Successfully Using SPC in Service Applications

Methods and Case Studies

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Objectives

Value of SPC/SQM in Service Settings
- Control Charts, Other Tools
- Cost of Quality → When to "Inspect"?

Examples:
- HMO Enrollment Process, Labs
- Customer Satisfaction, Others

References for Further Info

Background and Motivation

Essence of Dr. Deming's Message

"If I had to reduce my message to management to just a few words, I'd say it all had to do with reducing variation..."

"... developing an understanding of the process, and the optimization thereof."

SPC, TQM, and economic models can help develop this process understanding

Understand Process Performance

"Data Driven" vs. Intuition

"Simply stated, quality improvement refers to organized, rational, *scientifically valid* programs that analyze what people are doing - in industry, medicine, or any other area - and then devise ways in which the job can be done even better."[1]

SPC tools can help with this understanding

1. Nazarian, L.F. (1993). Preface to article by D. Bergman: "Quality Improvement: Buzz Words or Boon?", *Pediatrics in Review*, Vol. 14, No. 6, p. 207.

The Cost of TQM?

One Opinion . . . ?

"The reality is that (quality control procedures) increase work... and cost... Many studies have shown that a Total Quality Management system *adds* at least 25% to overall laboratory costs."[2]

"In my opinion, there are no known quality control procedures that do not impact workload or cost."[3]

2. Inhorn S: "Quality Assurance and Quality Control in Clinical Cytology...", *Compendium on Quality Assurance, Proficiency Testing, and Workload Limitations in Clinical Cytology*, 1995
3. Mango L, ibid.

Dr. W. Edwards Deming

A Different Way of Thinking About Quality and Costs

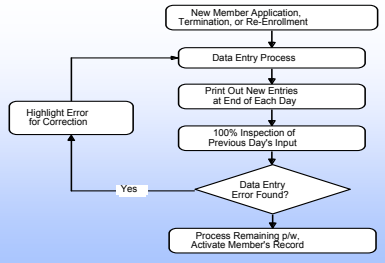
Improve Quality ⇒ Reduce Total Costs

The philosophy of "Quality Management", understood and instituted effectively, *reduces* long-term total costs:

- **Understand, improve, and control process quality**
- **Statistical process control**
- **Economic models to minimize total costs**

Member Enrollment Case Study

Member Enrollment Process



Process Improvement Team

High Data Entry Error Rate, Long T-A-T

Regular Meetings

- **Review data, Study process**
- **Identify root causes of errors**

Missing fields, Numeric Fields, Unfamiliarity

Training, Form simplification, others

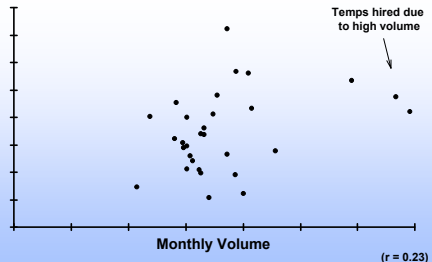
"Diagnostic Journey" . . .

Sources of Errors?

Pareto Chart

Due to High Volumes?

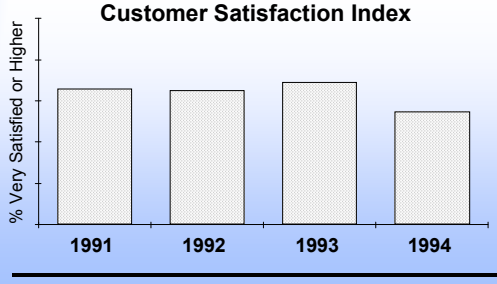
Scatterplot & Correlation Analysis



Control Chart Mini-Tutorial:

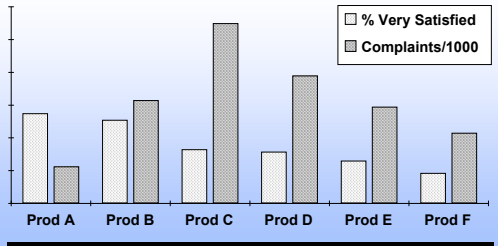
Customer Satisfaction and Service Complaints

Given the Following, What Do You Conclude...?

