Northeastern

Using Statistical Quality Control Charts in Healthcare

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Healthcare Systems Engineering Institute
CMS Innovation Healthcare Systems Engineering Center
NSF Center for Health Organization Transformation
AHRQ Patient Safety Learning Lab Center

Northeastern University, Boston MA
www.hsye.org

Outline

1. Background / About us (10)
2. Quality control charts (20)
   a. What are they, Why important, How used
   b. Key concepts to know, Management implications
3. Opportunities and discussion (10)

Key themes

1. Use of SPC in:
   a. Quality improvement
   b. System management

2. Statistical thinking
   a. Existence of common v. special cause variation
   b. Managing and responding to variation
   c. Over-reacting to natural variation
3. Monitoring process performance
   a. Real-time vs retrospective view

About us / Healthcare Systems Engineering Institute

***Mission*: Broad measureable impact on health care, nationally, thru integration of research, education, and application of industrial and systems engineering**

Partnerships

Texas Health Resources
Seattle Children's
CHA Health
Boston Medical
MD Anderson Cancer Center
Harvard Vanguard Medical Associates
Lahey Clinic
StuderGroup
Grady
Lone Star Circle of Care
SIEMENS
Georgia Trauma Commission
HIGHMARK

Project Types

Project Types	Criteria		
Research – *Discover*	"Developing what we don't know"	1 - 2 years	1
Applied – *Impact*	"Doing what we know"	3 - 9 months	2
Experiential – *Education*	"Teaching others by doing"	2 - 6 months	3

Mechanisms

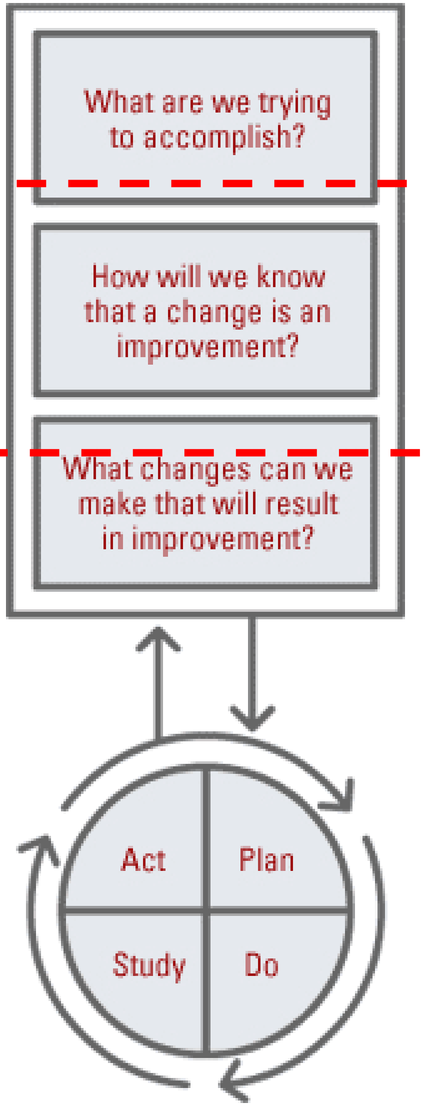
1. CHOT – Center for Health Organization Transformation
   NSF Research Center
   AHRQ Safety Center
   R01/other grants
2. Center for Medicare & Medicaid INNOVATION
   CMS Regional Extension
   VA Application Centers
3. Coops, Summer interns
   Postdoc training program
   Clinicians-in-residence

History of SPC

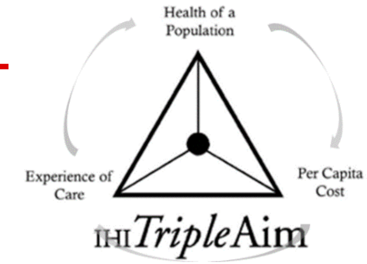
- Manufacturing origins
- 1920s - Walter Shewhart, W.E. Deming (Bell Labs)
- Easy for non-statisticians to detect process changes
- Ramped up extensively during WWII, post-war Japan, U.S. mfg
- Used in all industries, including health care

