Lektion 3

2007-11-14

Chapter 4

Statististical process control

High product quality

- Repeatability and
- Statistical process control.
- Control

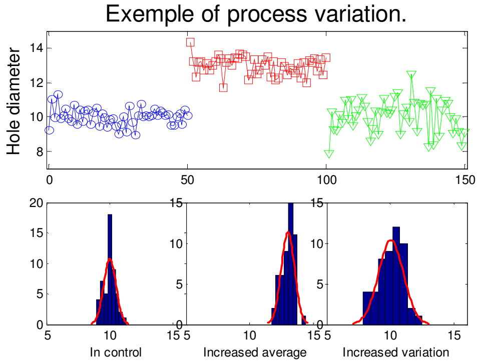
SPC
7 good QC-tools (Ischikawa)

1. Histogram
2. Check sheet (*datainsamling*)
3. Pareto diagram
4. Cause-and-effect diagram. (*fiskbensdiagram, Ishikawadiagram*)
5. Defect concentration diagram (*stratifiering??*)
6. Scatter diagram (*sambandsdiagram*)
7. Control chart (*styrdiagram*)

Statististical process control

- Chapter 4: *Methods and Philosophy*
- Chapter 5: *Control Charts for Variables*
- Chapter 6: *Control Charts for Attributes*
- Chapter 8: *CUMSUM and EWMA*
- Chapter 9: *SPC with autocorrelated data*
- Chapter 10: *Multivariate Process Monitoring and Control*
- (Chapter 11: *Engineering Process Control and SPC*)

Exemple of process variation.

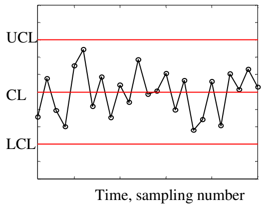


Kör matlabexemplet!

Sources of variation

- Chance causes (*Slumpmässiga källor*)
  - Random variation
  - Background noise
  - Statistical control, stable process
- Assignable causes (*Systematiska källor*)
  - There is a cause
  - Out of control
  - Not stable
- The purpose of SPC is to detect and eliminate systematic (assignable) sources of variation!

Control Charts



$$\begin{cases} H_0: & \mu = \mu_0 \\ H_1: & \mu \neq \mu_0 \end{cases}$$

Type I error: False alarm
Type II error: Not raise alarm

OBS: control limits ≠ specification limits

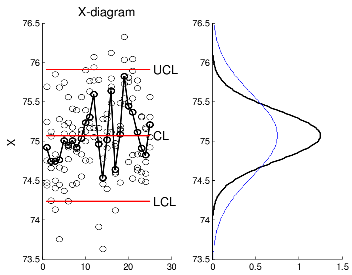
Shewhart control chart

$$\begin{cases} UCL = \overline{x} + L\sigma_{\overline{x}} \\ CL = \overline{x} \\ LCL = \overline{x} - L\sigma_{\overline{x}} \end{cases}$$

The average spreads less:

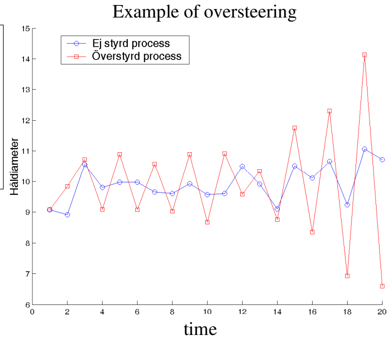
$$\sigma_{\overline{x}} = \frac{\sigma}{\sqrt{n}}$$

L=3 or 3.09 (often)



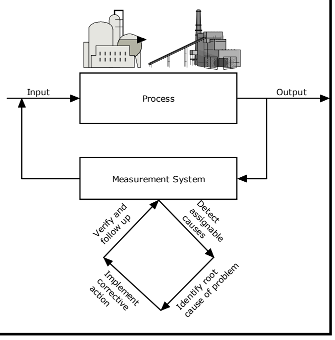
Do not control the process on individual values!

Gives more variation!



Control charts

- Supervision is not enought for good quality – Act!
- Out-of-Control Plan OCAP



OCAP – very important!

Analyse the system:
- S-FMEA
- Fault tree analysis (FTA)
- Design of experiments
- Fishbone diagram
- Et.c.

