# Improve health care with control chart

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# Outline

1. Data and information
2. Data analysis
3. Control  Chart
   - Understanding variation
   - Funnel experiment
   - Type of control chart, example

# Data Utilization

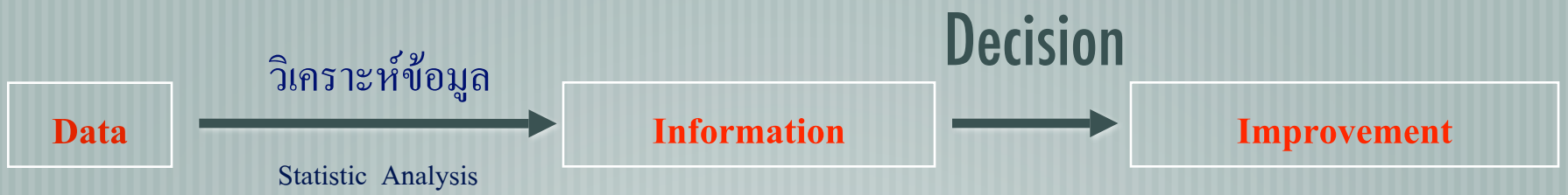
- การพัฒนาคุณภาพ (CQI)
- การวิจัย (R2R)

# Data Utilization

- การพัฒนาคุณภาพ
  - ความเข้าใจในระบบการให้บริการทางการแพทย์ จากข้อมูลที่เก็บอย่างถูกต้อง, ครบถ้วน จะมีประโยชน์อย่างมากในการค้นหาโอกาส ในการพัฒนา

# Data vs Information

Data : Facts, Observation, Measurements




**Garbage in** → **Garbage out**

" คุณภาพของข้อมูลจึงมีความสำคัญที่สุดเป็นอันดับแรก "

# Data Utilization

- สิ่งสำคัญ

1. จะวัดอะไร (What to measure)
2. วัดอย่างไร (How to measure)
3. วิเคราะห์อย่างไร (How to analyze)

# จะวัดอะไร (What to measure)

- Measure what matters to customers
  - Customers
    - Internal
    - External

# จะวัดอะไร (What to measure)

- What domain of quality
  - Clinical excellence (effectiveness)
  - Cost reduction
  - Patient satisfaction
  - Accreditation requirement
  - Safety requirement
  - Accessibility
  - Timeliness

# จะวัดอะไร (What to measure)

- Output / Process indicator
  - อัตราการเตรียมจำหน่ายผู้ป่วย
- Outcome indicator
  - อัตราการ  Re-admission ของผู้ป่วย

# วัดอย่างไร (How to measure)

คุณภาพของข้อมูล (Data)

- Accurate (ถูกต้อง)
- Complete (สมบูรณ์ ครบถ้วน)
- Consistent (ความเที่ยงตรง)

# Indicator development

1. Indicator identification
   1.1. What process are you trying to improve?
   1.2. Who is the primary customer of this process?
   1.3. What does the customer value most about the process?
   1.4. What domain of quality

# What domain of quality

- Clinical excellence (effectiveness)
- Cost reduction
- Patient satisfaction
- Accreditation requirement
- Safety requirement
- Accessibility
- Timeliness

# Indicator development

1. Indicator identification (cont.)

    1.5. What is the name of the indicator?

        1. Review literature, what indicator were used?
        2. Operational definition

    1.6. What department, service or unit will be affected?

# Indicator development

2. Data collection plan
    - Who will be responsible?
    - Sources for data?
    - How long , how often?
3. Plan for analysis
    - Control chart, other
    - Target, Benchmarking

# วิเคราะห์อย่างไร (How to analyze)

- Root cause analysis tool
  (รากเหง้าของปัญหา)
- Data analysis / display tool
  (การวิเคราะห์ข้อมูล)

# Root cause analysis tool

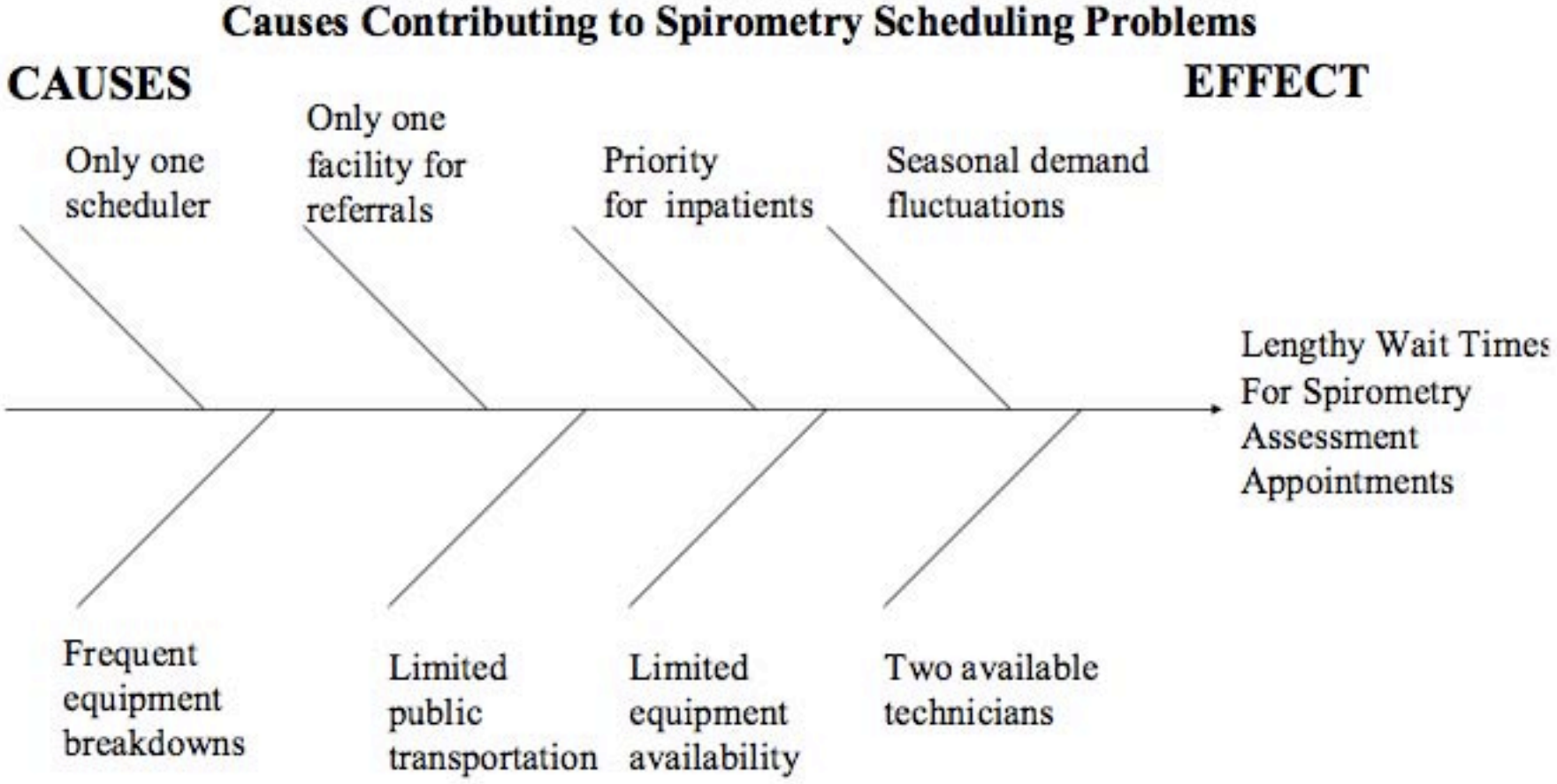
- Cause and effect Diagram (Fishbone)
- Flow Chart
- Pareto Chart
- Scatter Diagram

# Cause and effect Diagram (Fishbone)

- เป็นเครื่องมือที่สำคัญในกระบวนการพัฒนาคุณภาพ เพื่อค้นหา รากเหง้า หรือ สาเหตุของปัญหา
- หาความสัมพันธ์ของสาเหตุและปัญหา (Cause and problem relationship)

# Performance Improvement in Asthma Care

## Sample Cause and Effect Diagram

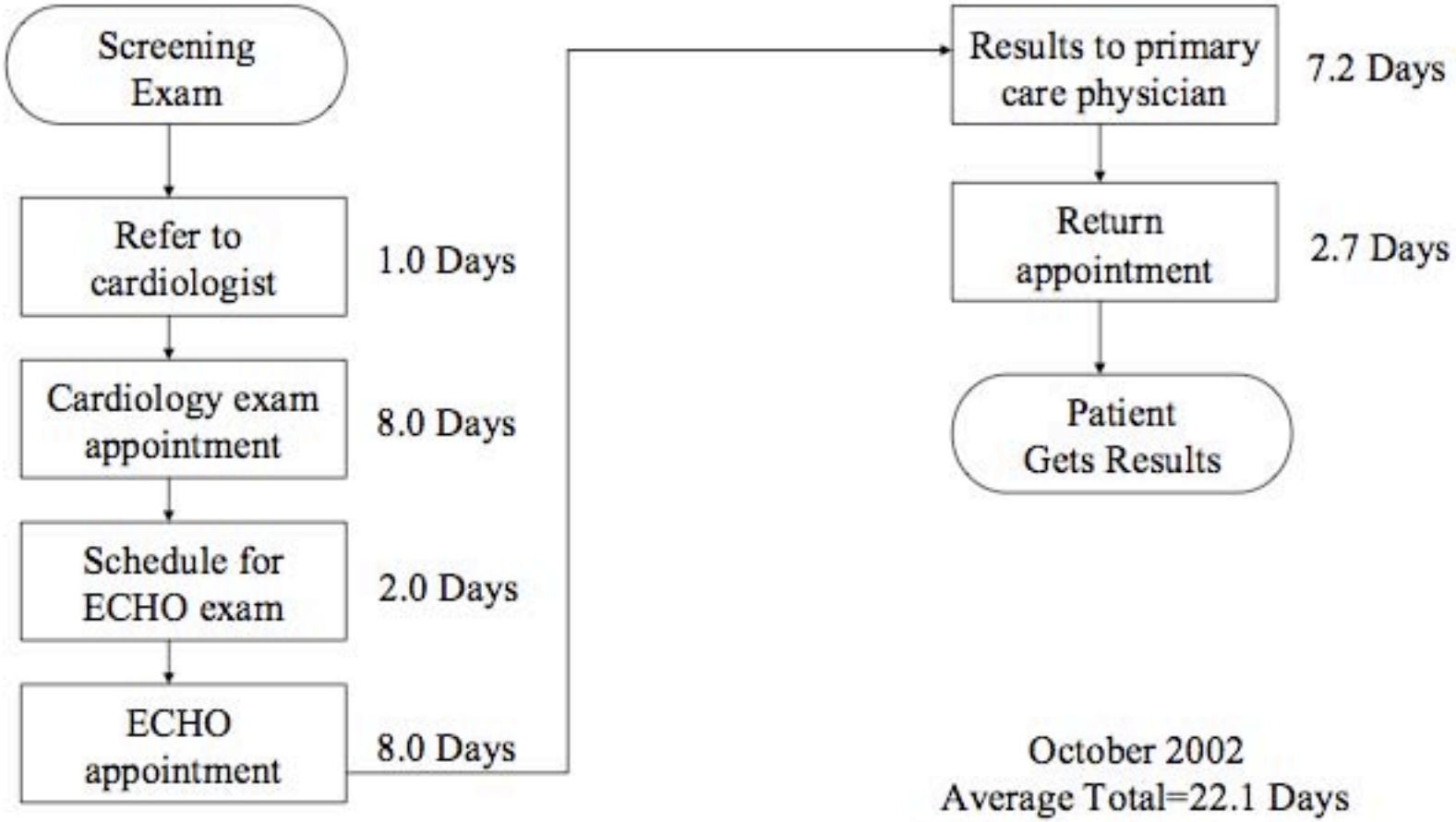


# Flow Chart

- Chart ที่แสดงกระบวนการให้บริการแต่ละขั้นตอน
  - เพื่อหาจุดบกพร่อง ความล่าช้า ความซ้ำซ้อน ในกระบวนการให้บริการ

# Performance Improvement in Heart Failure Care

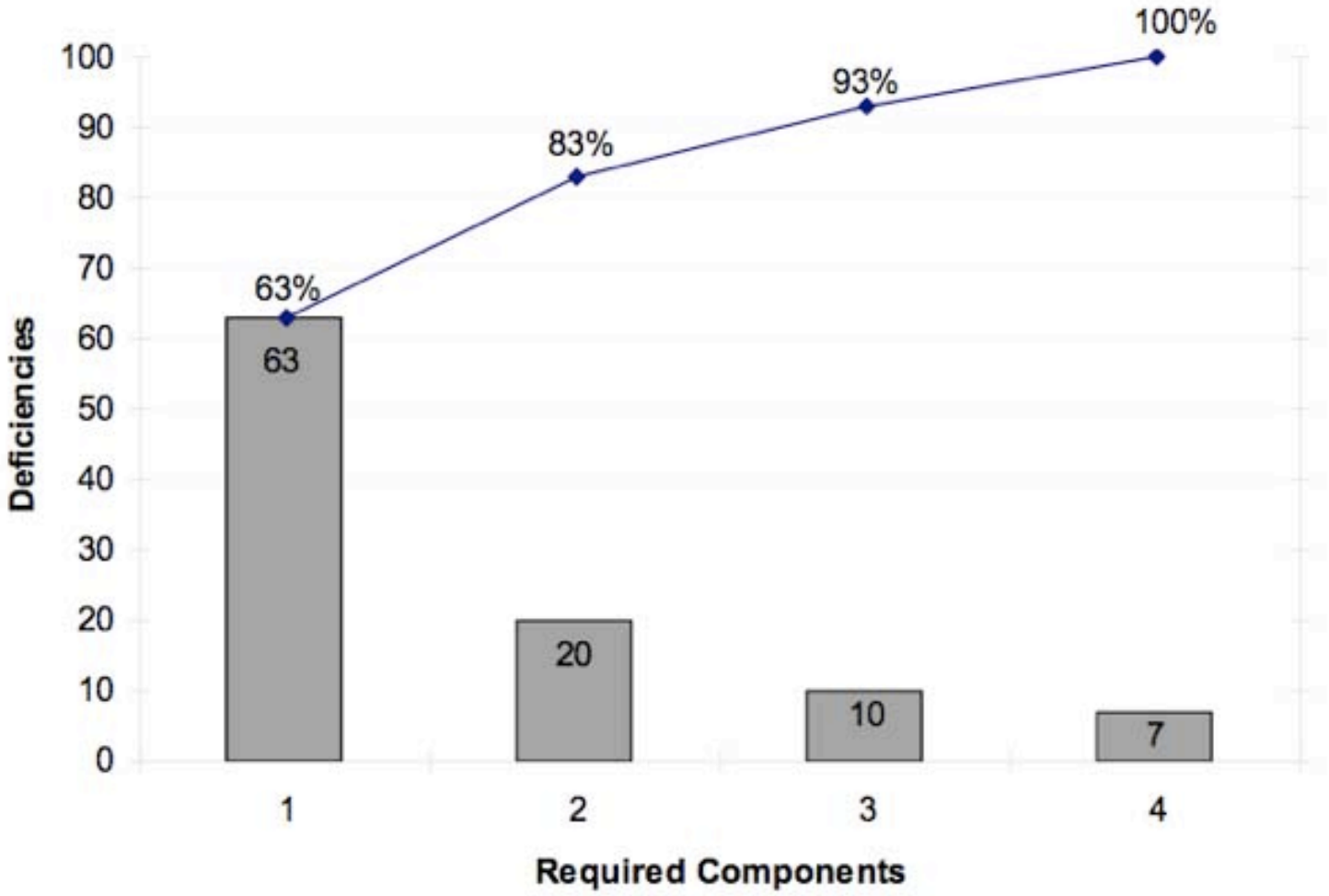
## Heart Failure Screening Flowchart
## LVF Assessment Process
## (Average Data)



# Pareto Chart

- กราฟแสดงลำดับความสำคัญตามความถี่ของสาเหตุ แห่งปัญหา
  - เพื่อจัดลำดับความสำคัญของสาเหตุ

# Pareto Chart on Deficiencies in Personnel File Audits




Key:
1 = Job Appropriate Credentials
2 = Competency
3 = Health Status
4 = Criminal Background Check

# Scatter Diagram

- กราฟแสดงความสัมพันธ์ของ 2 ปัจจัย
  - เพื่อหาความสัมพันธ์ของ 2 ปัจจัย ที่อยู่ในความสนใจ
  - แต่ไม่สามารถบอกได้ว่า ปัจจัยหนึ่ง เป็นสาเหตุของอีกปัจจัยหนึ่งได้

# Scatter Diagram

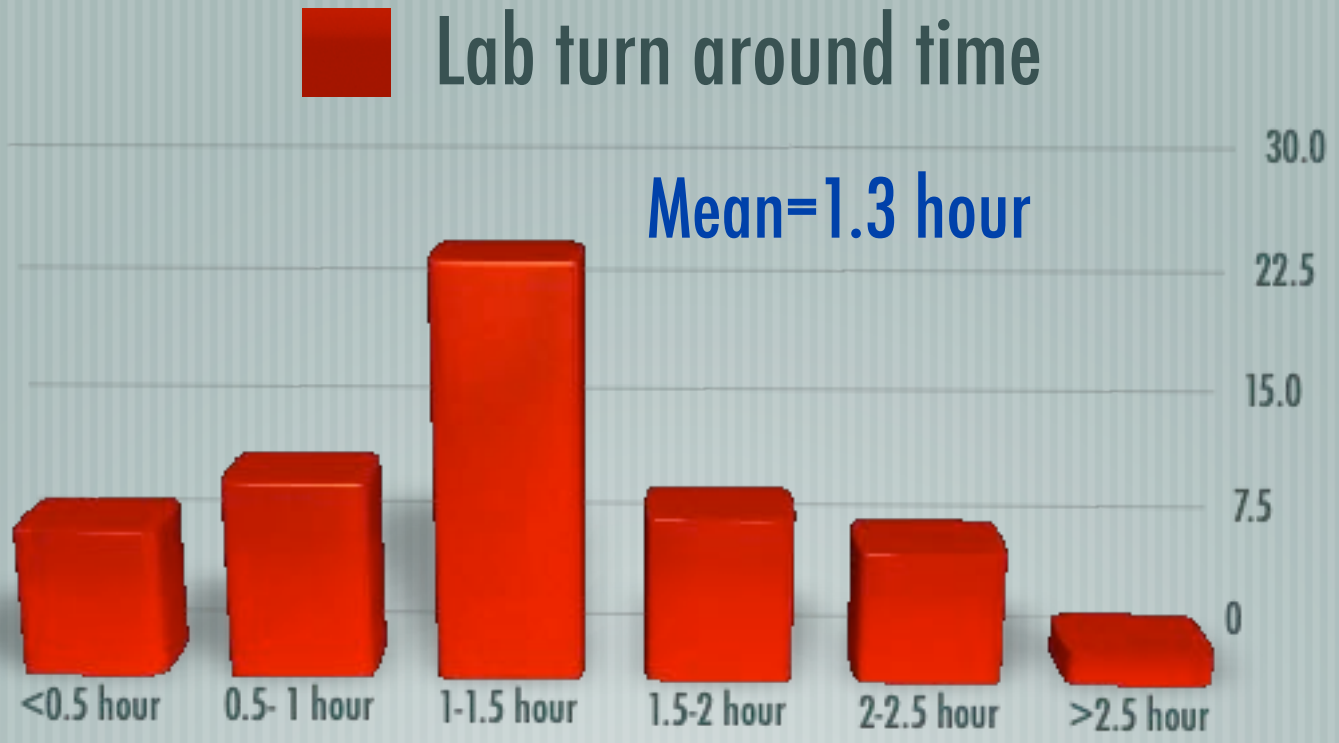
# Data analysis / Display tools

- Histogram
- Line graph
- Control Chart
- Run Chart

# Information

- Information
  - แนวโน้ม (Trend)
  - การเปลี่ยนแปลง (Change)
  - ความผันแปรอย่างสุ่ม (Random variations)
  - รูปแบบจำเพาะ (Pattern)
- เพื่อประโยชน์ในการหาโอกาสในการพัฒนา ,ติดตามประเมินผลให้บริการ

# Histogram

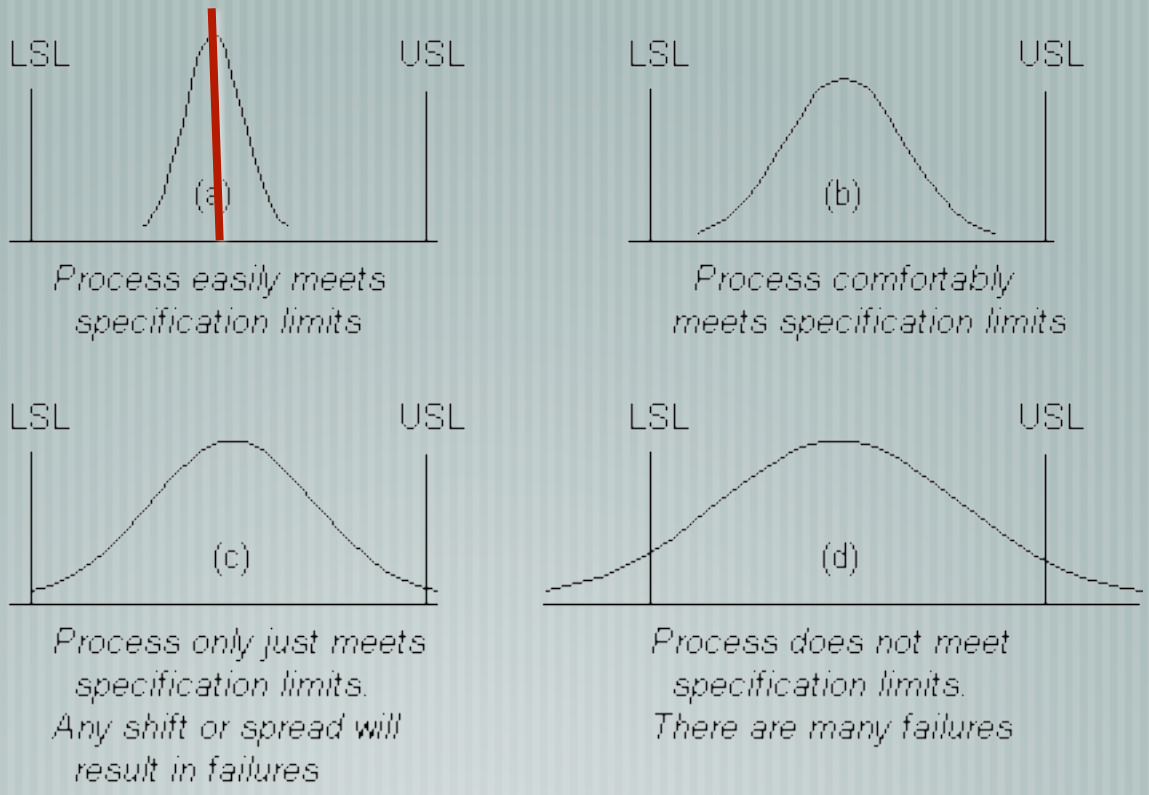



- Distribution in a process, probable causes of trouble
- Visualize central location, shape and spread of data

# Capability index

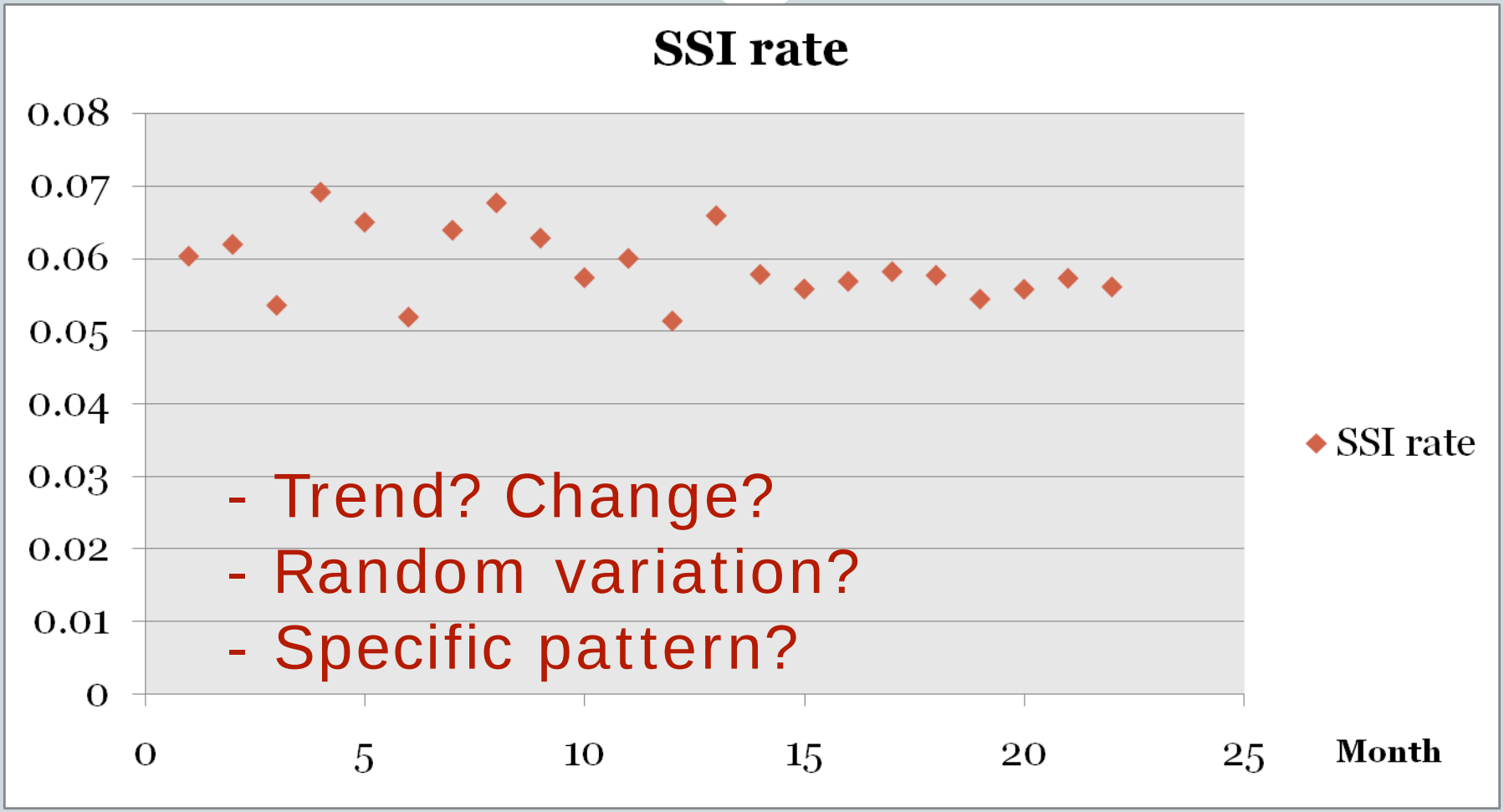
USL = Upper Specification Limit

LSL = Lower Specification Limit




$$C_p = \frac{USL - LSL}{6\sigma}$$

# Line Graph


SSI rate
0.08
0.07
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10
15
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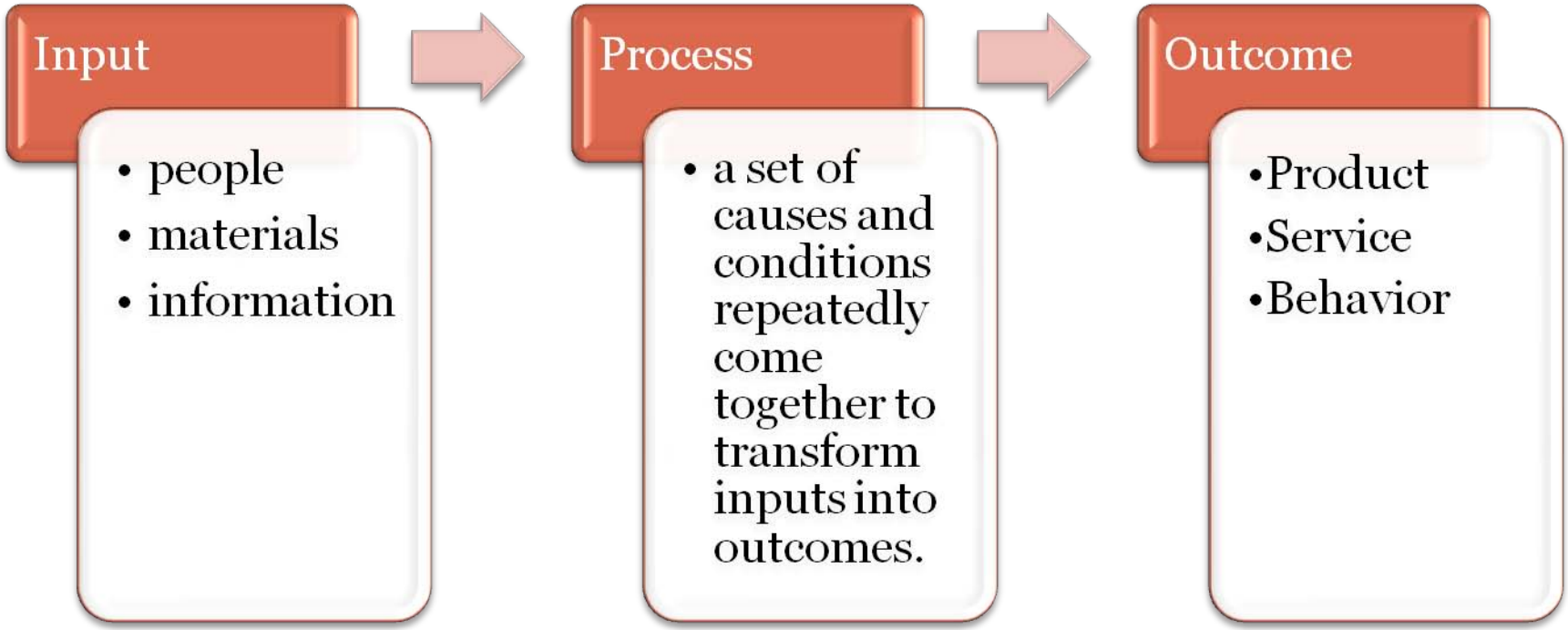
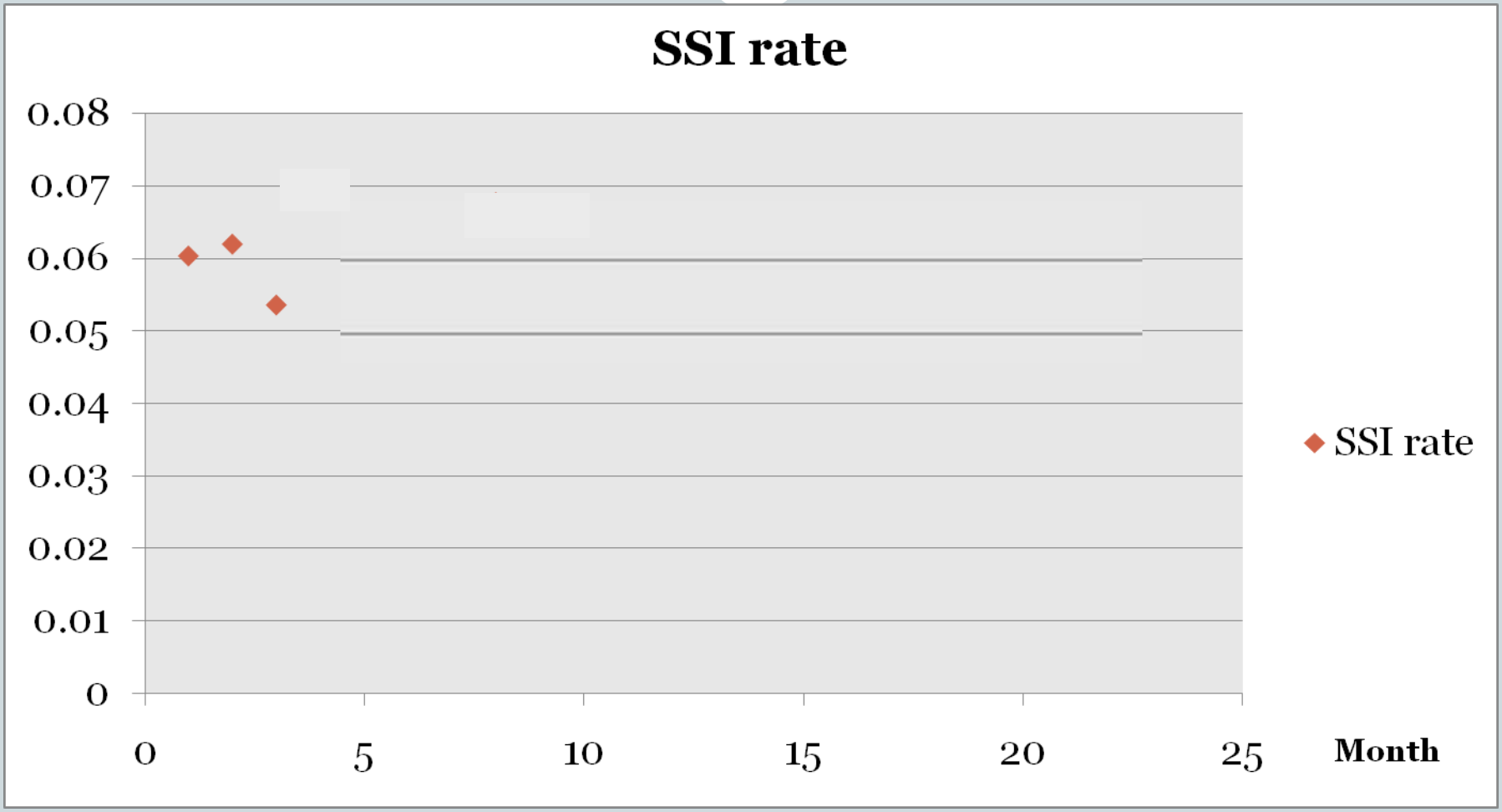
25
Month
SSI rate
- Trend? Change?
- Random variation?
- Specific pattern?

# Information

- Information
  - แนวโน้ม (Trend)
  - การเปลี่ยนแปลง (Change)
  - ความผันแปรอย่างสุ่ม (Random variations)
  - รูปแบบจำเพาะ (Pattern)
- เพื่อประโยชน์ในการหาโอกาสในการพัฒนา ,ติดตามประเมินผลให้บริการ

# The application of Statistical Process Control Chart (SPC)


Input
• people
• materials
• information
Process
• a set of causes and conditions repeatedly come together to transform inputs into outcomes.
Outcome
•Product
•Service
•Behavior


SSI rate
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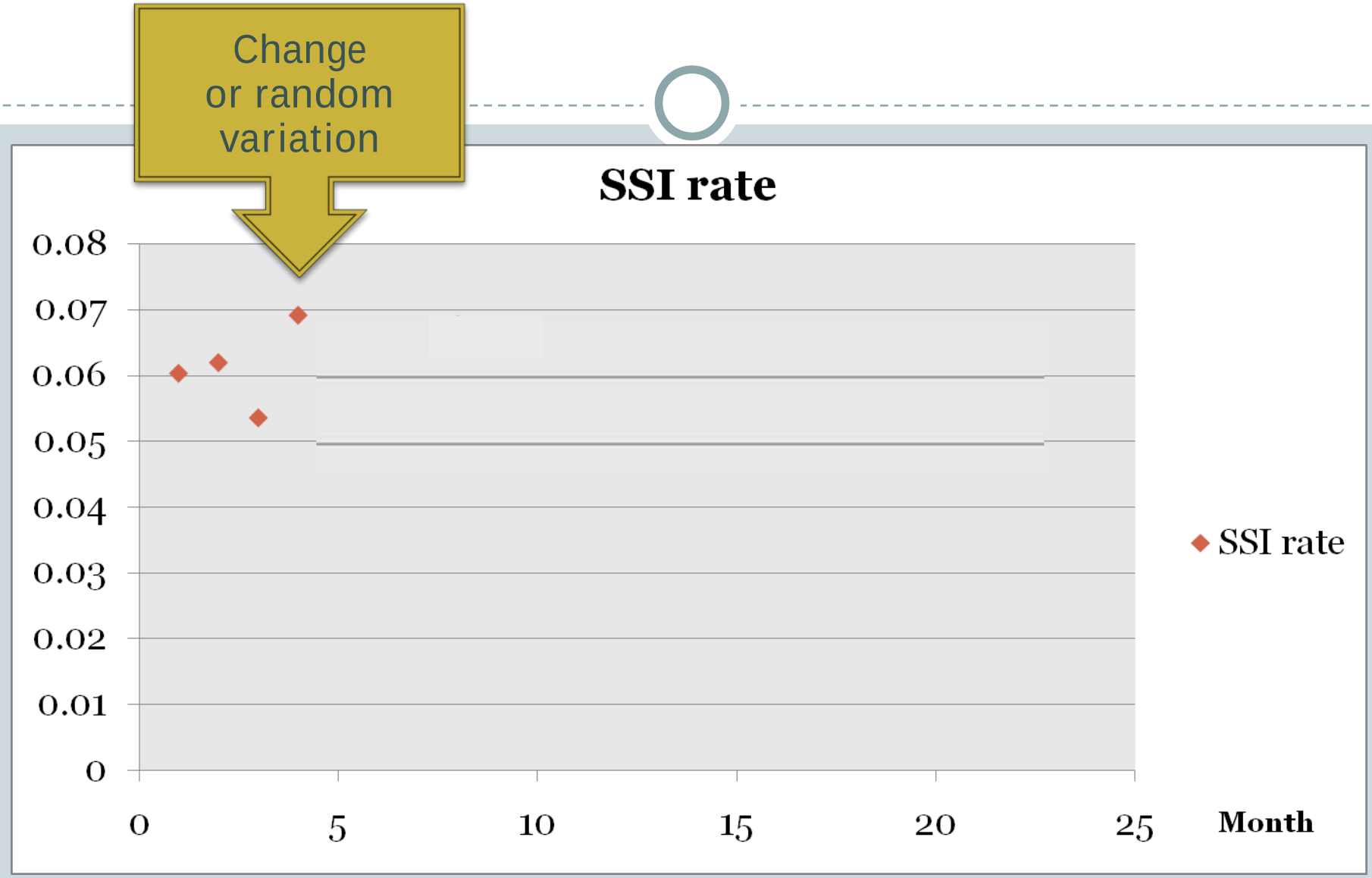
SSI rate


Change or random variation
SSI rate
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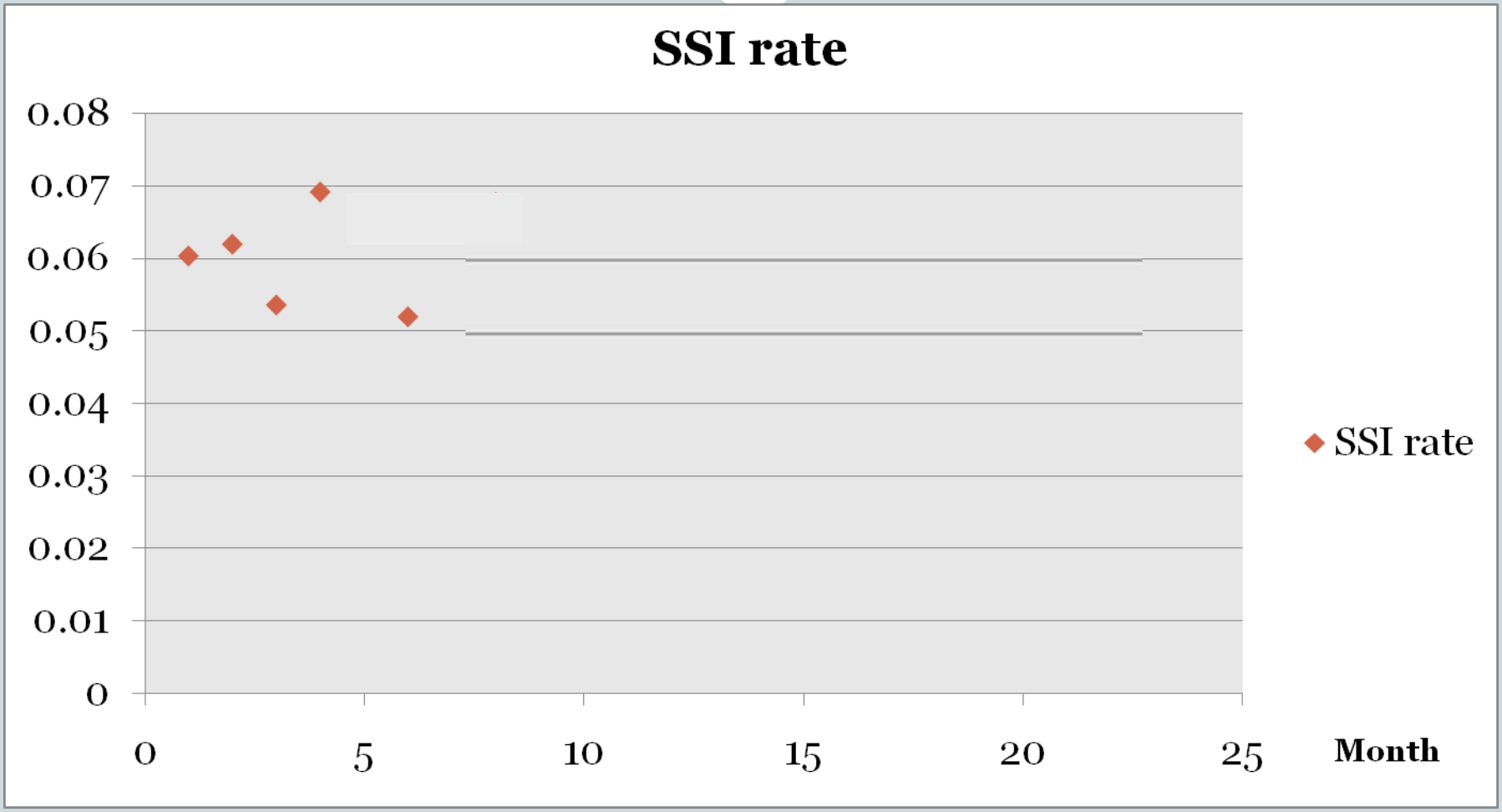
Month
SSI rate

