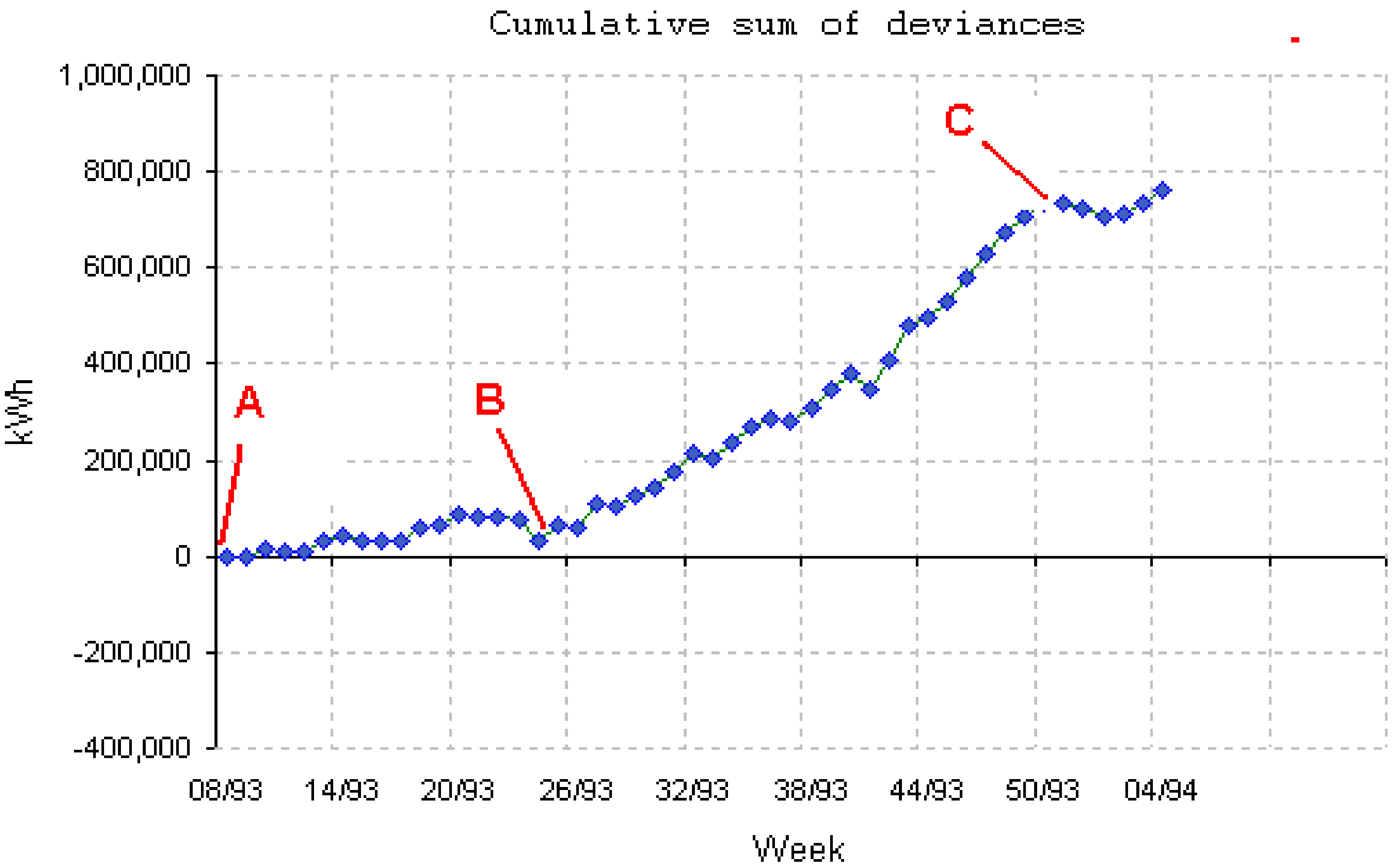


CUSUM Chart

- The CUSUM is the cumulative sum of differences between the values and the average.
- Interpretation of CUSUM:
  - Helpful for showing positive and negative variation from the average or benchmark over time.
    - Segments of the CUSUM chart with an upward slope indicates a period where the values tend to be above average.
    - Segments of a CUSUM chart with a downward slope indicates a period of time where the values tend to be below the average.
- Used to detect small changes of 0 to 0.5 sigma.
- Is based on the sum of the entire available process history.