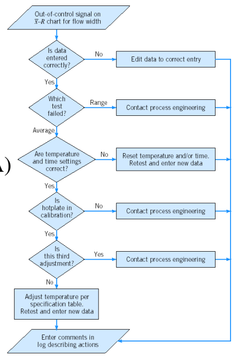


Figure 4-6 The out-of-control-action plan (OCAP) for the hard-bake process.

More principles

- Control charts can be used for analysis of *process capability*.
- Two types of charts:
  - Variable control
  - Attribute control
- Design of plans in SPC
  - Sample sizes, frequency, risk assessment…

Different types of process variation.

- Stationary and uncorrelated processes (white noise)
- Stationary and correlated processes
- Nonstationary

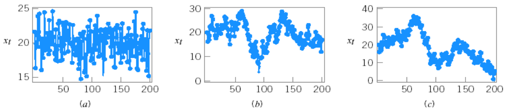


Figure 4-7 Data from three different processes. (*a*) Stationary and uncorrelated (white noise). (*b*) Stationary and autocorrelated. (*c*) Nonstationary.

Reasons for Popularity of Control Charts (according to Montgomery)

1. Control charts are a proven technique for improving productivity.
2. Control charts are effective in defect prevention.
3. Control charts prevent unnecessary process adjustment.
4. Control charts provide diagnostic information.
5. Control charts provide information about process capability.

Control limits

- Influences both **type I** and **type II** error.
- 3-σ control limits (normal data)
  - P(Type I) = 0.0027
- Probability limits
  - P(Type I)=0.002 → 3.09-σ limits (normal data).
  - P(Type I)=0.002 is called 0.001 limits (funny)
- Warning limits at 2σ
  - Increased sensitivity
  - Adaptive sampling plans

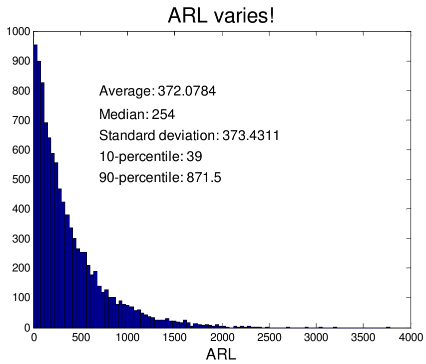
Sample size and sample frequency

- Small samples often or large not so often?
- Large samples detects small shifts easier.
- Average run length: $ARL = \frac{1}{p}$

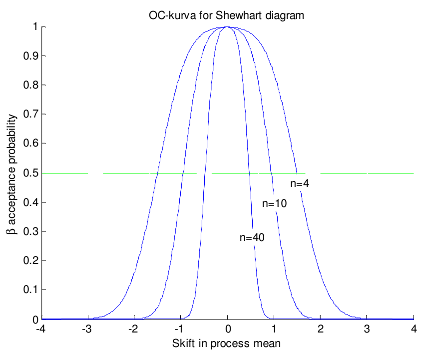
$$ARL_0 = \frac{1}{p} = \frac{1}{0.0027} = 370$$

- Average time to signal: $ARLS = ARL \cdot h$

$ARL \sim geo(p)$

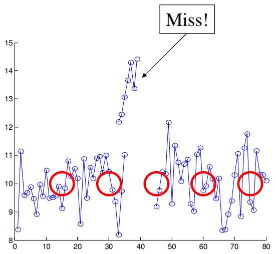


$X \sim N(0,1)$



Sampling frequency

- Depends ont he process and on potential systematic causes.
- We want to catch occasional systematic causes.



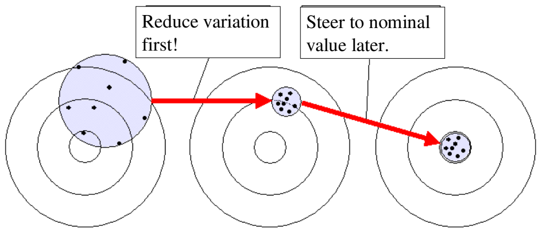
Rational subgroup

- Fundamental idea in SPC
- The idea is to choose sample groups so that
  - The chance for differences between subgroups will be maximized.
  - The chance for differences within subgroups will be minimized.