# ความผันแปร (Variation)

- ความผันแปรที่แสดงในข้อมูลเป็นการบ่งชี้ถึงการเปลี่ยนแปลง (Change) หรือ แนวโน้ม (Trend) หรือเป็นเพียงความผันแปรอย่างสุ่มที่เกิดขึ้นโดยธรรมชาติ (random variation)


SSI rate
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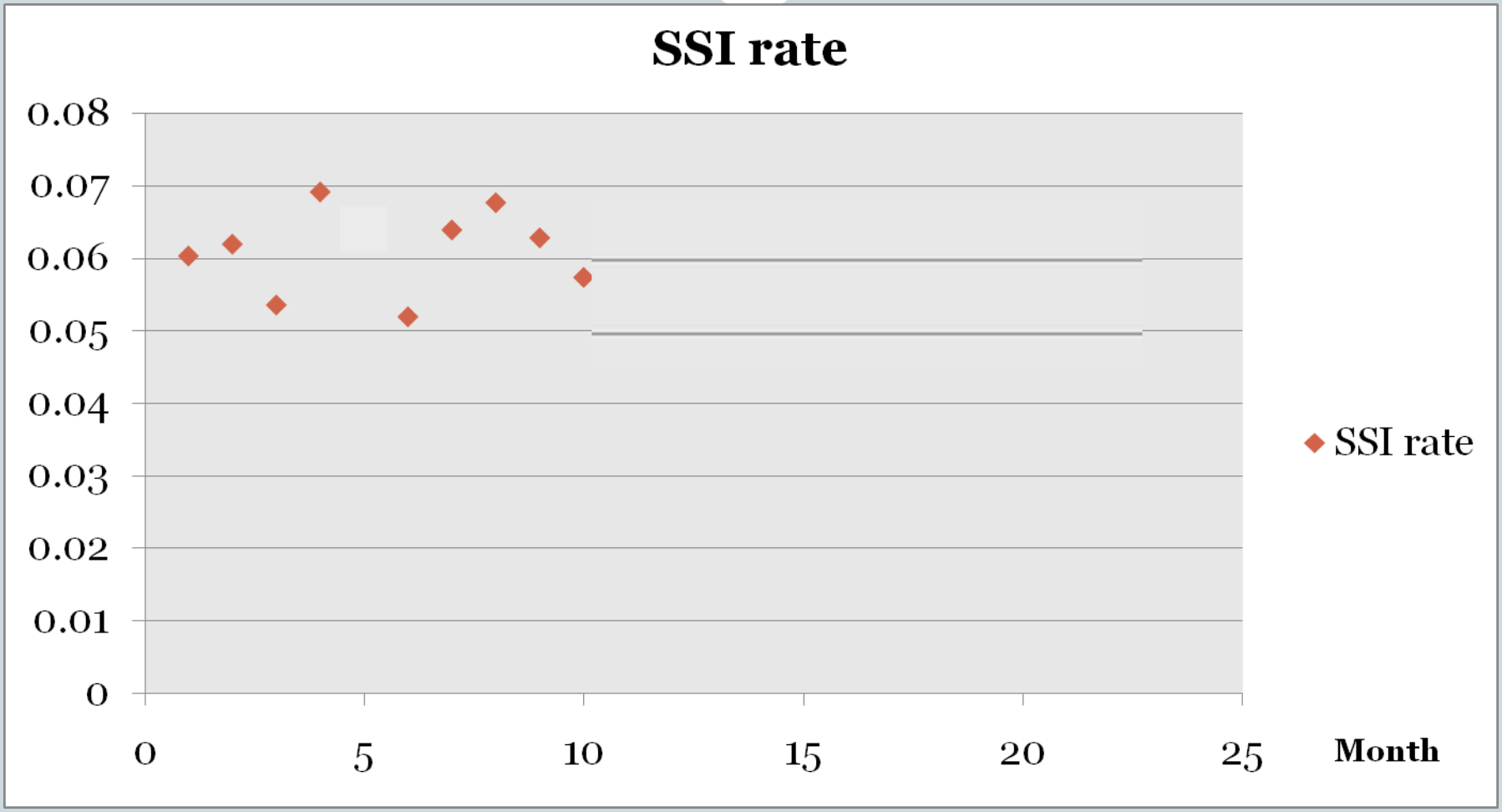
Month
SSI rate

# ความผันแปร (Variation)

- ความผันแปร (Variation) เกิดขึ้นในทุกสิ่งที่เราทำ
- การตัดสินใจในชีวิตประจำวันส่วนหนึ่งจากการแปรผลความผันแปรของข้อมูลที่เราเผชิญอยู่

# ความผันแปร (Variation)

- ดังนั้นการประเมินความผันแปร (Variation) ว่าเป็นการเปลี่ยนแปลงที่แสดงแนวโน้ม (trend or change)หรือเป็นเพียงความผันแปรอย่างสุ่มที่เกิดขึ้นโดยธรรมชาติ (random variation) จึงมีความสำคัญมาก


SSI rate
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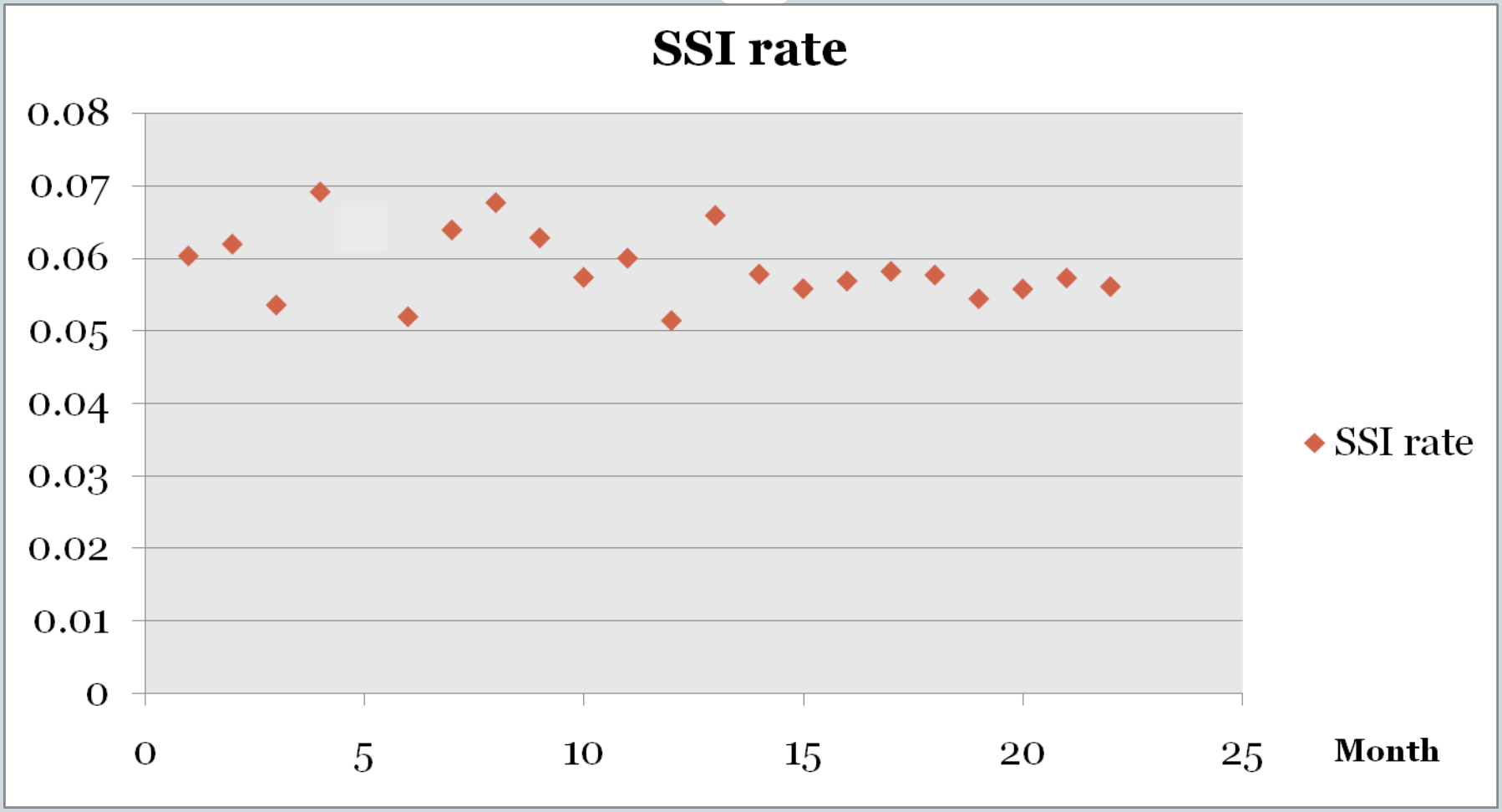
Month
SSI rate


SSI rate
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0.04
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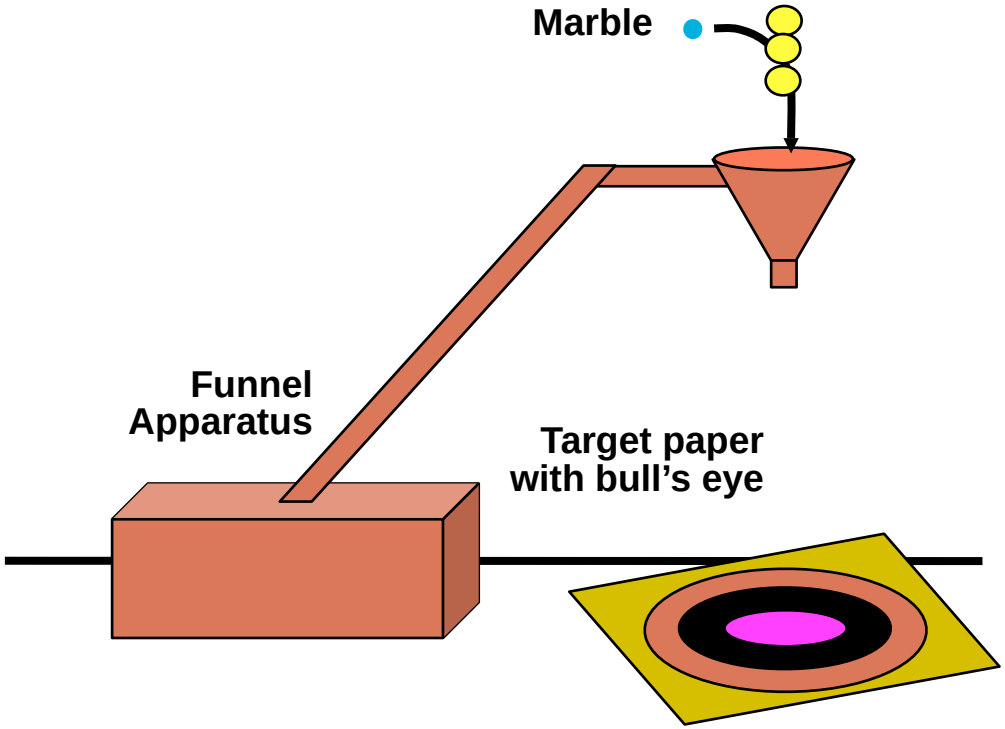
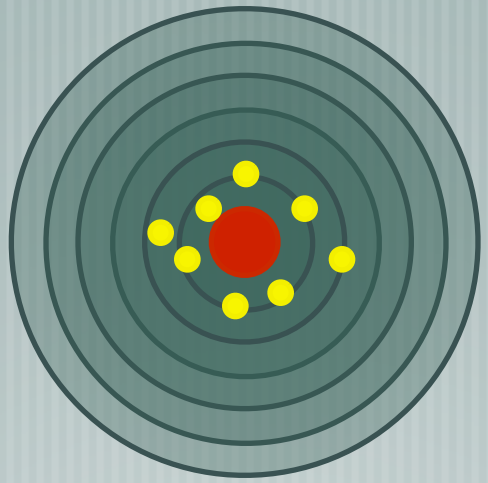
15
20
25
Month
SSI rate

# ผลเสียจากการแปลผลความผันแปรที่ผิดพลาด
# Deming Funnel Experiment



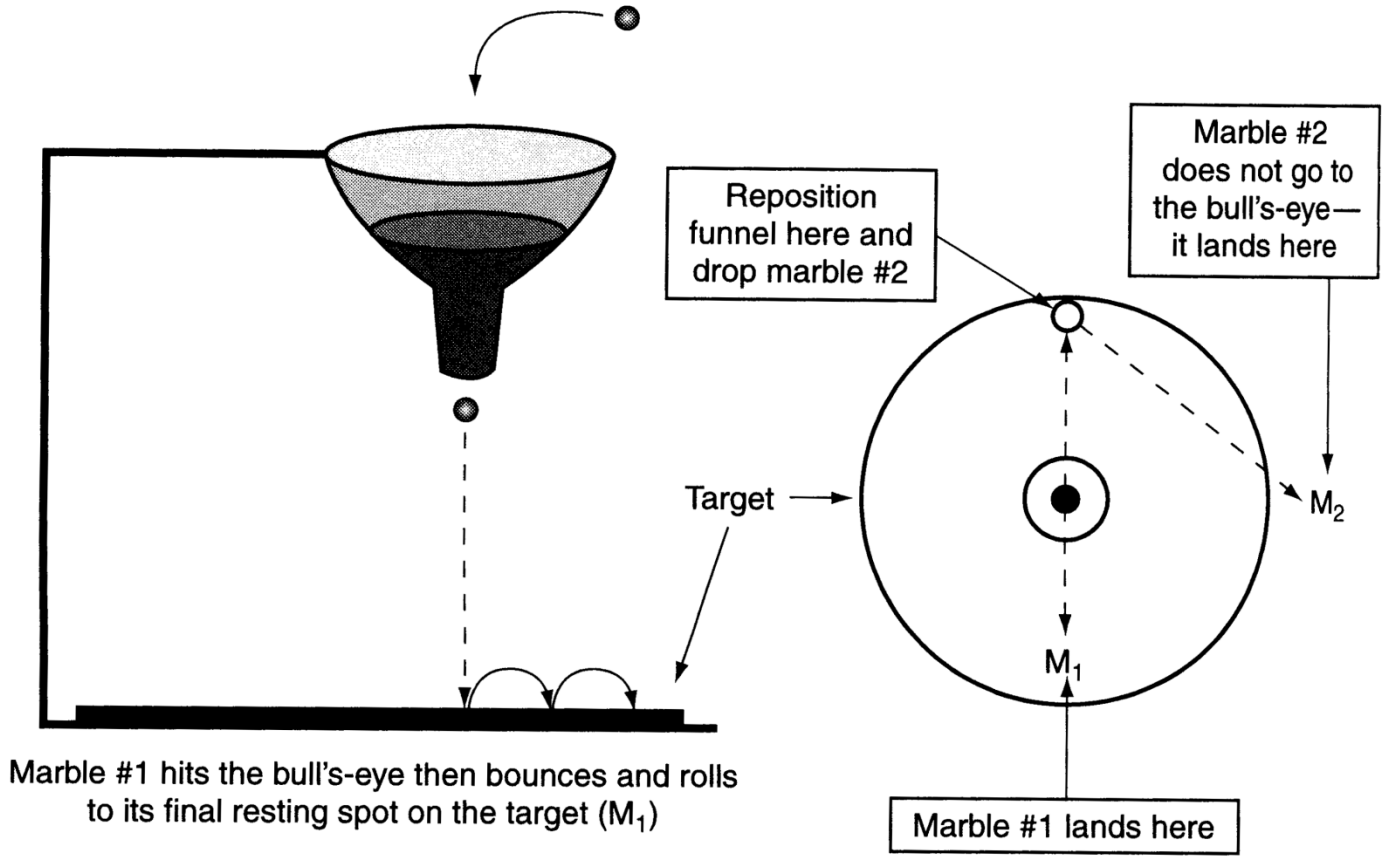


# Deming funnel experiment (drop the marble 1000 times)

- **Rule 1**
  - The funnel remains fixed, aimed at the target. target is located at the coordinates (0,0).
- **Rule 2**
  - Move the funnel from its previous position a distance equal to the current error (location of drop), in the opposite direction.
- **Rule 3 (Bow Tie Effect)**
  - Move the funnel to a position that is exactly opposite the point where the last marble dropped, relative to the target
- **Rule 4 (Random Walk)**
  - Move the funnel to the position where the last marble dropped

Rule 1

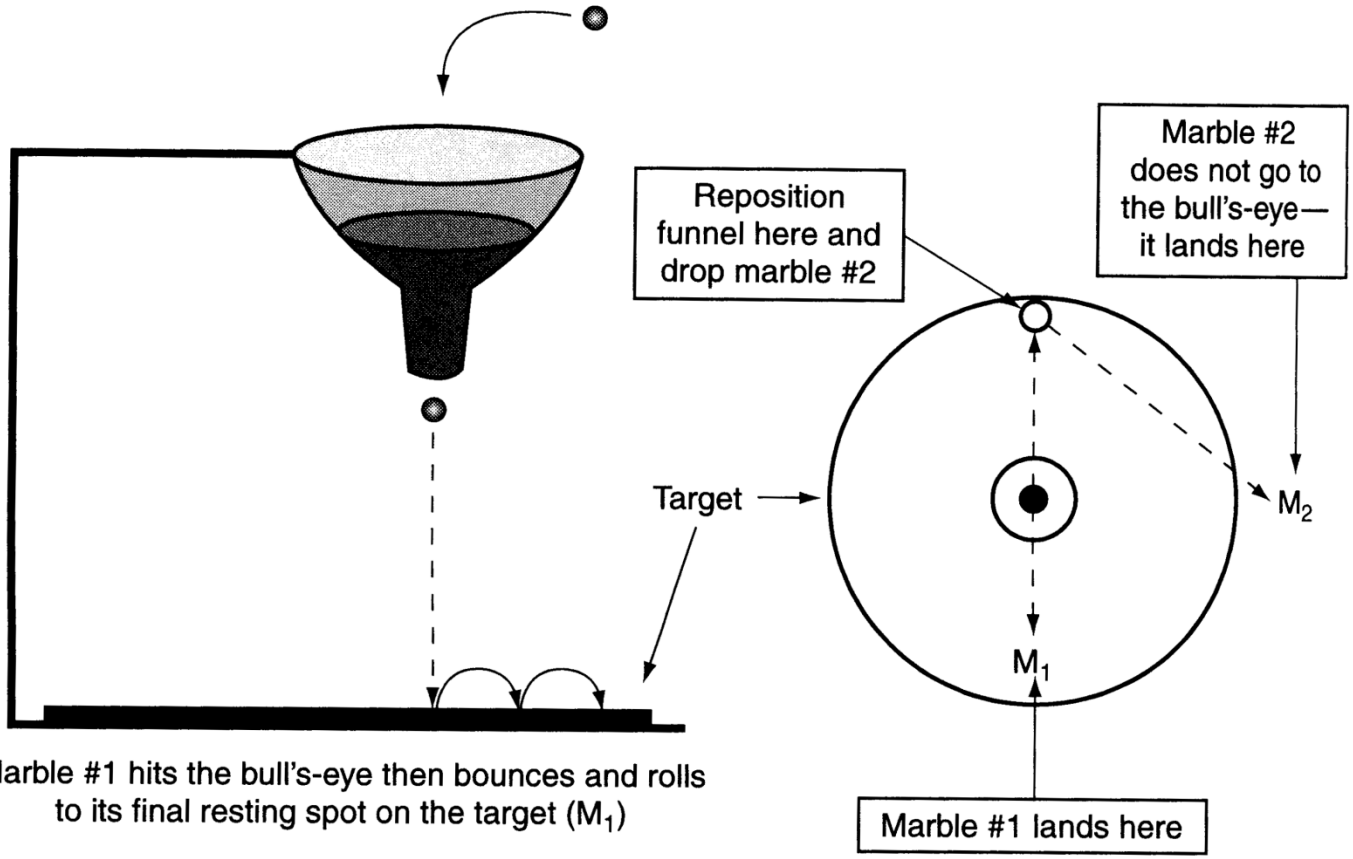
The funnel remains fixed, aimed at the target.




Marble #1 hits the bull's-eye then bounces and rolls to its final resting spot on the target ($M_1$)

Rule 2

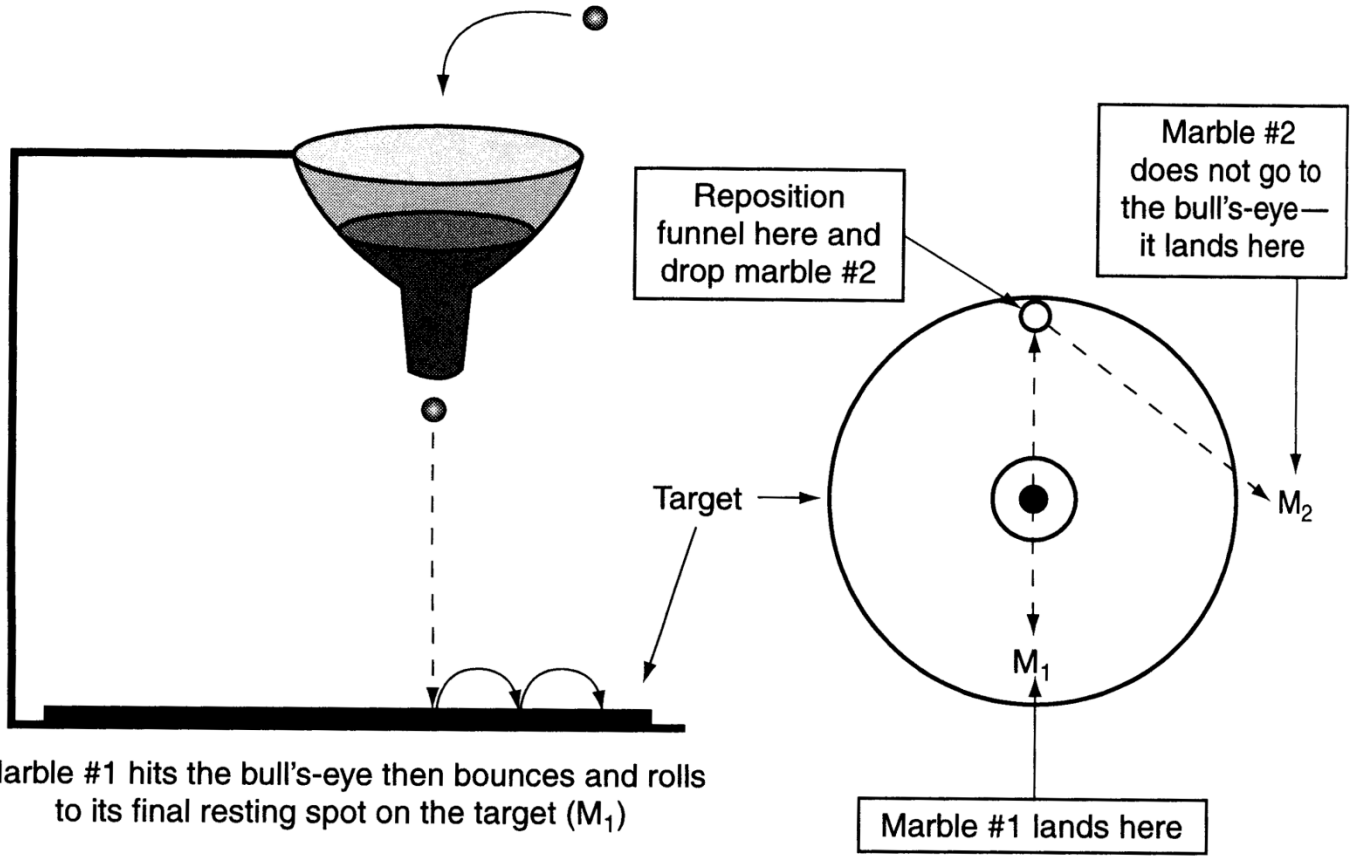
Move the funnel from its previous position a distance equal to the current error (location of drop), in the opposite direction.




Marble #1 hits the bull's-eye then bounces and rolls to its final resting spot on the target ($M_1$)

## Rule 3 (Bow Tie Effect)

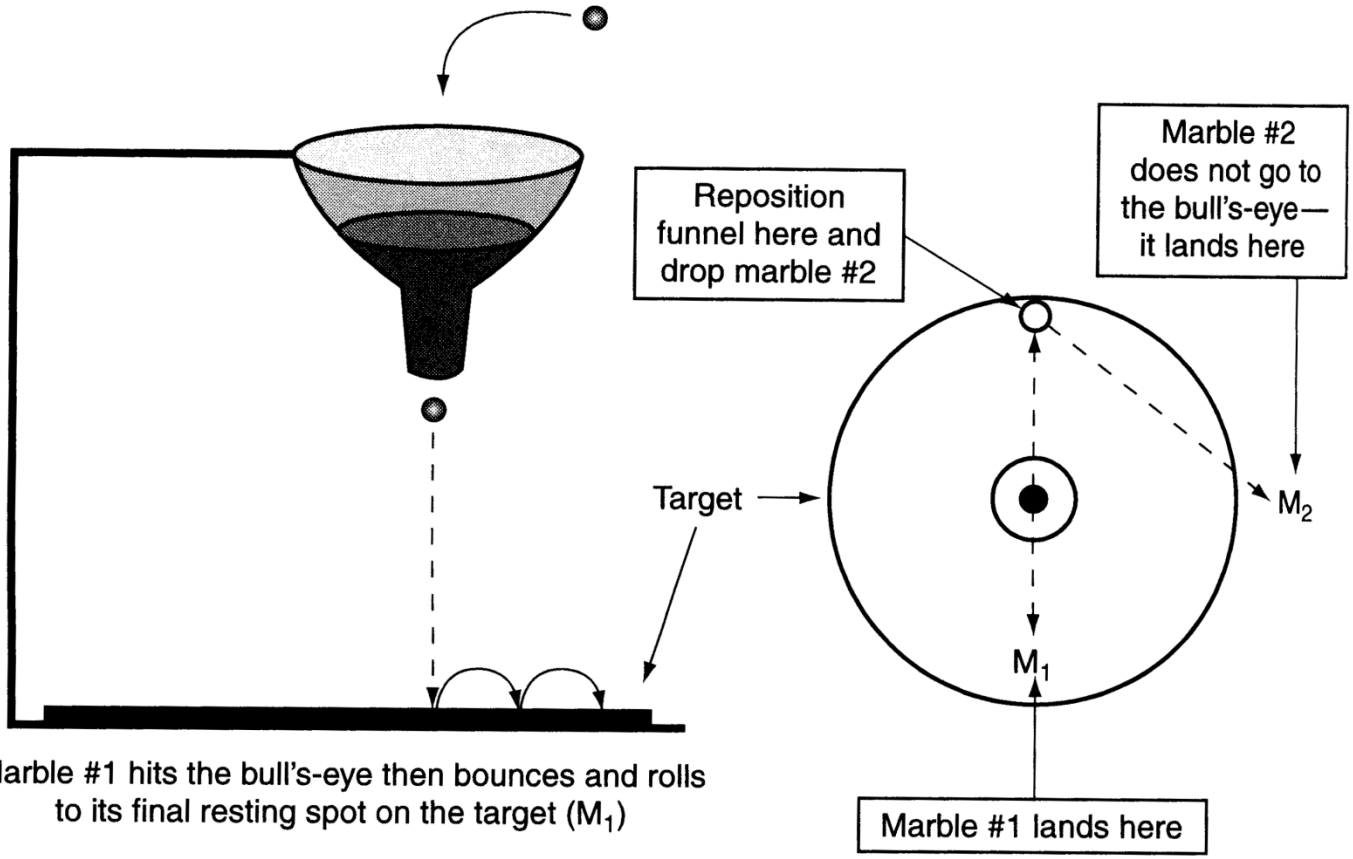
Move the funnel to a position that is exactly opposite the point where the last marble dropped, relative to the target



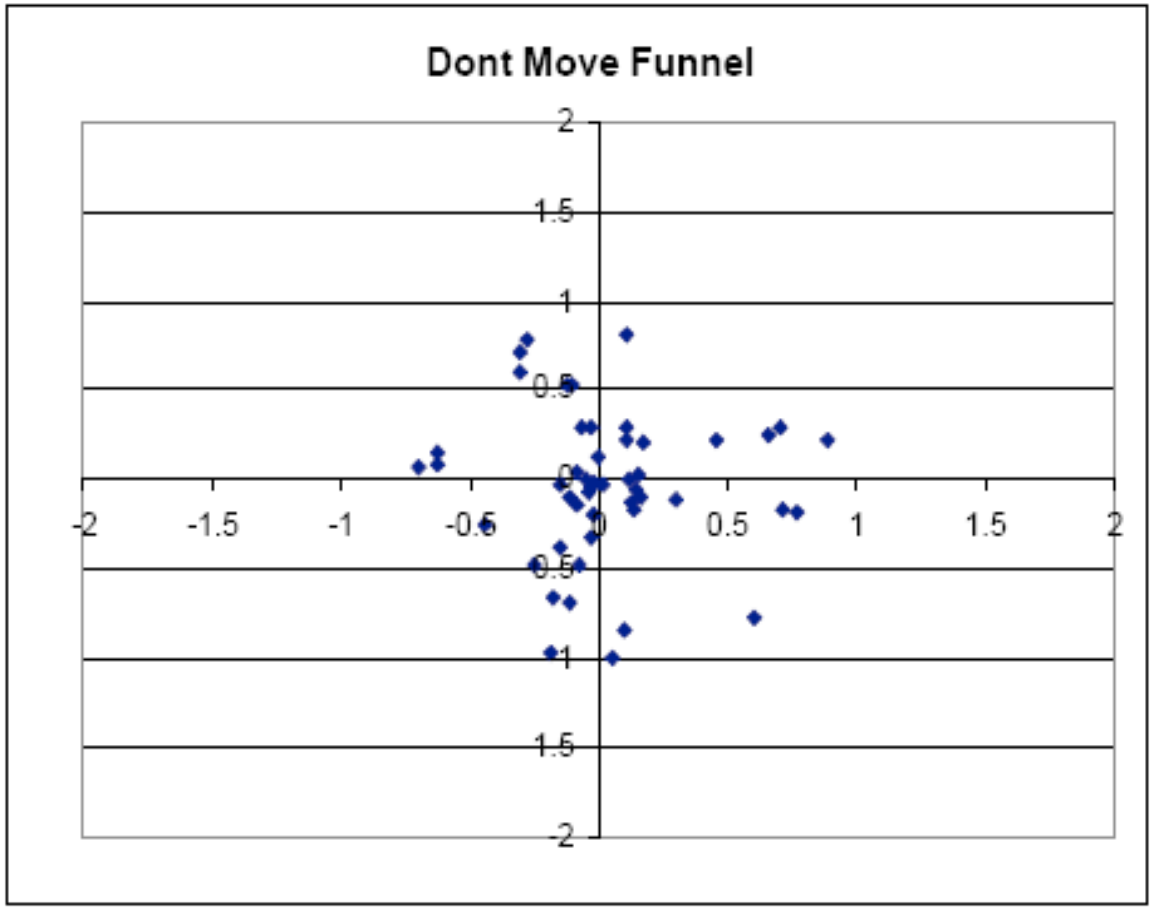

Marble #1 hits the bull's-eye then bounces and rolls to its final resting spot on the target ($M_1$)

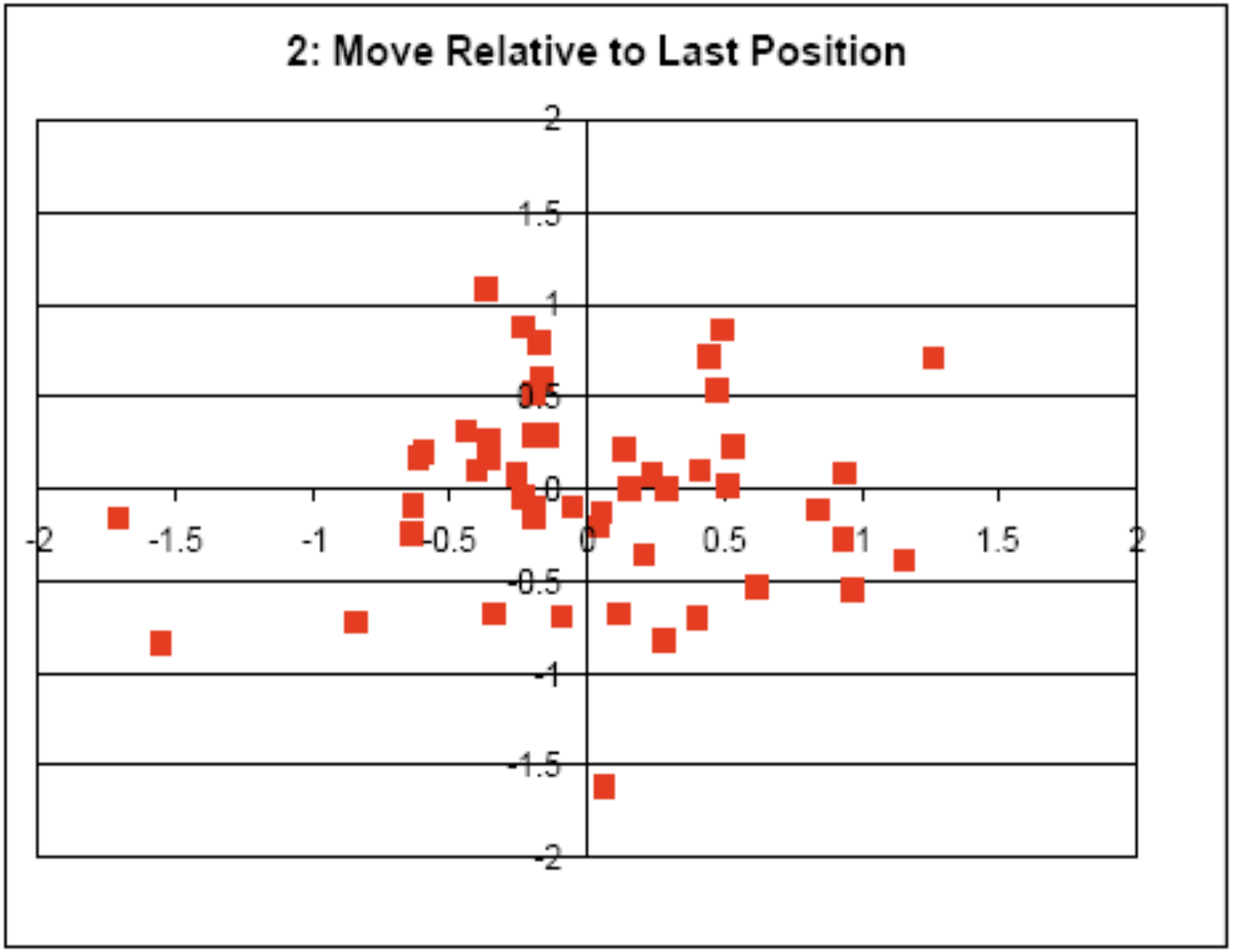
## Rule 4 (Random Walk)

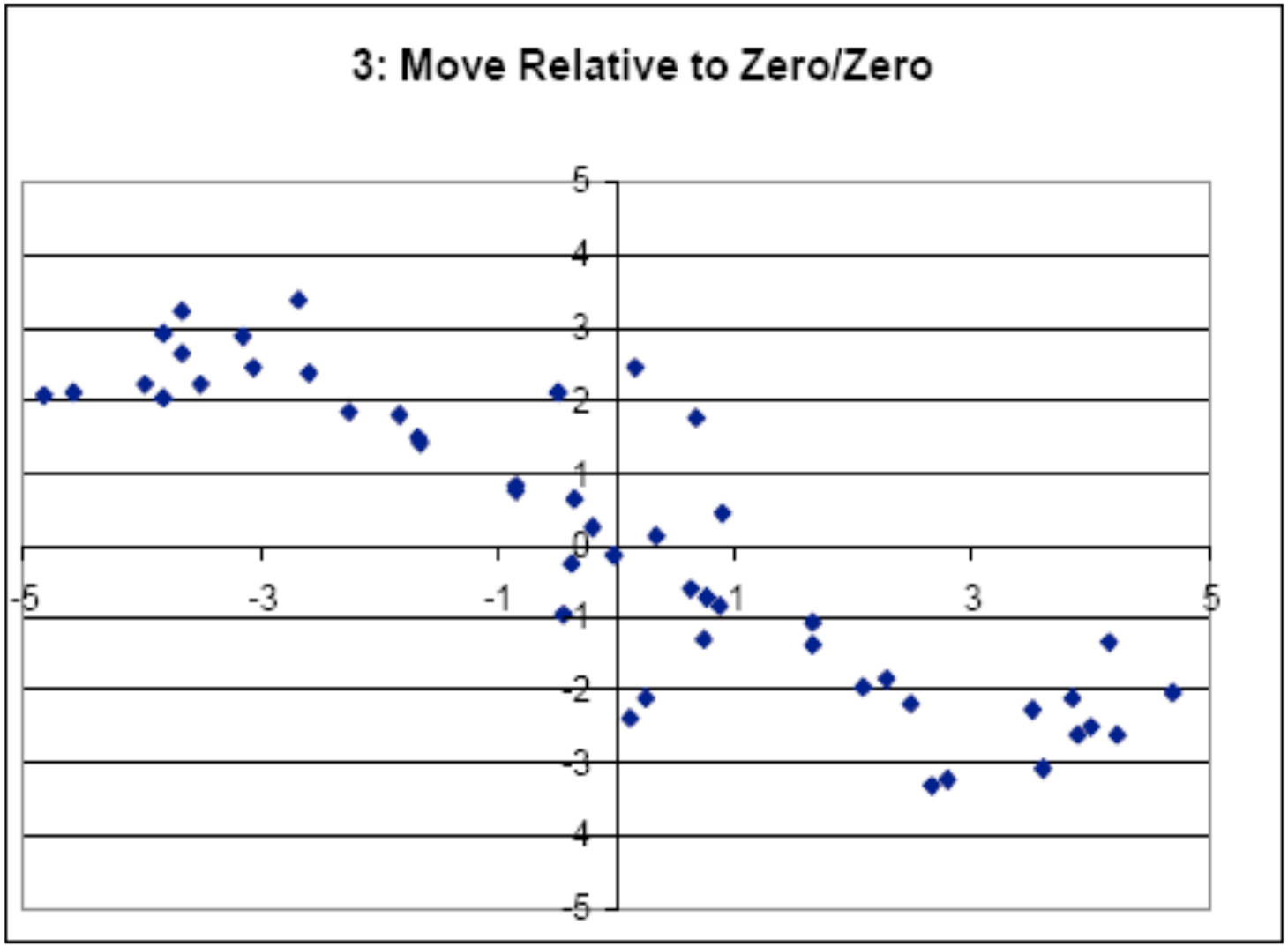
Move the funnel to the position where the last marble dropped

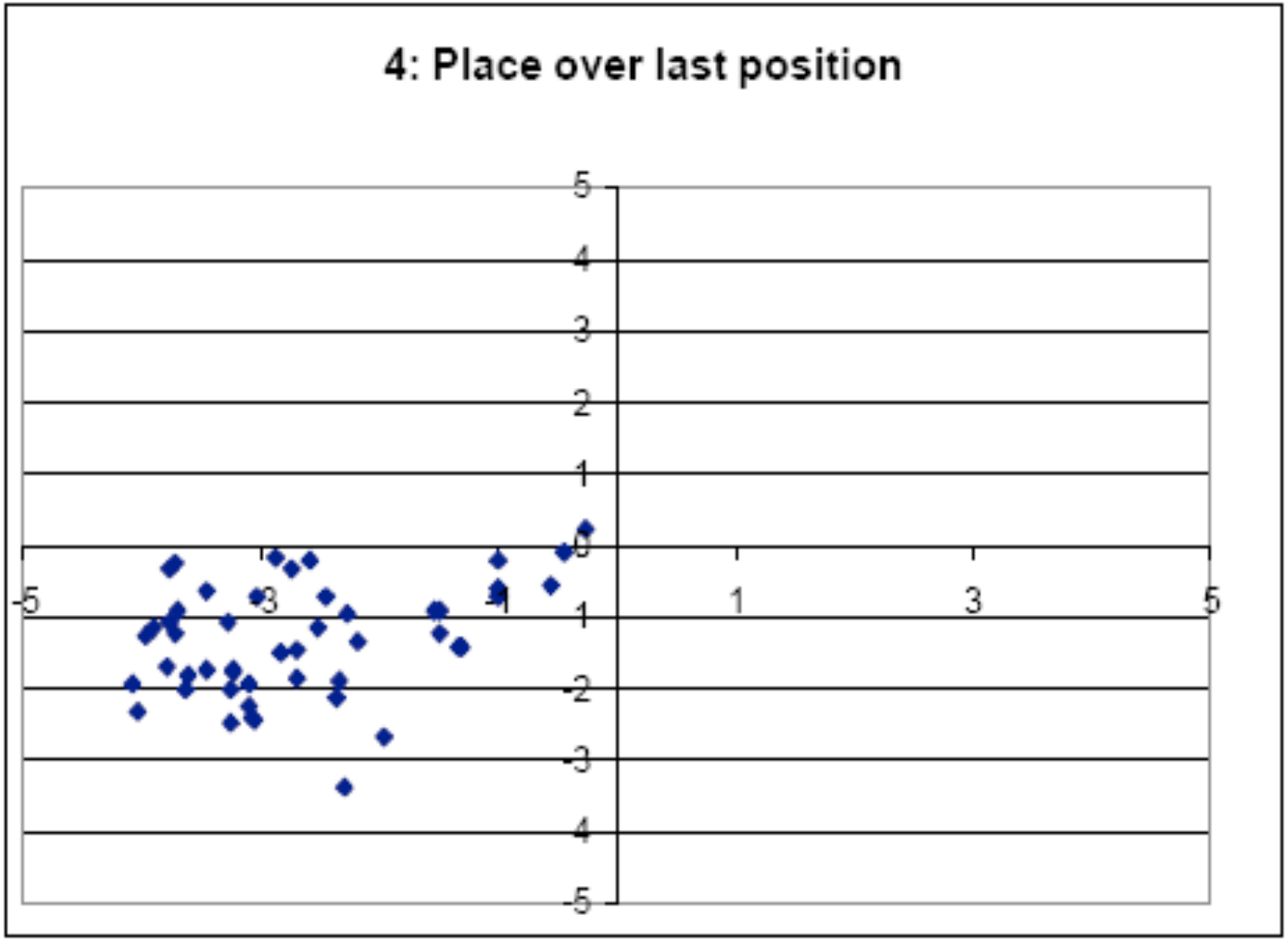



Marble #1 hits the bull's-eye then bounces and rolls to its final resting spot on the target ($M_1$)