Walter Shewhart

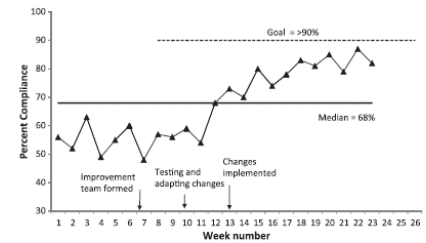
Role of SPC



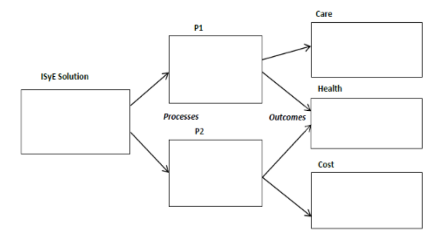
AIMS



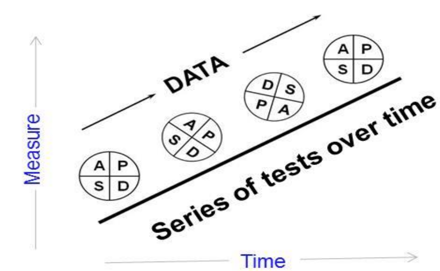
MEASURES



CHANGES

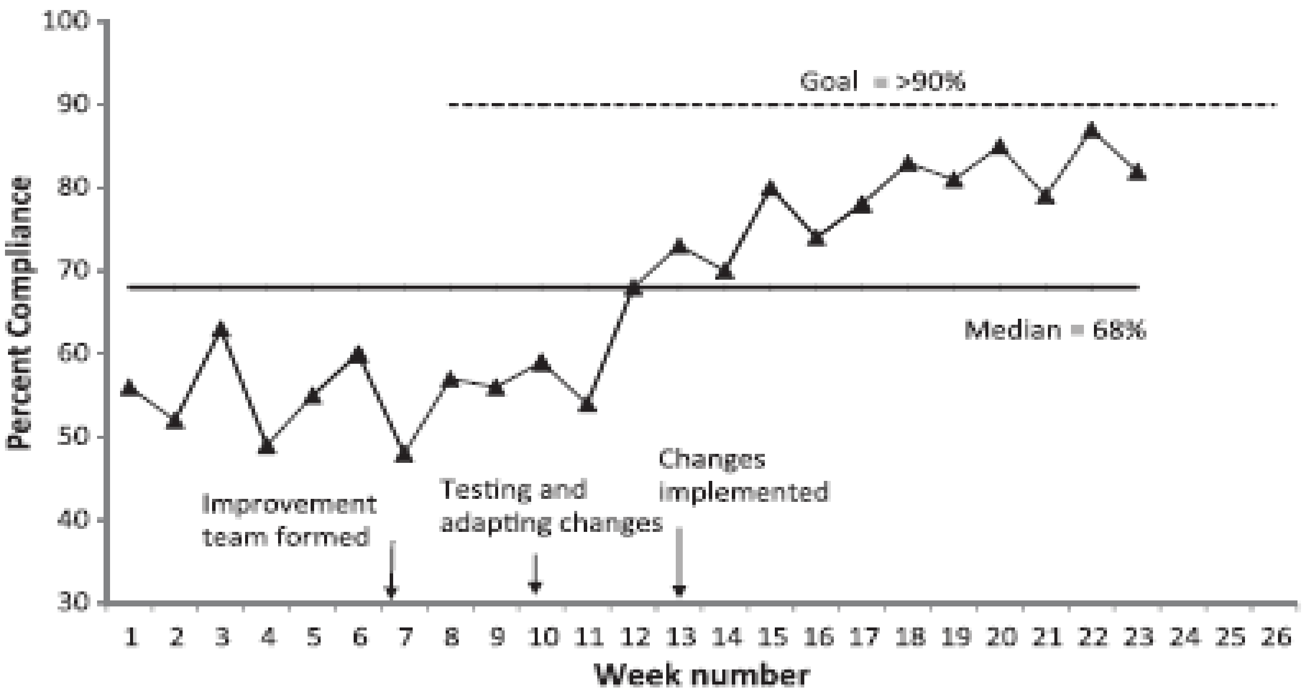


TESTS



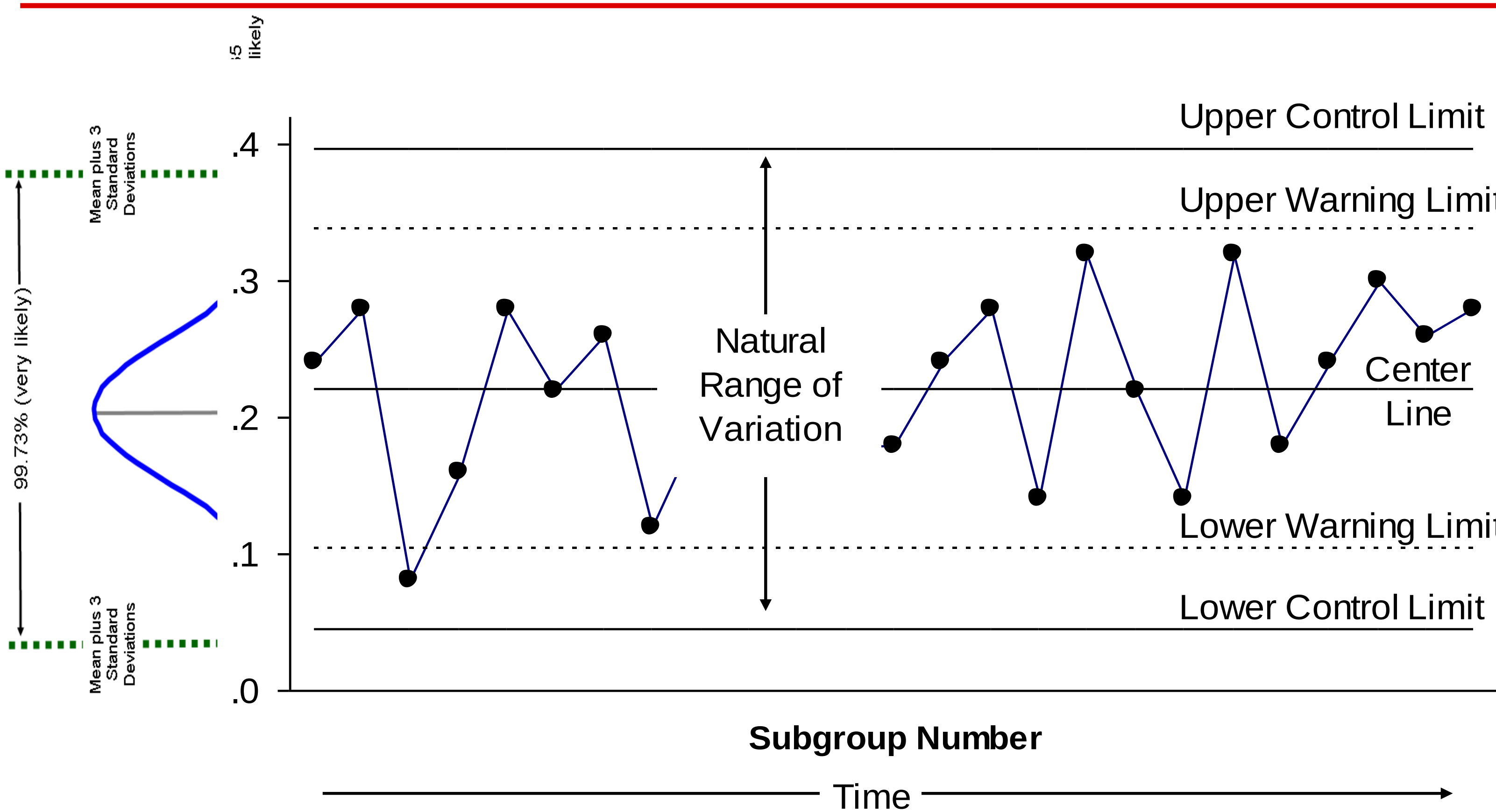
a. What is a run chart?

- Visual display of data over time
- Annotated (changes, goals, actions, signals, etc)
- Center line: Median or mean value for reference



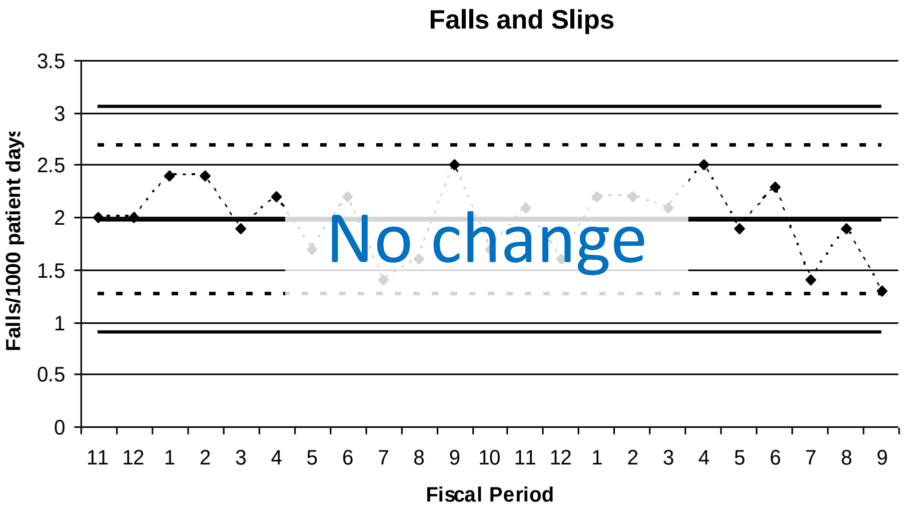
Perla et al, BMJ Qual Saf 2011; 20:46-51

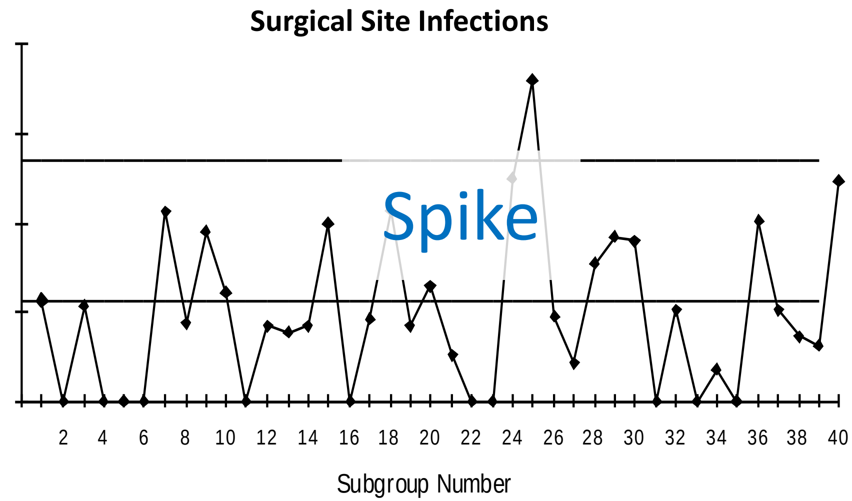
b. What is a control chart?

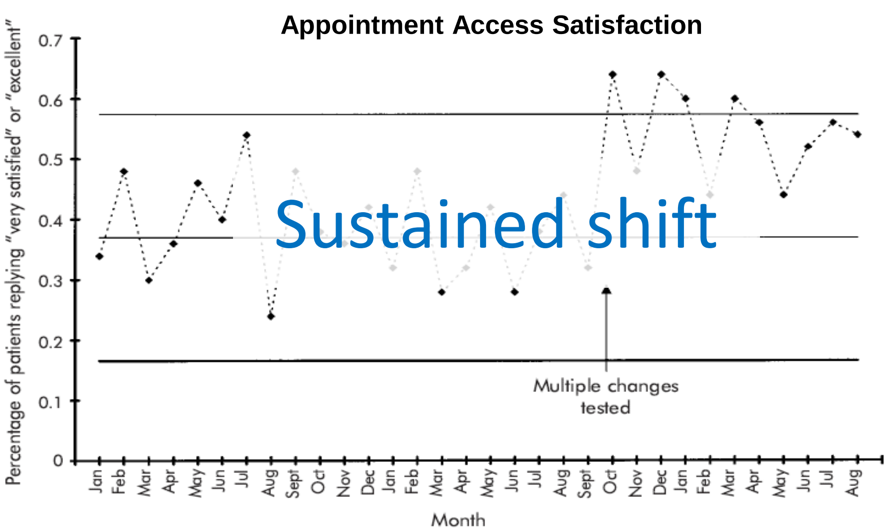


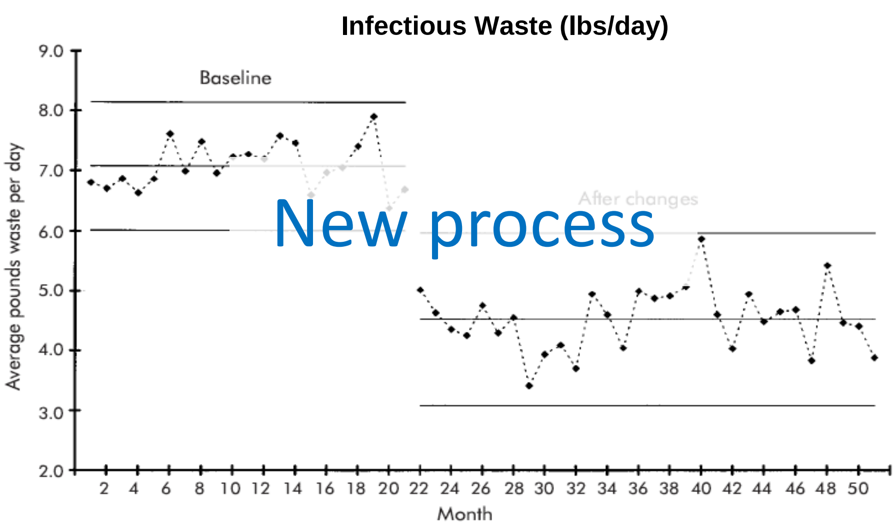
- Run chart with statistical limits
- ‘Hypothesis test over time’, simpler to use