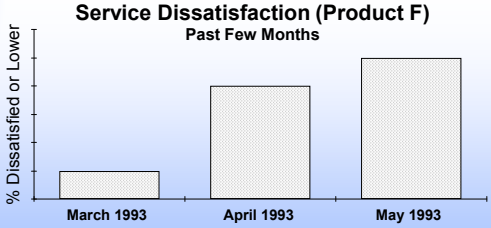


Annual Satisfaction Survey

Standard "Time-Static" Comparison



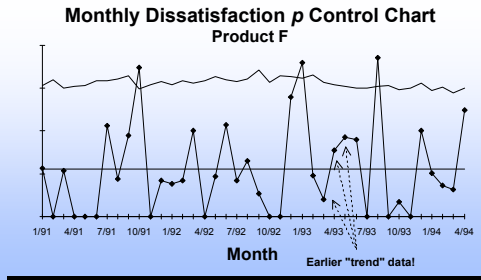
Given the Following, What Do You Conclude...?



What is the cause of this "trend"?

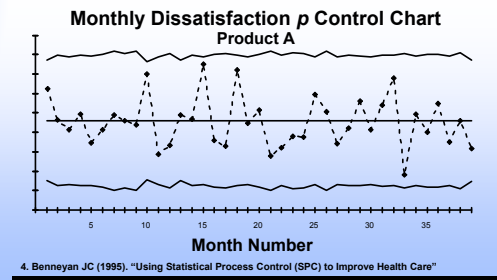
Yet There is Natural Variability Here

Also Unnatural Special Cause Variability



Example of "In Control" Process

No Irregular Events - Only "Natural" Variability[4]

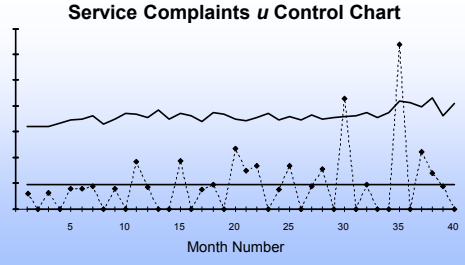


4. Benneyan JC (1995). "Using Statistical Process Control (SPC) to Improve Health Care"

A Different Kind of Variability

Poor Service Quality - Deteriorating Over Time

Service Complaints *u* Control Chart

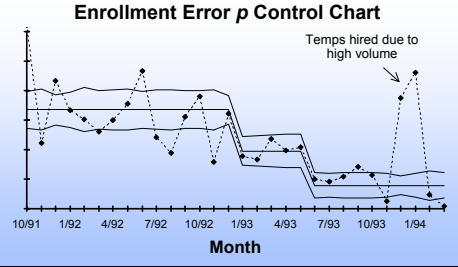


Back to the Member Enrollment Process...

Improving Enrollment Process

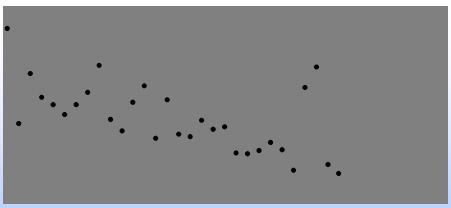
(Turn-Around-Time Also Control Charted)

Enrollment Error *p* Control Chart



Suppose Improving Trend Continues?

(Special-Purpose Trend Control Chart)



Should They Be Inspecting At All?

Dr. Deming's "14 Points" (Point 3)

"Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place."

- Dr. W. E. Deming

Inspection Time & Cost Still Justified . . . ?

4 General Inspection Approaches

Objective: Minimize Total Quality Costs

~ 100% Inspection ~
To ensure no costly errors passed along

~ 0% Inspection ~
To save associated time and $$$

~ Inspect a Random Sample ~
To balance above costs?

~ Multiple 100% Inspections ~
If costly inspection errors exists

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Deming's k_1/k_2 Cost Model

Simple "Cost of Poor Quality" Method

Simple Method to Minimize Costs

Cost / Input Estimates:

- **Fraction Data Entry Errors (p) - 0.005**
- **Number Entered per year - 150,000**
- **Cost to Inspect an Item (k_1) - $0.52**
- **Cost of Undetected Error (k_2) = ???** ($0.58 ↔ $35)

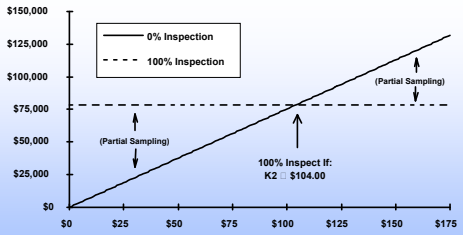
Annual Cost for Each Inspection Policy

- **See references for formulas**

Benneyan JC (1994) "Tutorial on Applying Deming's k1/k2 Inspection Cost Minimization Rule"