Dont Move Funnel
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

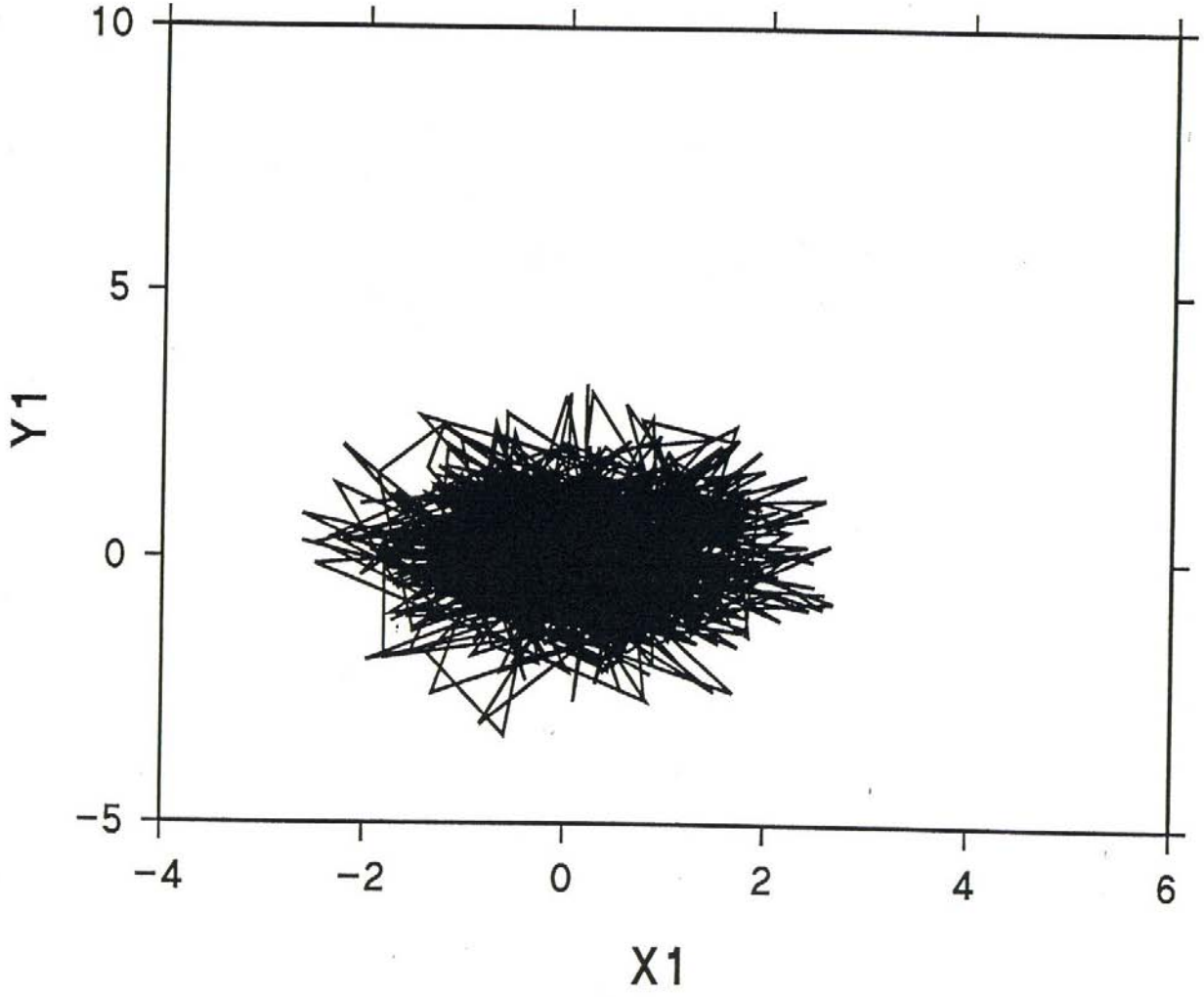

2: Move Relative to Last Position
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2


3: Move Relative to Zero/Zero
5
4
3
2
1
0
-1
-2
-3
4
-5
-5
-3
-1
1
3
5


4: Place over last position
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-3
-1
1
3
5

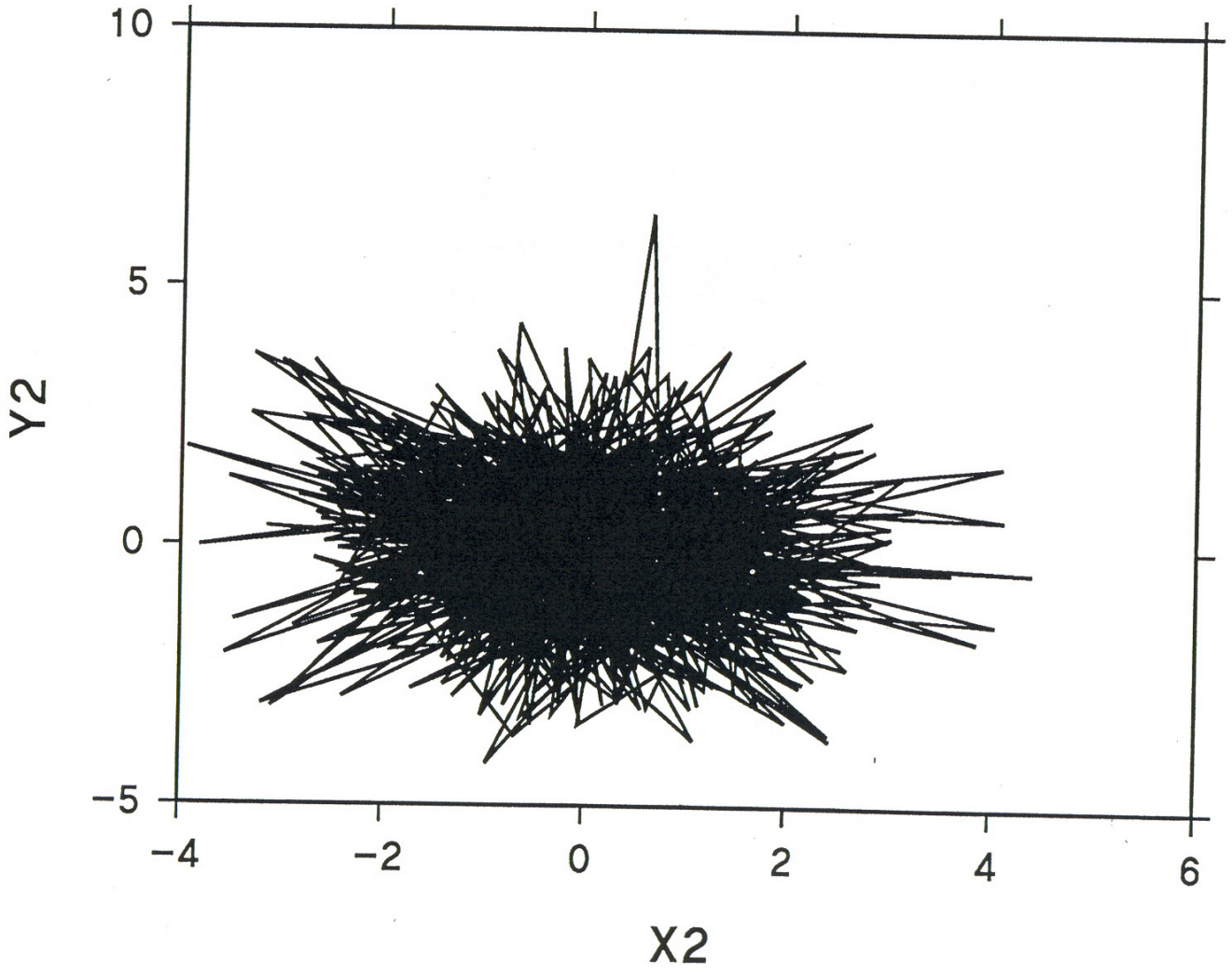
# Deming Funnel Experiment – Rule 1

Funnel Remains Fixed



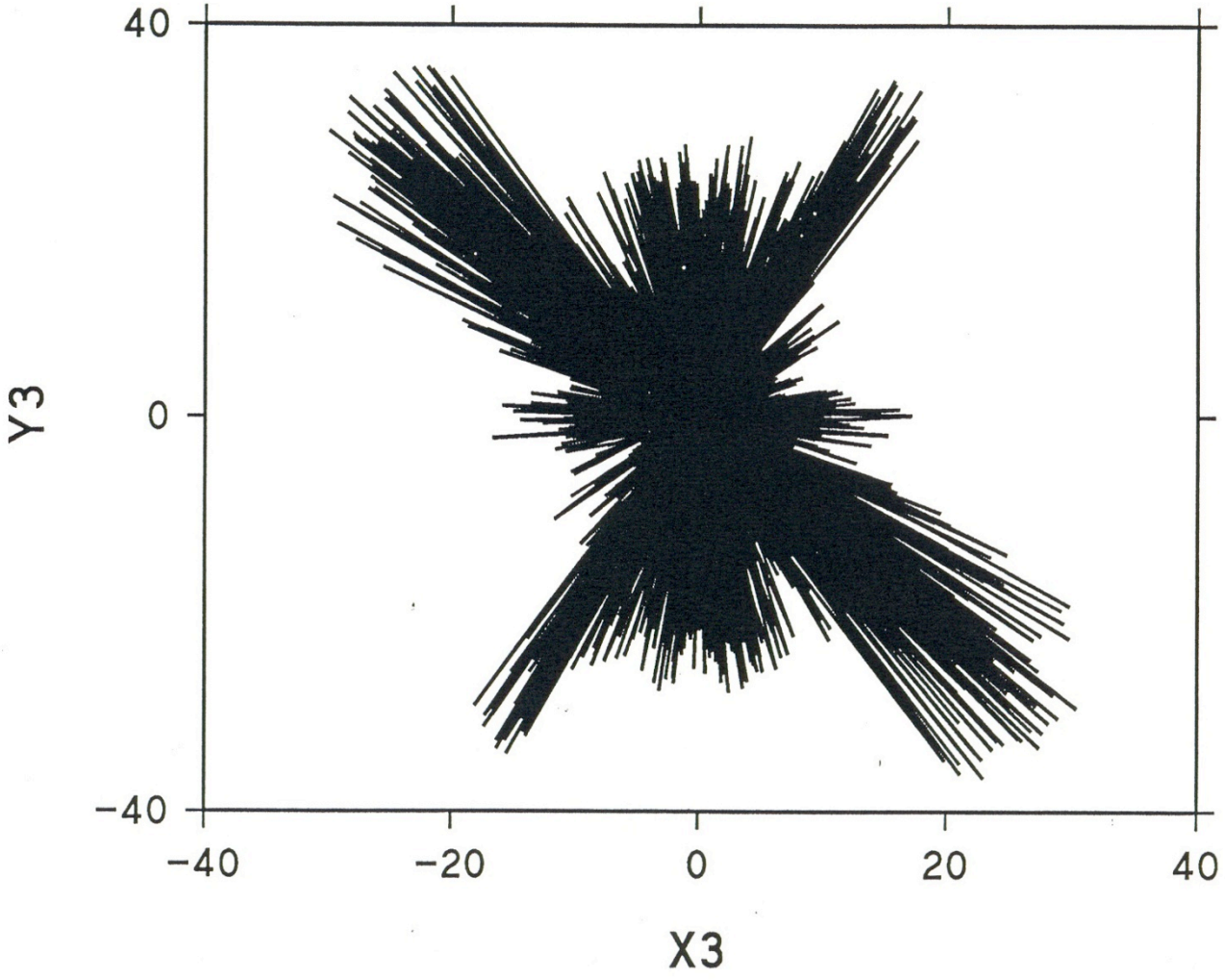
# Deming Funnel Experiment – Rule 2

Funnel Moved the Distance of the Current Error in the Opposite Direction



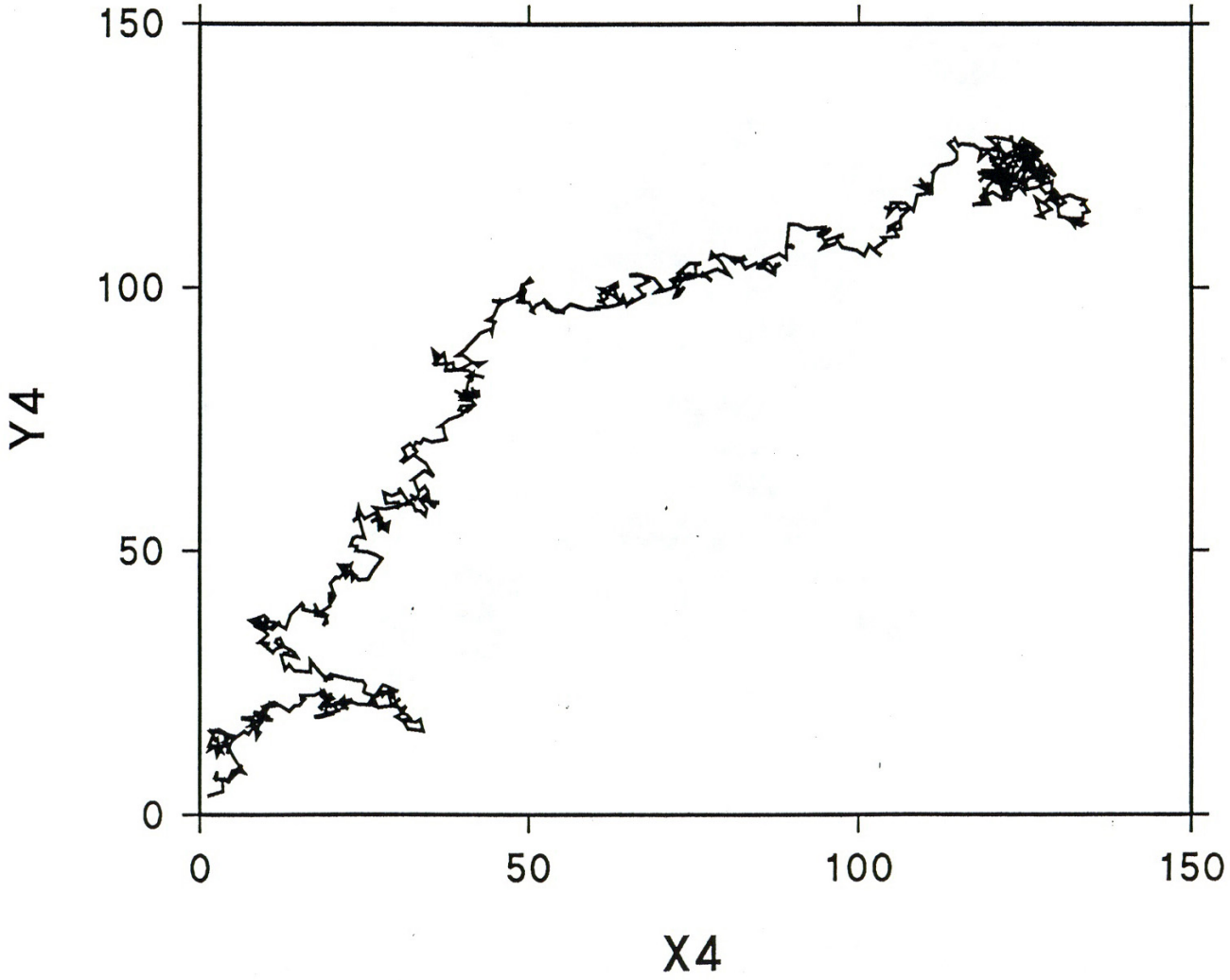
# Deming Funnel Experiment – Rule 3

Bow Tie Effect



# Deming Funnel Experiment – Rule 4

Random Walk



# Funnel Experiment

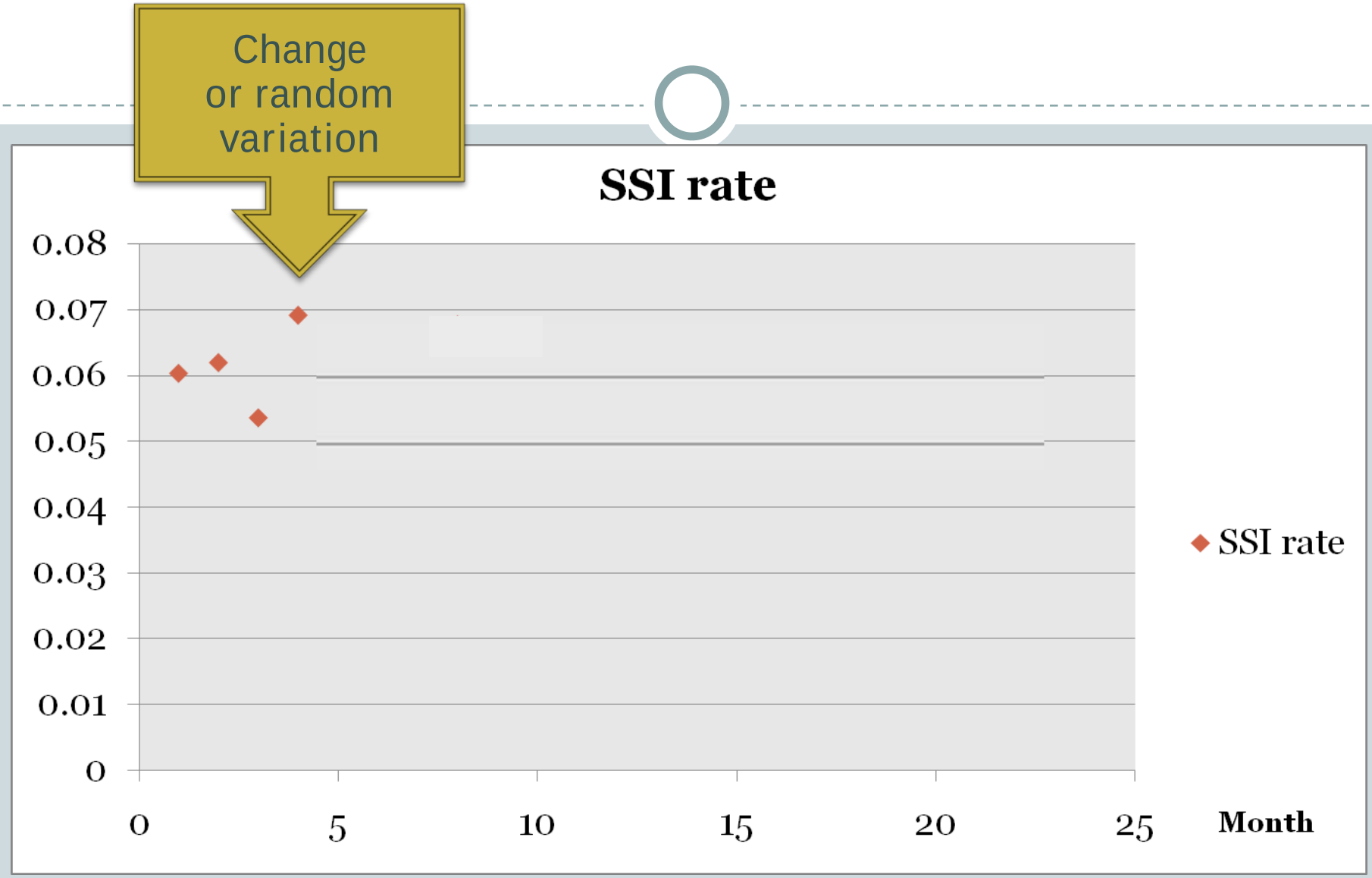
## Rule 2,3

- ปรับเปลี่ยนระบบเพียงเพราะมี SSI เพิ่มขึ้นเมื่อเทียบกับเดือนก่อน 1-2 ราย
- การปรับยาเบาหวานจากผลระดับน้ำตาลครั้งล่าสุด
- ตลาดหลักทรัพย์มีปฏิกิริยาต่อข่าวดีและข่าวร้าย

# Funnel Experiment

## Rule 4

- เกมสื่อสาร
- เฟลโลว์ สอน เรซซิเดนท์ , เรซซิเดนท์ สอน นศพ.ปี6


Change or random variation
SSI rate
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
Month
SSI rate

# ผลเสียจากการแปลผลความผันแปรที่ผิดพลาด

- ตำหนิบุคคลในปัญหาที่เขาไม่สามารถควบคุมได้
- ใช้เงินซื้อเครื่องมือโดยไม่จำเป็น
- เสียเวลาในการหาสาเหตุ
- ทำในสิ่งที่ไม่ควรทำ

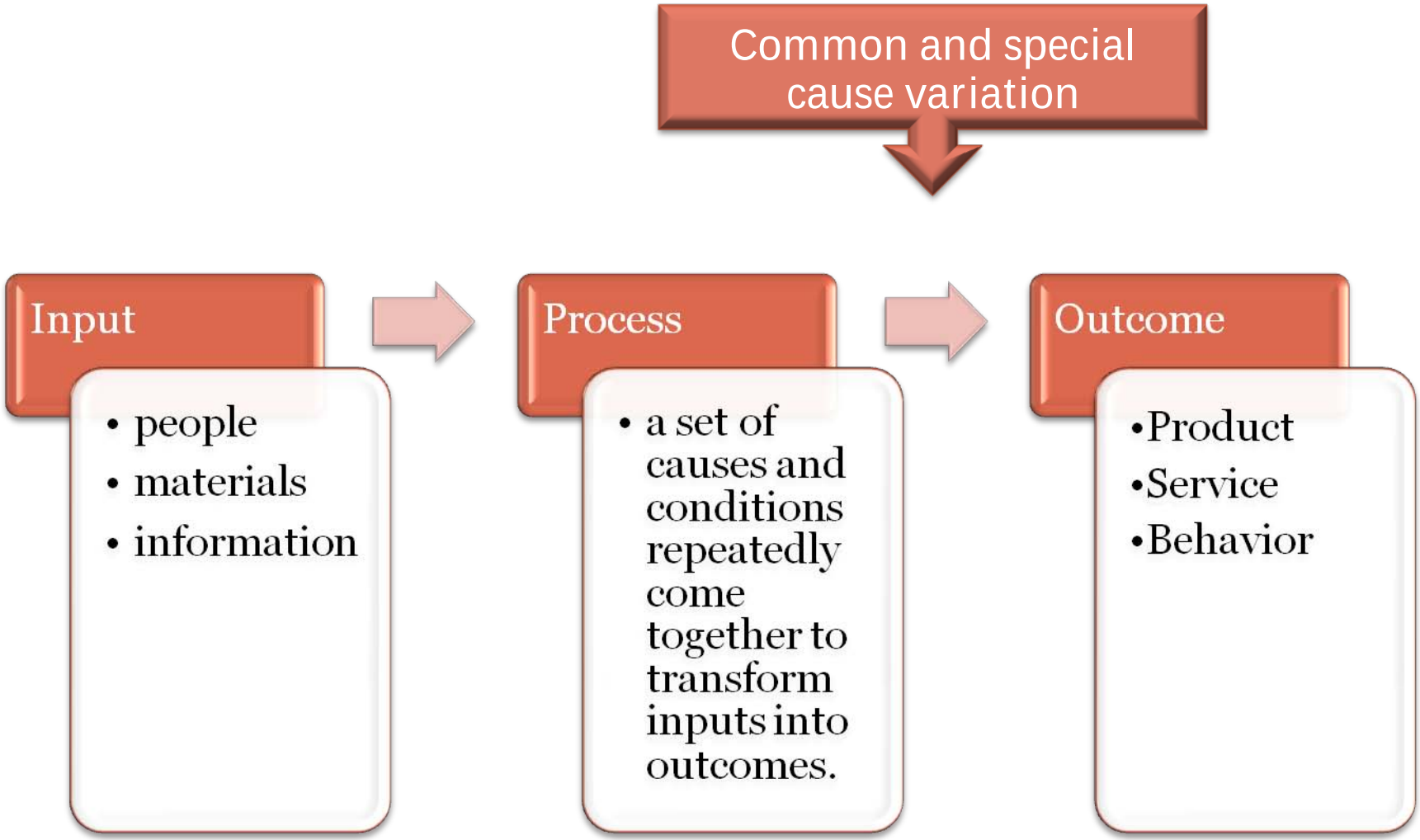
# Walter Shewhart
# Statistical process control chart

**THE CONCEPTS OF COMMON AND SPECIAL CAUSES OF VARIATION CAN BE USED TO HELP MINIMIZE THESE AND OTHER LOSSES RESULTING FROM MISINTERPRETATION OF VARIATION.**

# What is a control chart?

- A graphical display of data over time that can differentiate **common cause** variation from **special cause** variation

- Walter Shewhart 1920
  - Assignable and unassignable variation
- Edward Deming
  - Common and Special causes


Common and special cause variation
Input
• people
• materials
• information
Process
• a set of causes and conditions repeatedly come together to transform inputs into outcomes.
Outcome
•Product
•Service
•Behavior

# กรอบแนวคิดความผันแปรของ Walter Shewhart

## Common causes (สาเหตุที่เป็นปรกติวิสัย)

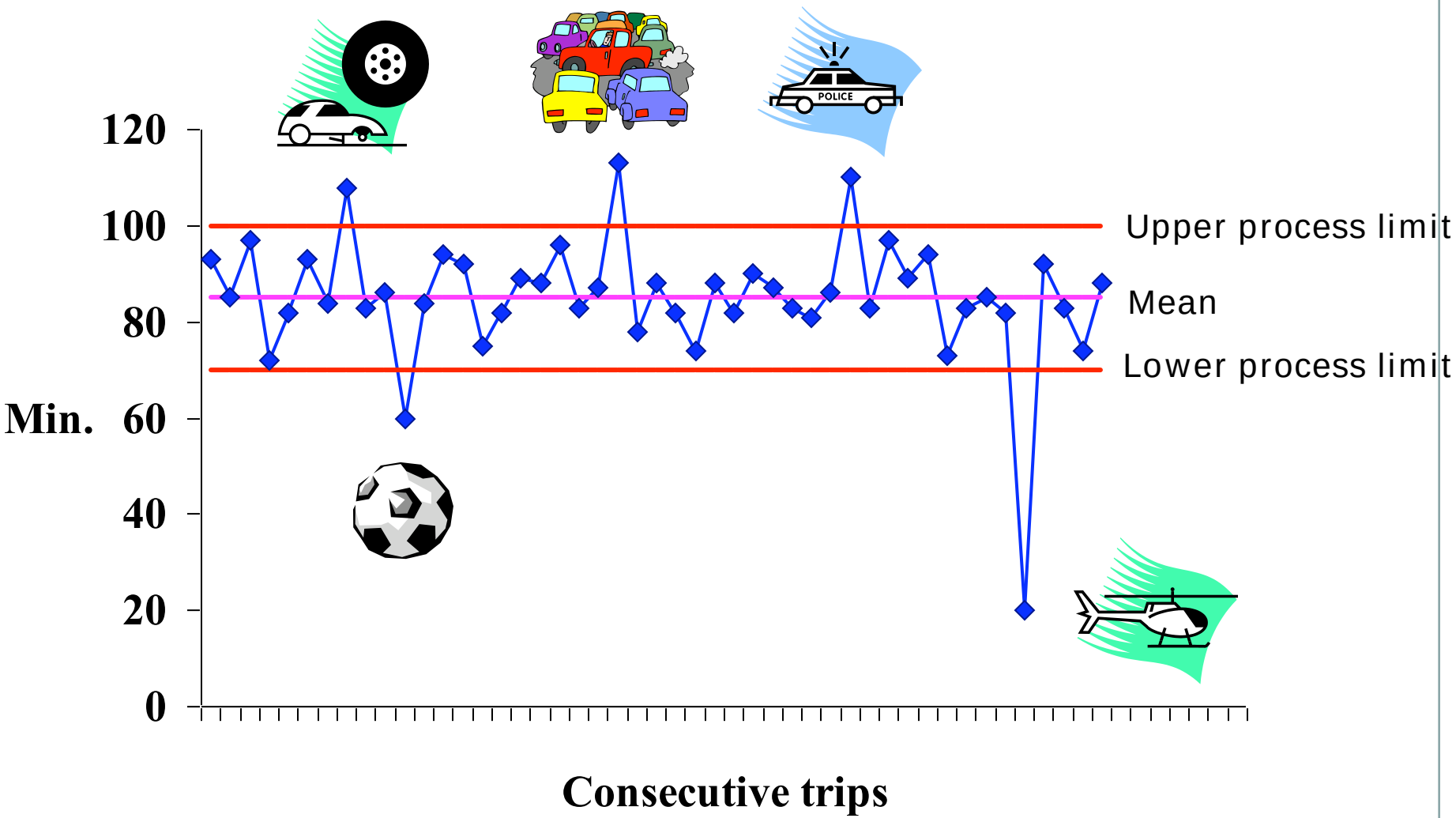
ความผันแปรแบบสุ่มที่เกิดจากสาเหตุที่เกิดตามธรรมชาติ,เป็นปรกติวิสัยและเกิดขึ้นสม่ำเสมอกับทุกผลผลิตของขบวนการผลิตและบริการนั้นๆ

# กรอบแนวคิดความผันแปรของ Walter Shewhart

## Special causes (สาเหตุที่ผิดปรกติวิสัย)

ความผันแปรที่เกิดจากสาเหตุที่เกิดไม่เป็นปรกติวิสัย, ไม่เป็นไปตามธรรมชาติและเกิดขึ้นเป็นครั้งคราวและอยู่นอกเหนือการควบคุมจากกระบวนการผลิตและบริการโดยปรกติ

# My trip to work



# กรอบแนวคิดความผันแปรของ Walter Shewhart

- Stable process (ระบบเสถียร)
  - กระบวนการผลิตที่มีความผันแปรที่เกิดจากสาเหตุที่เป็นปกติวิสัย (Common causes) เท่านั้น
  - ไม่ได้หมายความว่าระบบหรือกระบวนการผลิตไม่มีความผันแปร

# Stable process (ระบบเสถียร)

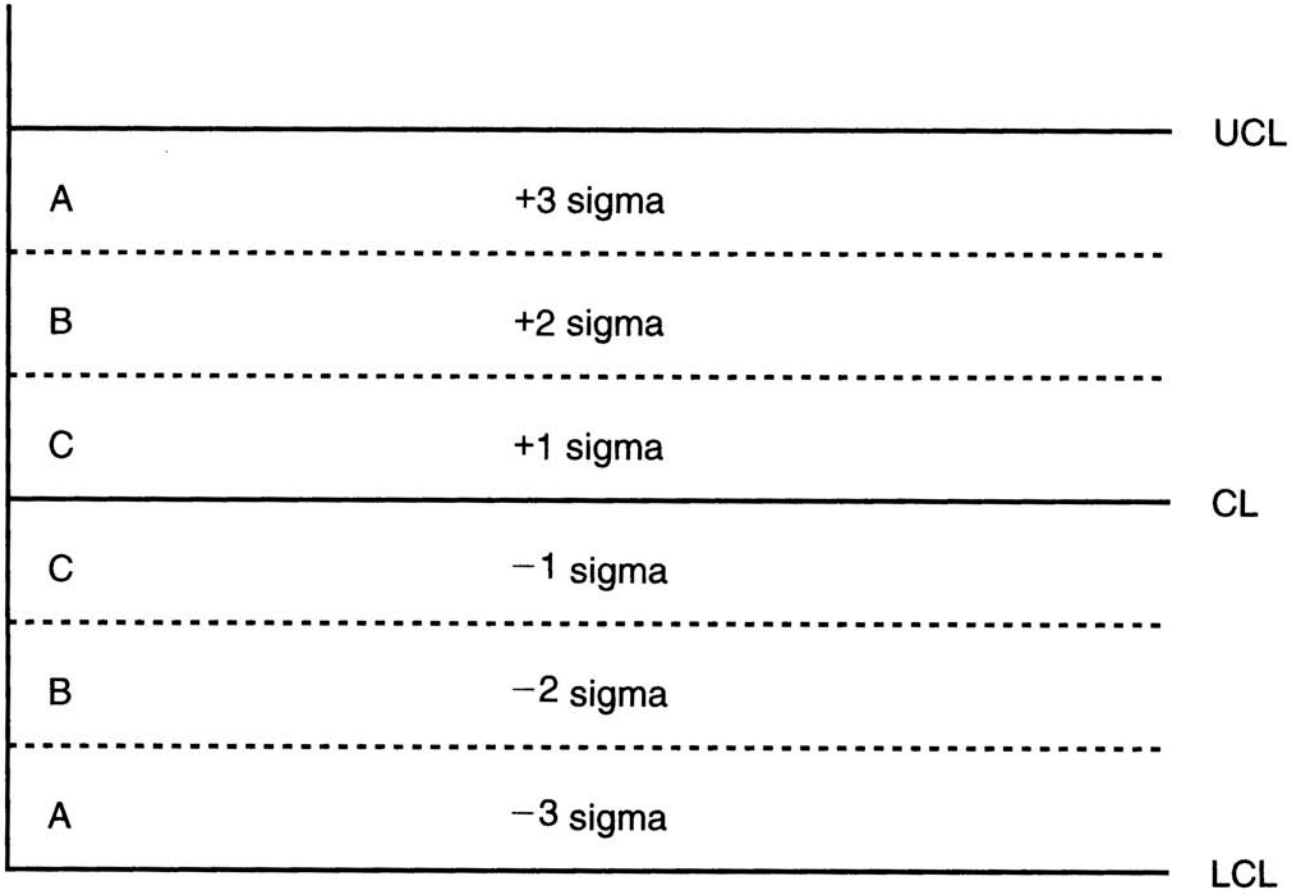
- ระบบที่เสถียรสามารถพยากรณ์ผลผลิตในอนาคตได้
- ผลผลิตจากระบบที่เสถียรอาจไม่เป็นที่พึงพอใจได้
- การปรับปรุงผลผลิตจะต้องเปลี่ยนแปลงระบบที่เป็นพื้นฐาน

# กรอบแนวคิดความผันแปรของ Walter Shewhart

- Unstable process
  - กระบวนการผลิตหรือระบบที่ความผันแปรเกิดจากทั้งสาเหตุที่เป็นปรกติวิสัย (common causes) และสาเหตุที่ผิดปรกติวิสัย (Special causes)
  - ไม่ได้หมายความว่ากระบวนการผลิตมีความผันแปรมาก
  - ขนาดของความผันแปรไม่สามารถพยากรณ์ได้
  - การปรับปรุงสามารถหาได้โดยการแก้ไขหรือป้องกันความผันแปรที่เกิดจากสาเหตุที่ผิดปรกติวิสัย (Special causes variation)

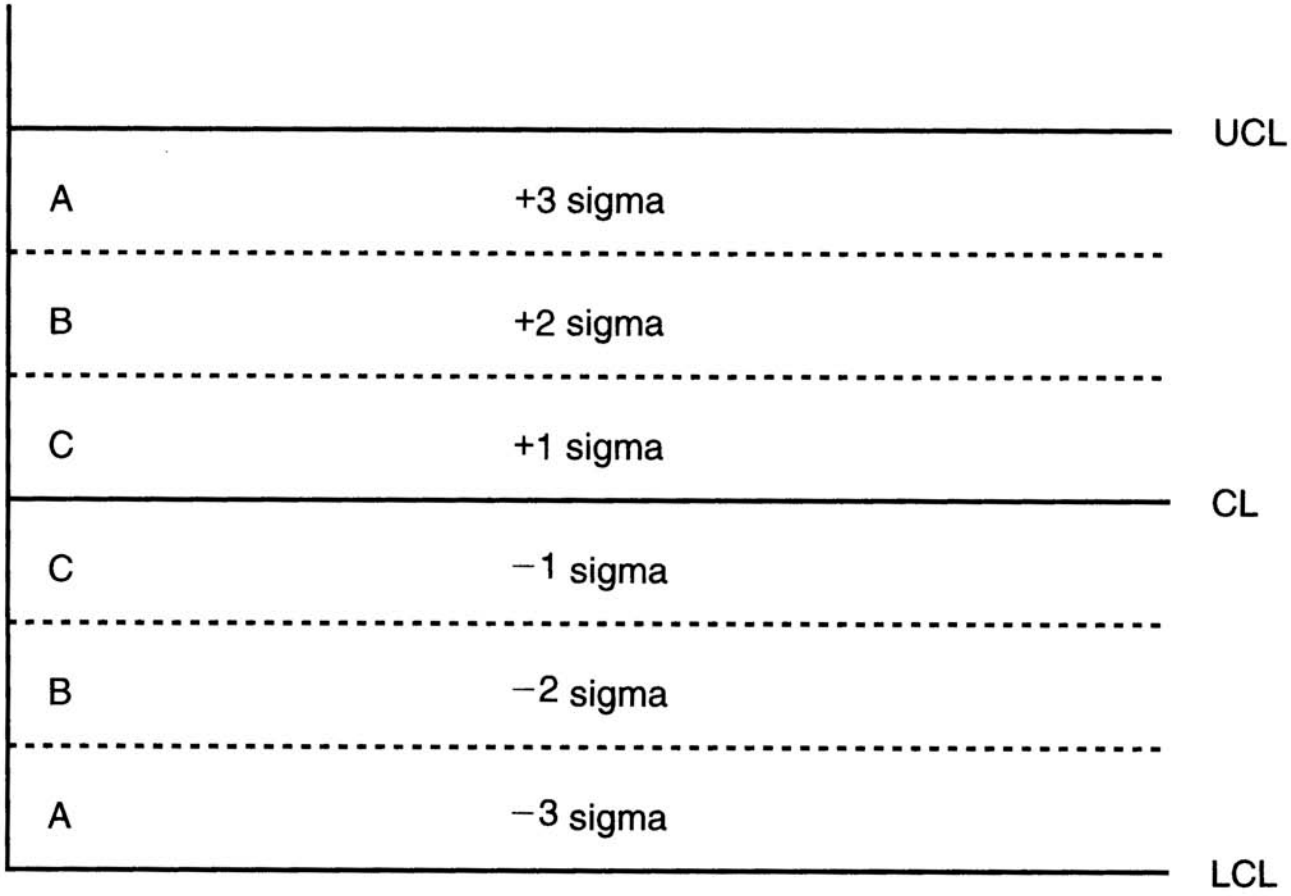
# Shewhart control chart

- It consists of three lines and points plotted on a graph.
- A control chart is constructed by obtaining measurements a some quality characteristic of the process