Examples


Falls and Slips
No change
Falls/1000 patient days
Fiscal Period

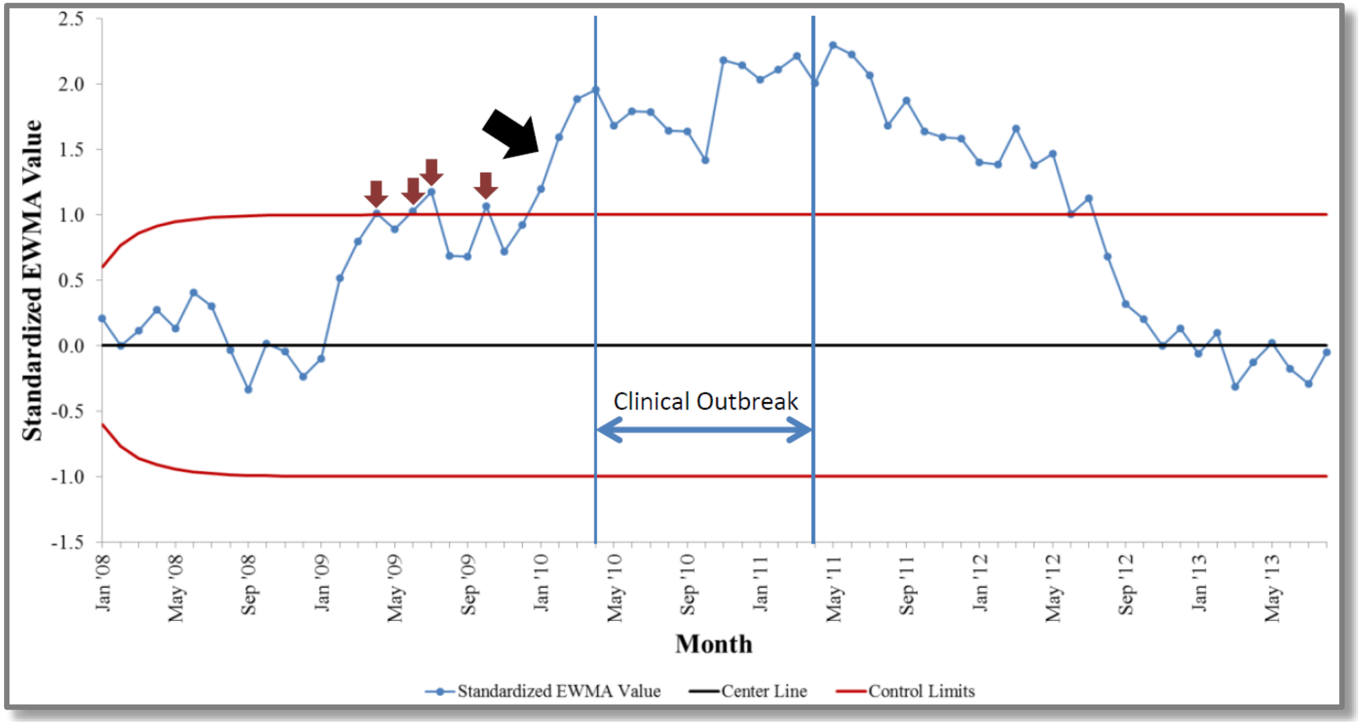

Surgical Site Infections
Spike
Subgroup Number


Appointment Access Satisfaction
Sustained shift
Multiple changes tested
Percentage of patients replying "very satisfied" or "excellent"
Month


Infectious Waste (lbs/day)
Baseline
After changes
New process
Average pounds waste per day
Month

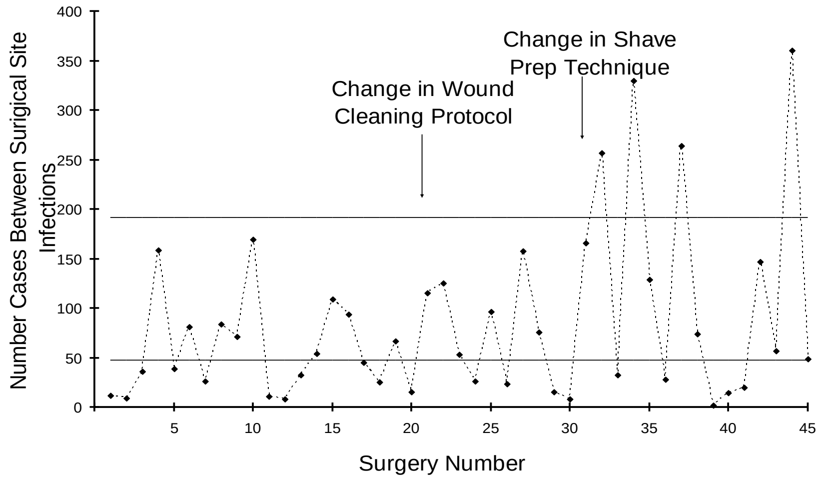
Second example

- 10 year retrospective SSI surveillance study
- 40 community hospitals, 5 states (VA, NC, SC, GA, FL)
- All outbreaks detected, All 0-12 months earlier