Cost of Poor Process Quality

0% vs. 100% vs. Partial Inspection



Simple k_1/k_2 Criterion

Minimize Total Poor Quality Cost

If		Optimal Inspection Policy
k_1 / k_2 Š p	⇒	100% Inspect
$k_1 / k_2 > p$	⇒	0% Inspect ¦

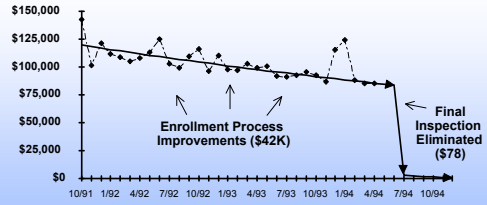
Partial Sampling Never Minimizes Total Costs!!

(Counter-Intuitive)

Higher Quality ⇒ Lower Costs

Deming was Right!

Annual Savings of Process Improvements



Other Benefits

"We have eliminated unnecessary work, streamlined our key processes, and replaced frustrating work with more meaningful work. The new process also significantly reduces turn-around-time... with less resources."

- Manager of Enrollment Process

- **Increased staff & customer satisfaction**
- **Other applications, transfer process . . .**

Other SPC and Inspection Service Applications

Other Identified HMO Applications

Possible Savings □ $600,000 / year

- **Medical Records**
- **Prescription Accuracy**
- **Internal Audit, Cash Handling**
- **Accounts Receivable**
- **Outside Utilization Authorization**
- **Clinical laboratories . . .**

Other k_1/k_2 Applications

Average □ 5% net operating costs common

- **Accounts Receivable Dept** **($.5M - $1M / year)**
- **Bank Payroll Dept** **($4.75 per transaction)**
- **Insurance Eligibility Review**
- **Integrated TV circuits** **($24 / set - 15% of mfg cost)**
- **Auto Engine Testing** **($47 / motor - $185,000 / day)**
- **Biomedical Device lawsuit** **(Loss of life)**

Where do <u>You</u> Partial, 0%, or 100% "Inspect"?

Some Other Service SPC Uses

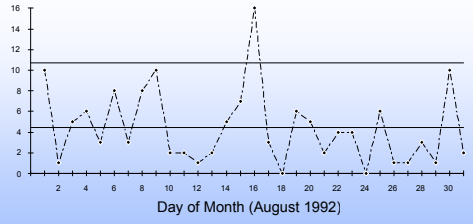
Many Others . . .

- Budget Variances, Sales, Utilization
- Timeliness of Subways, Trains, Planes
- Census Data Accuracy, Process Times
- U.S. Postal Service
- Banking, Finance, Insurance
- Public Utilities, Government, Accident Rates
- Customer Satisfaction / Complaints
- Service Calls & Response Times . . .

Information Systems Support

Help Desk Service Calls

Number of Service Calls *u* Control Chart

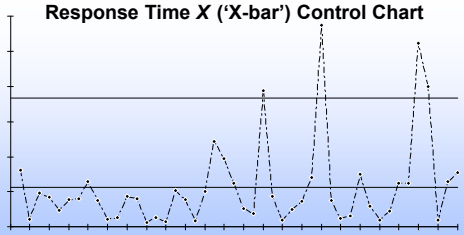


(* Also significant Day-of-Week differences...)

Time to Return Service Calls

Where Would You Start Investigating?

Response Time $\bar{X}$ ('X-bar') Control Chart

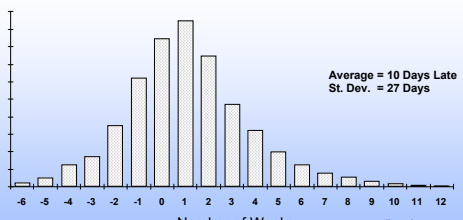


(*S* Chart also 'Out-of-Control')

On-Time Delivery

Deviation from Customer Requested Date

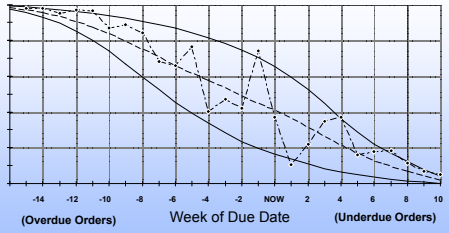
Histogram of Number of Weeks Late (Early)



Is It Getting Any Better?