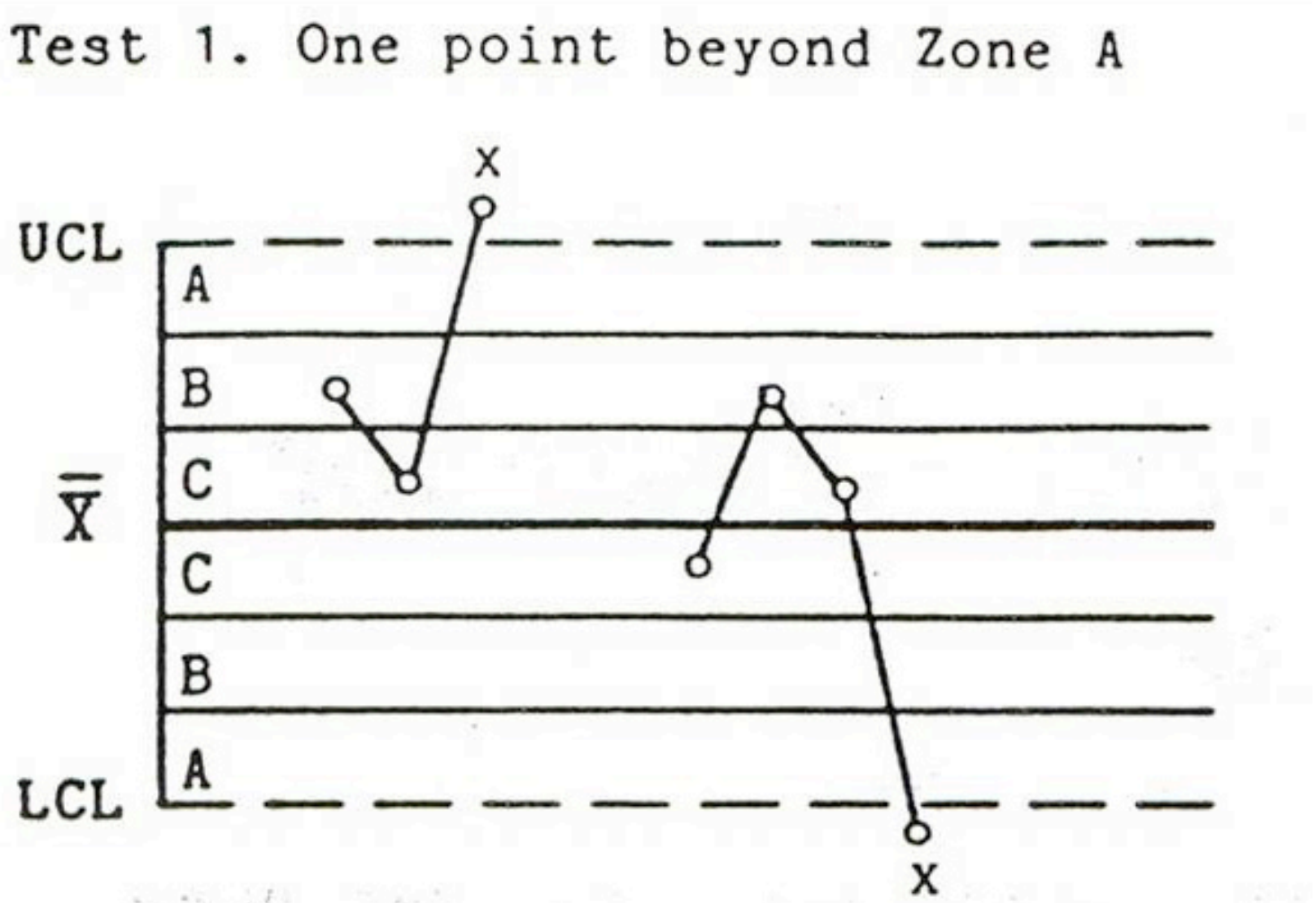

UCL
A
+3 sigma
B
+2 sigma
C
+1 sigma
CL
C
−1 sigma
B
−2 sigma
A
−3 sigma
LCL

# Shewhart control chart

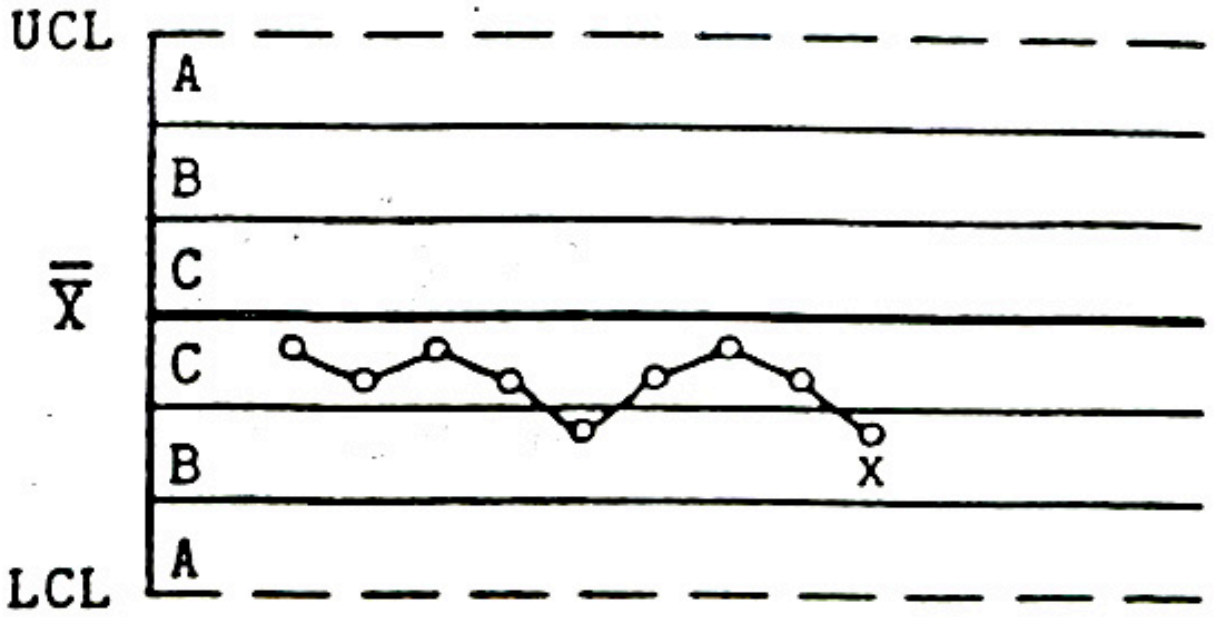
- เส้นขอบเขตควบคุมค่าสูง(Upper control limit = UCL) และค่าต่ำ(Lower control limit = LCL)
  - คำนวณได้จาก
    - UCL = u +3 sigma
    - LUL = u – 3 sigma
- ลักษณะของแผนภูมิควบคุมที่อยู่ภายใต้เส้นขอบเขตควบคุมค่าสูงและค่าต่ำ มีรูปแบบที่ปรกติในระบบเสถียร มีเพียงความผันแปรแบบสุ่ม(Common cause variation)


UCL
A
+3 sigma
B
+2 sigma
C
+1 sigma
CL
C
−1 sigma
B
−2 sigma
A
−3 sigma
LCL

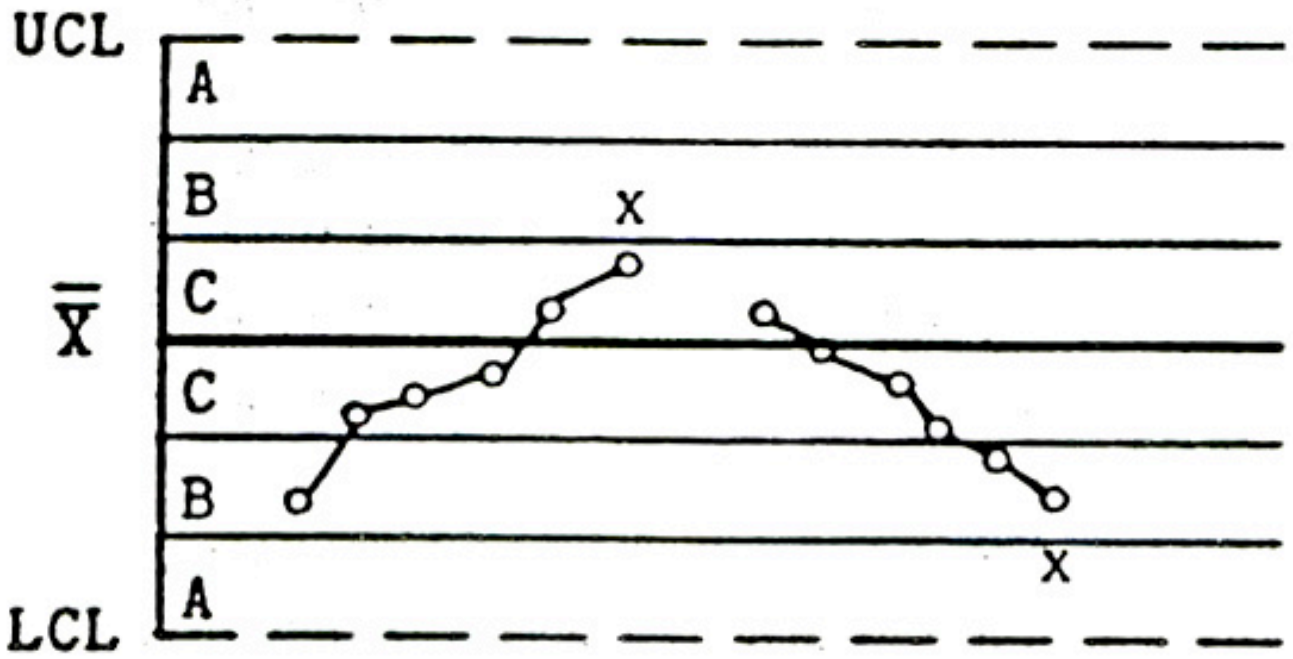
# Detecting Special Cause



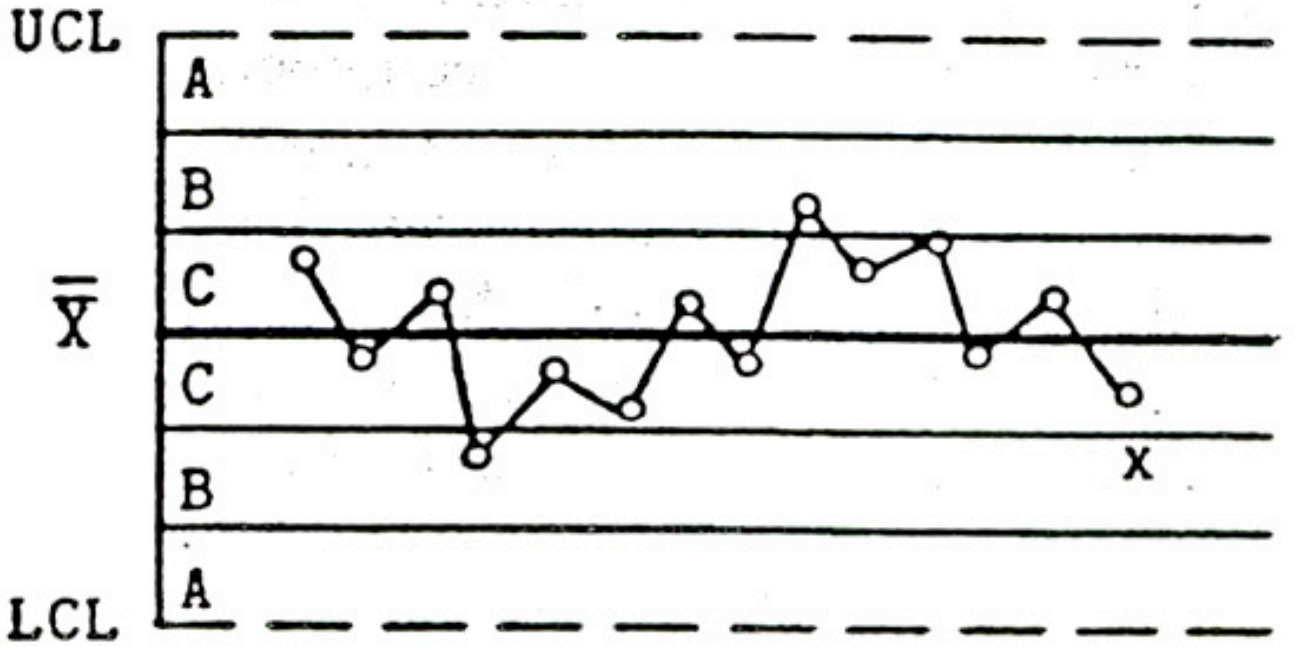
Test 2. Nine points in a row in Zone C or beyond



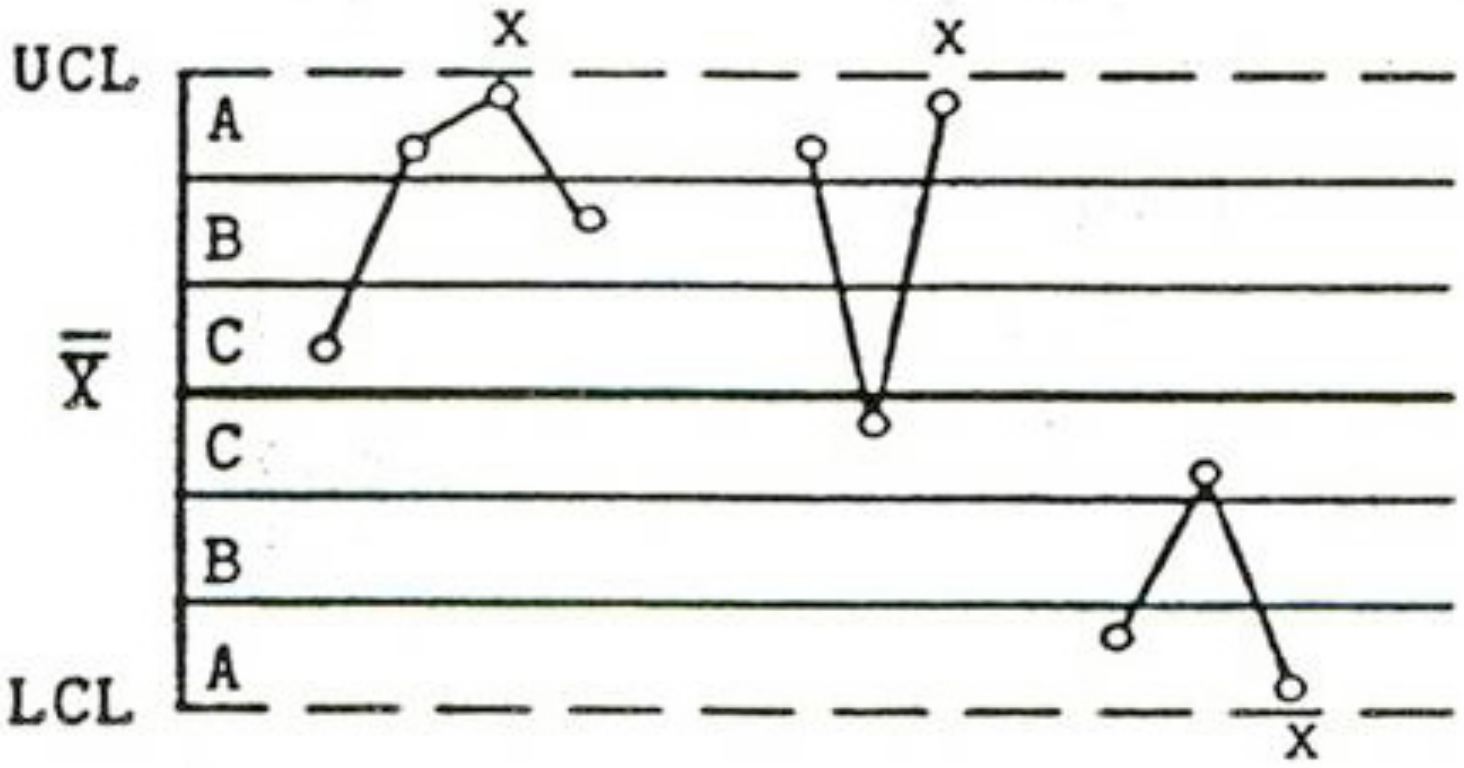
Test 3. Six points in a row steadily increasing or decreasing



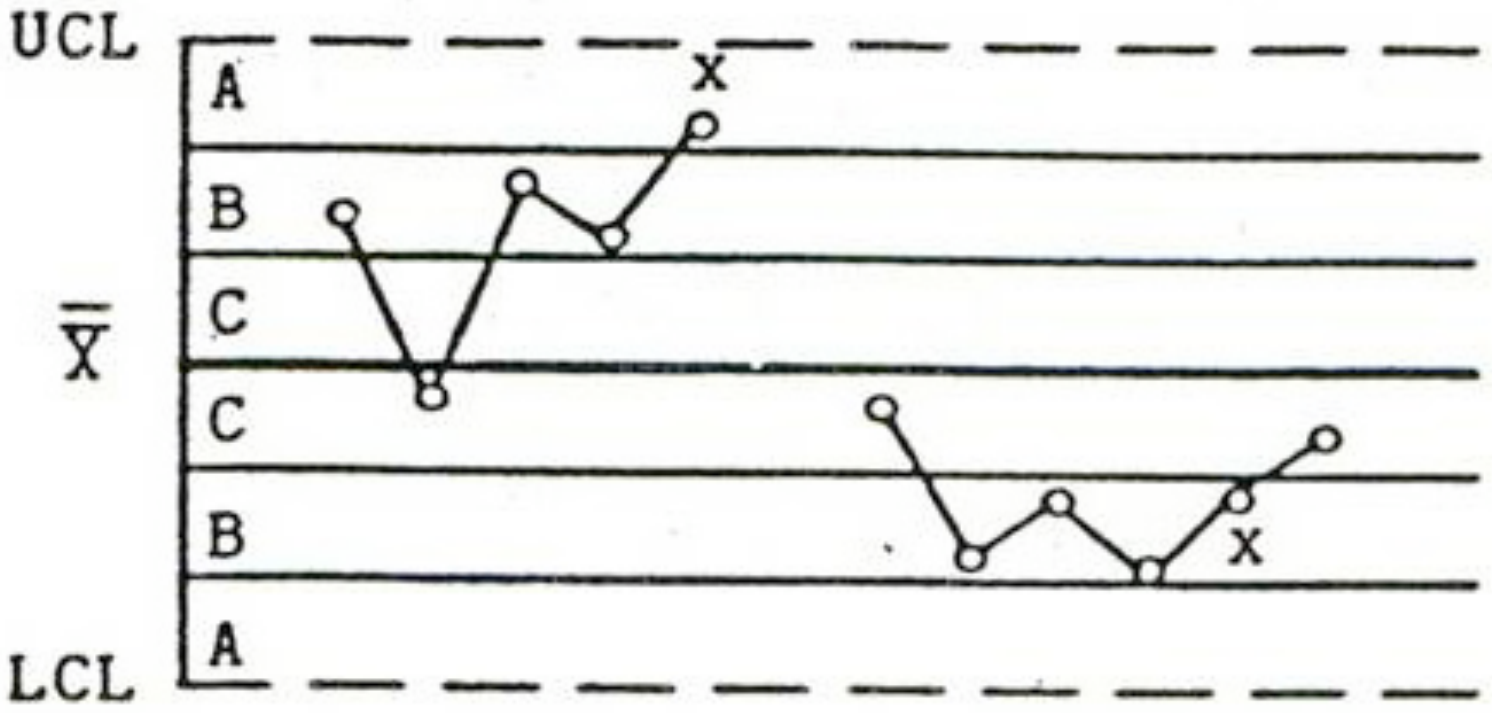
Test 4. Fourteen points in a row alternating up and down



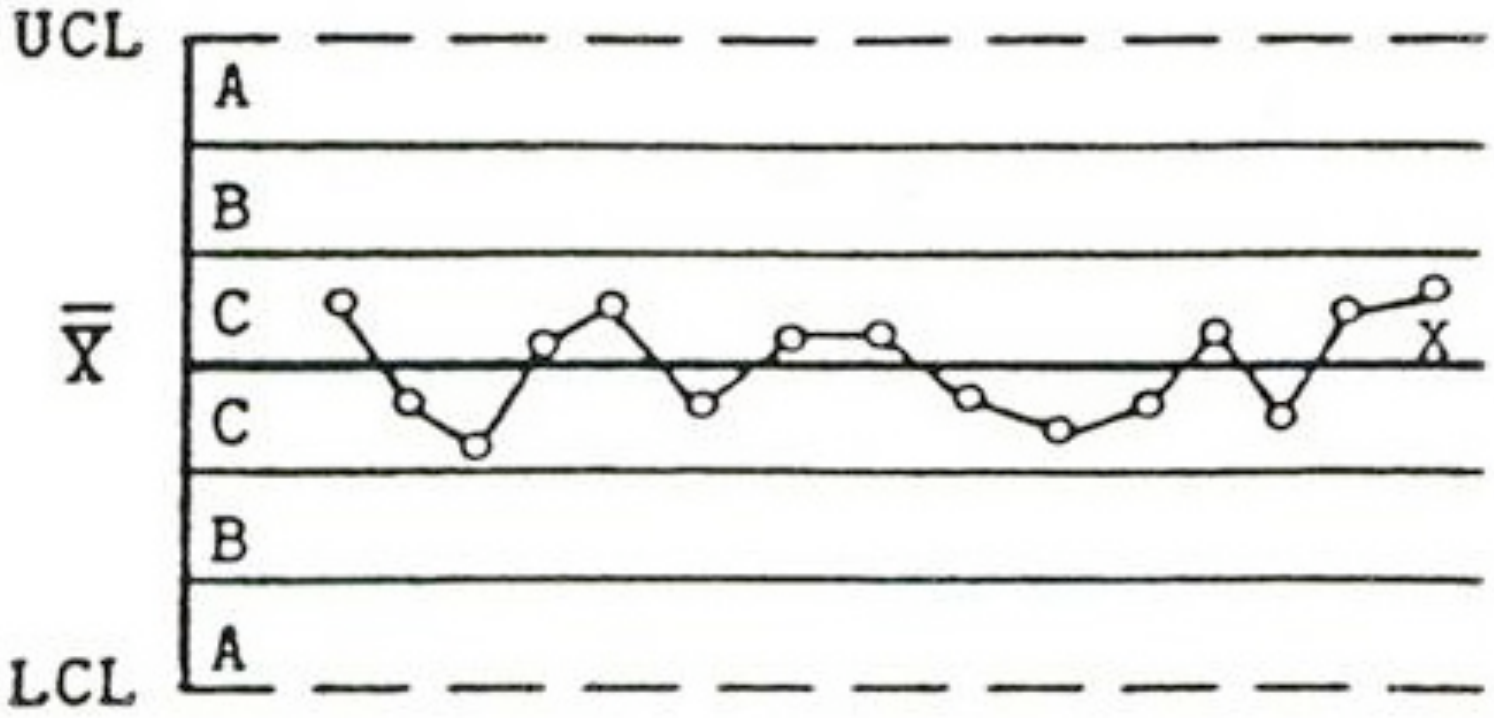
Test 5. Two out of three points in a row in Zone A or beyond



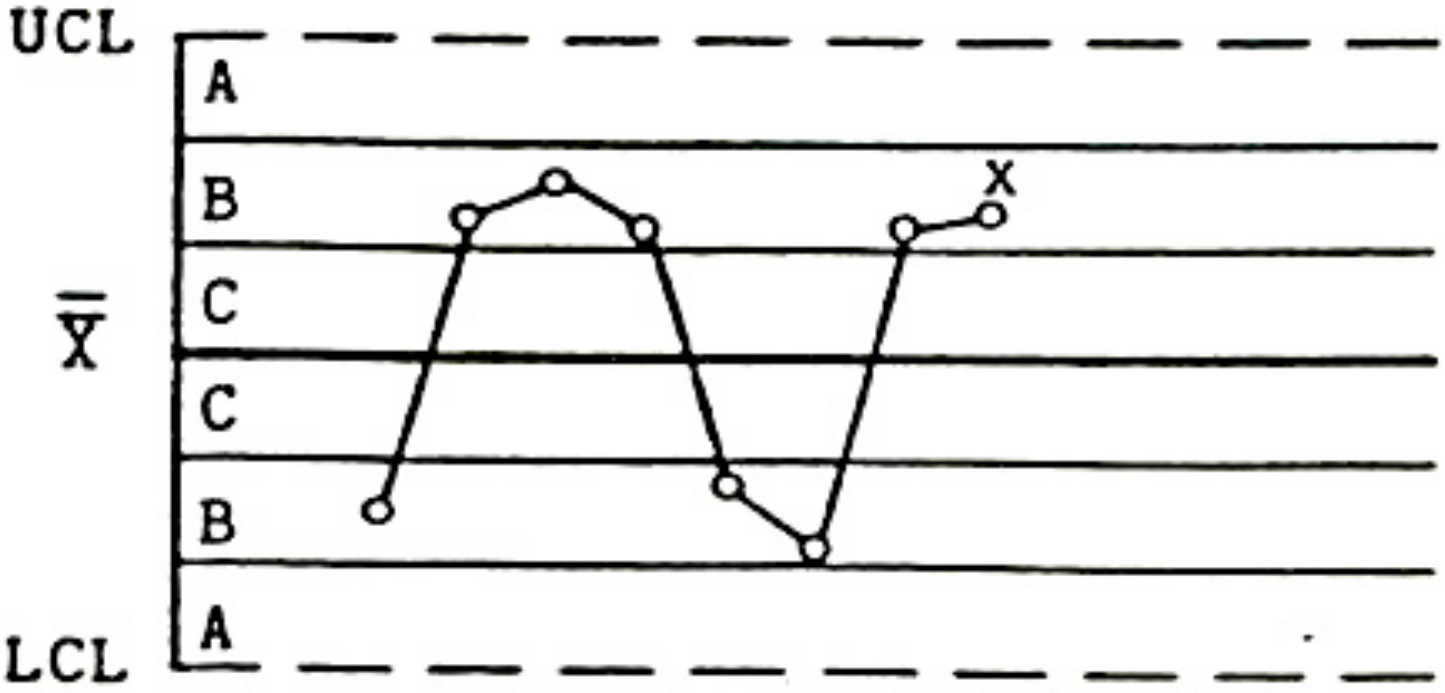
Test 6. Four out of five points in a row in Zone B or beyond



Test 7. Fifteen points in a row in Zone C (above and below centerline)

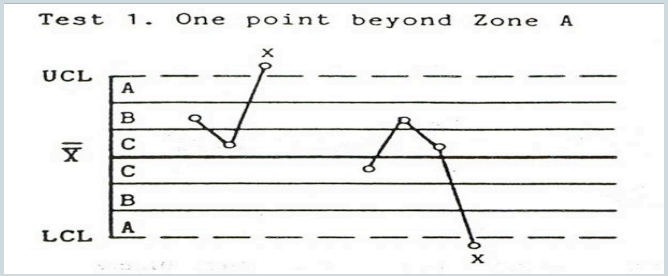


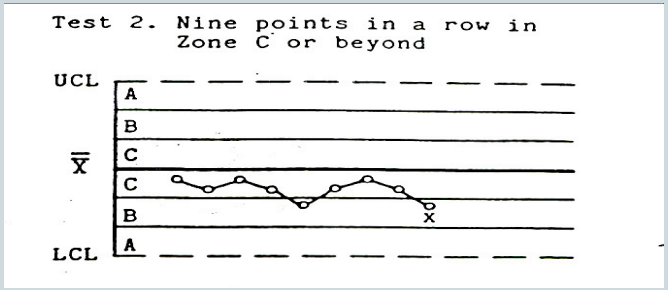
Test 8. Eight points in a row on both sides of centerline with none in Zones C

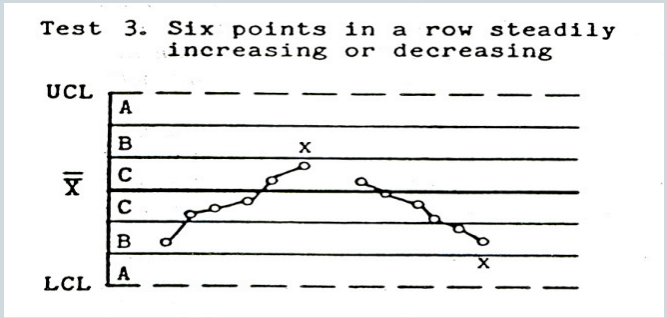


# Tests that occur most often in healthcare applications

- Test # 1: A single data point that exceeds the upper or lower control limit.
- Test #2: Eight or more consecutive data points that fall in Zone C or beyond.
- Test #3: A trend exists when there is a constantly increasing or decreasing series of 6 data points.

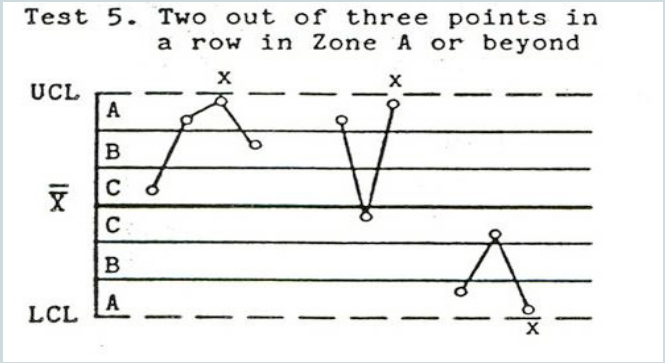


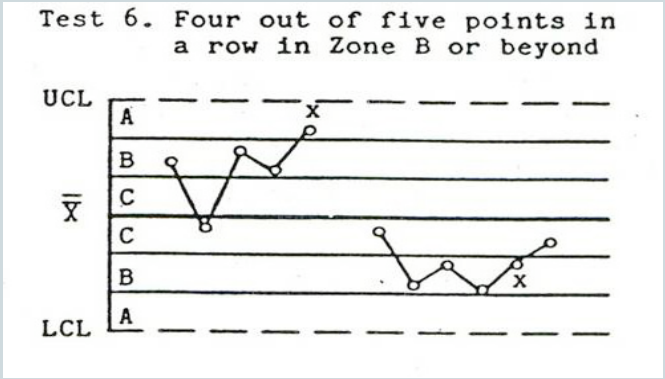



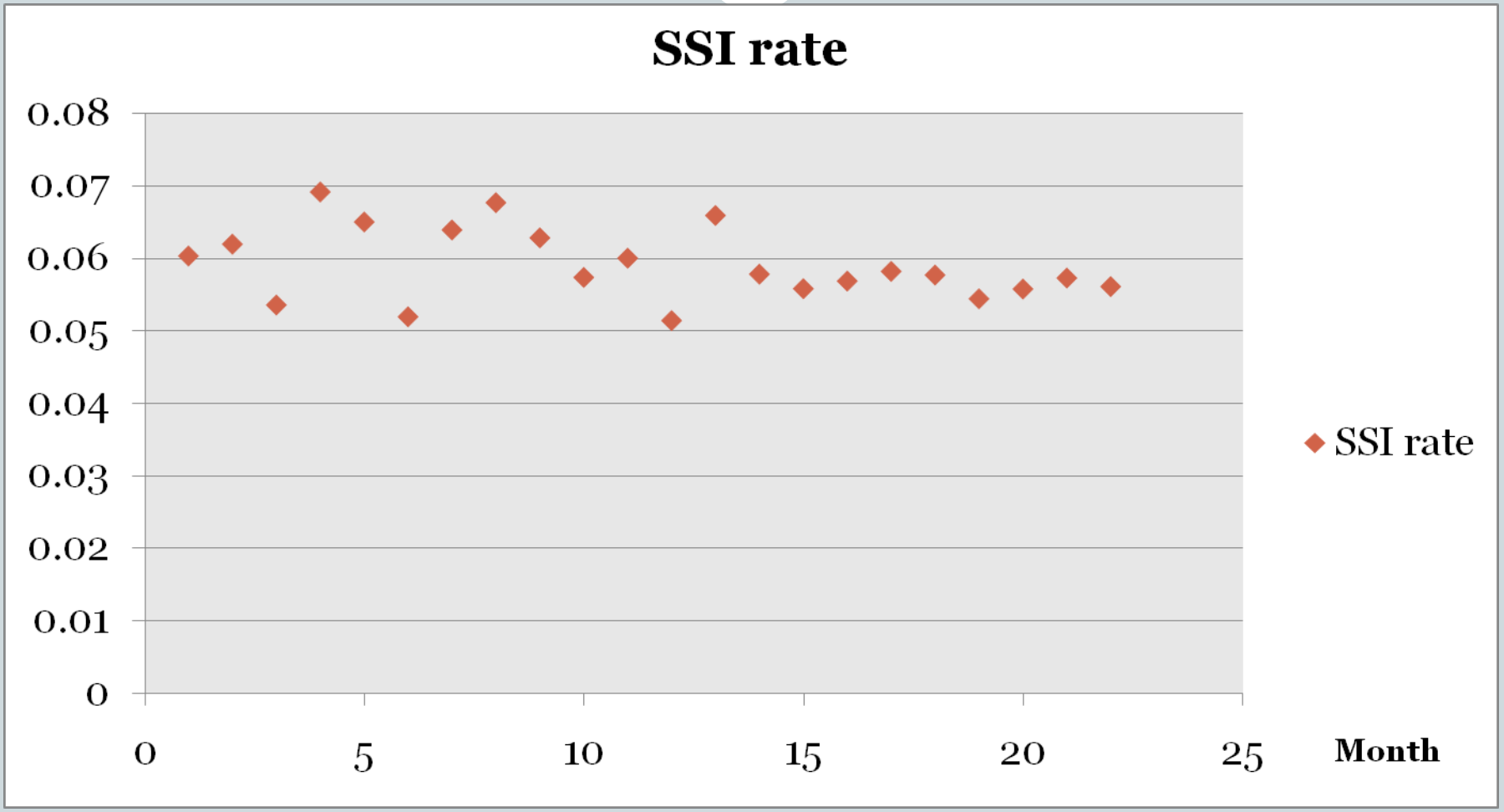
# Tests occurring with less frequency in healthcare applications

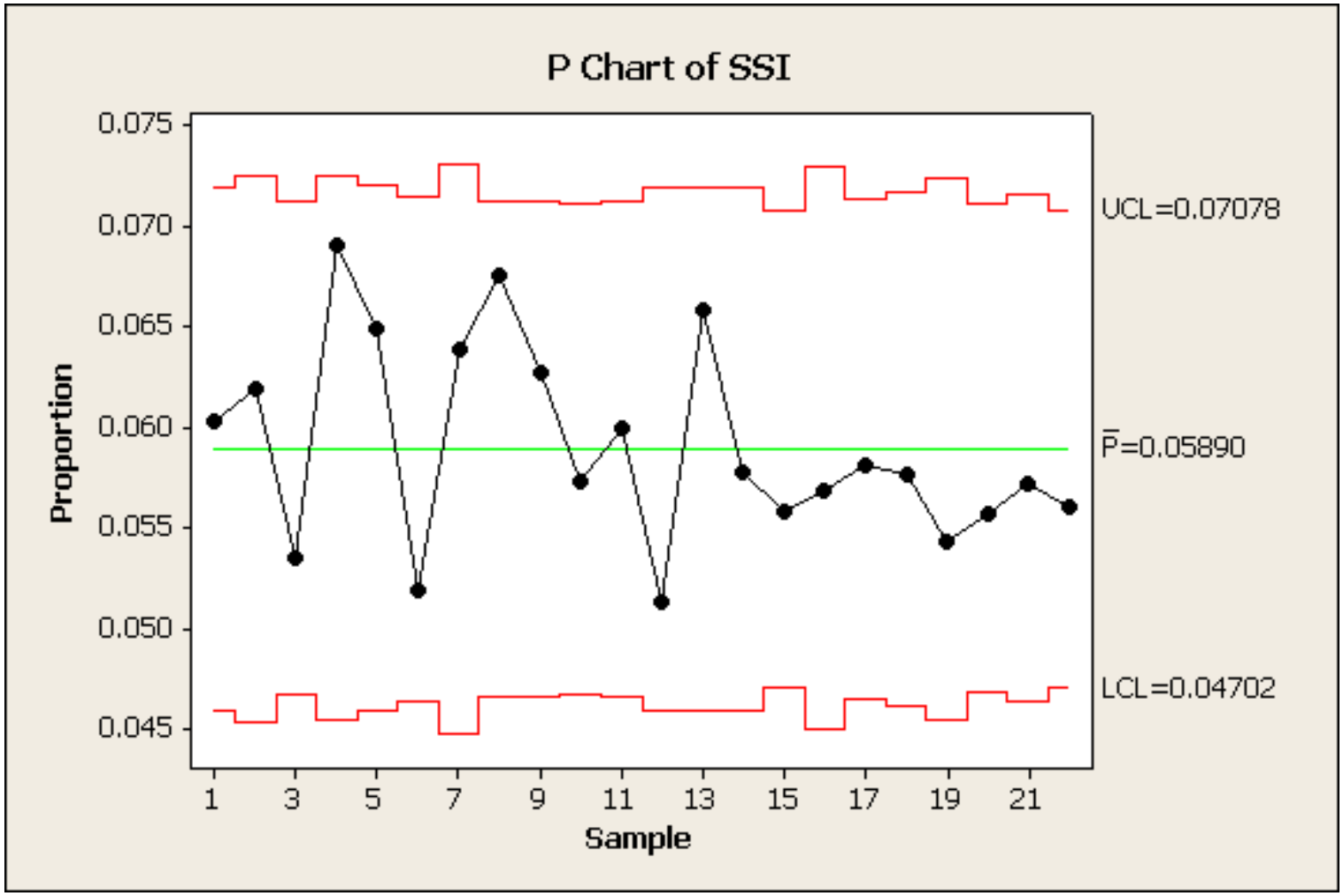
- Test #5: Two out of three consecutive data points that fall in Zone A or beyond.




- Test #6: Four out of five consecutive data points that fall in Zone B or beyond.




SSI rate
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
Month
SSI rate

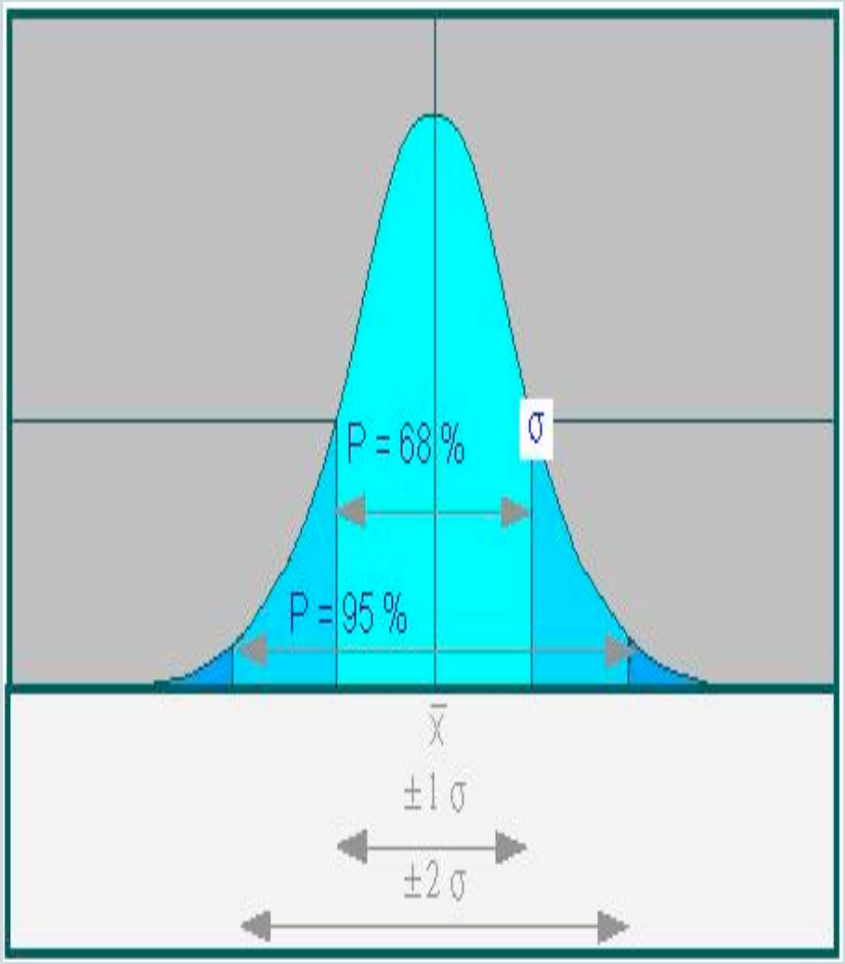

P Chart of SSI
Proportion
0.075
0.070
0.065
0.060
0.055
0.050
0.045
UCL=0.07078
P̄=0.05890
LCL=0.04702
1
3
5
7
9
11
13
15
17
19
21
Sample

- Control limits set at 3 sigma instead of 2 sigma, Why??

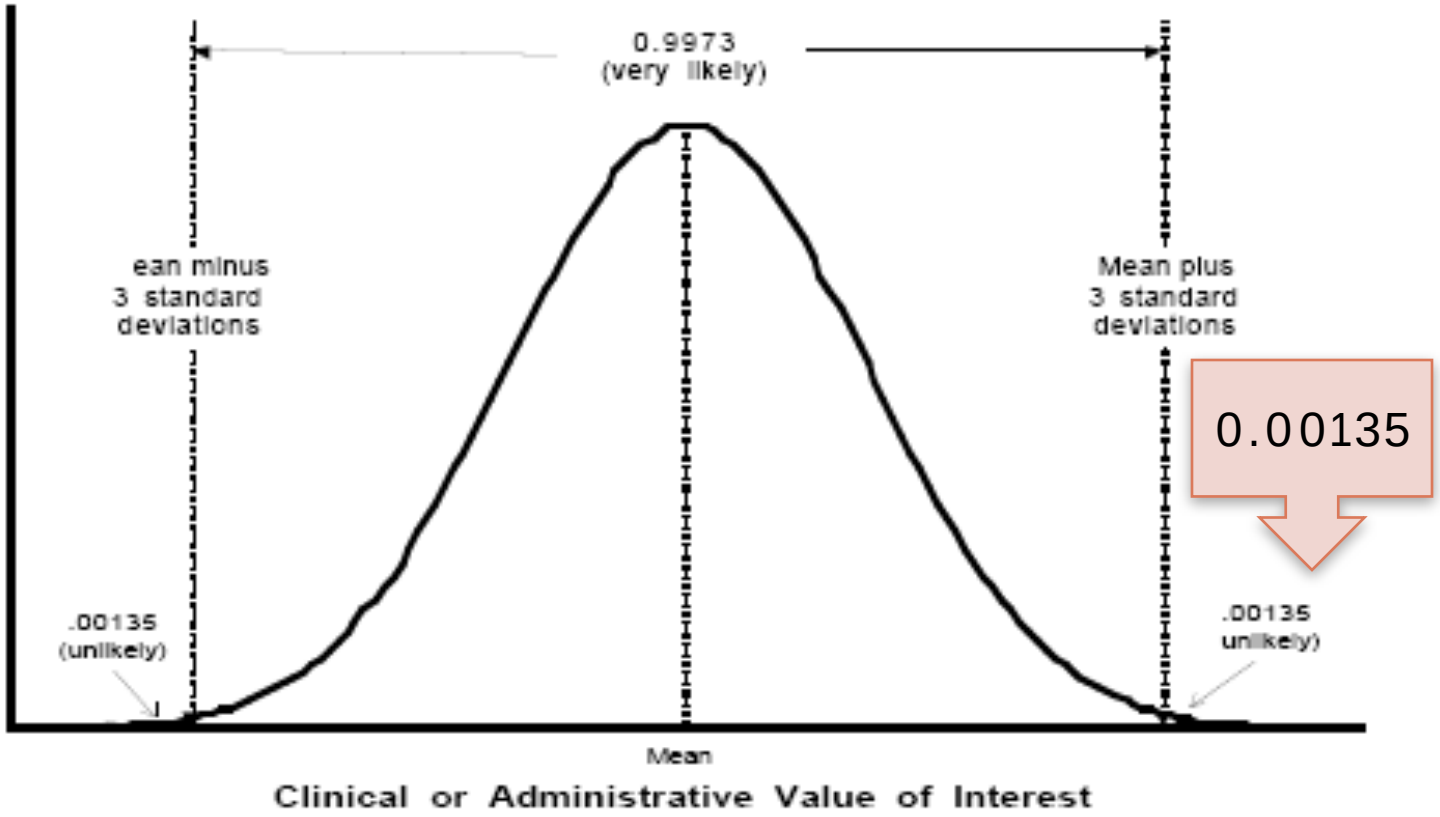
- Balance between two types of risks
  - Type I error  (false positive)
  - Type II error (false negative)

# 2 sigma VS 3 sigma?

- Normal distribution in stable process
  - **99.73%** of all plotted data are expected to fall within 3SD of the mean
  - **95%** of the values lie within 2SD of the mean
- A 2SD chart, type I error (false positive) rate for each plotted value would be about **5%** compared with **0.27%** for a 3SD chart.