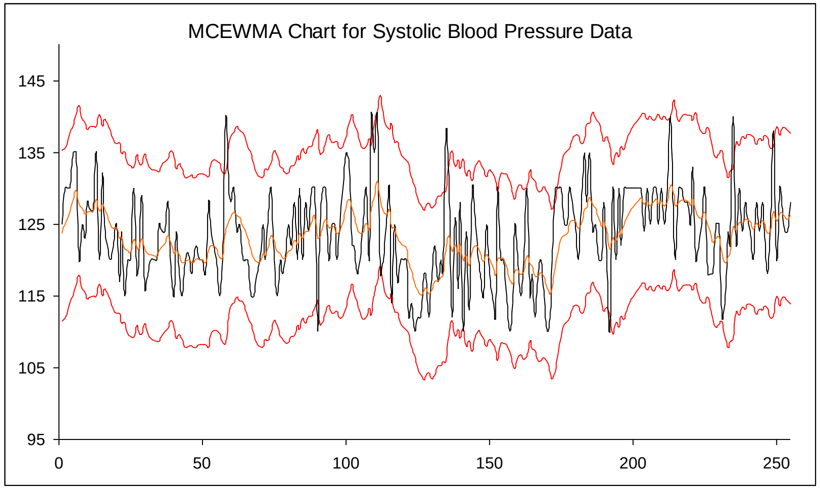


Special purpose methods

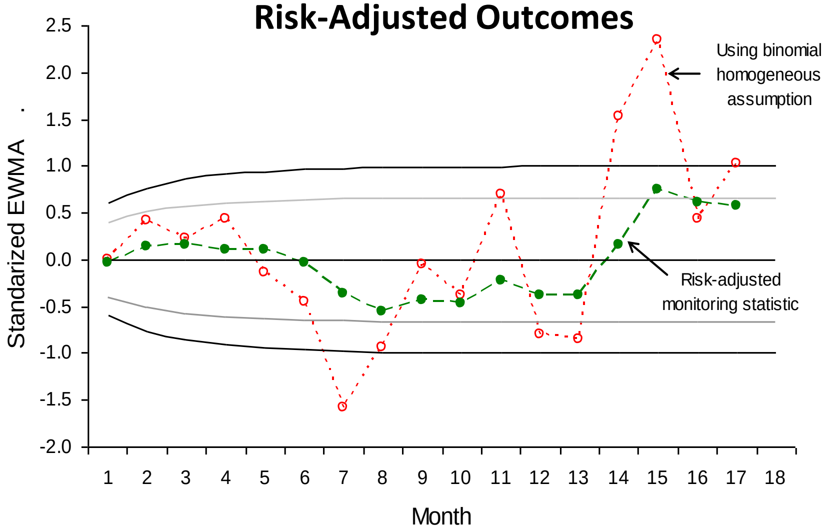
Rare Events



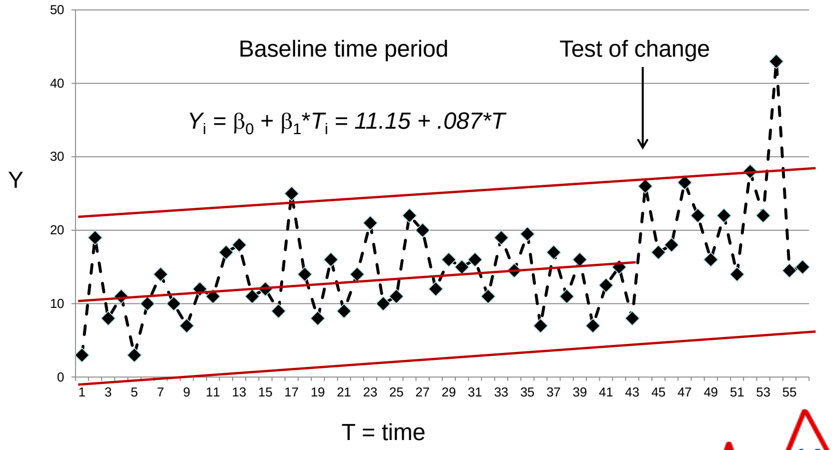
Auto-Correlated Processes



Risk-Adjusted Outcomes

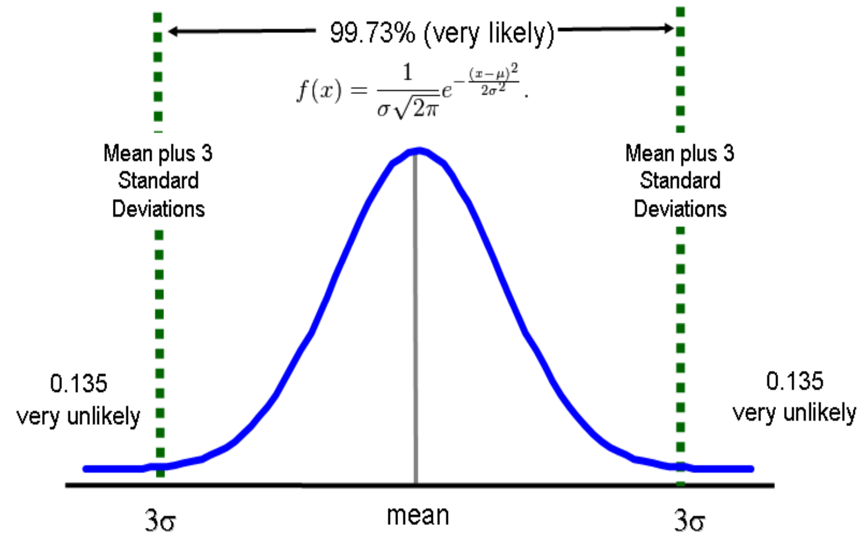


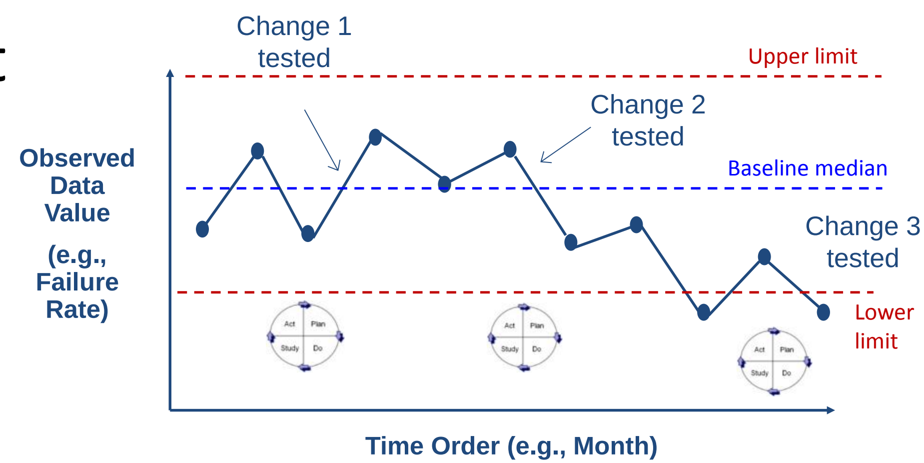
Background Improvement Trend



Recap - Key points

- Testing, lots of it, as key idea
- Data occur over time and should be viewed this way
- Data can be described mathematically
- Values in tails (& non-random patterns) are stat. significant
- Equivalent to (better than) classic hypothesis tests
- Time order is important





Recap - Terminology

1. **Common Cause Variation**: Causes inherent over time as part of usual process (good or bad).

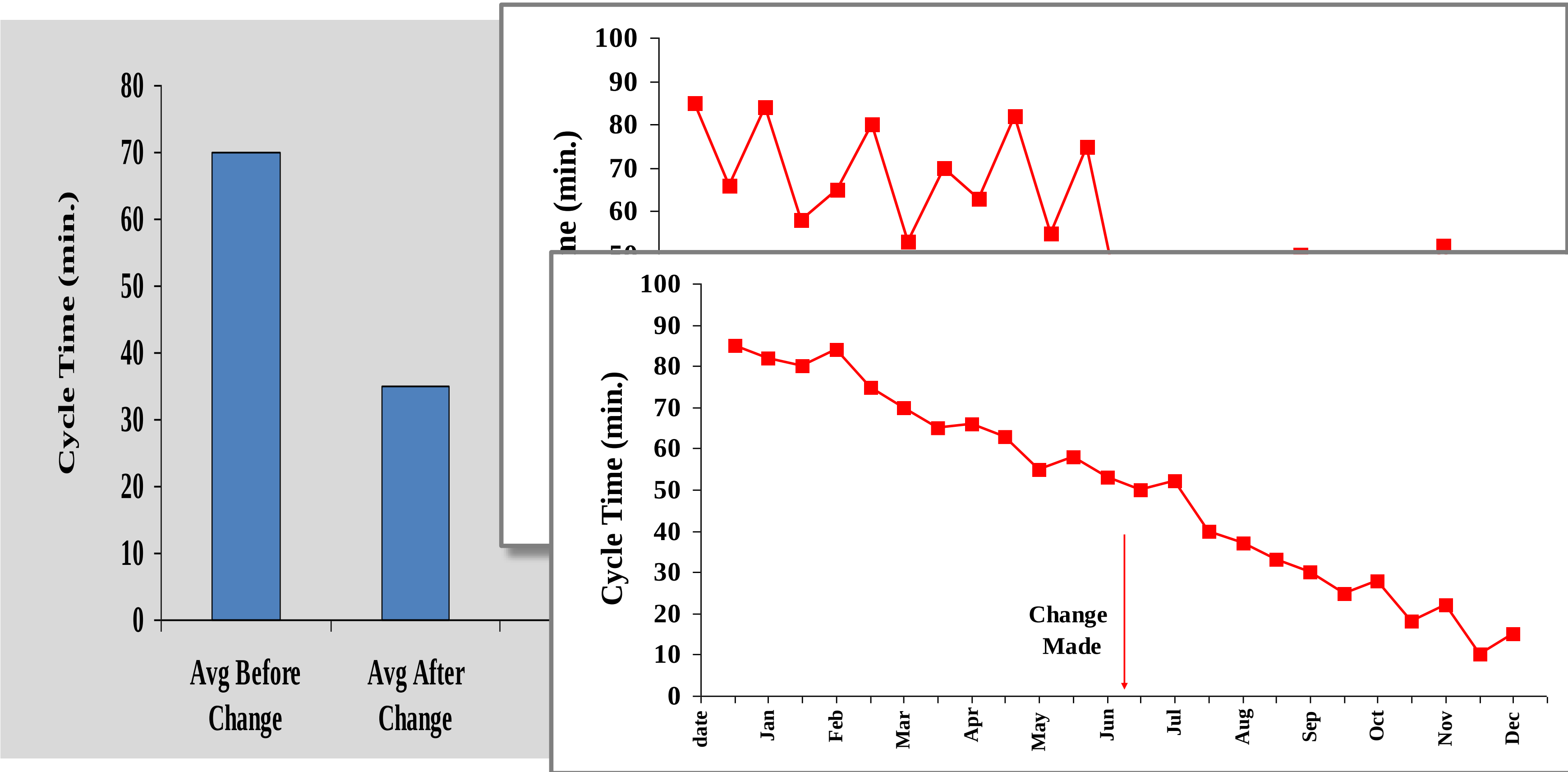
   Stable Process: Predictable variation within natural common cause bounds.

2. **Special Cause Variation**: Causes that arise from specific circumstances not part of usual process.