A Special Type of Control Chart: In-Process Orders

Fraction of Due Orders Shipped



Laboratory Applications

Lab Pap Smear Figures

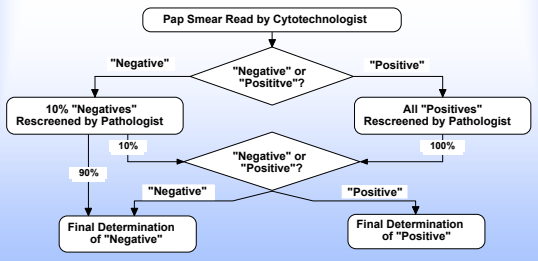
- **Approximately 50 Million Annually (USA)**
- **200,000 Cervical Cancer Deaths/year**
- **Estimated 1.5% of Pathologists Involved in Litigation for False Negative Readings**
- **Cure Rate in Early Stages Near 100%**
- **Advanced Cervical Cancer Much Less Successfully Treated**

Laboratory Quality Concerns

- **Several Recent False Negative Settlements:**
  - **$3.5 Million**
  - **$6.3 Million**
  - **Recent Criminal Charges**
- **Diane Sawyer (Newport Hospital) - 1994**
- **1988: Congressional Hearings and Federal *Clinical Laboratory Improvements Act* (CLIA)**

CLIA'88 10% QC Requirement

How Well Does This Process Perform?



Some Criticisms of CLIA'88

"... 10% rescreening ... is a waste of every-one's time and effort."

W.M. Hindman, M.D.

"Using rescreening of 10% of the negative gynecologic smears, it would take 11 years to distinguish between acceptable and unacceptable performance of a cytotechnologist."

G.M. Lundberg, M.D.

Lab "Inspection" Costs?

Multiple *n* Readings, *r*% Re-read

Expected Cost per *n* Processed Smears

$$EC = k_1 n \left\{ \frac{(1 - \alpha_c^{\,j})}{1 - \alpha_c} + (1 - p) \frac{\left[1 - (1 - \beta_c)^{\,j}\right]}{\beta_c} \right\} + k_2 \left[1 - (1 - r)\, p'\right] +$$

$$k_3\, n (1 - p) \beta_p \left[1 - (1 - \beta_c)^{\,j} (1 - r)\right] + k_4\, p\, n \left\{ - (1 - \alpha_p) \left[1 - \alpha_c^{\,j} (1 - r)\right] \right.$$

$$\text{where } p' = p\, \alpha_c^{\,j} + (1 - p)(1 - \beta_c)^{\,j}$$

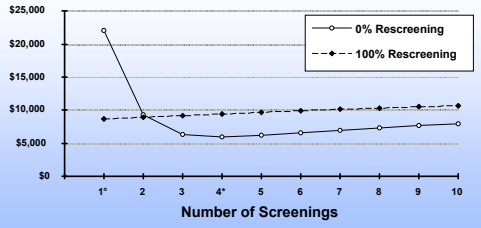
and p = Incidence rate of truly positive patients

Benneyan JC, Kaminsky FC (1996). "Statistical and Economic Models for Analysis and Optimal Design of Laboratory Screening Policies for Cervical Cancer", *Annals of Operations Research*

Optimal Number of Readings?

One Example

Total Cost per 100 Smears



Partial Rescreening Never Optimal!

Similar to the k_1/k_2 Criterion

$$\frac{k_2 + k_3 (1-\beta_c)^{j} \left[\frac{1-p}{p'} \beta_p\right]}{k_4 \left[\frac{p}{p'} (1 - \alpha_p)\, \alpha_c^{\,j}\right]} \quad \begin{matrix} < 1 \Rightarrow \text{100\% Rescreen} \\ > 1 \Rightarrow \text{0\% Rescreen} \end{matrix}$$

Sound Familiar . . . ?

(Widely applicable in many other settings . . .)

Benneyan JC and Kaminsky FC (1995): "Proof of Sub-Optimality of the CLIA 10% Pap Smear and Other Clinical Laboratory Partial Rescreening Policies from a Minimum Cost Viewpoint", working paper.

Summary of Pap Smear Analysis

Studied via SPC & Quality Cost Methods

- **CLIA'88 Increases Total Costs**
- **Negligible Reduction in False Negatives**
- **Never Optimal Policy**
- **Automated Screening often Much Worse!**

SPC is a Correct Quality Assurance Method

Management Recommendations

What To Do Instead? (*Any* Process)

1. **Optimize Current Process via Cost Models**
2. **Control Current Quality via SPC**
3. **Improve Process (Sensitivity & Specificity) via CQI, DOE, Human Factors, etc.**

What does doing it right mean?