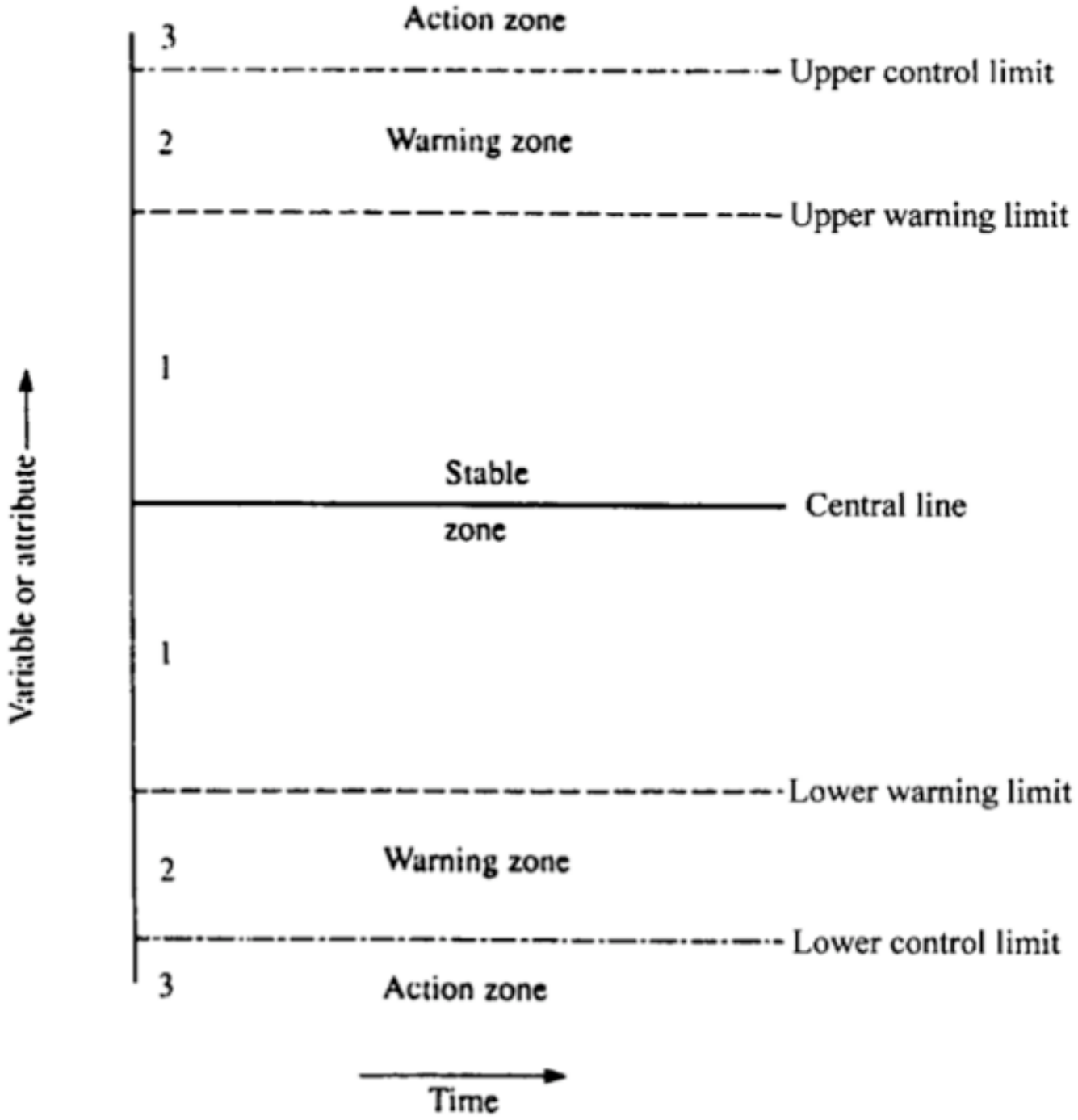
# 3 sigma


0.9973
(very likely)
ean minus
3 standard
deviations
Mean plus
3 standard
deviations
0.00135
.00135
(unlikely)
.00135
unlikely)
Mean
Clinical or Administrative Value of Interest

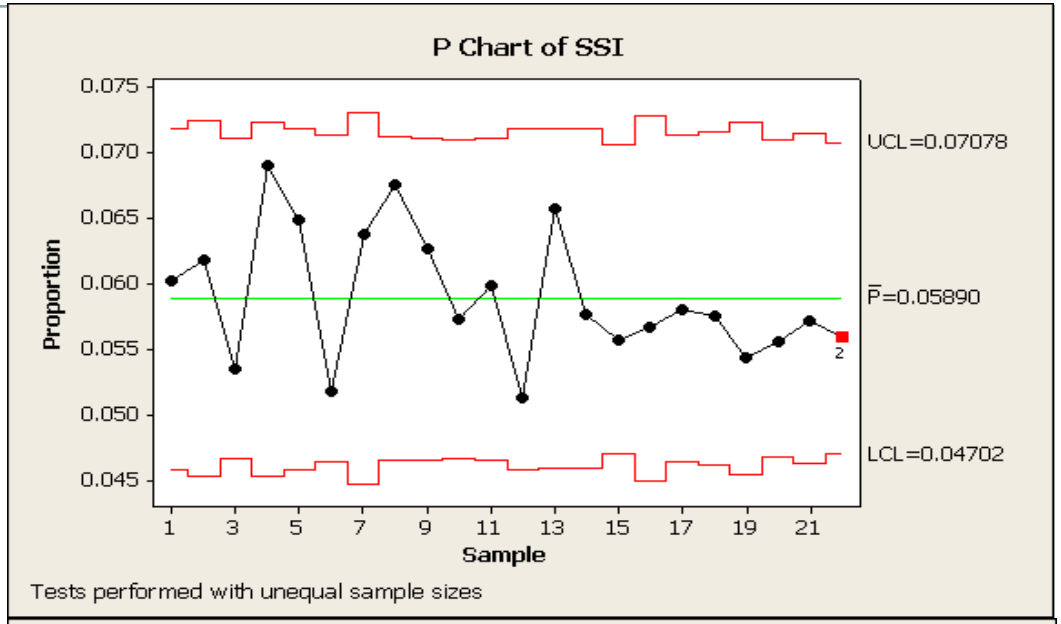
# Multiple comparison (Bonferroni)

- A control chart with 25 points
  - 3SD control limits has overall false positive probability of **$1-(0.9973)^{25}=6.5\%$**
  - 2SD limits would produce overall false positive probability of **$1-(0.95)^{25}=27.7\%$!**

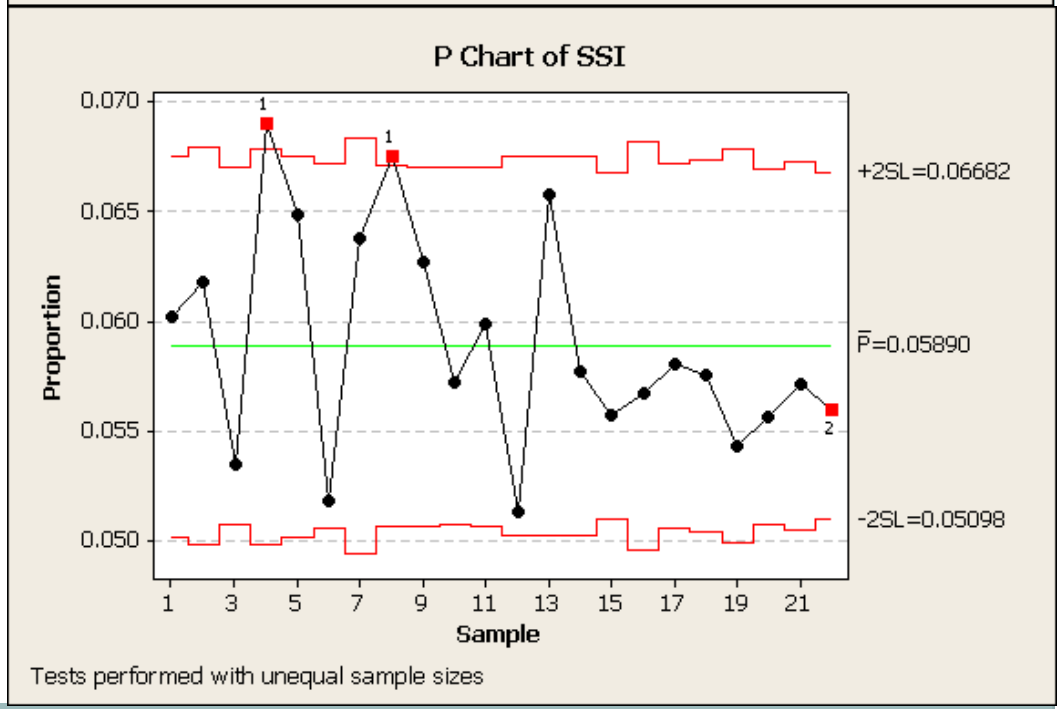
- Some situations
  - An additional pair of lines called warning limits sometimes are plotted at two sigma above and below the center line in order to provide earlier but less definite warnings of possible problems
  - Greater sensitivity but lower specificity


Action zone
3
Upper control limit
2
Warning zone
Upper warning limit
1
Stable
zone
Central line
1
Lower warning limit
2
Warning zone
Lower control limit
3
Action zone
Variable or attribute
Time

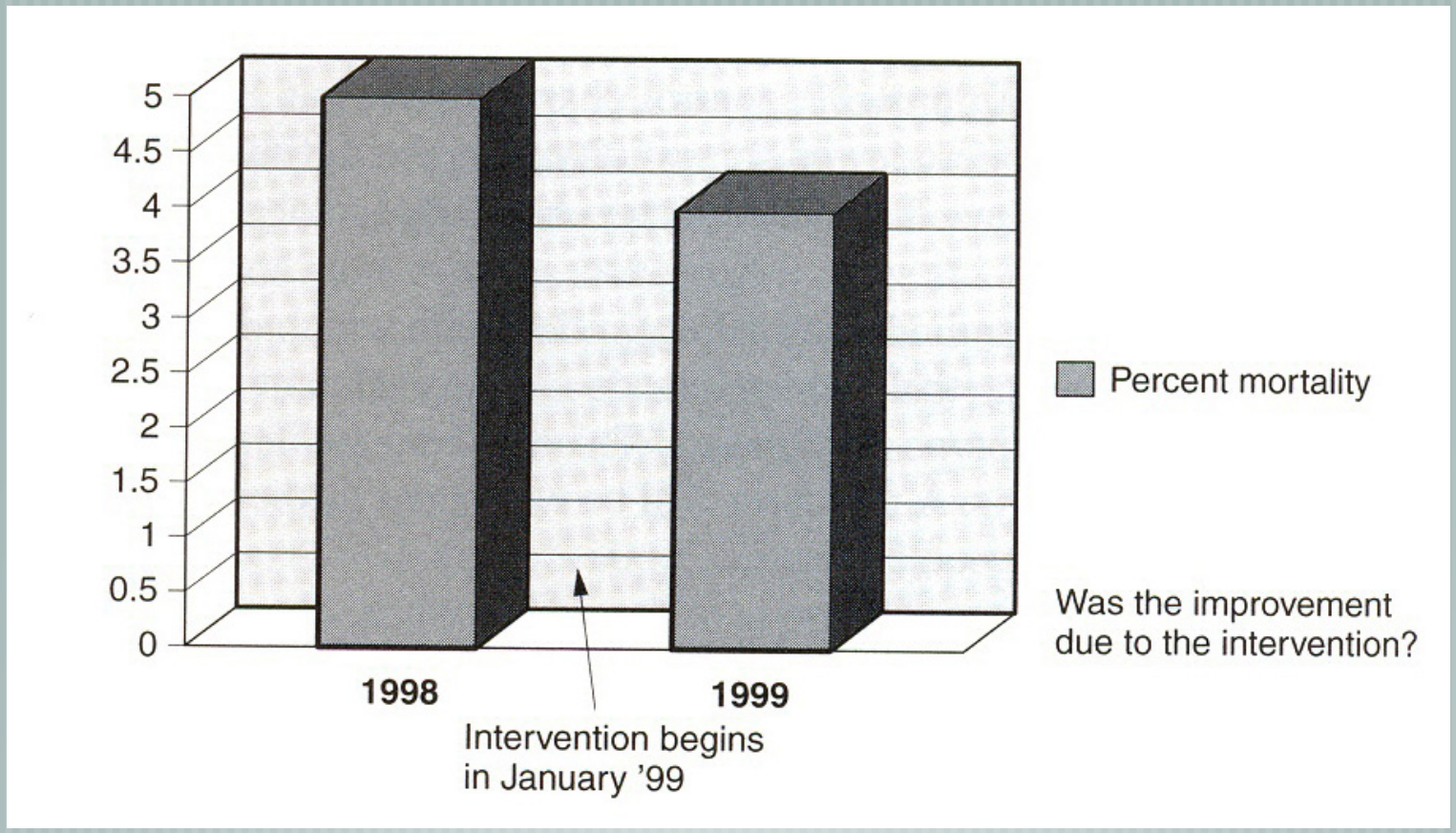
- 3SD false positive probability of **6.5%**

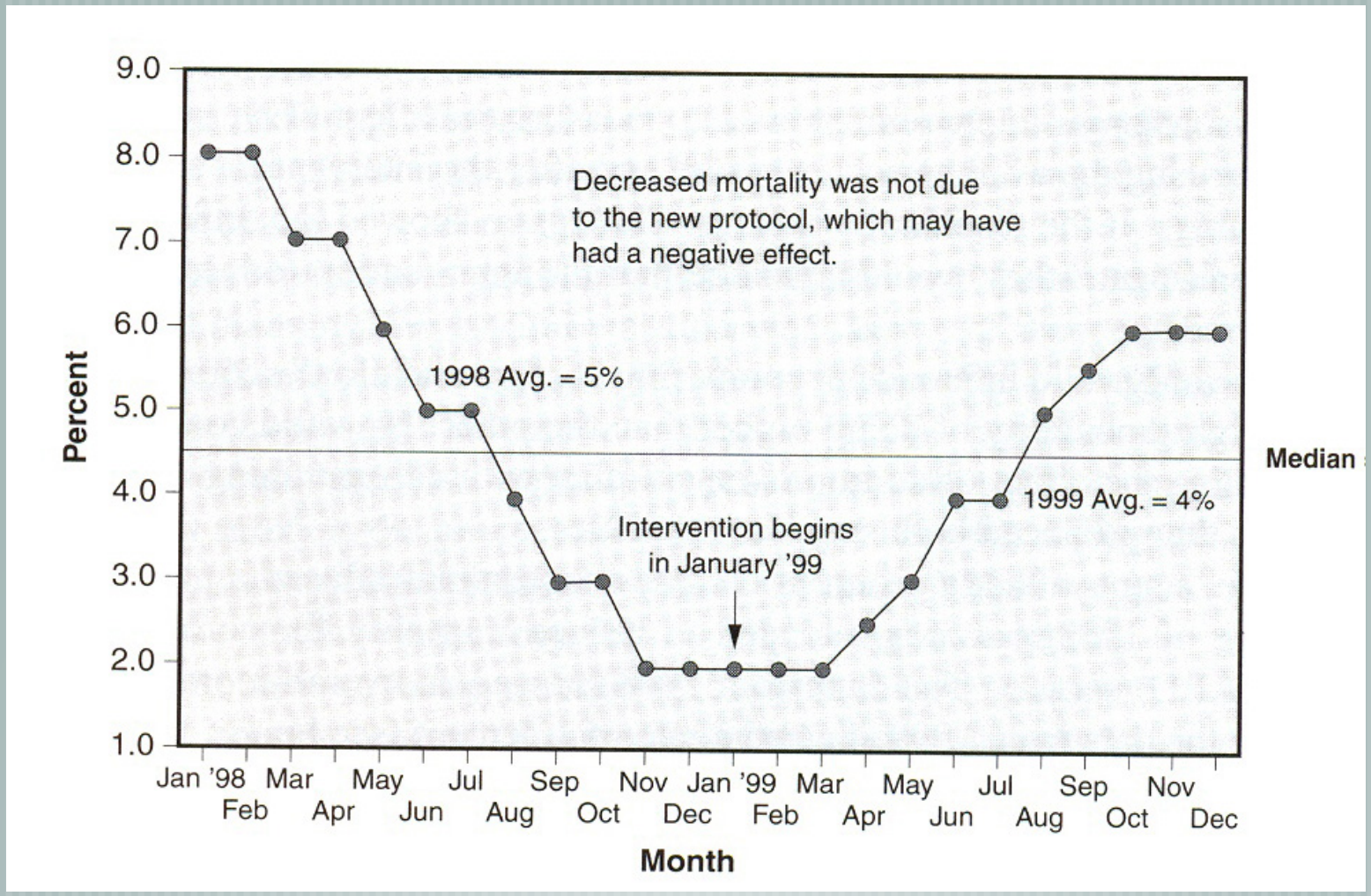



- 2SD false positive probability of **27.7%!**



# Average CABG protocol before and after implementation of new protocol




9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Percent
Decreased mortality was not due to the new protocol, which may have had a negative effect.
1998 Avg. = 5%
1999 Avg. = 4%
Intervention begins in January '99
Median
Jan '98
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan '99
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

# CHOOSING THE APPROPRIATE CONTROL CHART

- One of the most common difficulties that practitioners have in using SPC is determining which type of control chart they should construct.

- The chart type to use in any particular situation is based on identifying which type of data is most appropriate.

# CHOOSING THE APPROPRIATE CONTROL CHART

Type of data.

1. Count data
   - p-Chart
   - u-Chart
   - c-Chart
   - g-Chart
2. Measurement data (Continuous data)
   - I or XmR chart
   - X-bar and S-Chart

# ประเภทของข้อมูล

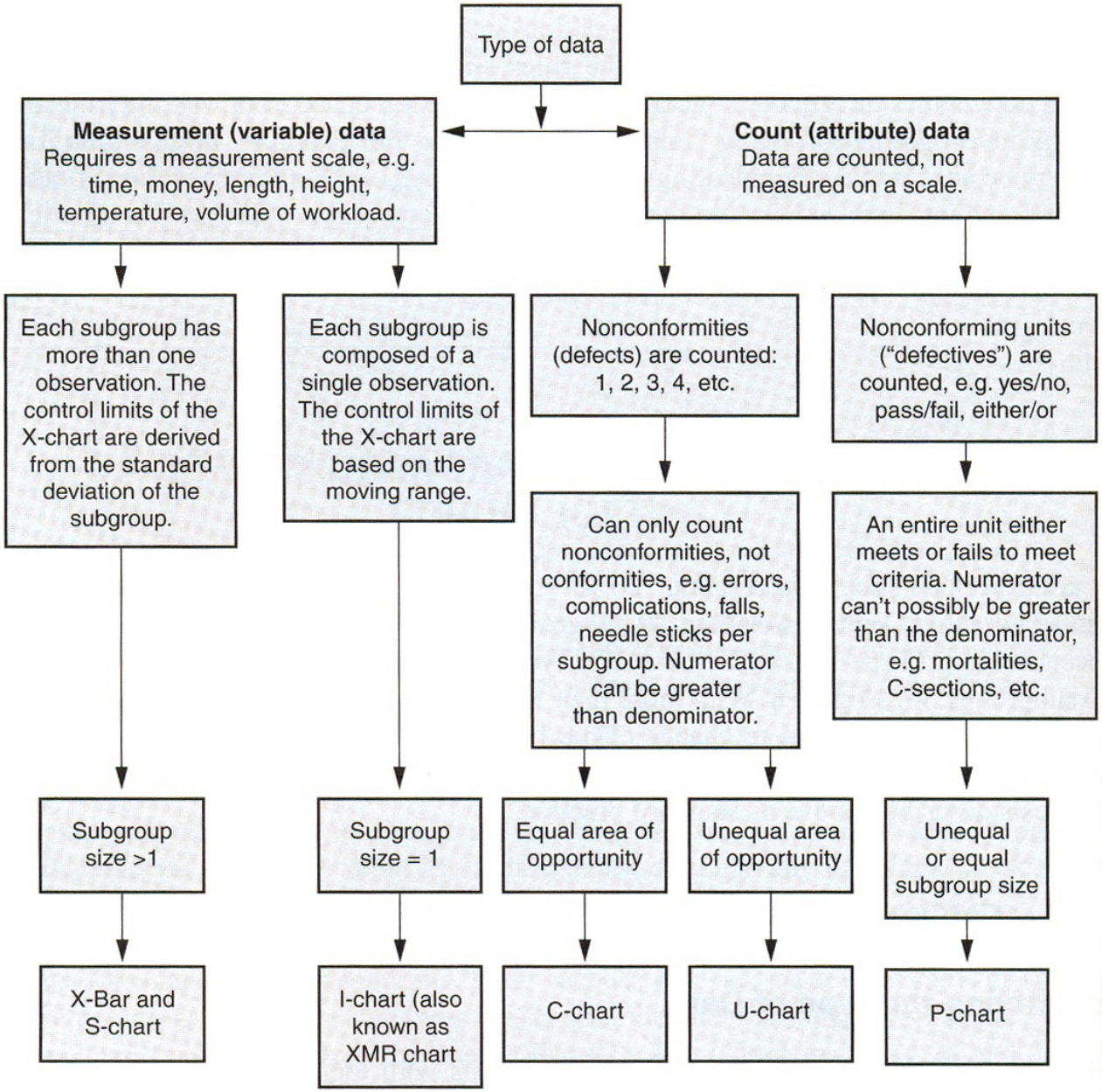
- Count data: Nominal scale (มาตรากลุ่ม)
  - เช่น เพศ (ชาย, หญิง), มีการติดเชื้อ (มี, ไม่มี), มีภาวะแทรกซ้อน (มี, ไม่มี), ฟันผุ (ผุ, ไม่ผุ), ผลMRI (normal, abnormal)

# ประเภทของข้อมูล

- Continuous data
  - Ratio scale : have true ‘zero’
    - เช่น ระดับน้ำตาลในเลือด (FBS), ระดับโซเดียมในเลือด, อายุ, ค่าใช้จ่าย
  - Interval Scale: without true ‘zero’
    - เช่น ระดับความรู้ของผู้ป่วย, คะแนนความปวด, อุณหภูมิ

# The Control Chart

- Choose appropriate variables/measurements
- Running record, time order sequence
- Calculate the mean
- Calculate upper and lower process limits


Type of data
Measurement (variable) data
Requires a measurement scale, e.g. time, money, length, height, temperature, volume of workload.
Count (attribute) data
Data are counted, not measured on a scale.
Each subgroup has more than one observation. The control limits of the X-chart are derived from the standard deviation of the subgroup.
Each subgroup is composed of a single observation. The control limits of the X-chart are based on the moving range.
Nonconformities (defects) are counted: 1, 2, 3, 4, etc.
Nonconforming units ("defectives") are counted, e.g. yes/no, pass/fail, either/or
Can only count nonconformities, not conformities, e.g. errors, complications, falls, needle sticks per subgroup. Numerator can be greater than denominator.
An entire unit either meets or fails to meet criteria. Numerator can't possibly be greater than the denominator, e.g. mortalities, C-sections, etc.
Subgroup size >1
Subgroup size = 1
Equal area of opportunity
Unequal area of opportunity
Unequal or equal subgroup size
X-Bar and S-chart
I-chart (also known as XMR chart
C-chart
U-chart
P-chart

# Count Data *(p- chart)*

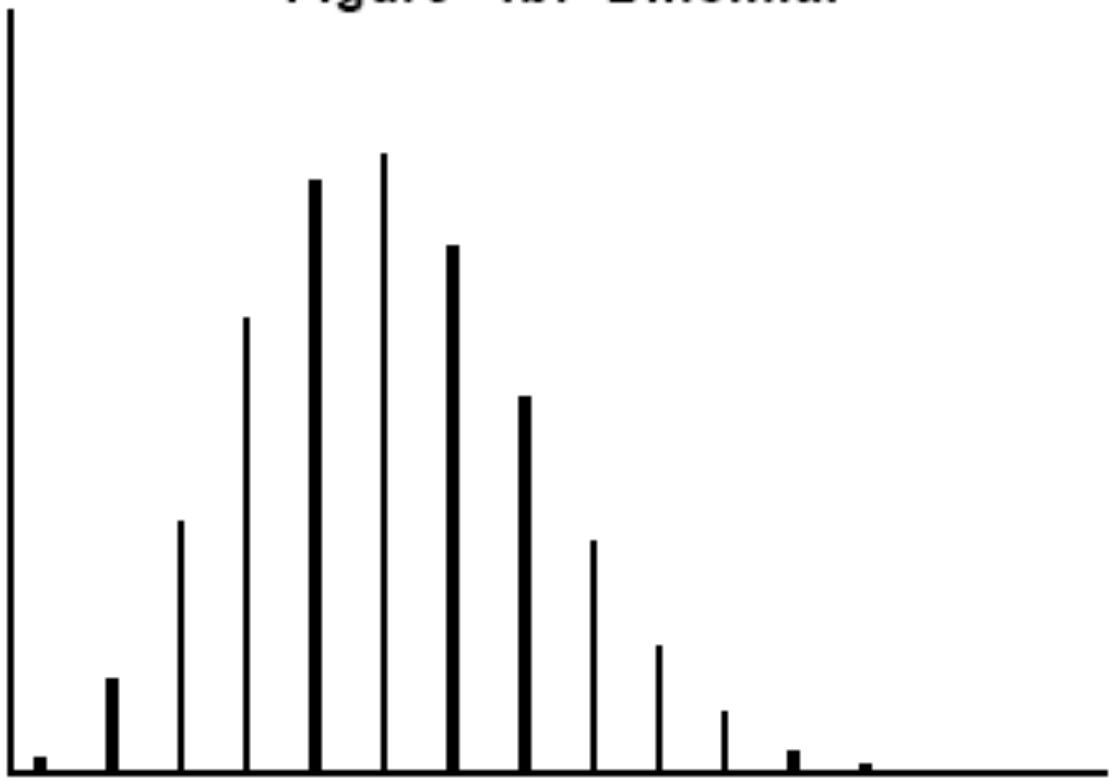
| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| *P-Chart* | binomial | •Nonconforming units<br>•Fraction of dichotomous cases<br>•The numerator is a subset of the denominator | •Fraction of surgeries that develop a surgical site infection<br>•Fraction of patients readmitted |

# Type of control chart

P-chart.

- Most easily understood
- Most often used control chart.
- Count data of nonconforming units, for example, mortalities or Falls.
- Based on Binomial distribution

Figure 4b: Binomial



## *p*-Charts

The centerline and control limits for *p*-charts are as follows:

$$\bar{p} = \frac{\text{total number of nonconforming items}}{\text{total number of items in study}}$$

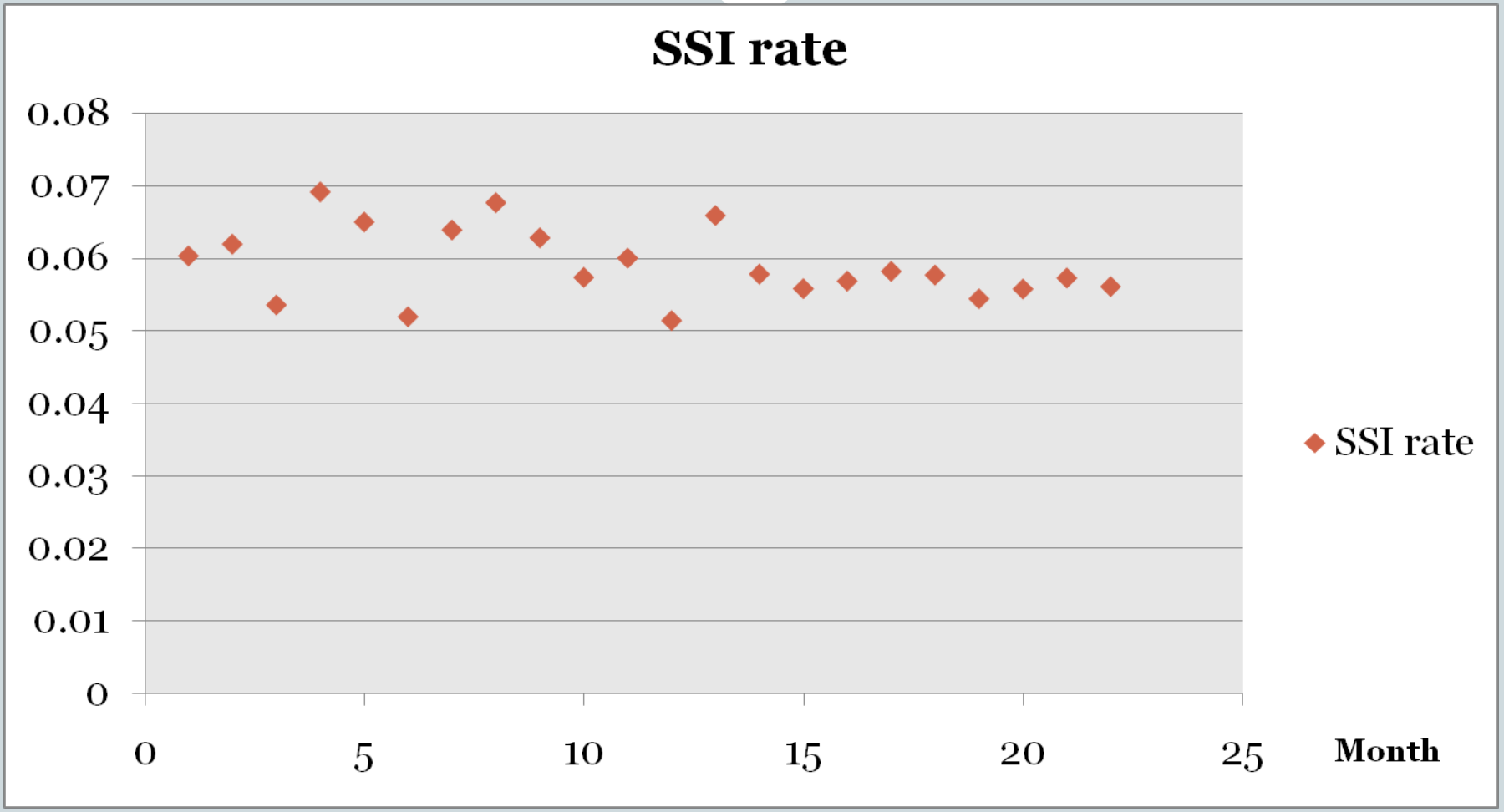
$$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \quad \text{and}$$

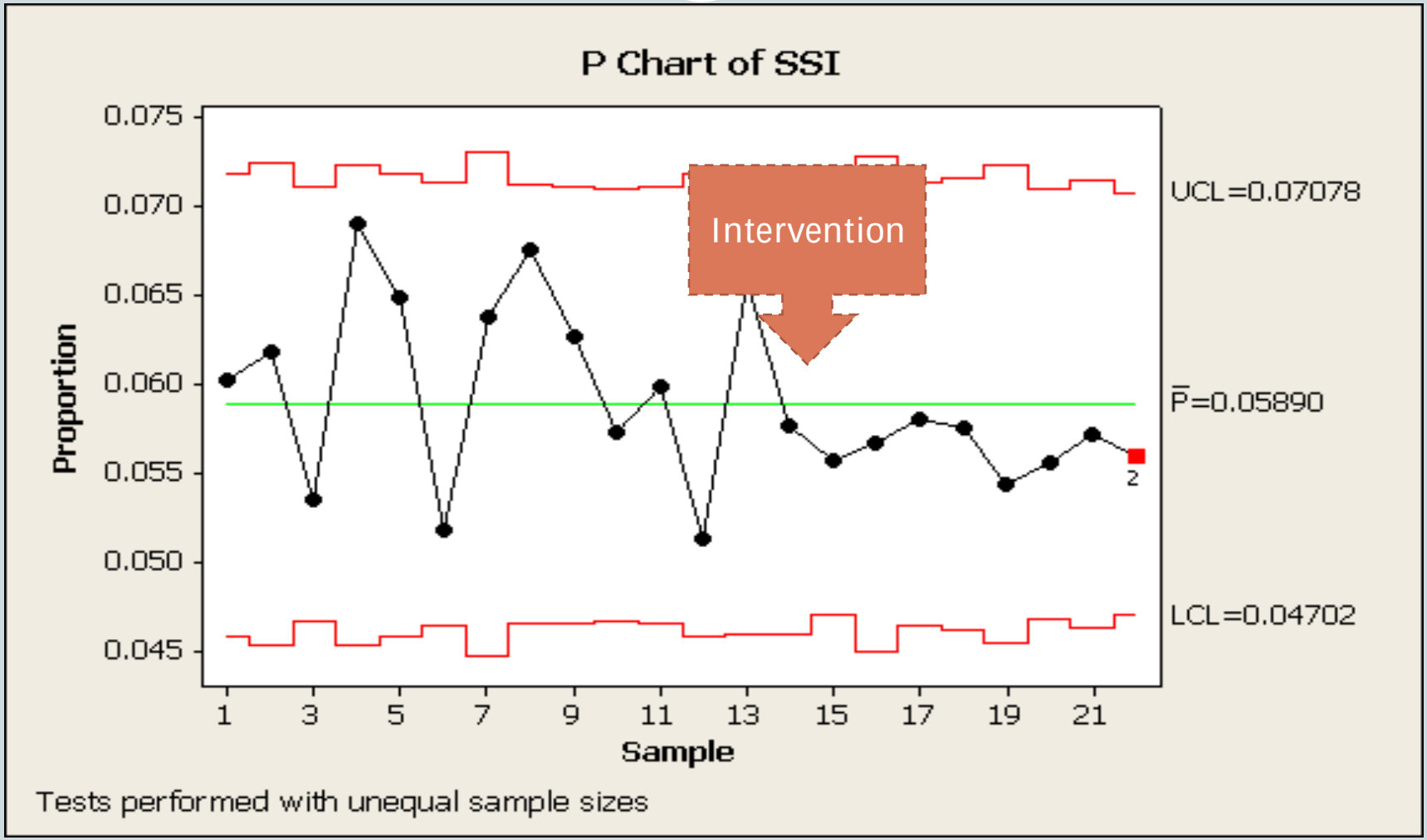
$$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

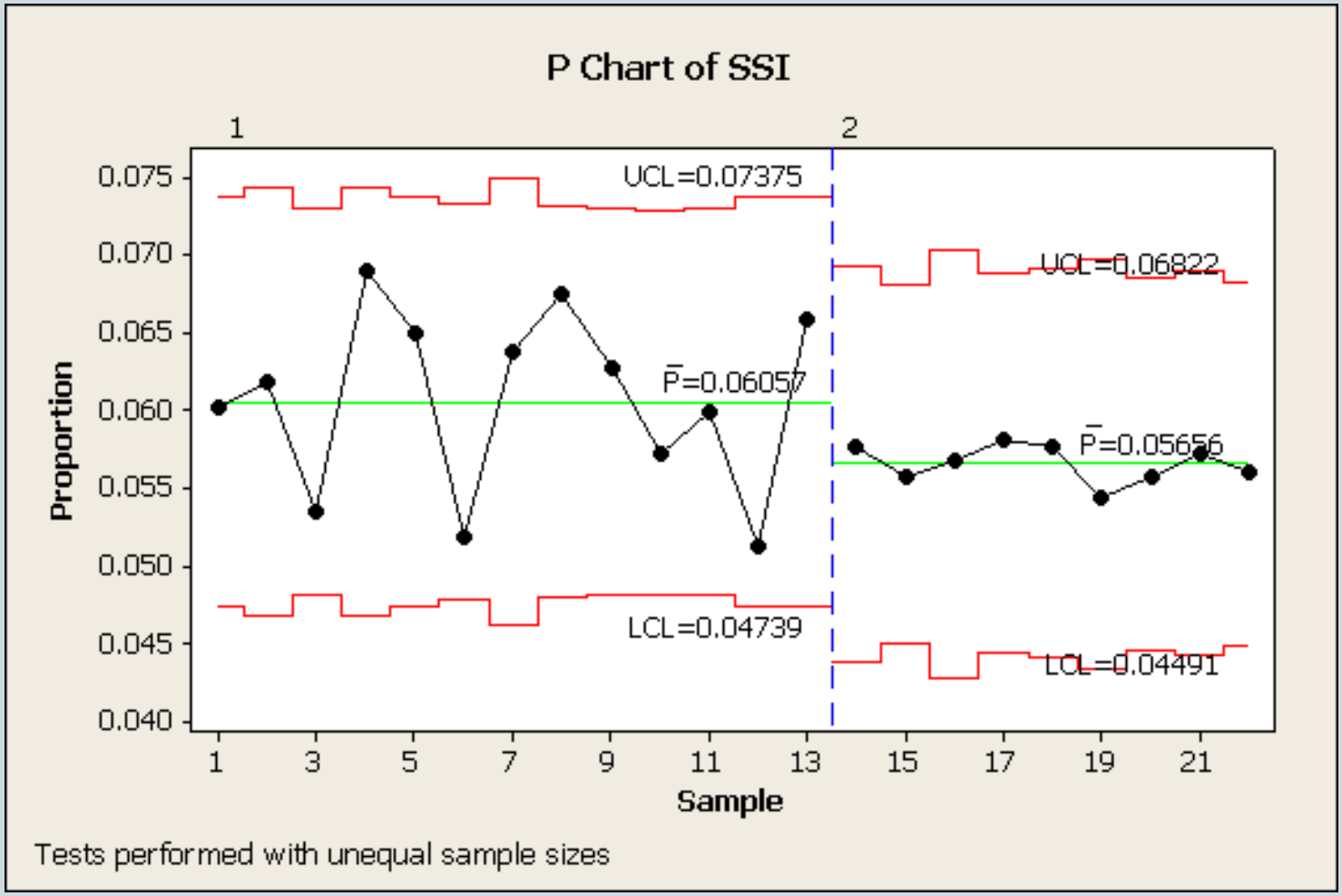
where $n$ is subgroup size,

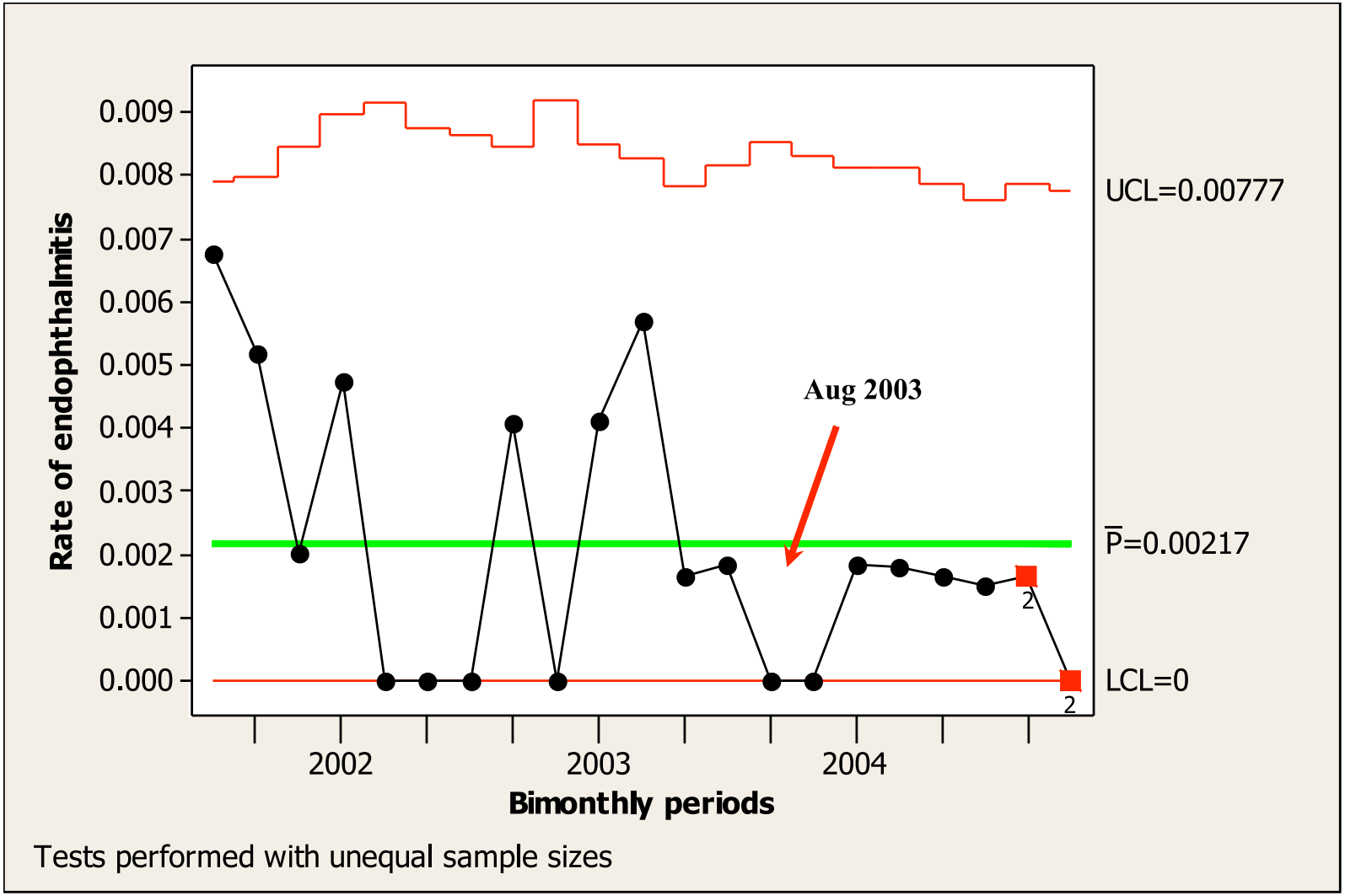
$\bar{p}$ is the average proportion of nonconforming items, and

$UCL$ and $LCL$ are the upper and lower control limits.