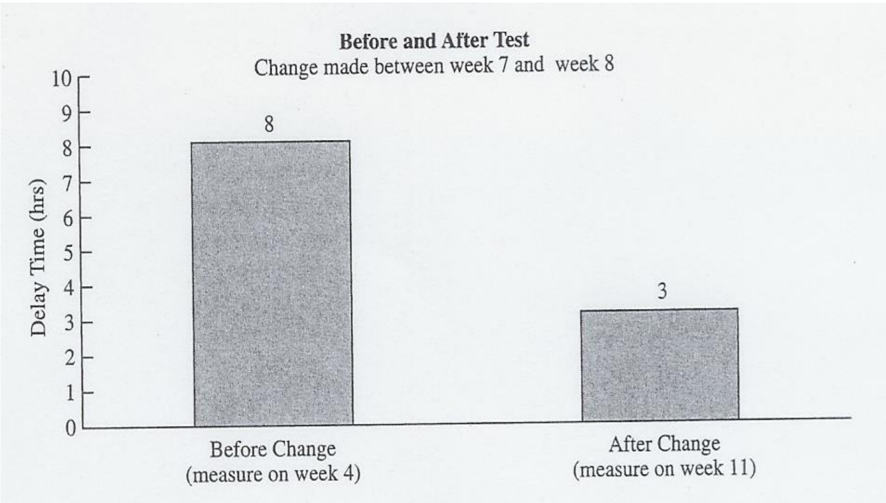
   Unstable Process: Affected by both special and common cause variation. Variation from one time period to next is unpredictable.

Why important

Evaluating a Change
(Large aggregated sample, 6 month pre-vs-post averages)



Second example



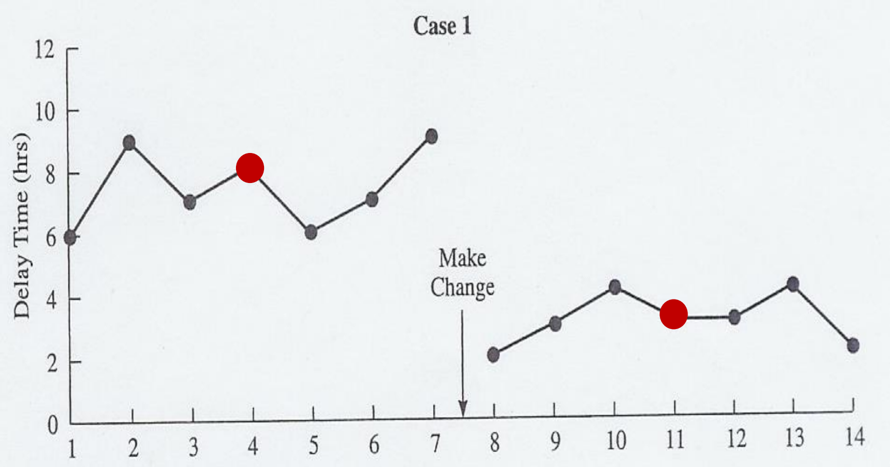
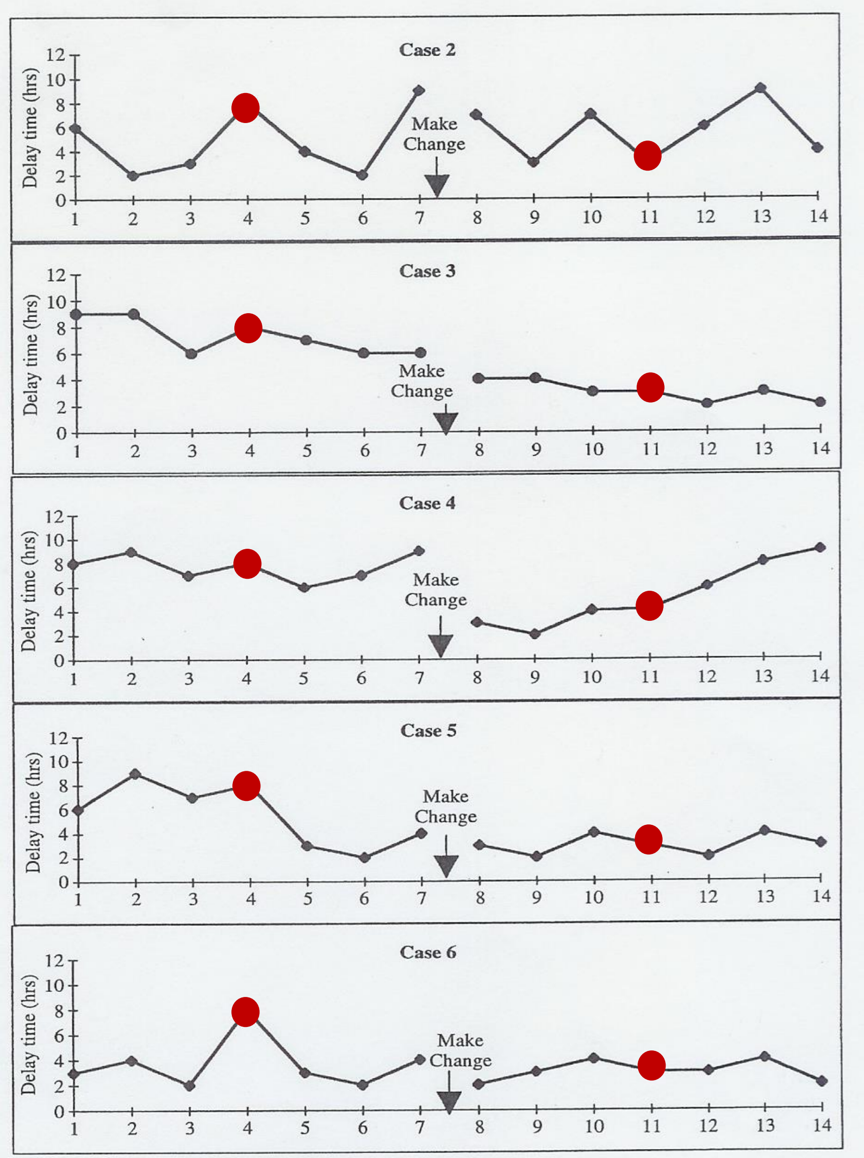
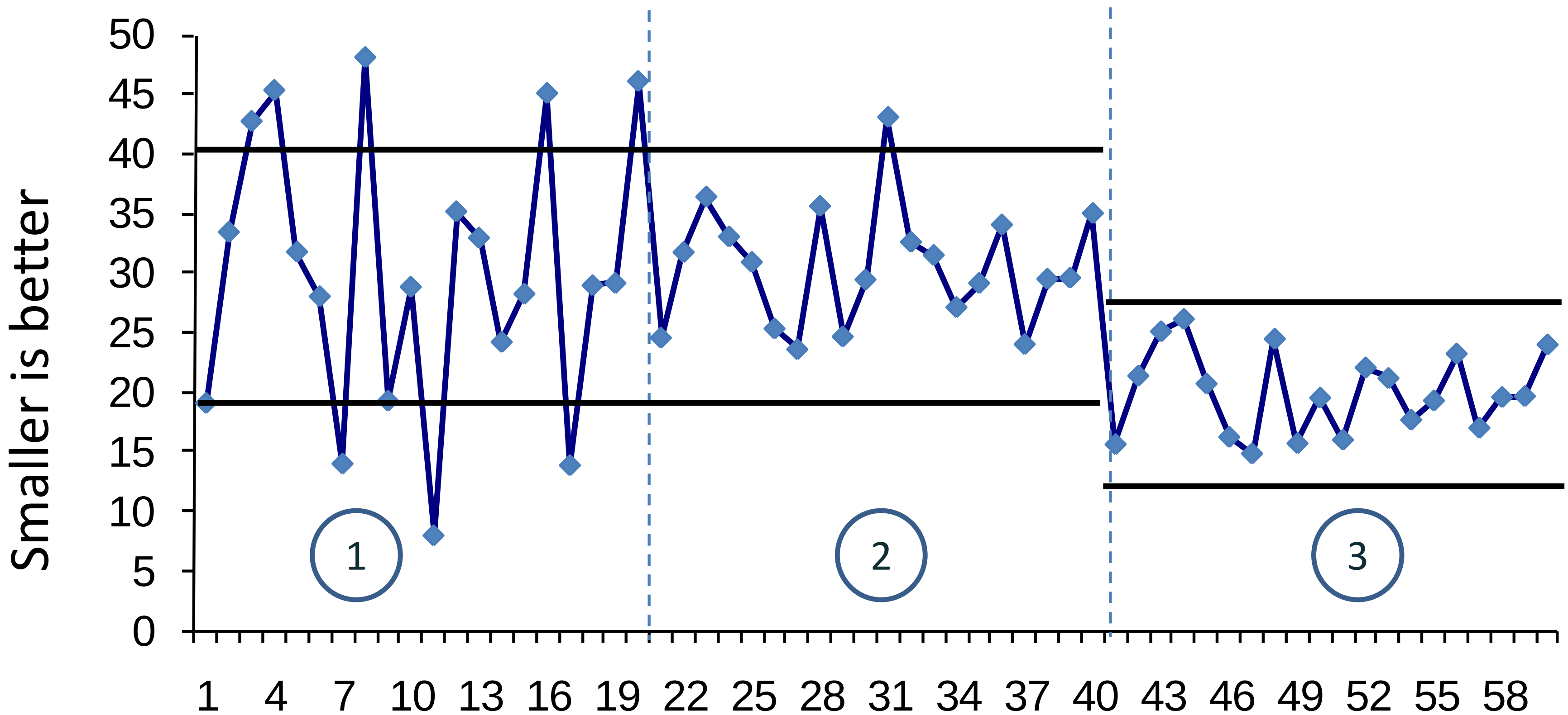


Figure 2.4 Results of a before-and-after test.