Role of SPC in Lab Quality

Mammography (Spring *et al*)

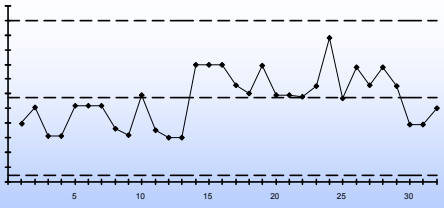
"A *continuing longitudinal study*, reviewing data over several years, may *detect* unexpected *sources* of false-negative errors..."

"*Monitoring* may identify areas of patient care that fall short of evolving national standards..."

"*Trends* in clinical performance that indicate less than optimal care can be identified..."

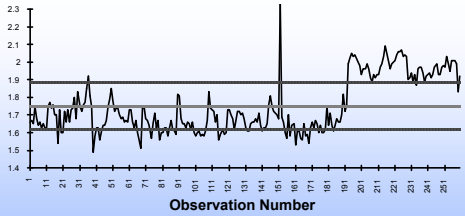
Sounds Like SPC!

Pap Smear Test for Cervical Cancer



Lab process quality has significantly changed.

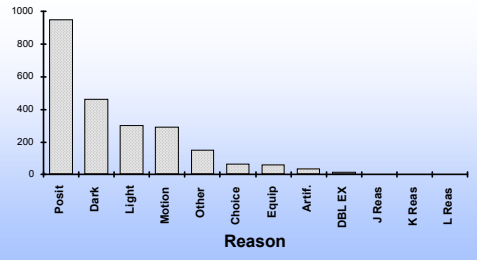
Mammography Control Chart



Poor Quality is Preventable!

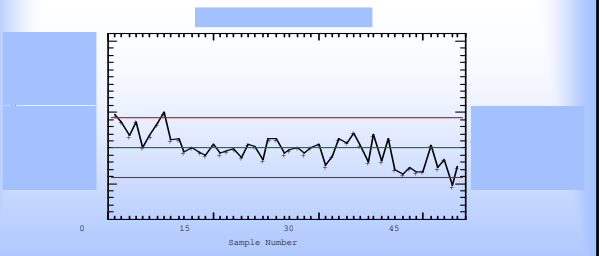
Reasons for Poor X-rays?

Pareto Chart



HIV Quality Control Chart

Downward Trend in Calibration



How Concerned Should Patients Be?

Pitfalls to Avoid and References

Endemic Philosophical Errors

- **Non-Mfg processes can not be interpretted via SPC and natural variability...?**
- **QA should focus on outcomes (inspection), rather than on *processes* (prevention)...?**
- **Over-reliance on high level metrics**
- **SPC ° Software and automation**

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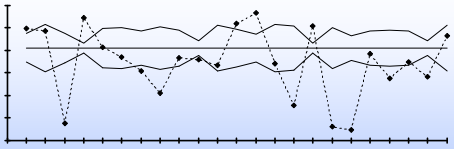
"SPC Not Applicable Here" Syndrome

Voluntary Disenrollment (Customer Dissatisfaction)



Month

"Our processes shouldn't be in control" !?

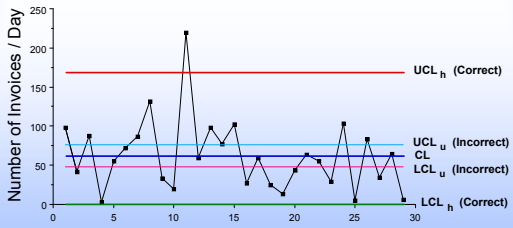
Common Statistical Errors

Much Bad Lay-Advice Out There

- Using an $\bar{X}$ chart without an *S* or S^2chart
- Overuse / misuse of "individuals" chart
- "Short-cut" control limit formulas
  - Invalid...!!
  - Not using 3 standard deviation limits
  - Not using *at least* 25 to 35 subgroups
- Frequent use of incorrect chart . . .

Accounts Receivable Controls

Freight Administration *h* Control Chart



Benneyan, J. C. (1994). "The Importance of Modeling Discrete Data in SPC: The *g*, *h*, and Related Charts", invited paper, *Tenth International Conference of the Israel Society for Quality*, pp. 640-646.

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For More Information . . .

For additional references, tutorial articles, case studies, specifics on any of the illustrated applications, and/or assistance with statistical quality control, please contact:

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