SSI rate
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
Month
SSI rate


P Chart of SSI
Proportion
0.075
0.070
0.065
0.060
0.055
0.050
0.045
Intervention
UCL=0.07078
P̄=0.05890
LCL=0.04702
1
3
5
7
9
11
13
15
17
19
21
Sample
Tests performed with unequal sample sizes


P Chart of SSI
1
2
UCL=0.07375
UCL=0.06822
$\bar{P}$=0.06057
$\bar{P}$=0.05656
LCL=0.04739
LCL=0.04491
Proportion
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
1
3
5
7
9
11
13
15
17
19
21
Sample
Tests performed with unequal sample sizes


Rate of endophthalmitis
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
UCL=0.00777
Aug 2003
$\bar{P}$=0.00217
LCL=0
2
2
2002
2003
2004
Bimonthly periods
Tests performed with unequal sample sizes

# Reduction of Endophthalmitis Rate after Cataract Surgery with Preoperative 5% Povidone-Iodine

Adisak Trinavarat[a] La-ongsri Atchaneeyasakul[a]
Cherdchai Nopmaneejumruslers[b] Kantima Inson[c]

[a]Department of Ophthalmology, [b]Ambulatory Medicine and [c]Eye Surgery Unit, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand

Dermatology

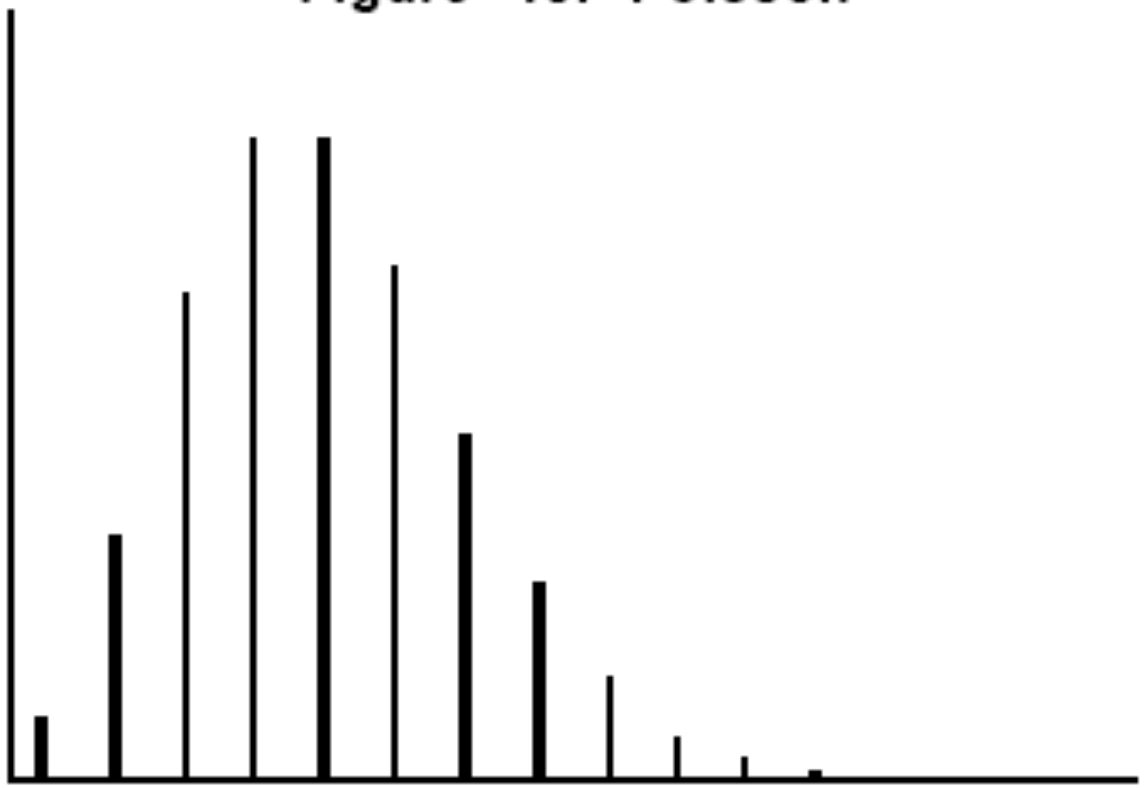
**Surgery and Other Invasive Manipulations**

Dermatology 2006;212(suppl 1):35–40
DOI: 10.1159/000089197

# Count Data (U-chart)

| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| U-Chart | binomial | •Nonconformities Unit<br>•count all defects<br>•The numerator can theoretically be greater than the denominator<br>•Rate of event can be more than one event per patient or sampling unit | •Number of central line infections per 1000 line-days<br>•Number of ventilator associated pneumonias per 1000 ventilator days |

Figure 4c: Poisson



control chart. $u$-Values are calculated with formula

$$u = \frac{c}{n}$$

where $c$ is the number of nonconformities in the subgroup, and
$n$ is the number of inspection units present in the subgroup.

$u$-Chart control limits are calculated in the same manner as those for $c$-charts but are adjusted for $n$, the number of inspection units in the subgroup

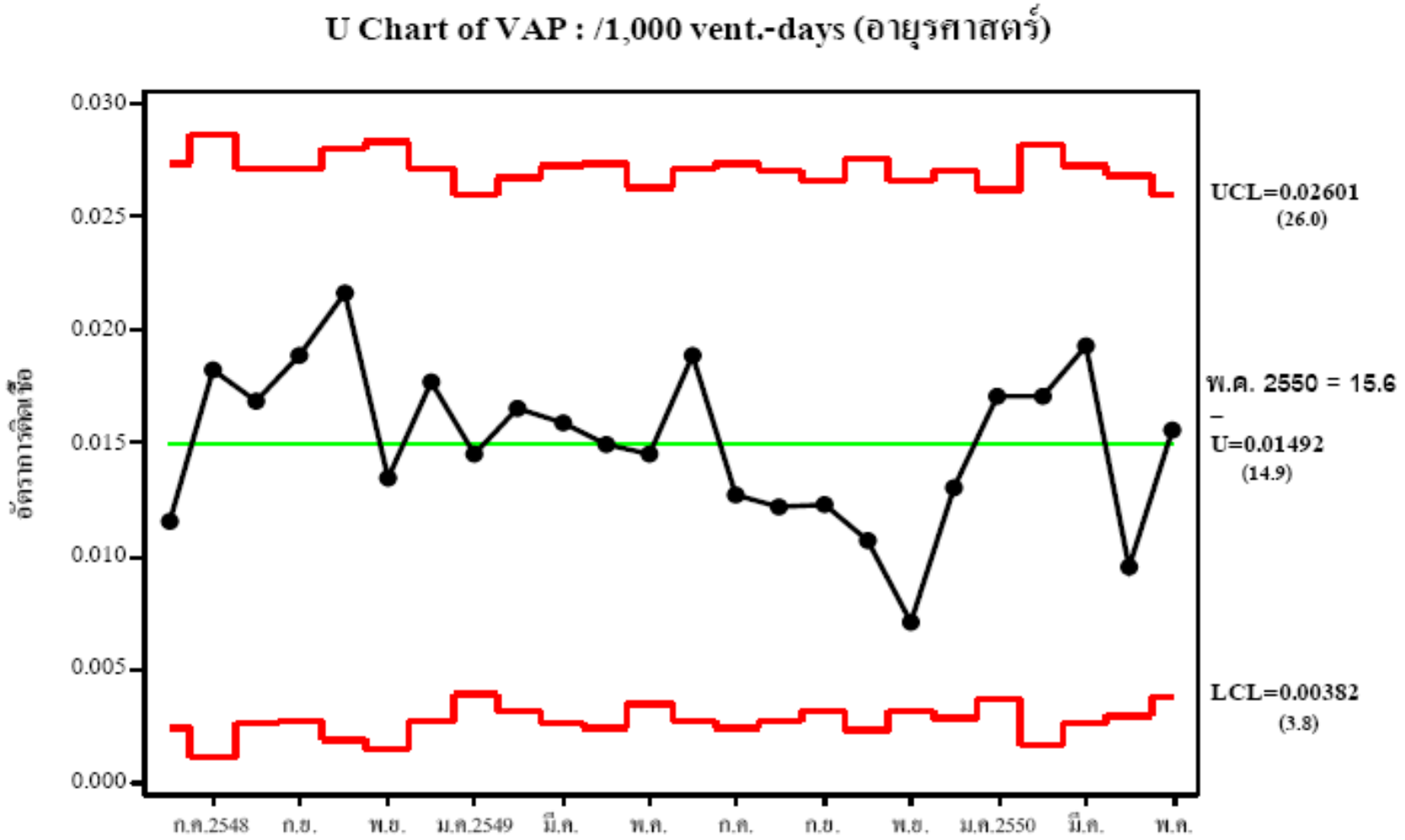
$$\bar{u} = \frac{\text{total number of nonconformities}}{\text{total number of inspection units}}$$

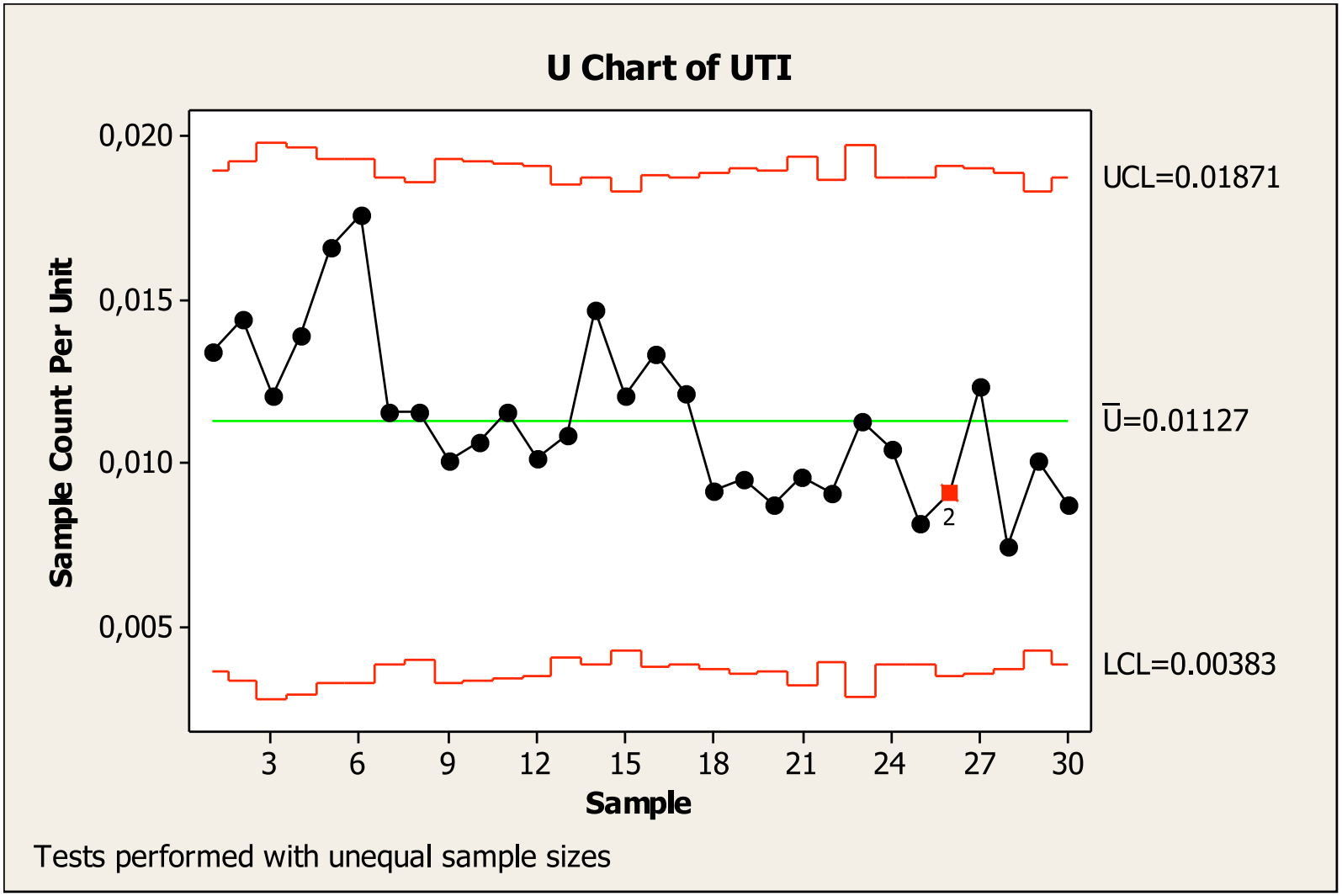
$$UCL_u = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$$

$$LCL_u = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$$

$n$ = the number of inspection units from which the nonconformities were found.

# U-Chart: VAP per 1000 Ventilator day




U Chart of UTI
Sample Count Per Unit
0,020
0,015
0,010
0,005
UCL=0.01871
Ū=0.01127
LCL=0.00383
2
3
6
9
12
15
18
21
24
27
30
Sample
Tests performed with unequal sample sizes

# Count Data (C-chart)

| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| C (Plot sample rate) | binomial | Assumes constant opportunity or sampling area in each time period | •Number of central line infections<br>•Number of MRSA<br>•Number of needle sticks |

# C-chart

- C-chart is an alternative to the U-chart for counts of nonconformities where there is an equal or virtually equal area of opportunity

- plot the actual count of nonconformities (for example, the total number of MRSA, needle stick) for each time period."

The $c$-chart control limit formulas follow:

$$\bar{c} = \frac{\text{total number of nonconformities}}{\text{total number of inspection units}}$$

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

# C-Chart: MRSA in vascular unit

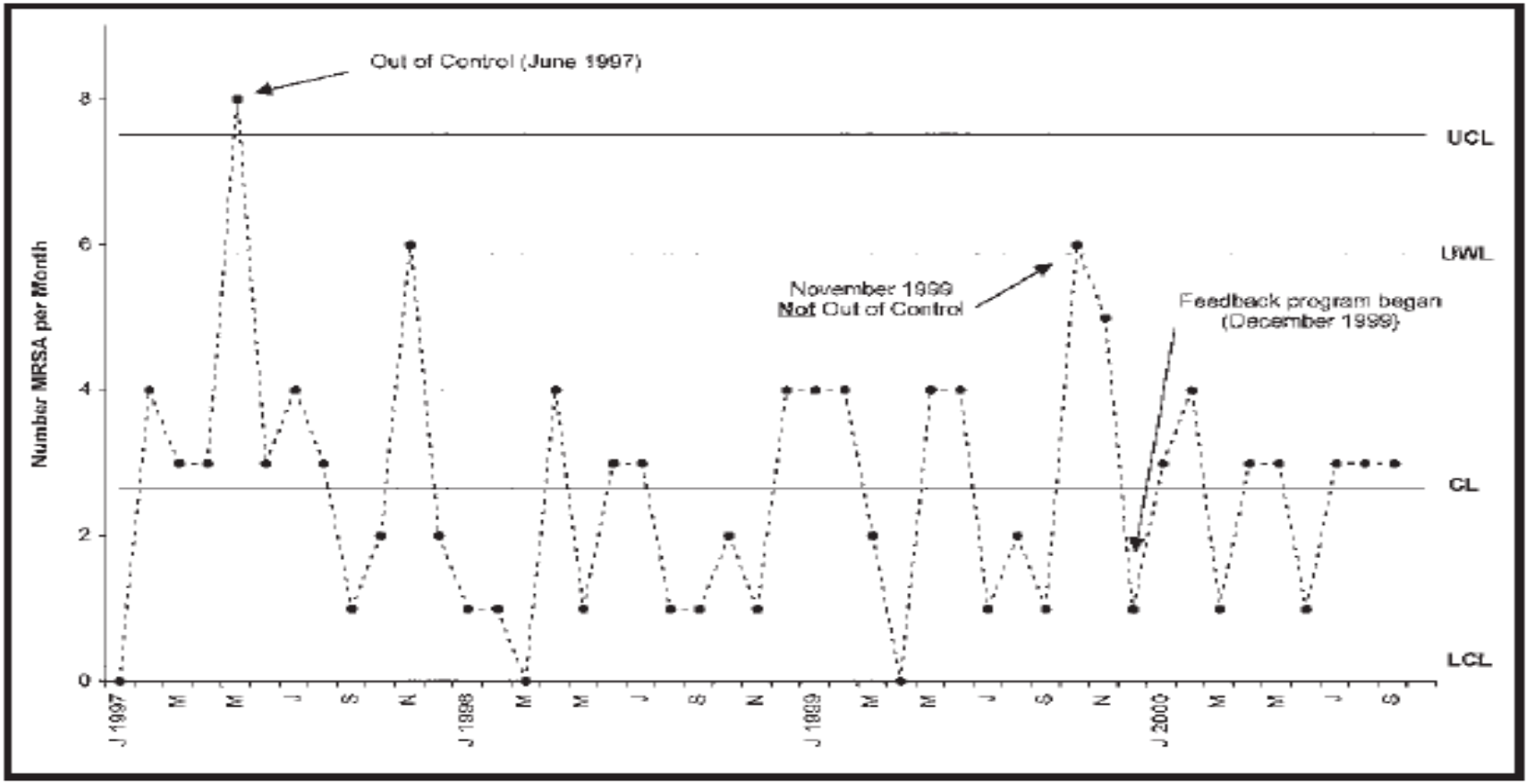
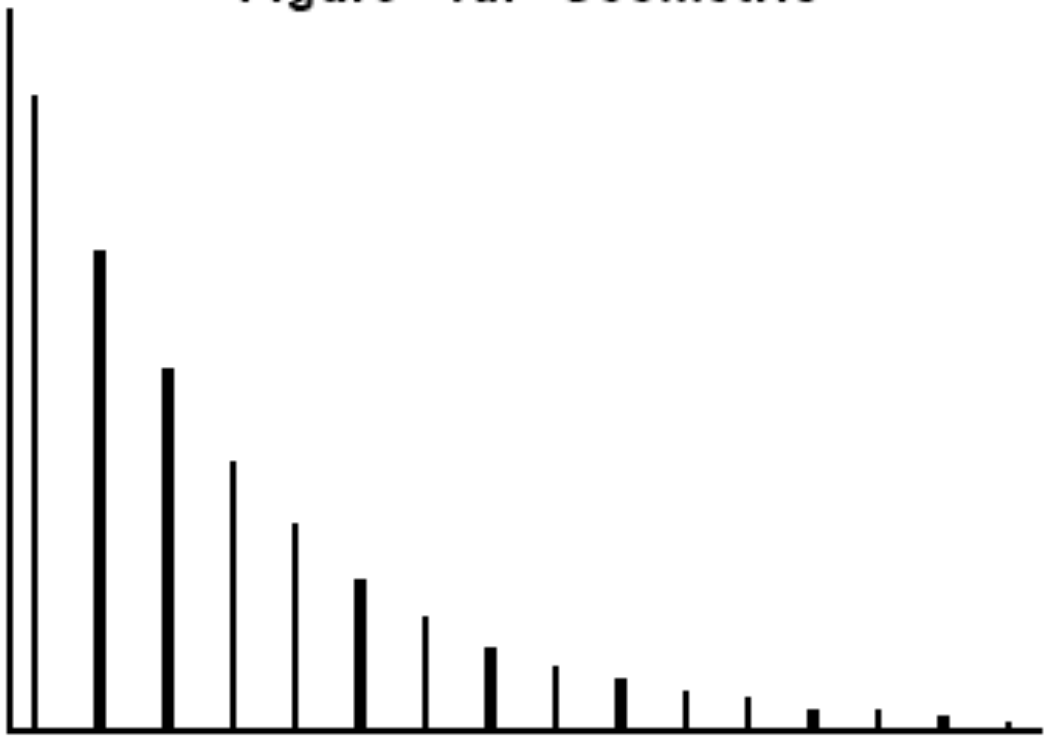



**FIGURE 4.** Methicillin-resistant *Staphylococcus aureus* (MRSA) control chart showing the monthly acquisition rate in a vascular unit. The chart was used in the decision-making process not to close the unit in November 1999. UCL = upper control limit; UWL = upper warning limit; CL = center line; LCL = lower control limit.

# Count Data (g-chart)

| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| G-Chart (Plot count between events) | geometric | Number of cases or amount of time between occurrences. (rare events) | •Number of surgeries between infections<br>•Number days between adverse drug events<br>•Number days between needle sticks |

Figure 4d: Geometric

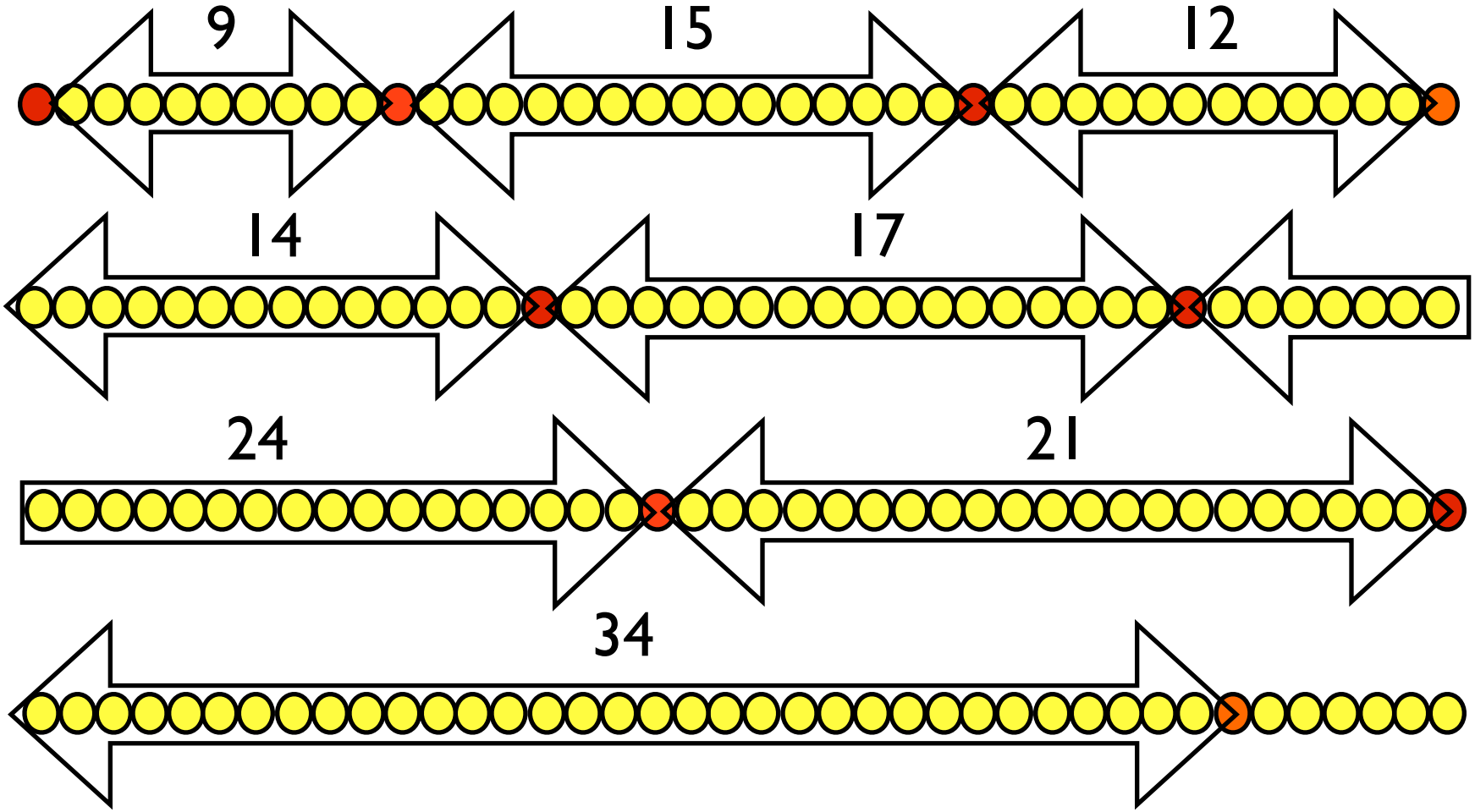


# Count Data (g-chart)

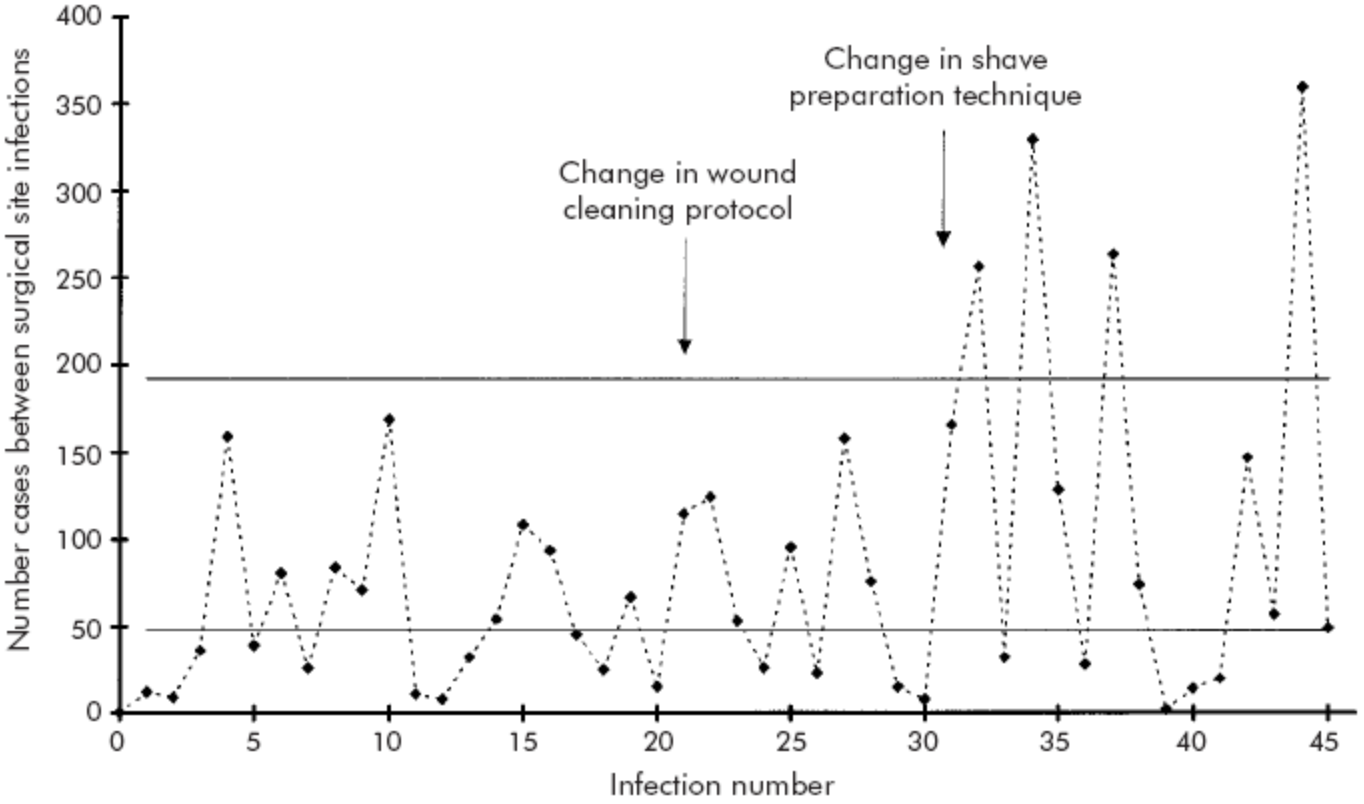
- R= $\frac{\text{Number of cases between event}}{\text{Number of cases with event}}$

- Then the UCL can be calculated as follows:
- $UCL = R + 3\,[R(1+R)]^{0.5}$

# g-chart



# g-Chart: Surgical site infection

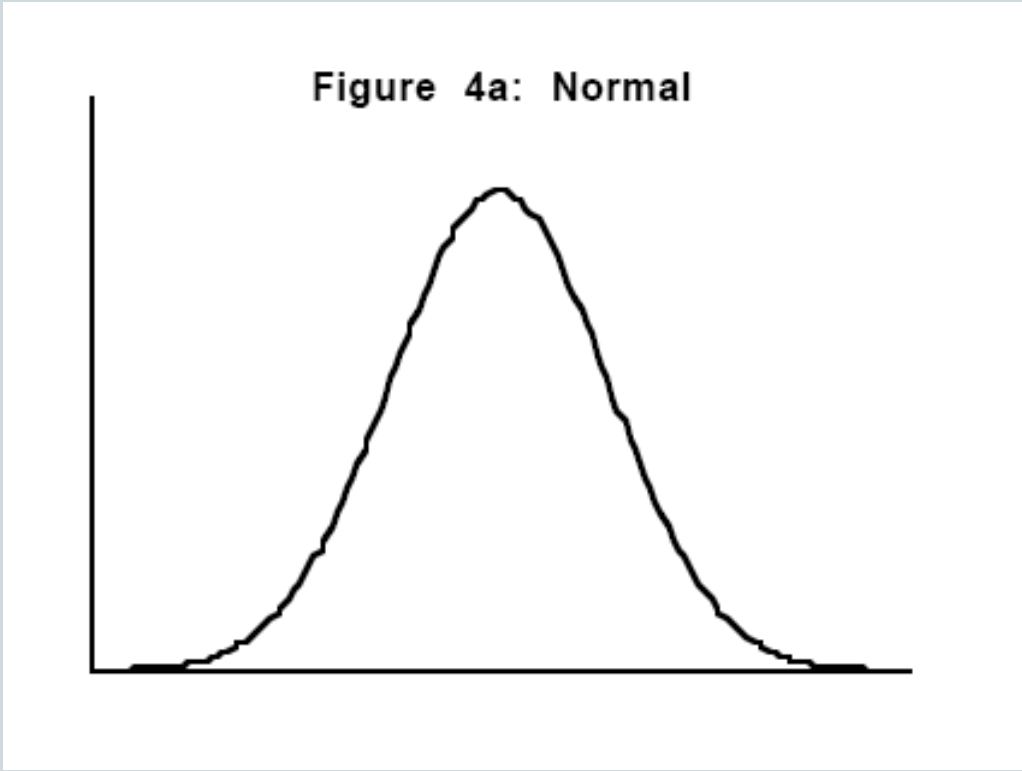


# Type of Data

Measurement data (Continuous data)

X-bar and S-Chart

I or XmR Chart



# Measurement data (X-bar and S-Chart)

| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| *Xbar and S chart*<br><br>(Plot sample mean and standard deviation) | Normal (Gaussian) | •Continuous measurements (Bell shape)<br><br>•Subgroup size >1 | •Length of patient waits<br>•Procedure durations<br>•Timing of perioperative antibiotics |

# X-bar and S-chart

- Measurement data (Normal distribution)
- Each subgroup has more than one observation
- "X-bar" = "average" (Mean)
  - Examines variation between subgroups over time
- "S"" = "standard deviation."
  - Examines variation within subgroups

# X-bar and S-chart

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x})}{n - 1}} \qquad \bar{s} = \frac{\Sigma s_i}{k}$$

| แผนภูมิ | $\bar{x}$ chart | s chart |
|---|---|---|
| เส้นกลาง, CL | $\bar{\bar{x}}$ | $\bar{s}$ |
| เส้นขอบเขตควบคุมค่าต่ำ, LCL | $\bar{\bar{x}} - A_3\bar{s}$ | $B_3\bar{s}$ |
| เส้นขอบเขตควบคุมค่าสูง, UCL | $\bar{\bar{x}} + A_3\bar{s}$ | $B_4\bar{s}$ |

| ขนาดของกรุ๊ปย่อย, $n$ | ค่าคงที่สำหรับเส้นขอบเขตควบคุม | | | | | | | | | | | ค่าคงที่สำหรับเส้นกลาง | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A$ | $A_2$ | $A_3$ | $B_3$ | $B_4$ | $B_5$ | $B_6$ | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $C_4$ | $1/C_4$ | $d_2$ | $1/d_2$ |
| 2 | 2.121 | 1.880 | 2.659 | 0.000 | 3.267 | 0.000 | 2.606 | 0.000 | 3.686 | 0.000 | 3.267 | 0.7979 | 1.2533 | 1.128 | 0.8865 |
| 3 | 1.732 | 1.023 | 1.954 | 0.000 | 2.568 | 0.000 | 2.276 | 0.000 | 4.358 | 0.000 | 2.574 | 0.8862 | 1.1284 | 1.693 | 0.5907 |
| 4 | 1.500 | 0.729 | 1.628 | 0.000 | 2.266 | 0.000 | 2.088 | 0.000 | 4.698 | 0.000 | 2.282 | 0.9213 | 1.0854 | 2.059 | 0.4857 |
| 5 | 1.342 | 0.577 | 1.427 | 0.000 | 2.089 | 0.000 | 1.964 | 0.000 | 4.918 | 0.000 | 2.114 | 0.9400 | 1.0638 | 2.326 | 0.4299 |
| 6 | 1.225 | 0.483 | 1.287 | 0.030 | 1.970 | 0.029 | 1.874 | 0.000 | 5.078 | 0.000 | 2.004 | 0.9515 | 1.0510 | 2.534 | 0.3946 |
| 7 | 1.134 | 0.419 | 1.182 | 0.118 | 1.882 | 0.113 | 1.806 | 0.204 | 5.204 | 0.076 | 1.924 | 0.9594 | 1.0423 | 2.704 | 0.3698 |
| 8 | 1.061 | 0.373 | 1.099 | 0.185 | 1.815 | 0.179 | 1.751 | 0.388 | 5.306 | 0.136 | 1.864 | 0.9650 | 1.0363 | 2.847 | 0.3512 |
| 9 | 1.000 | 0.337 | 1.032 | 0.239 | 1.761 | 0.232 | 1.707 | 0.547 | 5.393 | 0.184 | 1.816 | 0.9693 | 1.0317 | 2.970 | 0.3367 |
| 10 | 0.949 | 0.308 | 0.975 | 0.284 | 1.716 | 0.276 | 1.669 | 0.687 | 5.469 | 0.223 | 1.777 | 0.9727 | 1.0281 | 3.078 | 0.3249 |
| 11 | 0.905 | 0.285 | 0.927 | 0.321 | 1.679 | 0.313 | 1.637 | 0.811 | 5.535 | 0.256 | 1.744 | 0.9754 | 1.0252 | 3.173 | 0.3152 |
| 12 | 0.866 | 0.266 | 0.886 | 0.354 | 1.646 | 0.346 | 1.610 | 0.922 | 5.594 | 0.283 | 1.717 | 0.9776 | 1.0229 | 3.253 | 0.3069 |
| 13 | 0.832 | 0.249 | 0.850 | 0.382 | 1.618 | 0.374 | 1.585 | 1.025 | 5.647 | 0.307 | 1.693 | 0.9794 | 1.0210 | 3.336 | 0.2998 |
| 14 | 0.802 | 0.235 | 0.817 | 0.406 | 1.594 | 0.399 | 1.565 | 1.118 | 5.696 | 0.328 | 1.672 | 0.9810 | 1.0194 | 3.407 | 0.2935 |
| 15 | 0.775 | 0.223 | 0.789 | 0.428 | 1.572 | 0.421 | 1.544 | 1.203 | 5.741 | 0.347 | 1.653 | 0.9823 | 1.0180 | 3.472 | 0.2880 |
| 16 | 0.750 | 0.212 | 0.763 | 0.448 | 1.552 | 0.440 | 1.526 | 1.282 | 5.782 | 0.363 | 1.637 | 0.9835 | 1.0168 | 3.532 | 0.2831 |
| 17 | 0.728 | 0.203 | 0.739 | 0.466 | 1.534 | 0.458 | 1.511 | 1.356 | 5.820 | 0.378 | 1.622 | 0.9845 | 1.0157 | 3.588 | 0.2787 |
| 18 | 0.707 | 0.194 | 0.718 | 0.482 | 1.518 | 0.475 | 1.496 | 1.424 | 5.856 | 0.391 | 1.608 | 0.9854 | 1.0148 | 3.640 | 0.2747 |
| 19 | 0.688 | 0.187 | 0.698 | 0.497 | 1.503 | 0.490 | 1.483 | 1.487 | 5.891 | 0.403 | 1.597 | 0.9862 | 1.0140 | 3.689 | 0.2711 |
| 20 | 0.671 | 0.180 | 0.680 | 0.510 | 1.490 | 0.504 | 1.470 | 1.549 | 5.921 | 0.415 | 1.585 | 0.9869 | 1.0133 | 6.735 | 0.2677 |
| 21 | 0.655 | 0.173 | 0.663 | 0.523 | 1.477 | 0.516 | 1.459 | 1.605 | 5.951 | 0.425 | 1.575 | 0.9876 | 1.0126 | 3.778 | 0.2647 |
| 22 | 0.640 | 0.167 | 0.647 | 0.534 | 1.466 | 0.528 | 1.448 | 1.659 | 5.979 | 0.434 | 1.566 | 0.9882 | 1.0119 | 3.819 | 0.2618 |
| 23 | 0.626 | 0.162 | 0.633 | 0.545 | 1.455 | 0.539 | 1.438 | 1.710 | 6.006 | 0.448 | 1.557 | 0.9887 | 1.0114 | 3.858 | 0.2592 |
| 24 | 0.612 | 0.157 | 0.619 | 0.555 | 1.445 | 0.549 | 1.429 | 1.759 | 6.031 | 0.451 | 1.548 | 0.9892 | 1.0109 | 3.895 | 0.2567 |
| 25 | 0.600 | 0.153 | 0.606 | 0.565 | 1.435 | 0.559 | 1.420 | 1.806 | 6.056 | 0.459 | 1.541 | 0.9896 | 1.0105 | 3.931 | 0.2544 |

Source : ASTM, Philadelphia, PA, USA

| Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test 1 | 86 | 90 | 101 | 76 | 102 | 81 | 75 | 92 | 93 | 109 | 70 | 80 | 85 | 69 | 106 | 89 | 85 | 95 | 72 | 95 | 75 | 60 | 77 |
| Test 2 | 73 | 82 | 74 | 71 | 76 | 82 | 50 | 65 | 71 | 92 | 84 | 79 | 63 | 71 | 93 | 95 | 101 | 89 | 60 | 84 | 97 | 110 | 55 |
| Test 3 | 75 | 95 | 89 | 105 | 115 | 55 | 95 | 93 | 82 | 76 | 67 | 58 | 110 | 112 | 82 | 73 | 68 | 88 | 97 | 61 | 115 | 56 | 99 |

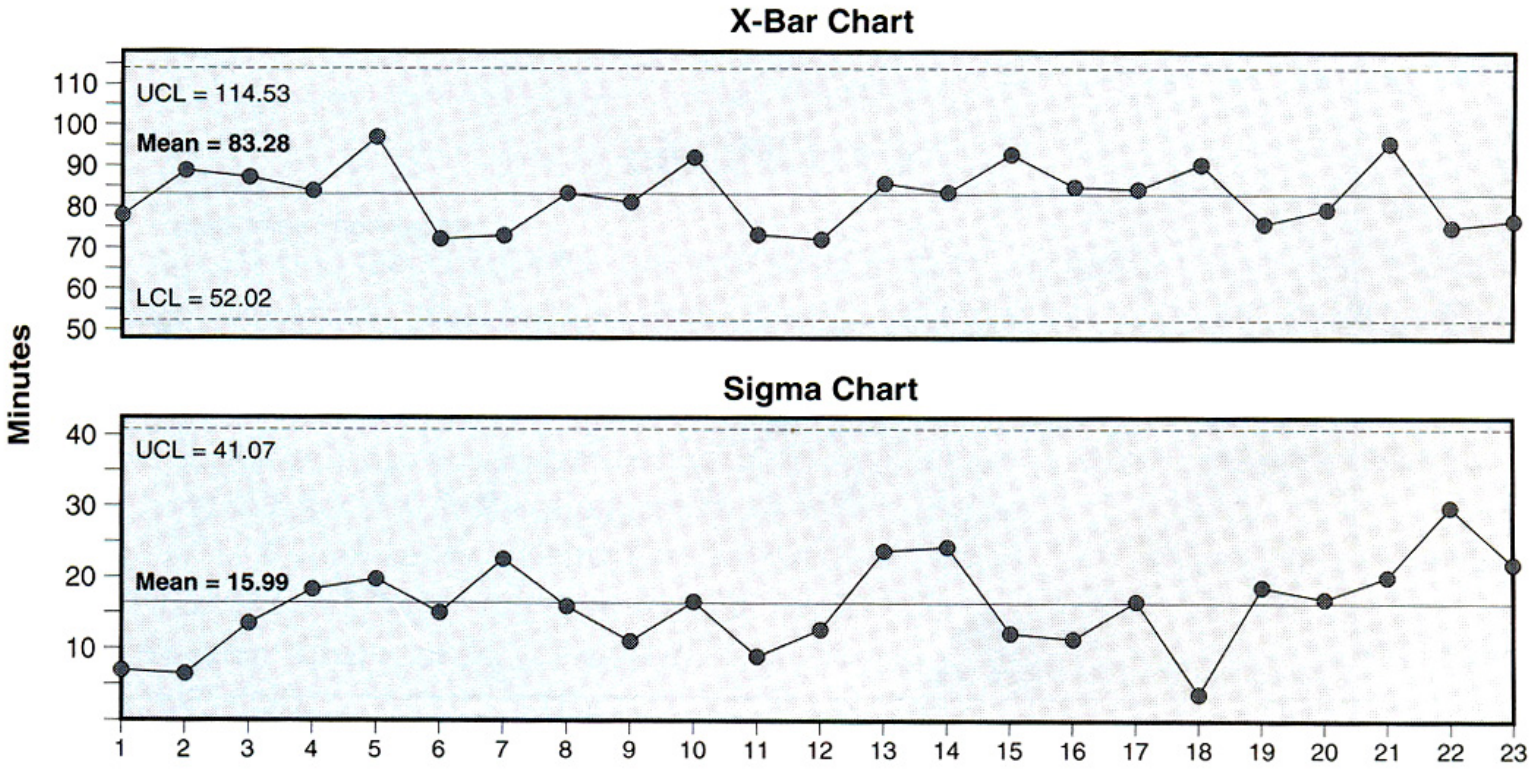



**Figure 2.7** CBC turnaround time from lab to ED (X-bar and S-chart), using a sample of three tests each day for 23 consecutive weekdays.