The Long Term Goal

(Moving from Chaos to Consistency to Improvement)

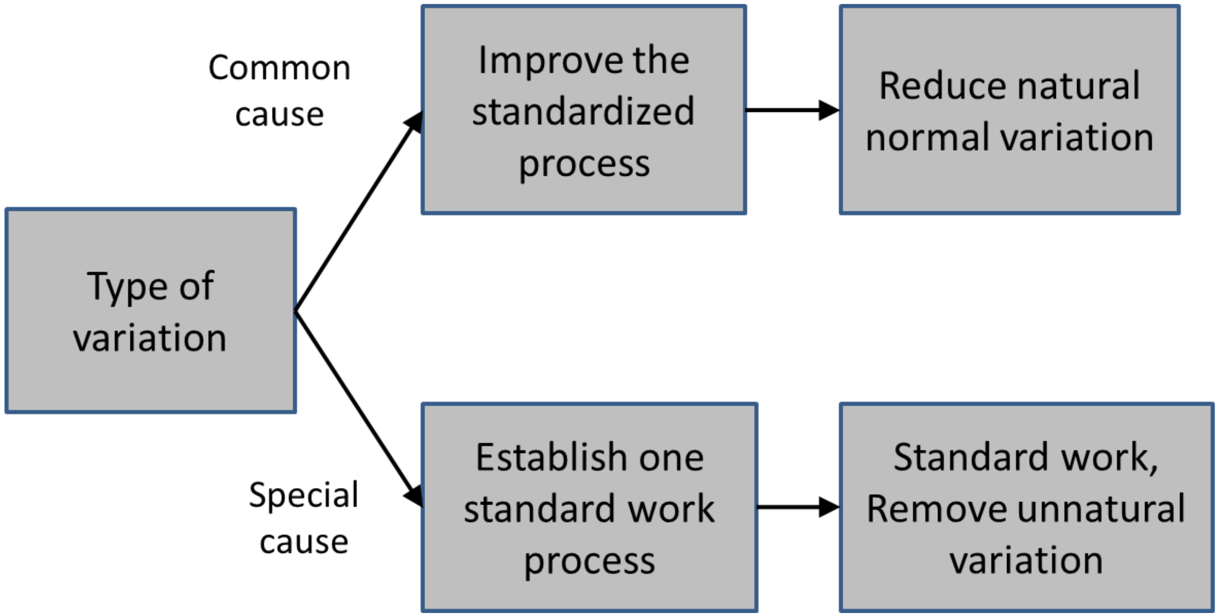


Pure chaos
No standard process

Monitoring
Std process

Improved
process

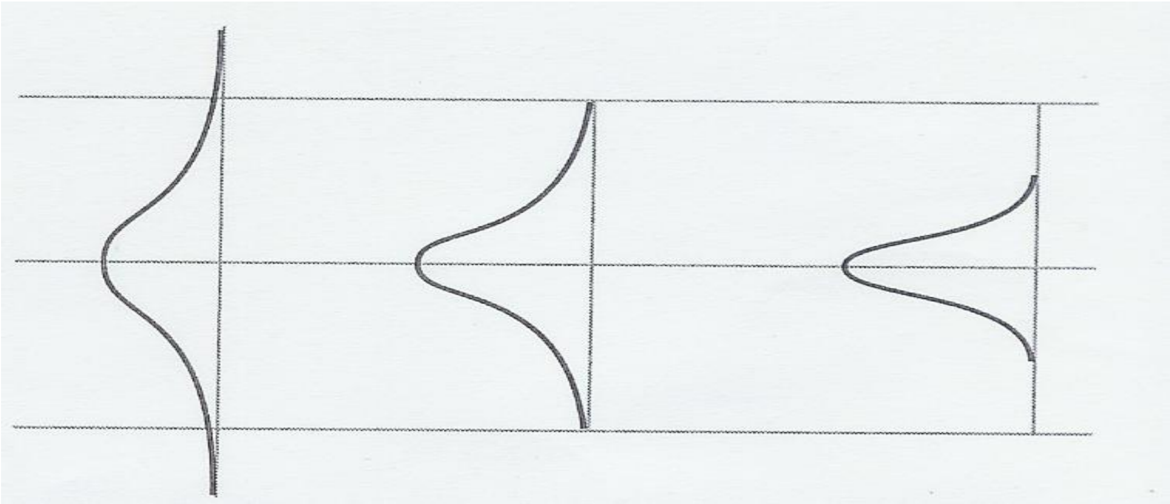
Boring but important



- Type of variation $\rightarrow$ Type of reaction
- ‘Standard work’ = Consistent processes
- Consistent process exhibits only common cause variability

Deming's message

"If I had to boil my entire message to management down to just one thing, I'd say it all has to do with … understanding, managing, and reducing variability."



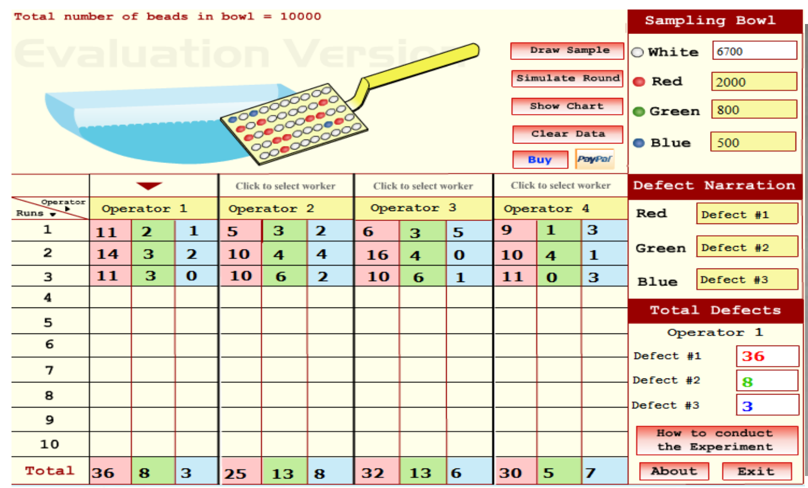
Time →

W. Edwards Deming

1 Deming's red bead game

- Red beads = process defects (e.g. AE's)
- 4 managers and 1 chief ('willing workers')
- 5 months of operation
- Focus on rewards and penalties (shake the box better)
- No improvement focus (improve the box)

Red Bead Experiment with Dr. W. Edwards Deming



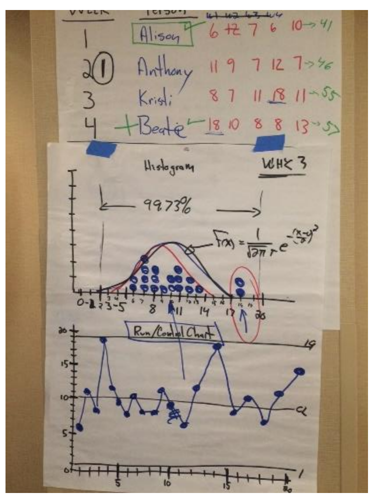
Lessons from the red beads

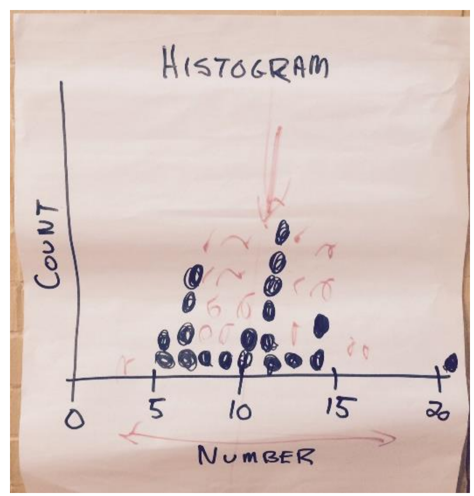
Management

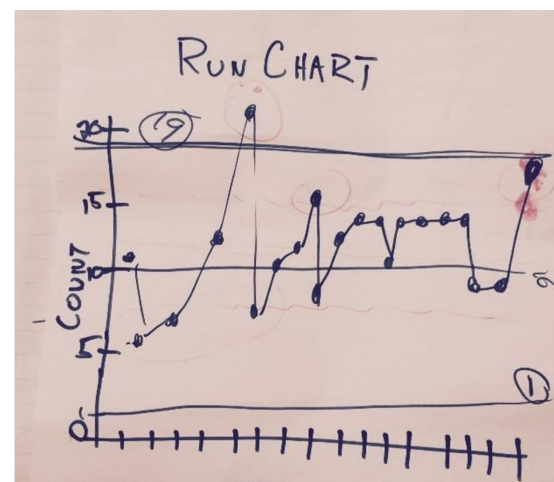
- Importance of testing and learning system
- Process vs. people causes
- 85% problems due to system