When to Use CUSUM

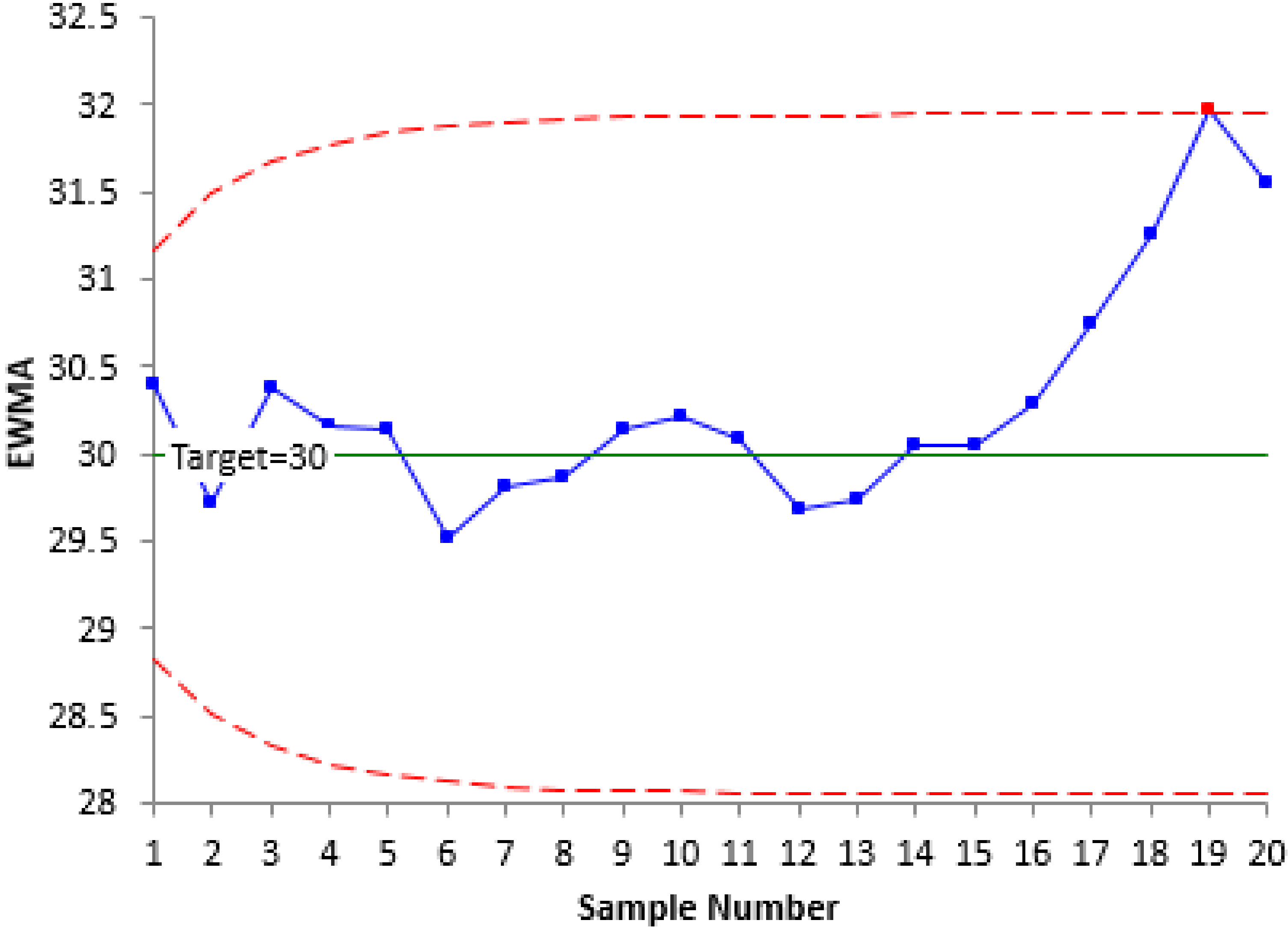
- Imagine you have a stable process where you want to be able to detect small deviations from the baseline.
- The sensitivity of the XmR chart can be quite poor, and an Individuals Chart can be even worse.
  - CUSUM is used to detect changes in a process of 2 sigma or less.
- If you know your baseline, the CUSUM measures the cumulative deviations from that baseline over time.
- Processes in control will show little deviation above or below the baseline or benchmark value, whereas, processes out of control will show significant deviation above or below benchmark value.



Cumulative sum of deviances
kWh
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
08/93
14/93
20/93
26/93
32/93
38/93
44/93
50/93
04/94
Week
A
B
C

EWMA (Exponentially Weighted Moving Average) Charts

- Also known as EMWA charts
- Like XmR, the EWMA chart uses variable data such as time, costs, weight, distance, etc.
- The EWMA chart helps to detect small changes in performance but places more importance on recent changes.
- Unlike CUSUM which uses all the available data for the entire process, EWMA is geometrically designed to weight the most recent data points higher than older data points.
- Like CUSUM it measures deviation from a benchmark.
- Like CUSUM attention to the slope is important and EWMA is mainly used to find small changes in process variation that might be missed with Shewhart charts.



32.5
32
31.5
31
30.5
30
29.5
29
28.5
28
EWMA
Target=30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Sample Number

Variable Life Adjusted Display (VLAD) Charts: How They Originated

- Background: In the mid-1990's, cardiac surgeons and surgical units were comparing 30-day mortality rates.
  - Using adjusted risk model developed by US academic surgeon Parsonnet to ensure fairer comparison with surgeons who took on a less challenging mix of patients.
- UK Surgeon Tom Treasure asked the Clinical Operational Research Unit at UCL to assist him in developing a way of incorporating such risk-adjustment into the time-series presentation of surgical results.

Source: http://mashnet.info/casestudy/vlad-monitoring-outcomes-for-cardiac-surgery/

VLAD Explained

- In truth, the VLAD is a simple graphical tool for the presentation of risk-adjusted mortality data in a time-series.
  - A running tally of the expected number of deaths minus the actual number deaths, the expected number of deaths calculated using a risk model.
  - Most versions now use color coding to present exact prediction intervals associated with a sequence of cases and the use of chronological time rather than case number on the x axis.
  - Used extensively in cardiovascular cases in the UK.

Variable Life Adjusted Display Charts