# X-bar R Chart Interpretation

- If “S” chart is out of control, find special causes and re-collect data. x-bar chart is invalid if “S” chart is out of control.

- If “S” chart is in control and x-bar chart is out of control, find special cause and recollect data.

# X-bar R Chart Interpretation

- If both “S” and x-bar charts are in control, process is in control and calculations may be used as predictions for the future and to identify changes in the process that put it out of control.

# Measurement data (I or XmR Chart)

| Type of Control chart | Probability Distribution | When appropriate to use | Example |
|---|---|---|---|
| I Chart or XmR chart | Normal (Gaussian) | •Continuous measurements<br>•Subgroup or data point, is composed of a single observation | •Length of patient waits<br>•Procedure durations<br>•Timing of perioperative antibiotics |

# I-chart or XmR chart

- Measurement data
- Subgroup or data point, is composed of a single observation
- "individual values and moving range (ค่าพิสัยเคลื่อนที่ ) chart "

# I-chart or XmR chart

- ค่าพิสัยเคลื่อนที่หาได้จาก $MR_i = |X_i - X_{i-1}|$
- ตัวประมาณค่าของ $\sigma$ คือ

$$\hat{\sigma} = \frac{\overline{MR}}{d_2} = \frac{\overline{MR}}{1.128}$$

- เปิดตารางหาค่า $d_2$ มีค่าเท่ากับ 1.128

# I-chart or XmR chart

The center line and upper and lower control limits for a control chart for individuals are

$$UCL = \bar{x} + 3\frac{\overline{mr}}{d_2} = \bar{x} + 3\frac{\overline{mr}}{1.128}$$
$$CL = \bar{x} \qquad (16\text{-}19)$$
$$LCL = \bar{x} - 3\frac{\overline{mr}}{d_2} = \bar{x} - 3\frac{\overline{mr}}{1.128}$$

and for a control chart for moving ranges

$$UCL = D_4\overline{mr} = 3.267\overline{mr}$$
$$CL = \overline{mr}$$
$$LCL = D_3\overline{mr} = 0$$

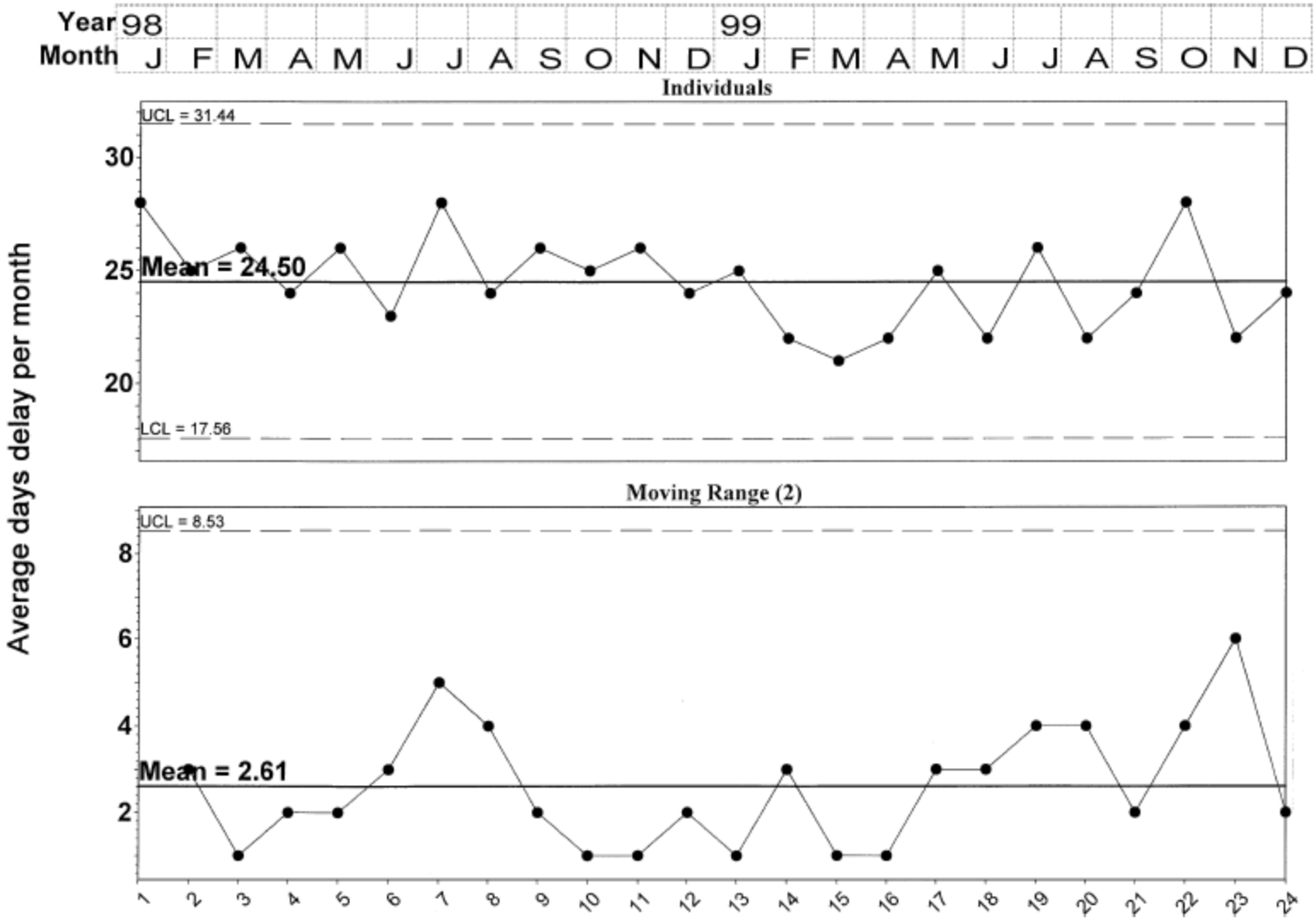
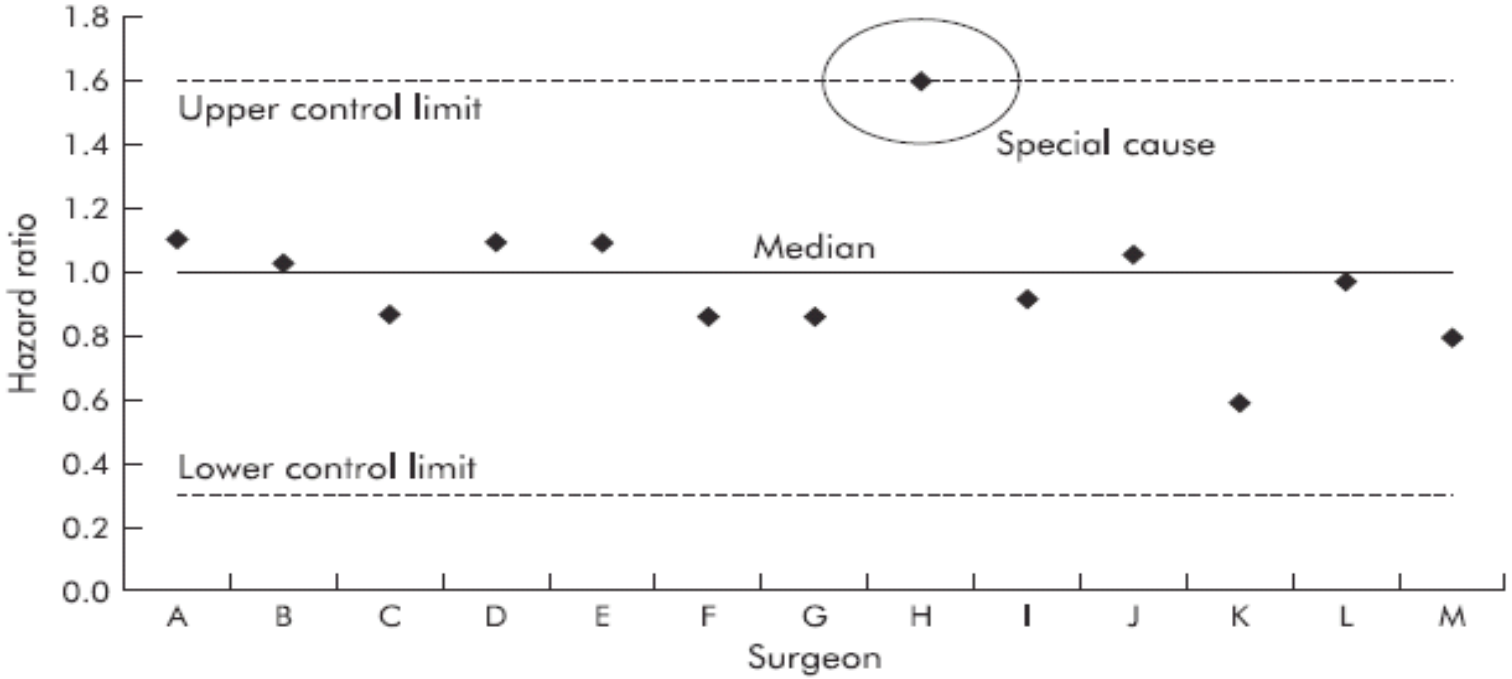


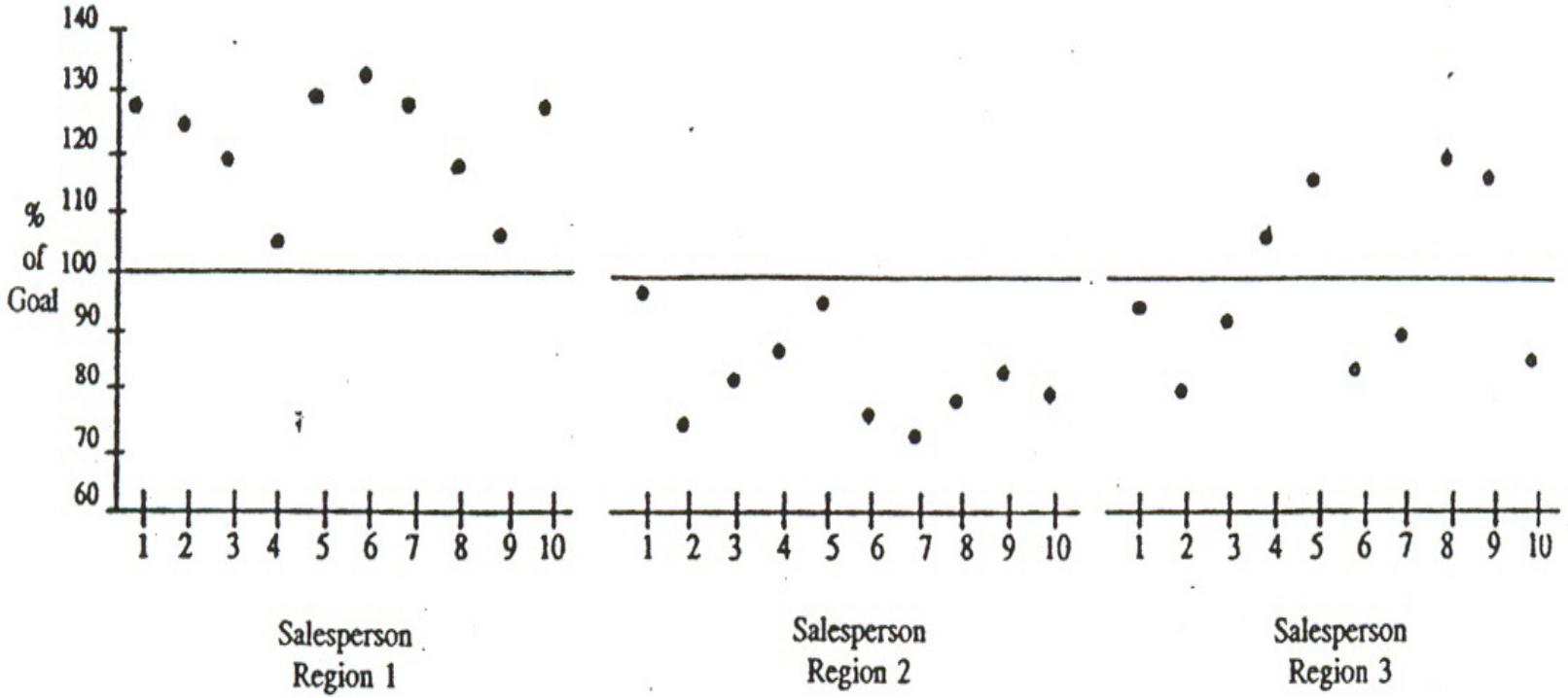

**Figure 4. Average days delay per month between positive mammogram and biopsy.**
Process is stable and predictable at 24.5 days.

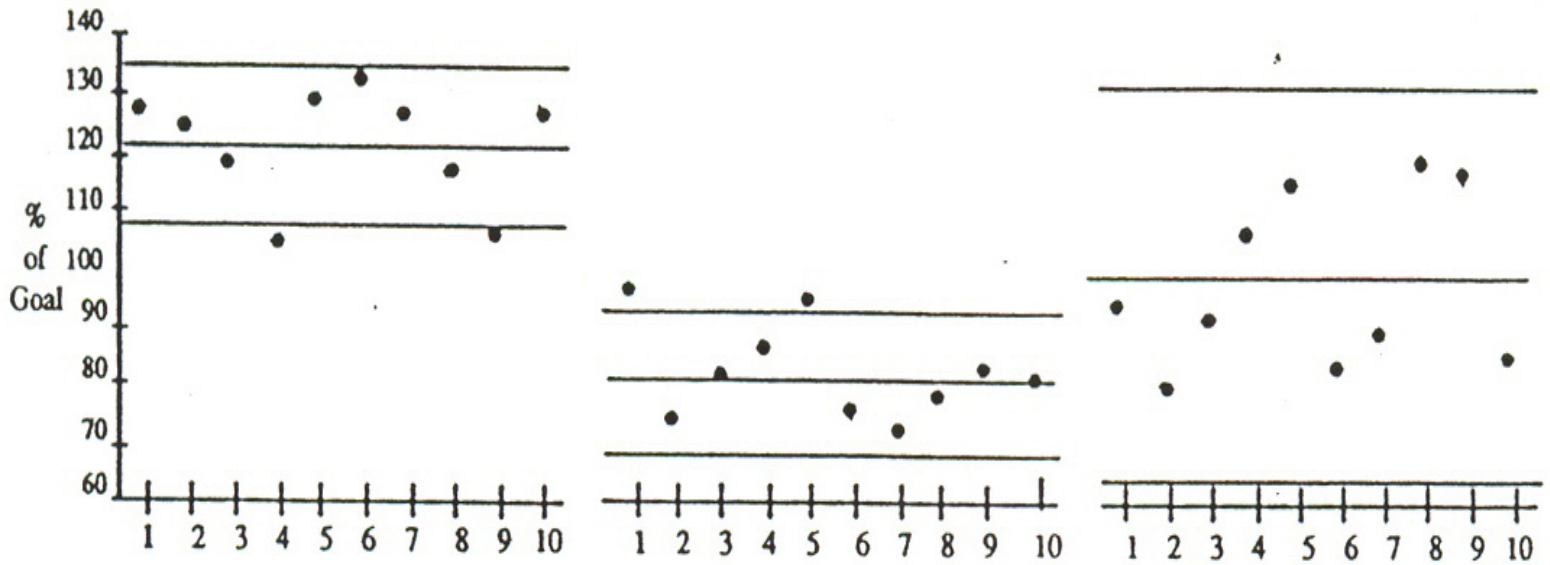
**Table 1** Surgeon specific mortality rates following colorectal cancer surgery

| Surgeon | No of cases | No (%) died | Case mix adjusted HR |
|---|---|---|---|
| A | 98 | 16 (16) | 1.10 |
| B | 66 | 8 (12) | 1.03 |
| C | 58 | 9 (16) | 0.87 |
| D | 52 | 7 (13) | 1.09 |
| E | 52 | 15 (29) | 1.09 |
| F | 46 | 5 (11) | 0.86 |
| G | 38 | 3 (8) | 0.86 |
| H | 37 | 11 (30) | 1.61 |
| I | 36 | 5 (14) | 0.91 |
| J | 34 | 7 (21) | 1.05 |
| K | 32 | 4 (13) | 0.59 |
| L | 21 | 2 (10) | 0.97 |
| M | 21 | 3 (14) | 0.79 |

HR, hazard ratio.


1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Hazard ratio
Upper control limit
Special cause
Median
Lower control limit
A
B
C
D
E
F
G
H
I
J
K
L
M
Surgeon


140
130
120
110
100
90
80
70
60
% of Goal
1 2 3 4 5 6 7 8 9 10
Salesperson Region 1
1 2 3 4 5 6 7 8 9 10
Salesperson Region 2
1 2 3 4 5 6 7 8 9 10
Salesperson Region 3




Salesperson
Region 1
Everyone gets bonus
Two outside of lower control limit

Salesperson
Region 2
No one gets bonus
Two outside upper control limit

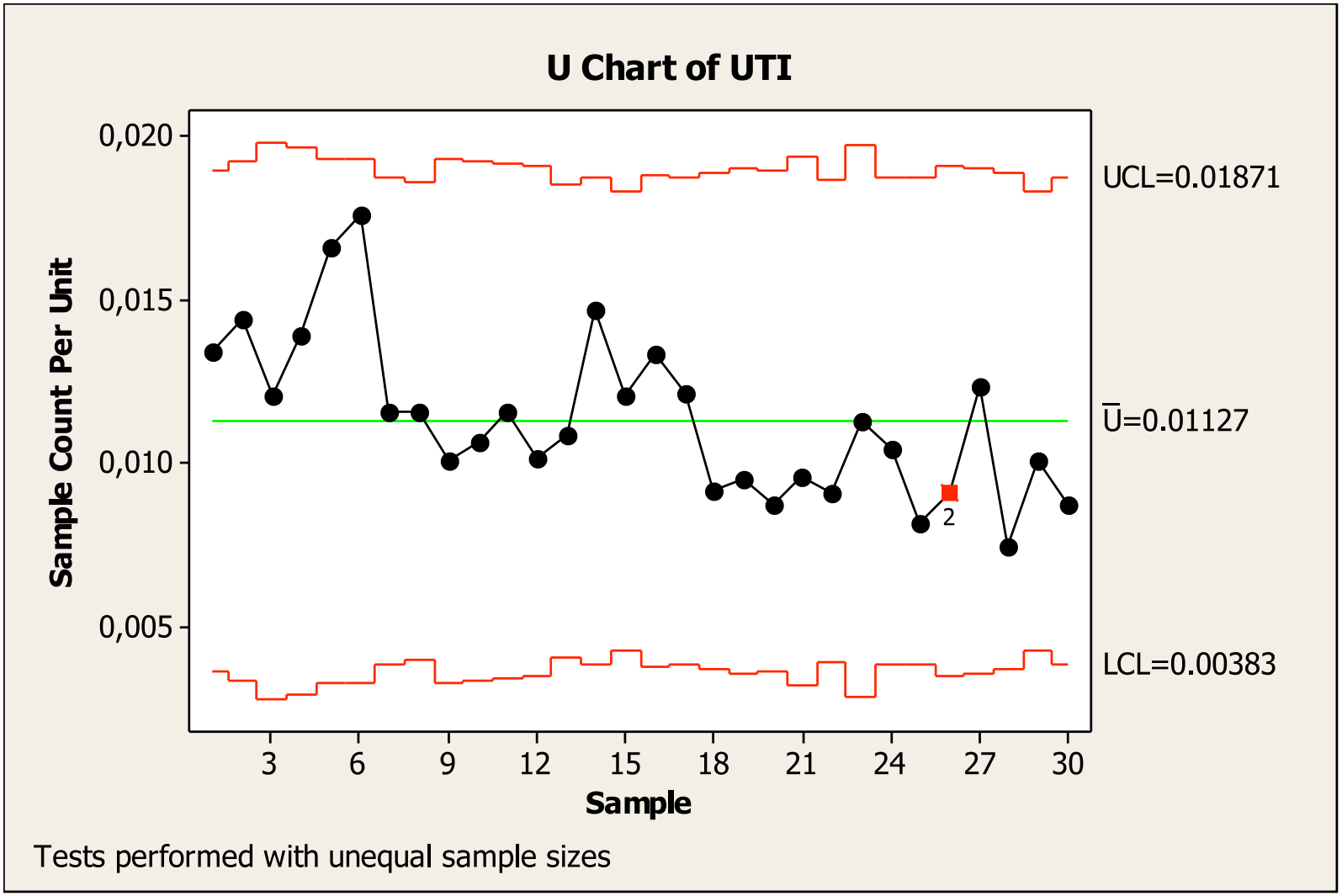
Salesperson
Region 3
Everyone in control limits
Four get bonus, six don't

# Which control chart is the best?

- Measurement data are more powerful for detecting special causes than charts for Attribute data; that the X-Bar and S-chart is more powerful than the I-chart
- U-charts or C-chart is more powerful than the P-chart.
- Try to collect data in such a way that they will be able to use the better chart

# HOW MANY SUBGROUPS ARE REQUIRED FOR A CONTROL CHART?

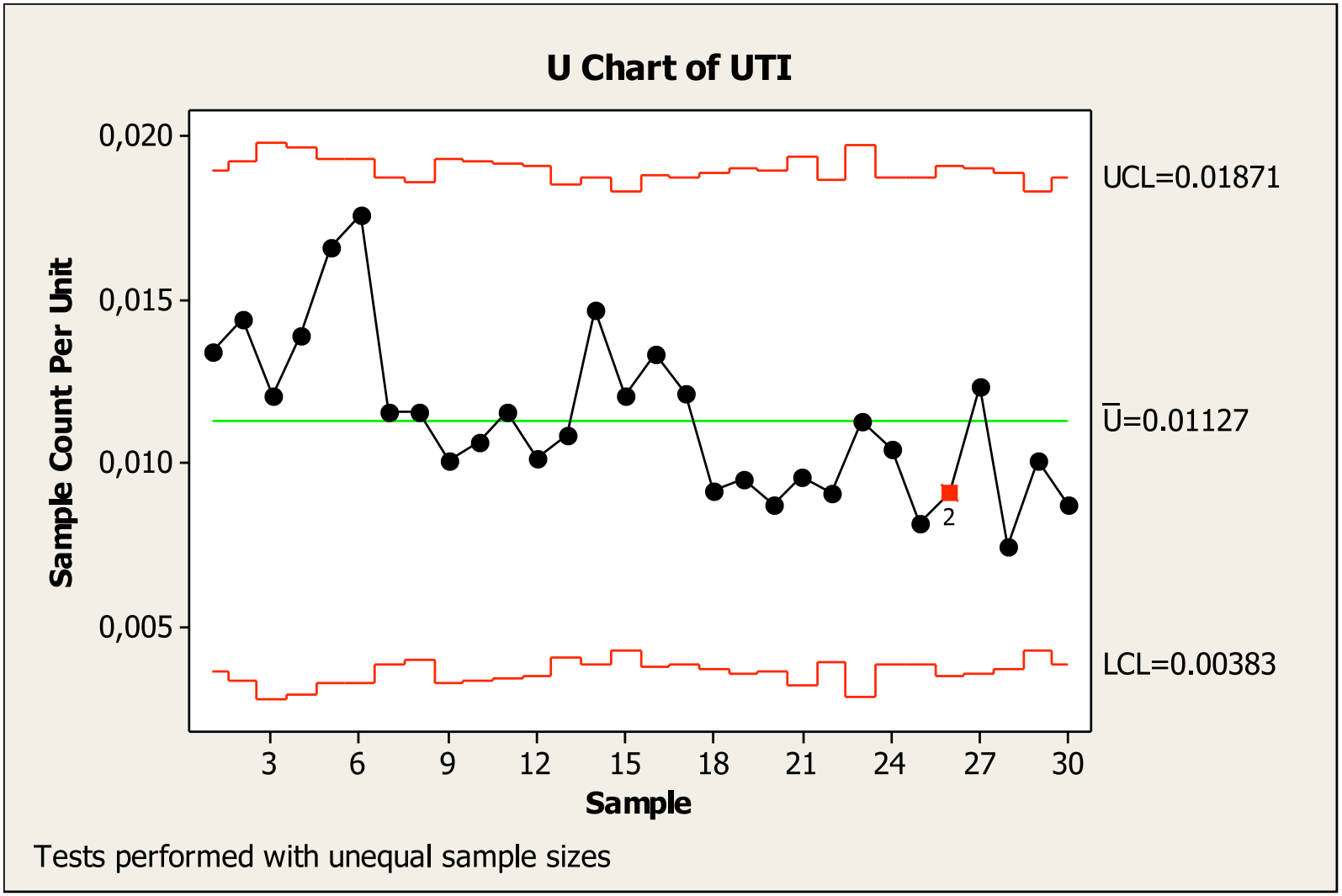
- A control chart should have about 20 to 25 data subgroups
- < 20 subgroups, there is increased danger of missing special causes (Type-II error).
- > 35-40 subgroups there is increasing danger of finding special causes due to chance (Type-I error).


U Chart of UTI
Sample Count Per Unit
0,020
0,015
0,010
0,005
UCL=0.01871
Ū=0.01127
LCL=0.00383
2
3
6
9
12
15
18
21
24
27
30
Sample
Tests performed with unequal sample sizes

# Sample size of sub-group

- P and U-Chart
  - Appropriate
    - Sample size > 4/average percentage (pBar or uBar)
  - Minimum
    - Sample size >1/average percentage (pBar or uBar)
- C- Chart
  - Appropriate
    - cBar >4
  - Minimum
    - cBar >1

- Example: u-Chart
  - VAP ( per ventilator day)
    - Sample size per subgroup should be
      - At least sample size =1/average percentage (uBar)
        - If your hospital average VAP=8/1000 ventilator day=0.008
        - Sample size (ventilator day) per subgroup
        - =1/0.008
        - = 125 ventilator days
      - Appropriate =4/average percentage (u-Bar) = 4/0.008
        - = 500 ventilator days


U Chart of UTI
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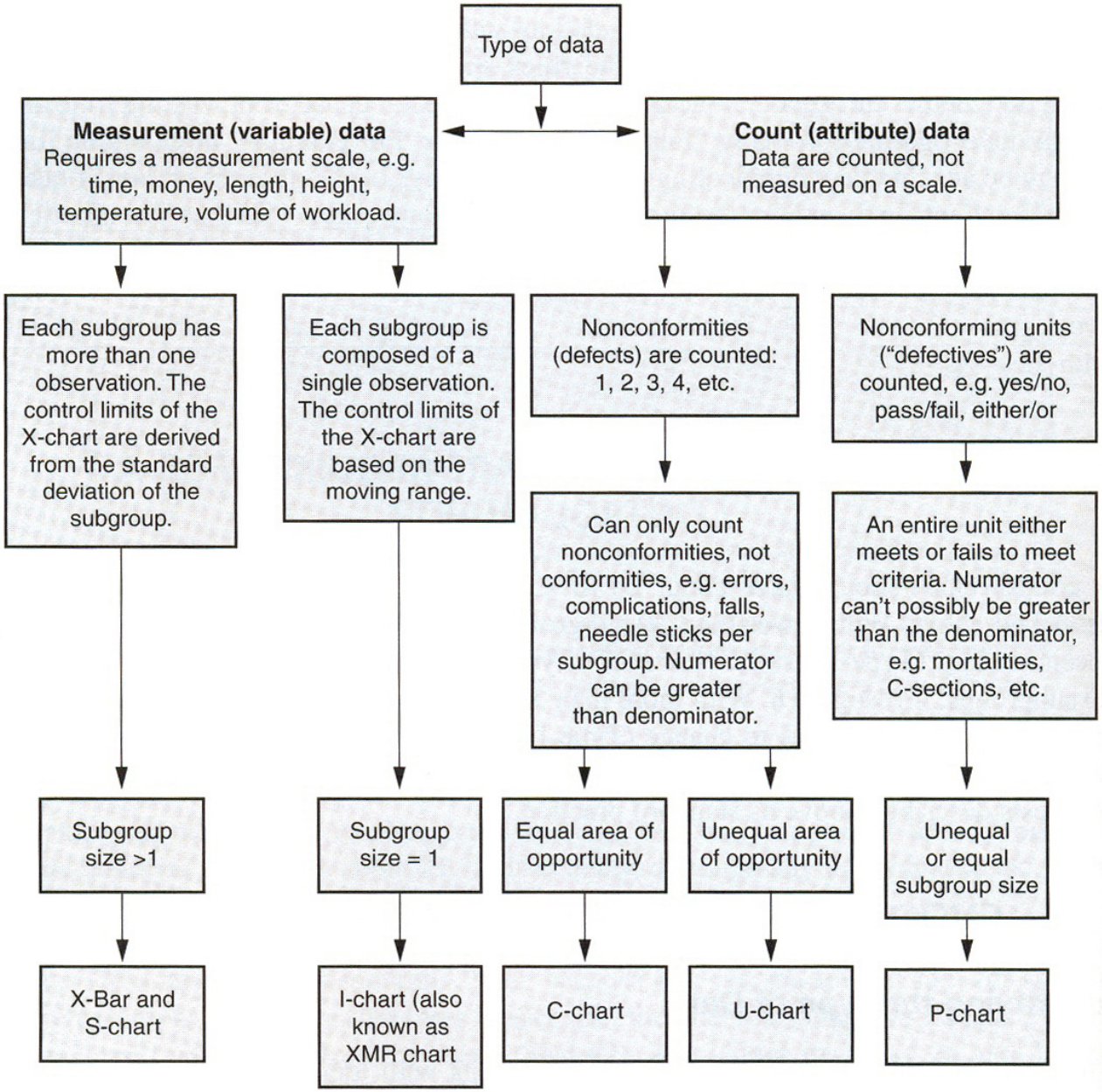
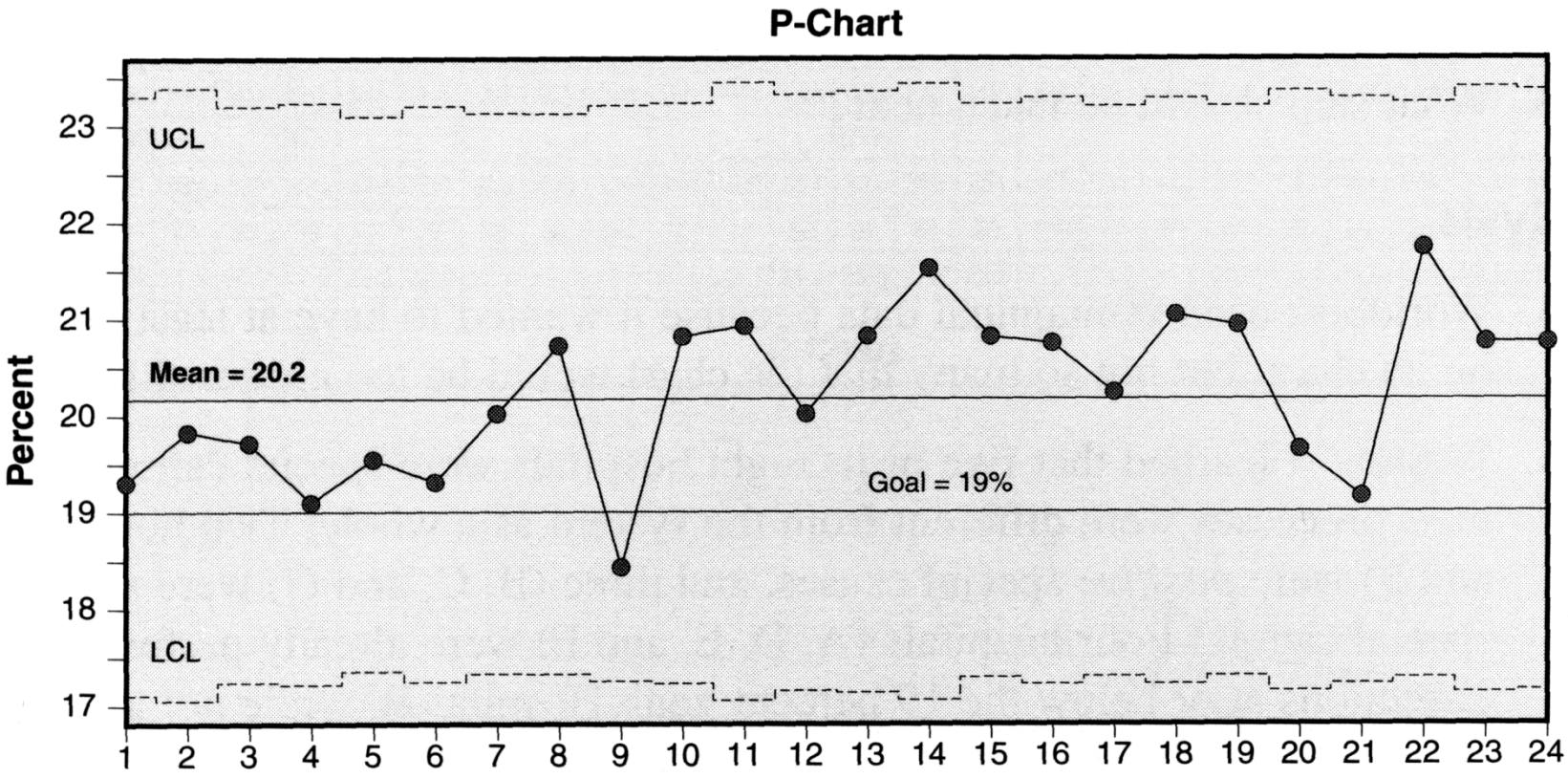
0,015
0,010
0,005
UCL=0.01871
Ū=0.01127
LCL=0.00383
2
3
6
9
12
15
18
21
24
27
30
Sample
Tests performed with unequal sample sizes

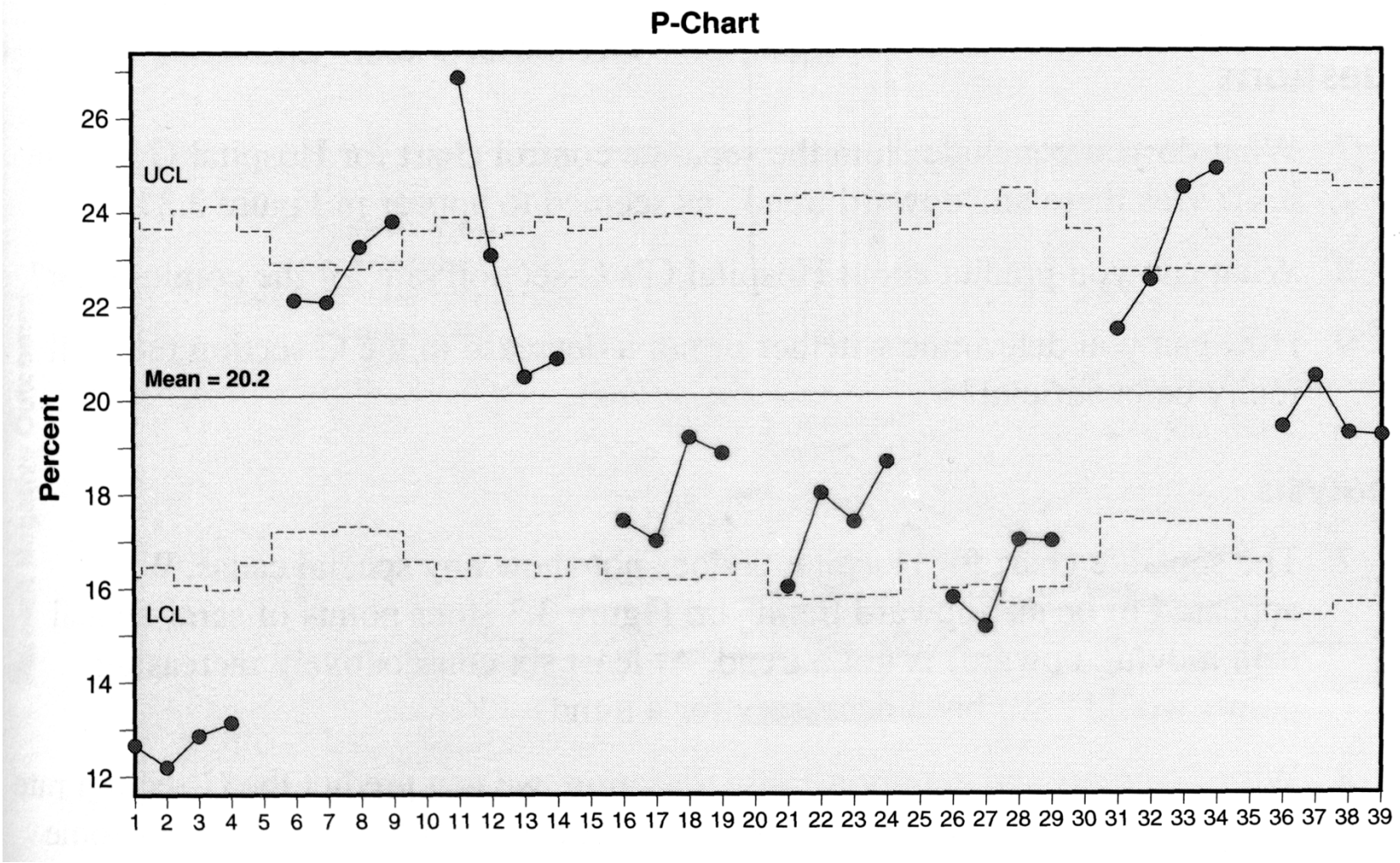
- Example: p-Chart
  - Endophthalmitis rate ( per case)
    - Sample size per subgroup should be
      - At least sample size =1/average percentage( p-Bar)
      - If your hospital average endophthalmitis rate =2/1000
        - Sample size (cases) per subgroup =1/0.002= 500 Cases
      - Appropriate sample size =4/average percentage
        - = 4/0.002
        - = 2,000 Cases


Type of data
Measurement (variable) data
Requires a measurement scale, e.g. time, money, length, height, temperature, volume of workload.
Count (attribute) data
Data are counted, not measured on a scale.
Each subgroup has more than one observation. The control limits of the X-chart are derived from the standard deviation of the subgroup.
Each subgroup is composed of a single observation. The control limits of the X-chart are based on the moving range.
Nonconformities (defects) are counted: 1, 2, 3, 4, etc.
Nonconforming units ("defectives") are counted, e.g. yes/no, pass/fail, either/or
Can only count nonconformities, not conformities, e.g. errors, complications, falls, needle sticks per subgroup. Numerator can be greater than denominator.
An entire unit either meets or fails to meet criteria. Numerator can't possibly be greater than the denominator, e.g. mortalities, C-sections, etc.
Subgroup size >1
Subgroup size = 1
Equal area of opportunity
Unequal area of opportunity
Unequal or equal subgroup size
X-Bar and S-chart
I-chart (also known as XMR chart
C-chart
U-chart
P-chart