Statistical

- Natural variation
- Valid/invalid interpretation
- Data over time importance
- Statistical thinking

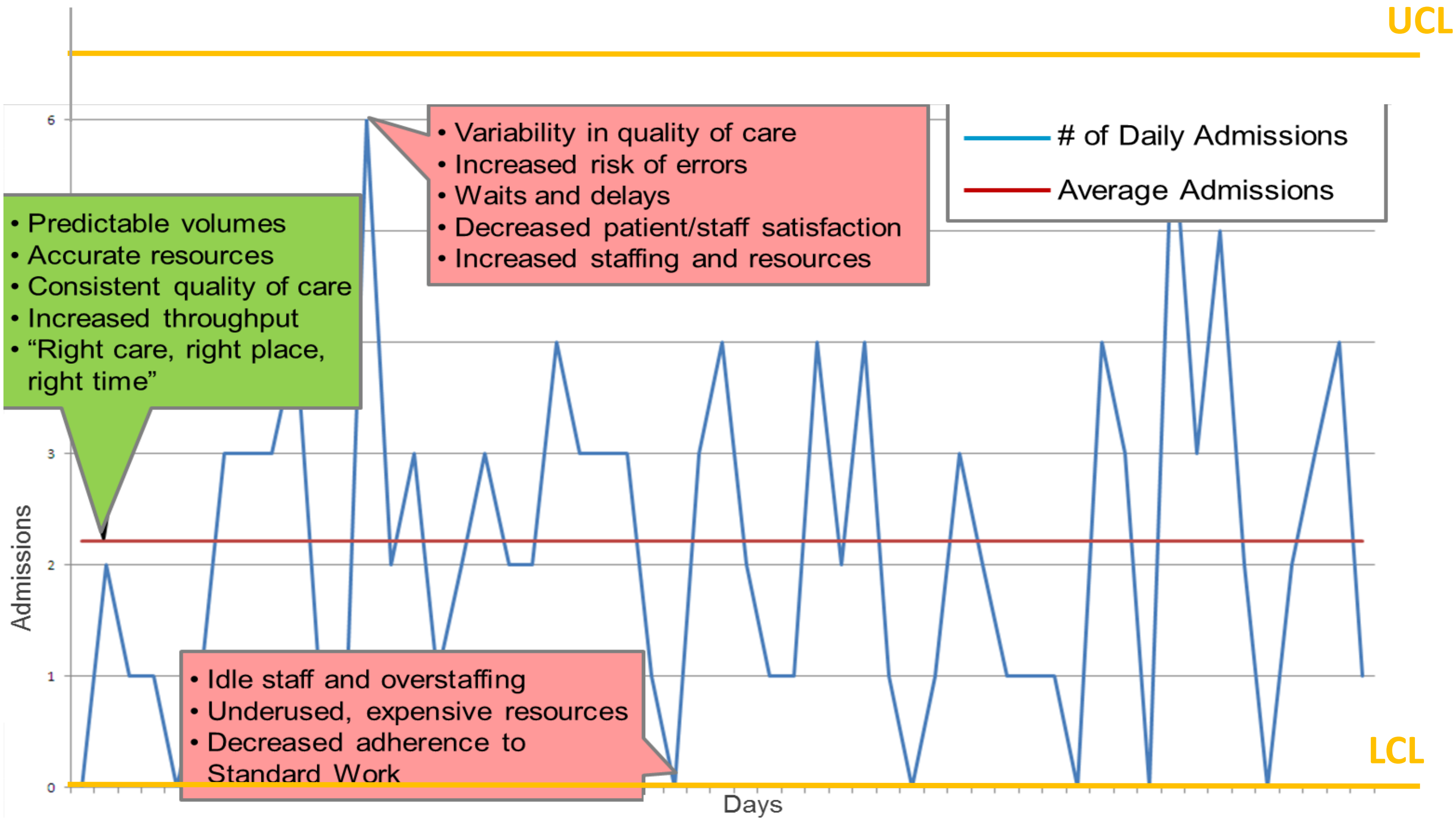






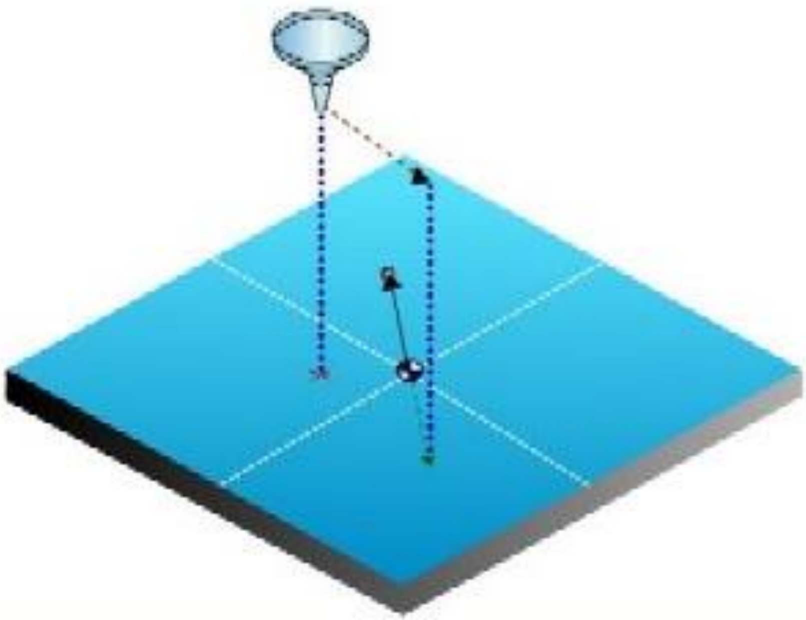
Reacting to natural variation

- Recent example, well-know "LSS" system

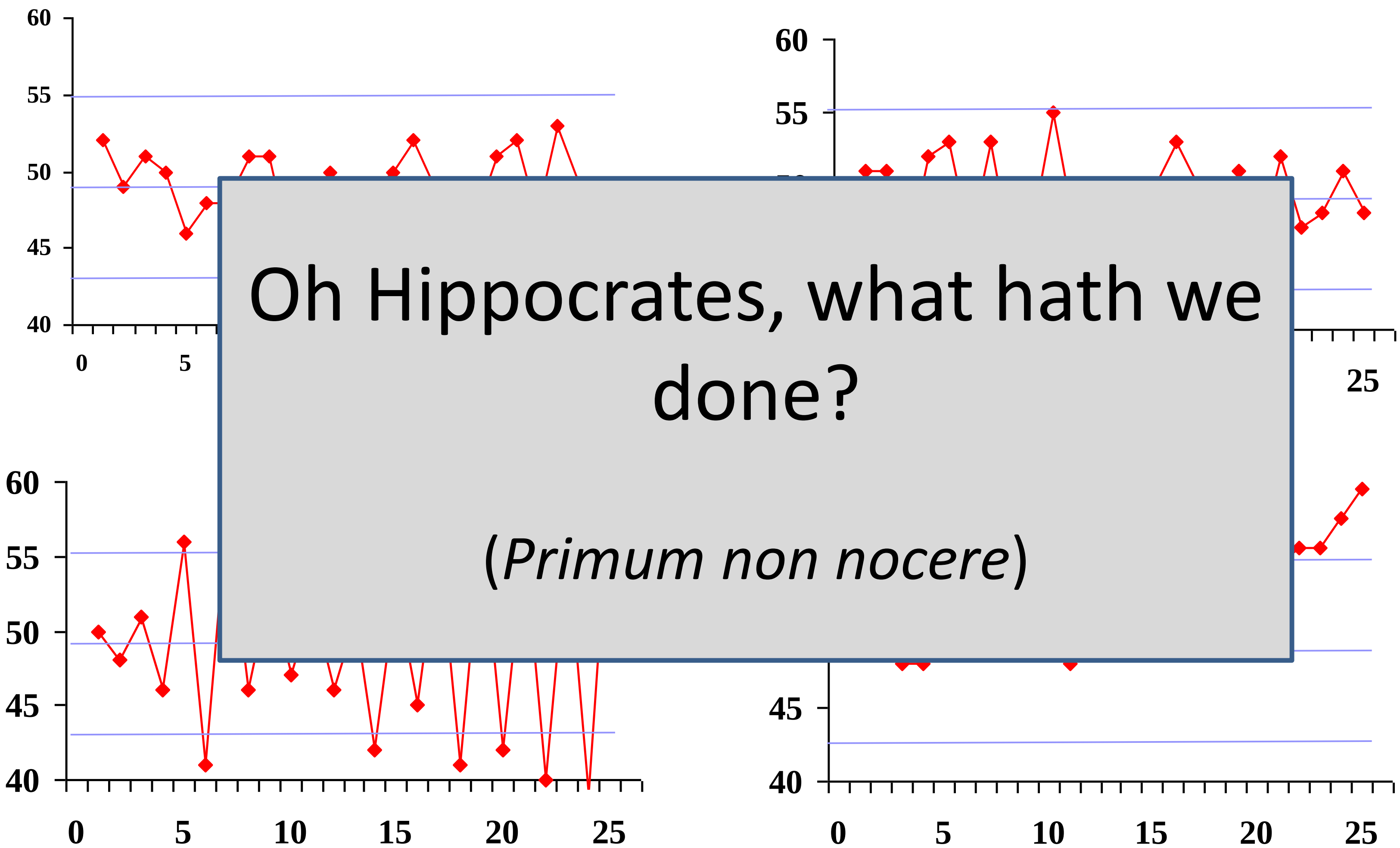


2 Nelson's funnel game

- Reacting to natural variation
- Improvement intent
- Strategies
  1. Leave stable process alone (rule 1)
  2. Adjust in some way (rules 2-4)



Why this matters



Oh Hippocrates, what hath we done?

(*Primum non nocere*)

What would Shewhart say?

***Controlling Variation in Healthcare: A Consultation from Walter Shewhart*, Berwick, 1991, <u>Medical Care</u>*, 29 (12), 1212-25**

Measure prothrombin times and change anticoagulants. Measure oxygen tensions and change respirator settings. Measure fever and change antibiotics. Measure blood pressure and change antihypertensive. Measure leukocytes and change chemotherapies. Measure pain and change analgesia. Measure electrolytes and change …

a few mechanics

Constructing control charts

Type of data → Type of chart → Sample size → Math (software)

<u>Variable (Continuous) Data</u>

1. Numerical value for each unit in a group

<u>Attribute (Integer) Data</u>

2. Classification: presence or not of an attribute
3. Count: how many attributes occur in sample

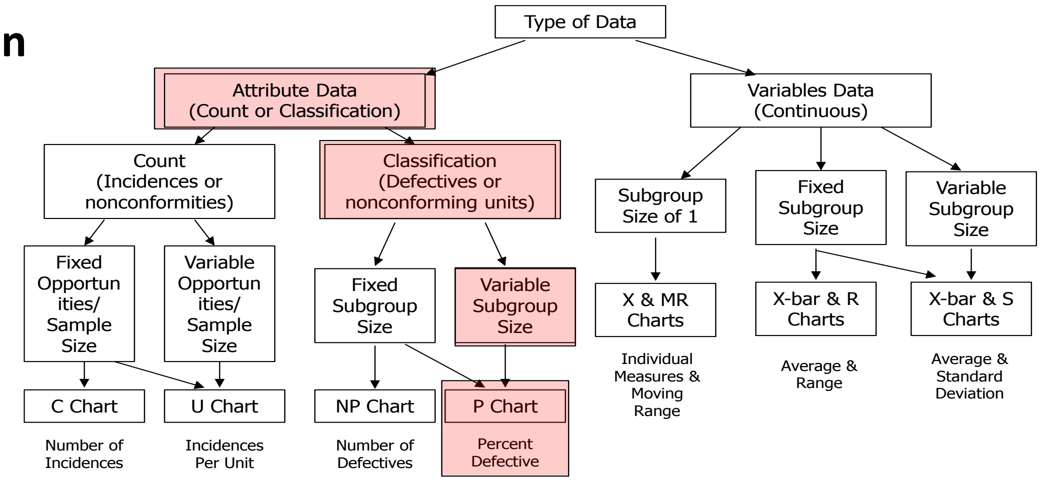
Statisticians: Data type → chart type

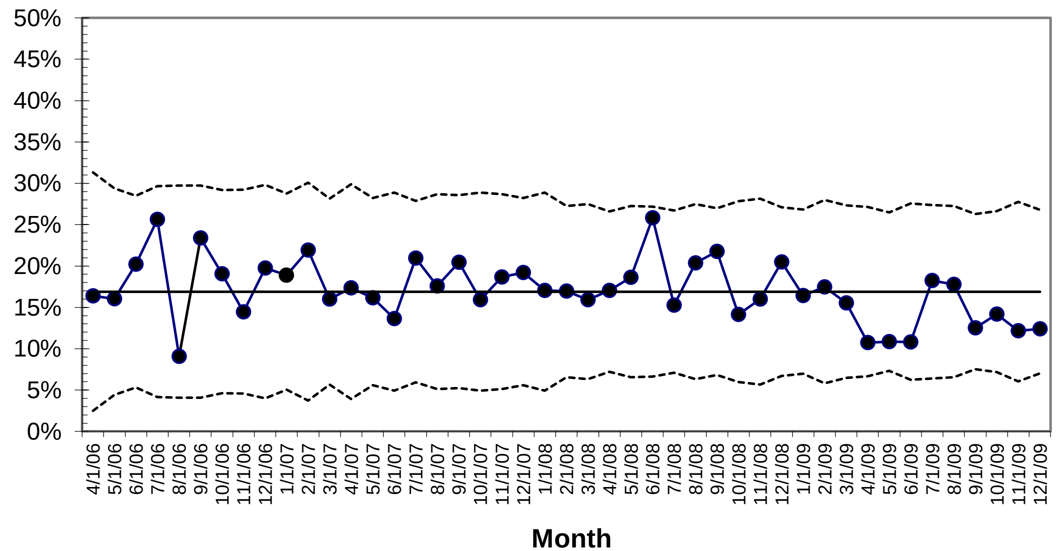
	Common cause probability model	Example	Chart type
Discrete	**Binomial** $$\Pr(X=k) = \binom{n}{k} p^k (1-p)^{n-k}$$ Parameter: *p*	Fraction of patients who develop an SSI	*p* √ (or *np*)
	Poisson $$\Pr(X=k) = \frac{\lambda^k e^{-\lambda}}{k!},$$ Parameter: λ	Number of device-associated HAIs per 100 device days	*u* √ (or *c*)
Continuous	**Normal** $$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}.$$ Parameters: μ, σ	Average time to deliver thrombolitics	*Xbar, S* √ (or others)

Example

Fraction VLBW babies discharged per month who had ≥ 1 infection during hospitalization

Month	Infants with ≥ 1 Infection	Patients Discharged
4/1/2006	10	61
5/1/2006	13	81
6/1/2006	19	94
7/1/2006	20	78
8/1/2006	7	77
9/1/2006	18	77
10/1/2006	16	84
11/1/2006	12	83
12/1/2006	15	76
1/1/2007	17	90
2/1/2007	16	73
3/1/2007	16	100
4/1/2007	13	75
5/1/2007	16	99
6/1/2007	12	88
7/1/2007	22	105
8/1/2007	16	91
9/1/2007	19	93





SPC phases – establishing standard work

- Most processes initially are not in-control
- Identify and remove assignable causes
- Eliminate associated data
- Re-compute limits
- Repeat until in-control
- A (single one) process exists

Unnatural variation

Natural variation

Understand Past Performance

- Is process unstable or in statistical control?
- Begin trial control charting

Establish Consistent Process

- Iterative process using trial control charts
- Bring process into statistical control
- Remove *existing* sources of <u>unnatural</u> variability until in-control

Improve Stable Process

- Remove sources of <u>natural</u> variability
- Position the average & reduce variability until acceptable
- Test and verify impact of interventions and improvements

Monitor Process for Instability

- Maintain a state of statistical control
- "Hold the gains"
- Identify & remove *new* special causes of unnatural variability

Implementation details

- Sample/subgroup size
- Unequal samples
- When adjust limits
- What data to use in limits
- Standards, benchmarks
- 2 vs. 3 standard deviations
- Non-normal data
- others

Pandora's Box

Summary

- SPC useful tool and way of thinking
- Different uses of SPC
- Common types of control charts
- Selection, construction (important)
- More advanced methods

Discussion

www.hsye.org

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