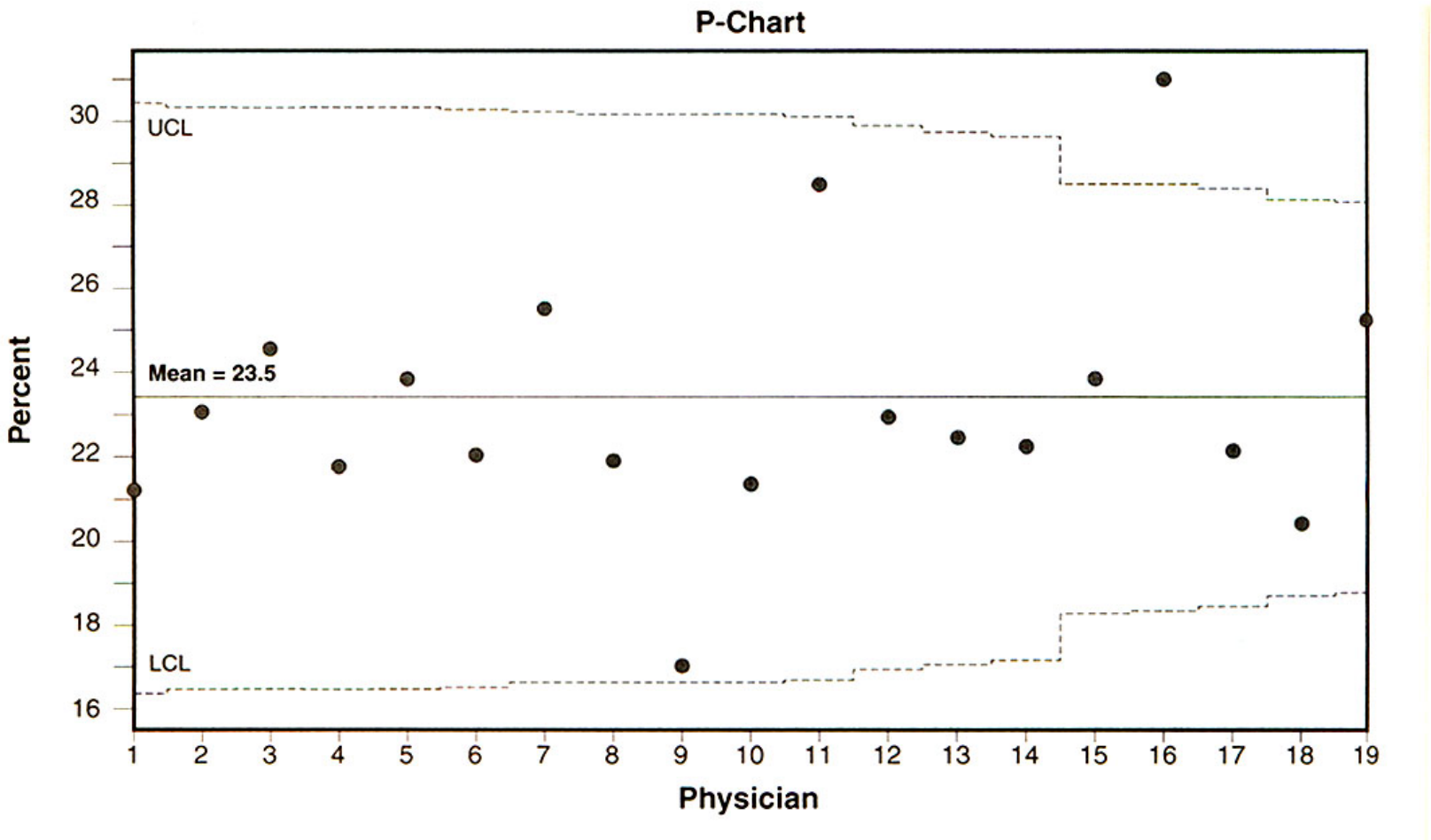
# Stratify control charts

- Rational ordering
- Rational subgrouping


P-Chart
Percent
UCL
Mean = 20.2
Goal = 19%
LCL
23
22
21
20
19
18
17
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

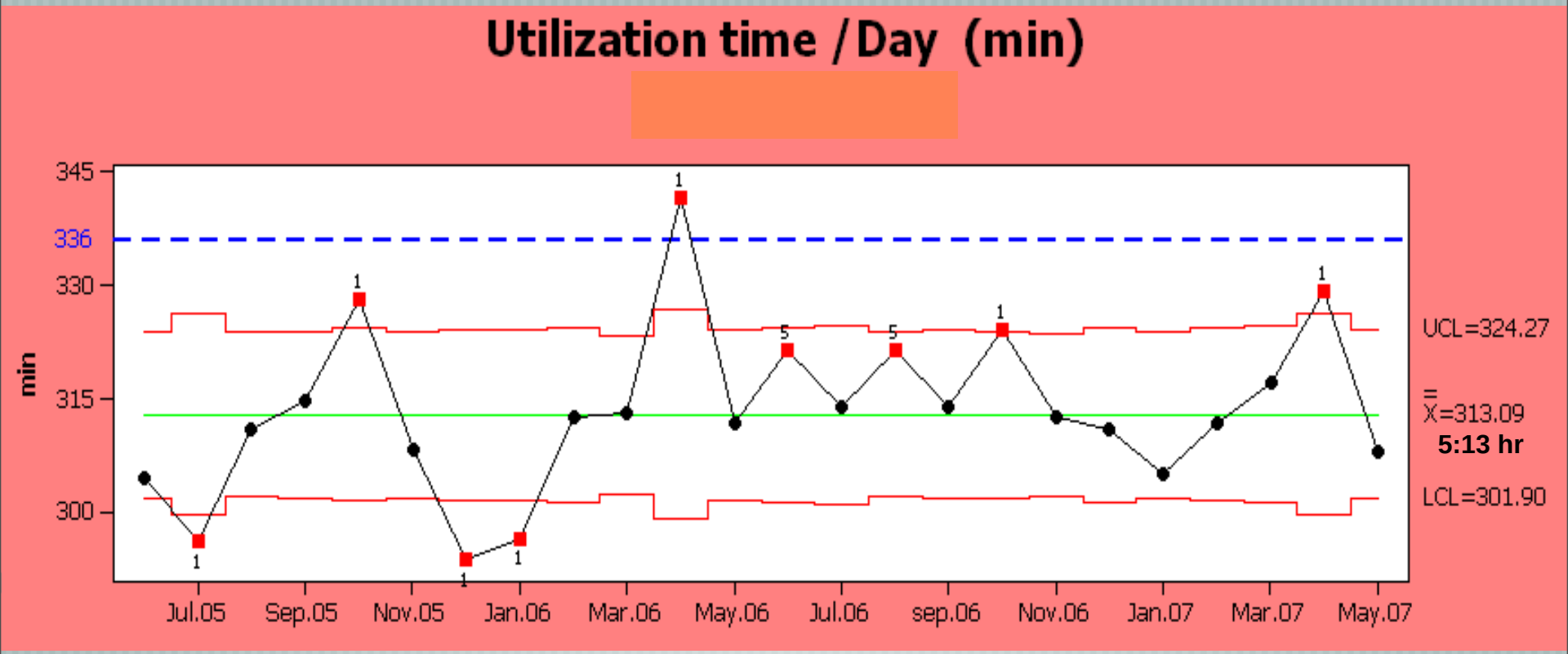



# Rational Ordering

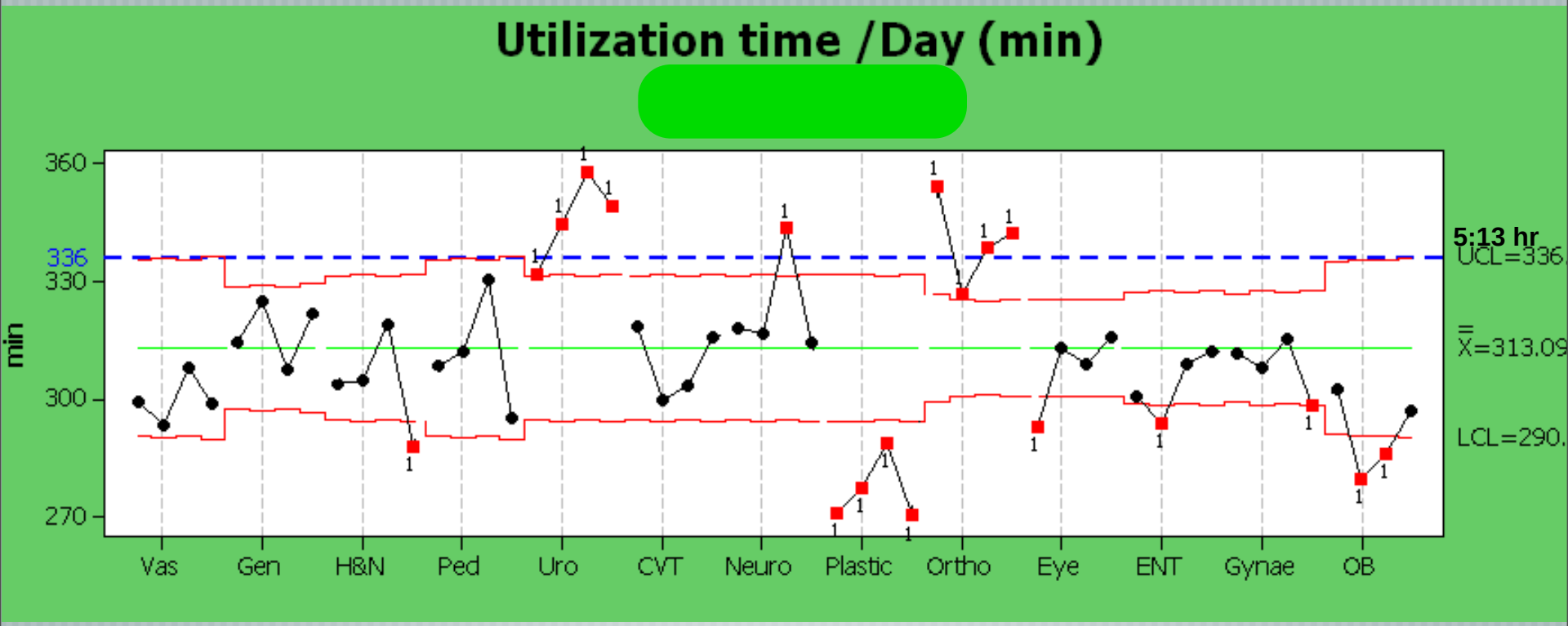



# Rational Subgrouping

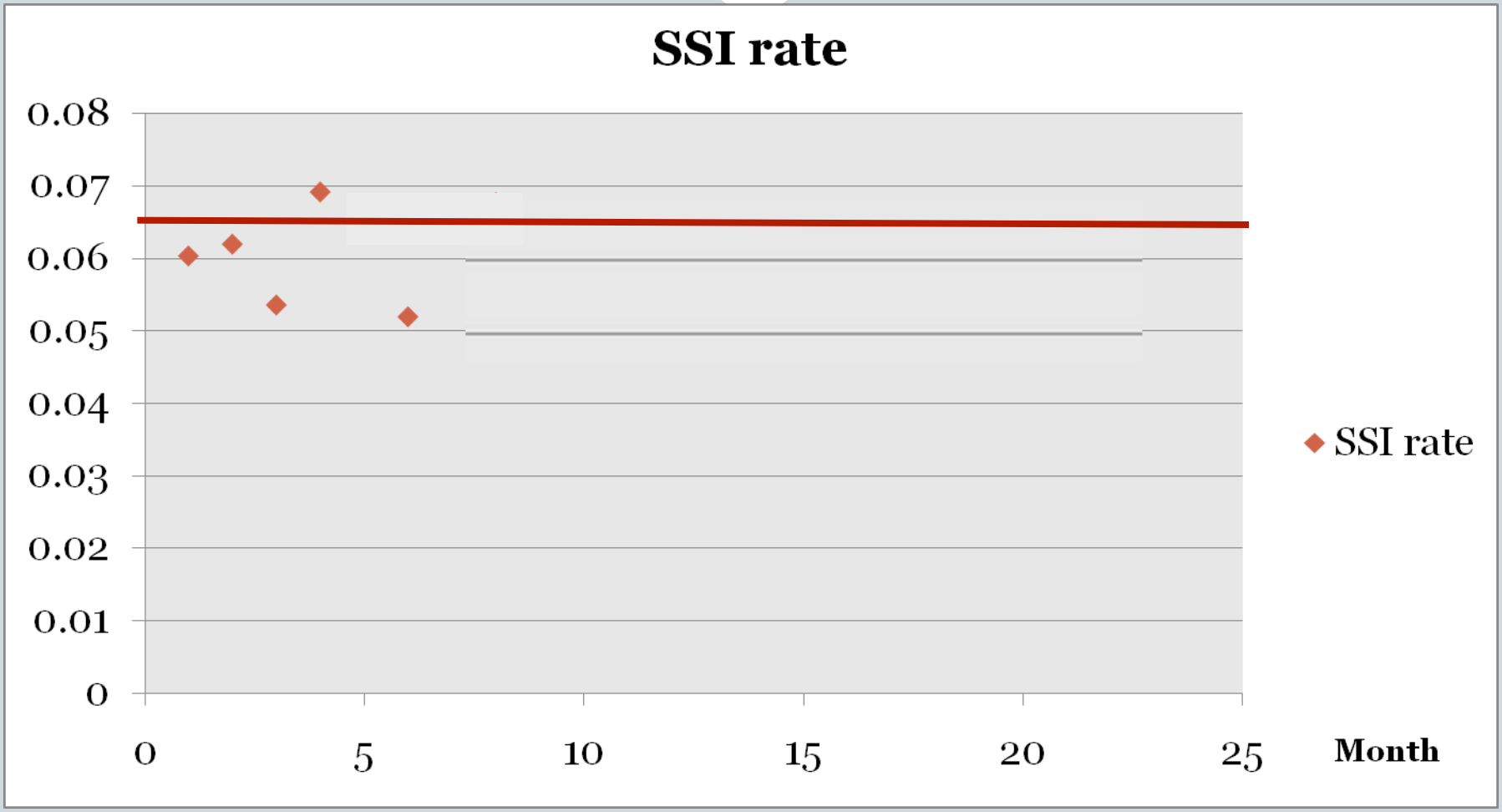
# การใช้ห้องผ่าตัดในเวลาทำการ



# OR Utilized time : เปรียบเทียบตามสาขาวิชา



| | Variation that indicates good or bad performance | Variation that results from common or special causes |
|---|---|---|
| Focus | Outcomes of the process (product or service) | Causes of variation in the process |
| Aim | Classify outcomes as acceptable or not | Provide a basis for action on the process |
| Basis | What the customer wants or needs | What the process is actually delivering |
| Methods | Specifications, budgets, forecasts, numerical goals, other tools for judging performance | Control charts |


SSI rate
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
Month
SSI rate

[Workers] will likely meet the targets—even if they have to destroy the enterprise to do it.

—W. Edwards Deming

# Summary

# What is SPC?

- A way of thinking
- Measurement for improvement, not judgement
- Better way for making decisions
- Evidence based management
- Easy, sustainable

# What can it do for me?

- Evaluate and improve underlying process
  - is it stable? can it meet “targets”?
- Recognize variation
- Prove/disprove assumptions and (mis)conceptions
- Help drive improvement
- Use data to make predictions and help planning
- Reduce data overload

# Control charts do not answer the following questions

- What is the reason for special cause?
- Should a common process be improved?
- What should I do to improve the process?

**BUT**

- Ignoring a special cause will guarantee that it will occur again.
- Every special cause is not negative or undesirable.

# 2 ways to improve a process

If uncontrolled variation

identify special causes (may be good or bad)

- process is unstable
- variation is extrinsic to process
- cause should be identified and “treated”

If controlled variation

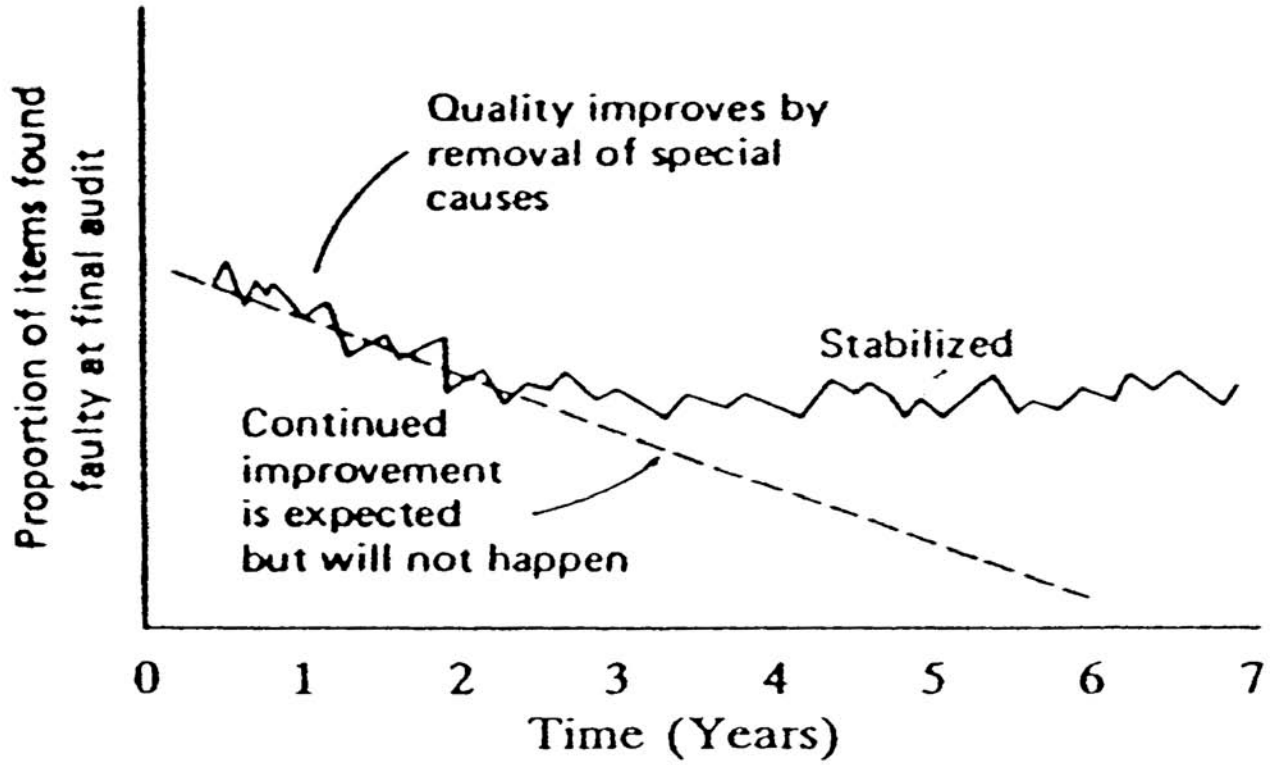
reduce variation, improve outcome

- process is stable
- variation is inherent to process
- therefore, process must be changed

# JCAHO

- Joint Commission on Accreditation of Healthcare Organization ได้กำหนดให้โรงพยาบาลที่จะผ่านกระบวนการรับรองคุณภาพ ต้องมีการทำ Control Chart ในทุกกระบวนการ

## Figure 8. Typical path of frustration.

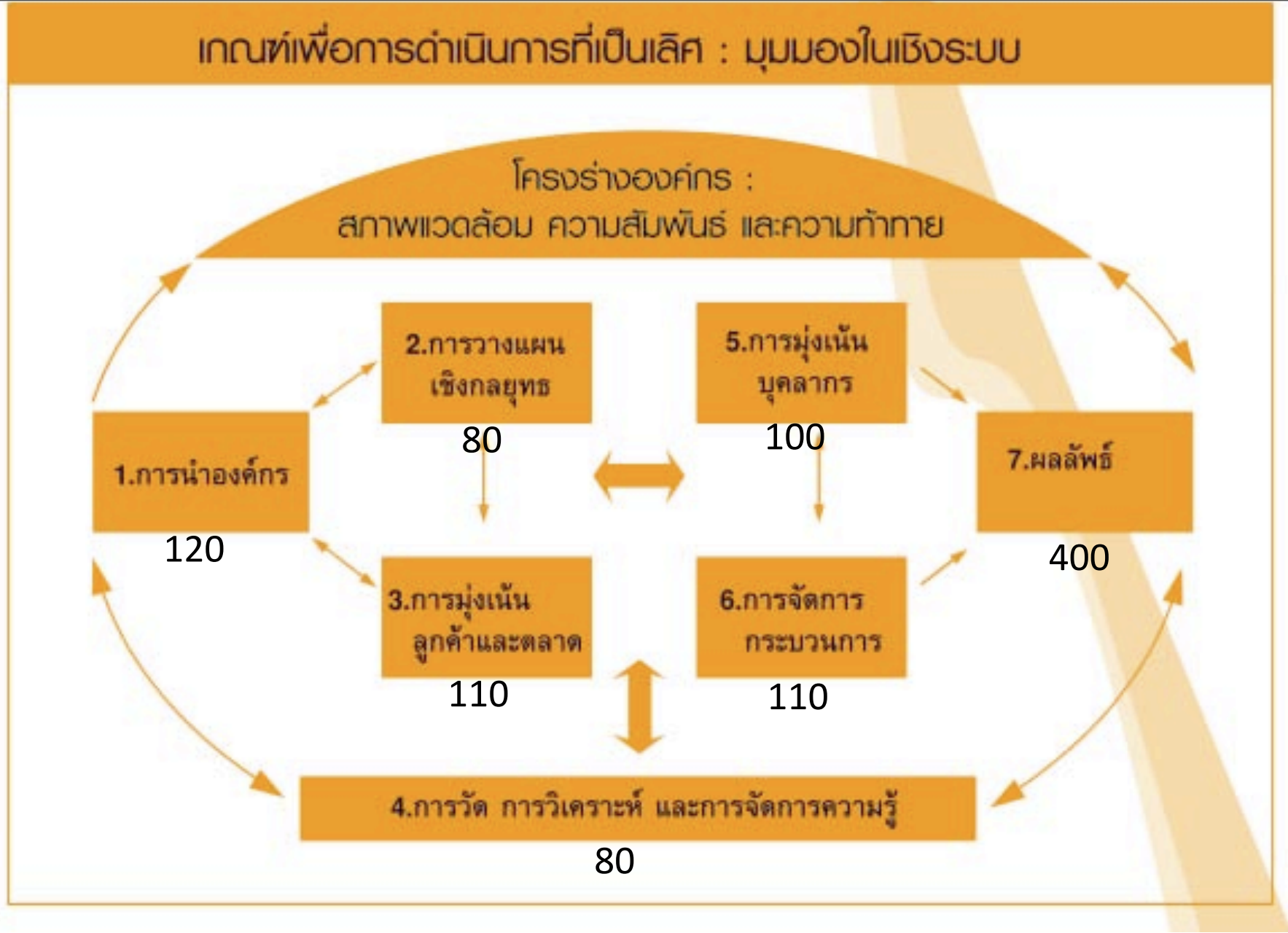



Used with permission of W. Edwards Deming.

# THAILAND QUALITY AWARD

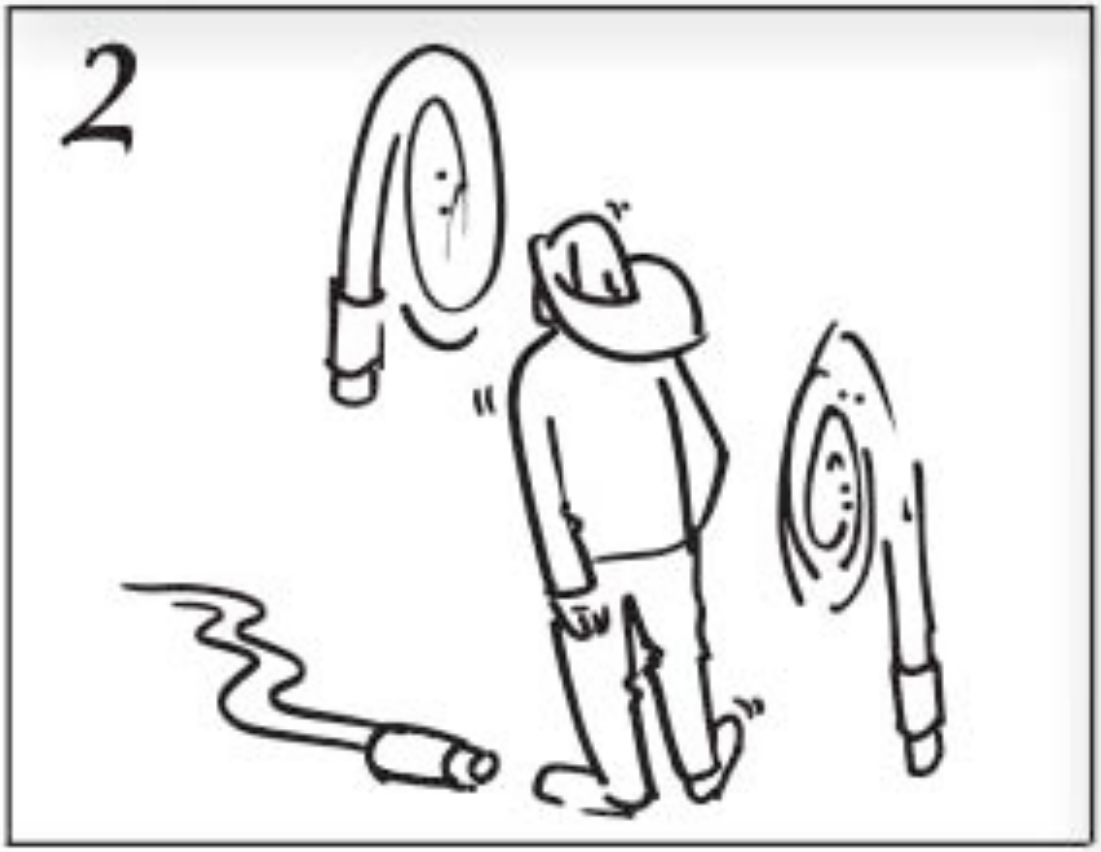
เกณฑ์รางวัลคุณภาพแห่งชาติ เพื่อองค์กรที่เป็นเลิศ ปี 2551


18 หัวข้อ, 32 ประเด็น, 84 คำถาม, 71 หมายเหตุ

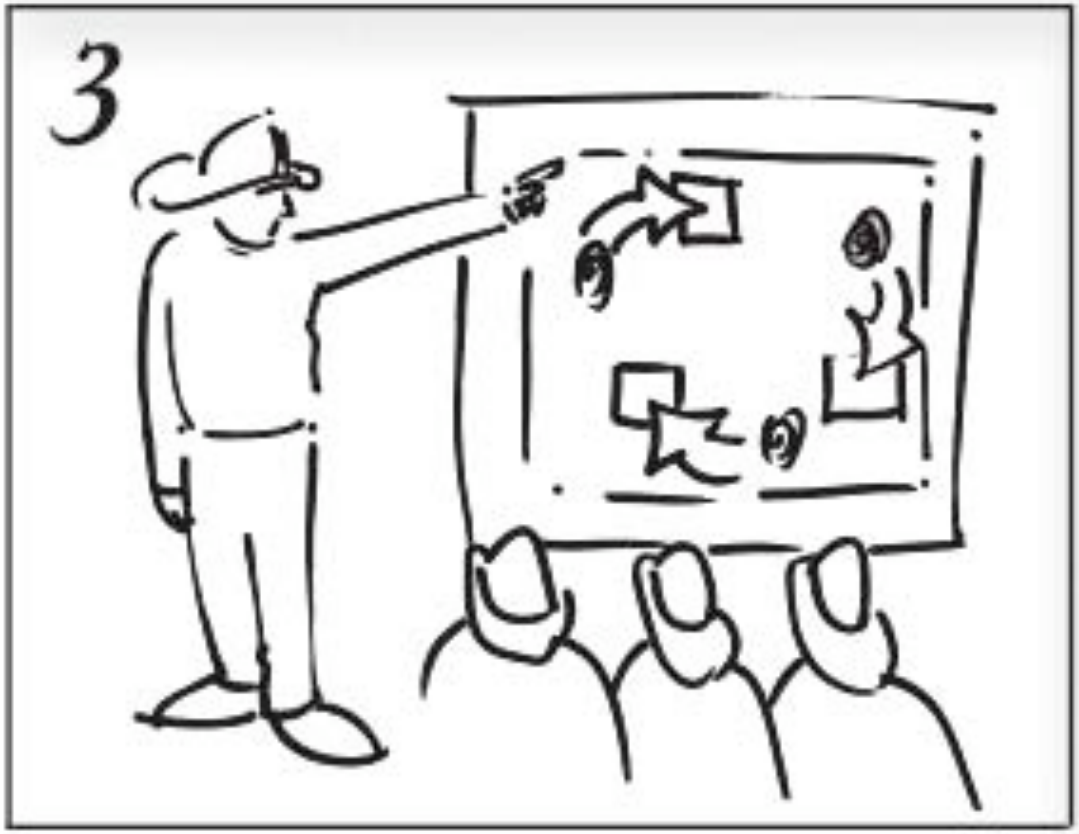



คะแนนรวม= 1,000 >650 = TQA >350= TQC

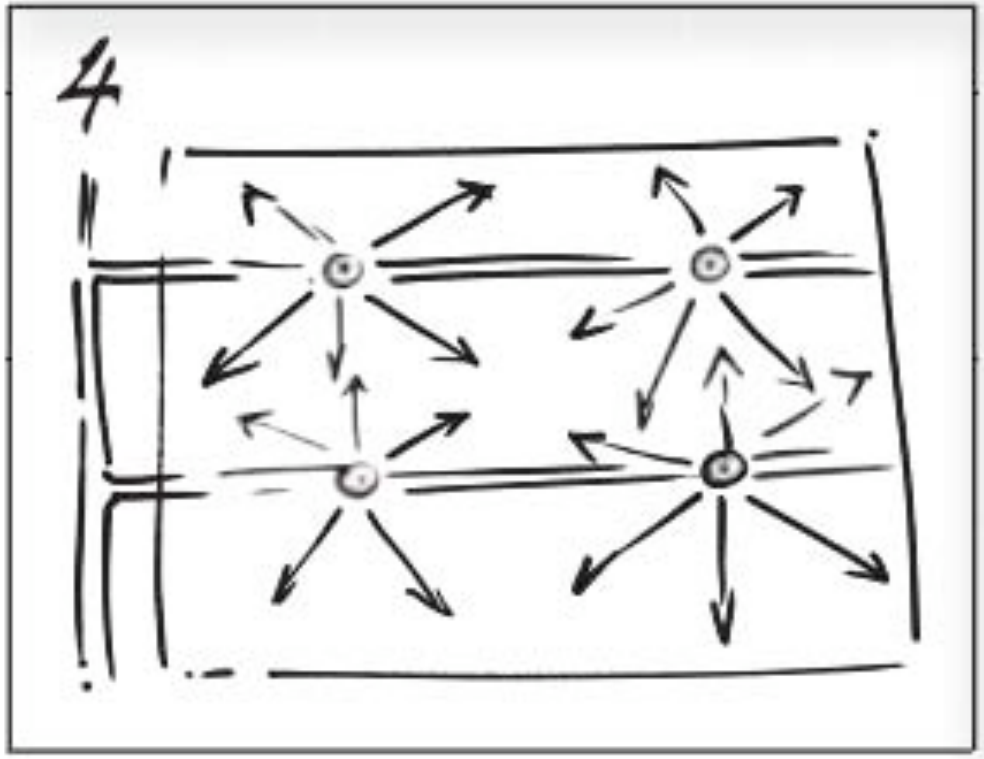

**Reacting to the problem:**
Run with the hose and put out the fire.
(0–5%)



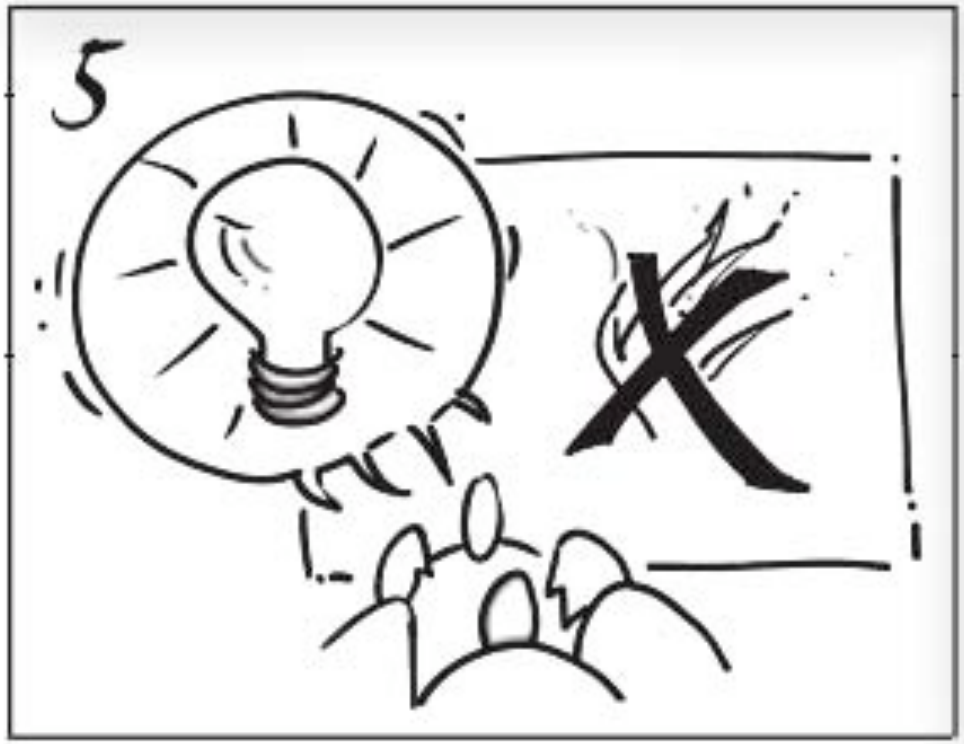

**General improvement orientation:**
Install more fire hoses to get to the fires quickly and reduce their impact.
(10–25%)




**Systematic evaluation and improvement:**
Evaluate which locations are most susceptible to fire.
Install heat sensors and sprinklers in those locations.
(30–45%)

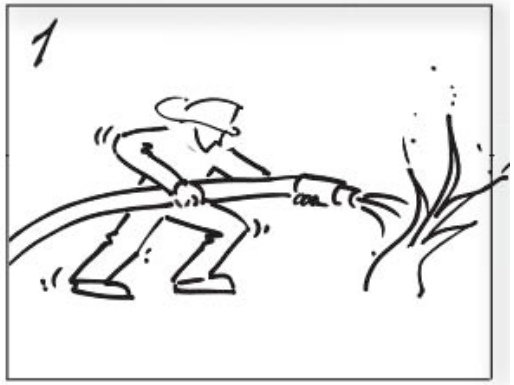



**Learning and strategic improvement:**
Install systemwide heat sensors and a sprinkler system that is activated by the heat preceding fires.
(50–65%)




**Organizational analysis and innovation:**
Use fireproof and fire-retardant materials.
Replace combustible liquids with water-based liquids.
Sensors and sprinklers become the secondary line of protection,
with prevention the primary approach for protection.
(70–100%)

# Where are we now?

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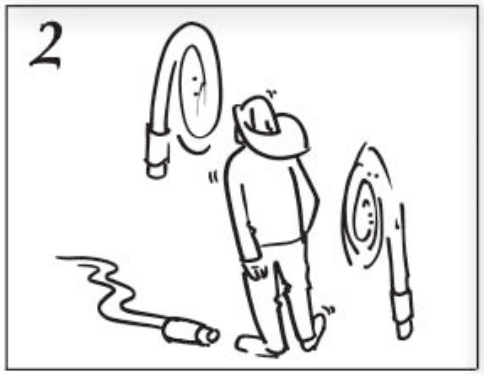


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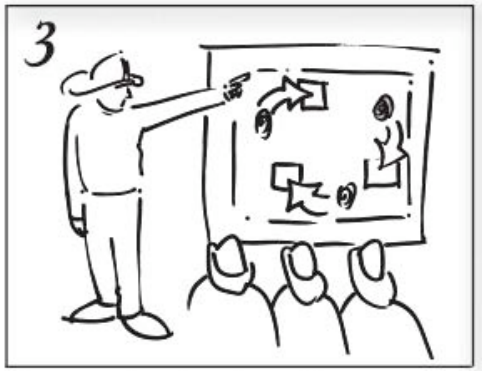


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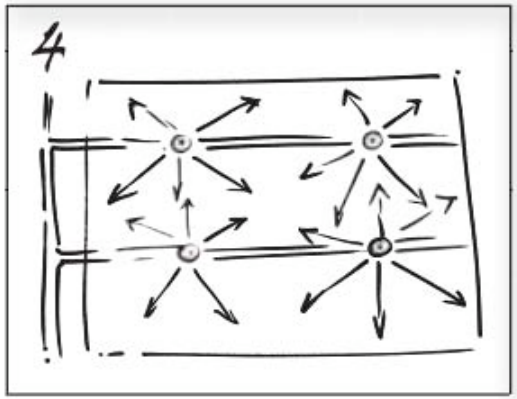


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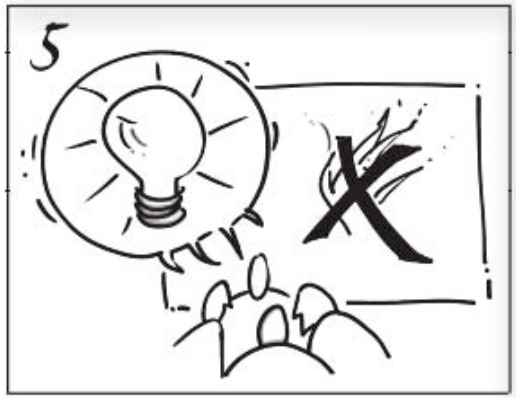


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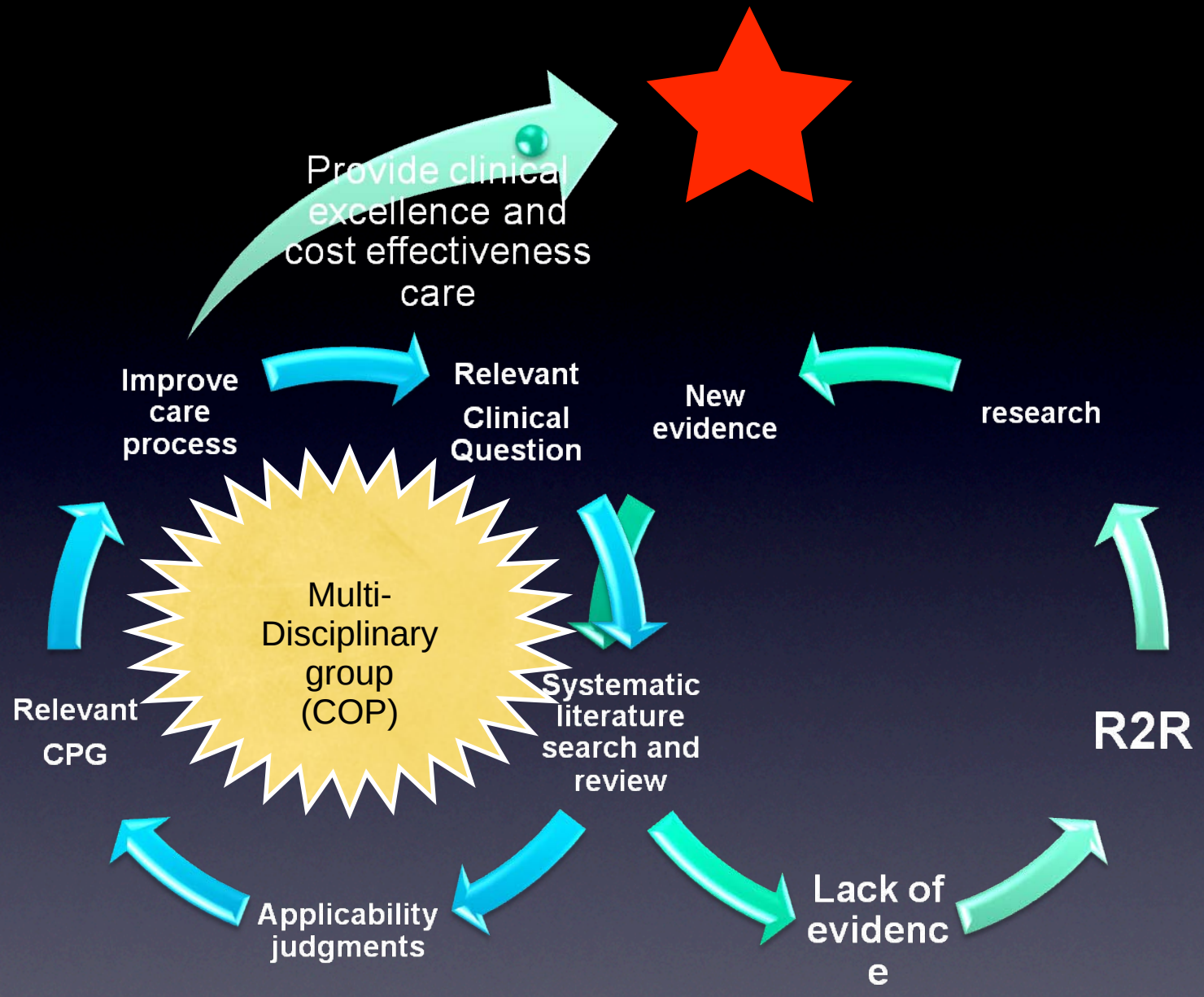
Provide clinical excellence and cost effectiveness care
Improve care process
Relevant Clinical Question
New evidence
research
Multi-Disciplinary group (COP)
Relevant CPG
Systematic literature search and review
R2R
Applicability judgments
Lack of evidenc e