Two types of sub groups

1. The units are manufactured at the same time.
   - ”Snapshot”
   - Detect shift in average.
2. The units are a random sample from the whole period between the sampling time points.
   - Acceptance
   - Easier to detect fast temporariliy shifts in process average.
   - Observe that every process seems to be stable if the time between observations is long enough.

Study always two diagrams average and spread

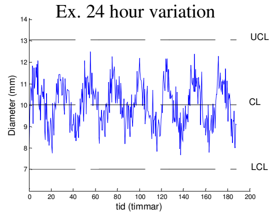


Analyze patterns in diagram.

Western Electric handbook:

1. One point outside three-sigma control limits.
2. Two out of three consecutive points pllot beyond the two-sigma warning limits.
3. Four out of five consecutive points plot at a distance of one-sigma or beyond from the center line.
4. Eight consecutive points plot on one side of the center line.

Ex. 24 hour variation



Warning: Increased risk of false alarm!

Phase I and Phase II of Control Chart Application

- **Phase 1:** Analyze process data to design *trial control limits. (Retrospective)*
  - Stabilize the process by elimination of systematic sources of variation.
  - MSA, wrong data handling, human error et.c.
- **Phase 2:** *Monitor the process*
  - Processen is rather stable.
  - Monitoring instead of stabilizing.

4-4 THE REST OF THE "MAGNIFICENT SEVEN"
(the rest of this presentation is borrowed from Montgomery)

1. Histogram or stem-and-leaf plot
2. Check sheet
3. Pareto chart
4. Cause-and-effect diagram
5. Defect concentration diagram
6. Scatter diagram
7. Control chart

Check Sheet

CHECK SHEET
DEFECT DATA FOR 2002–2003 YTD

Part No.: TAX-41
Location: Bellevue
Study Date: 6/5/03
Analyst: TCB

	2002												2003					
Defect	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	Total
Parts damaged		1		3	1	2		1		10	3		2	2	7	2		34
Machining problems			3	3				1	8		3		8	3				29
Supplied parts rusted			1	1		2	9											13
Masking insufficient		3	6	4	3	1												17
Misaligned weld	2																	2
Processing out of order	2															2		4
Wrong part issued		1						2										3
Unfinished fairing			3															3
Adhesive failure				1							1		2			1	1	6
Powdery alodine					1													1
Paint out of limits						1								1				2
Paint damaged by etching			1															1
Film on parts						3		1	1									5
Primer cans damaged								1										1
Voids in casting									1	1								2
Delaminated composite										2								2
Incorrect dimensions											13	7	13	1		1	1	36
Improper test procedure										1								1
Salt-spray failure													4			2		4
TOTAL	4	5	14	12	5	9	9	6	10	14	20	7	29	7	7	6	2	166

Figure 4-16 A check sheet to record defects on a tank used in an aerospace application.

Pareto Chart

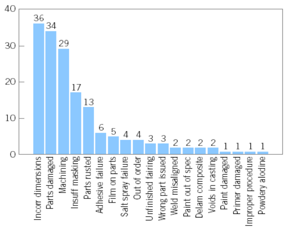


Figure 4-17 Pareto chart of the tank defect data.

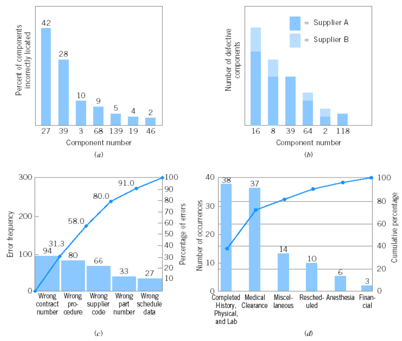


Figure 4-18 Various examples of Pareto charts.

Cause-and-Effect Diagram

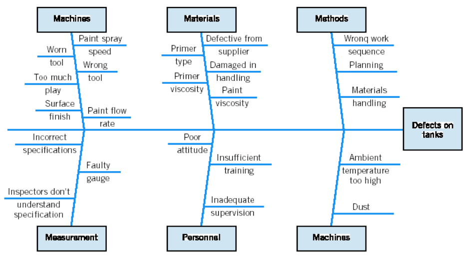


Figure 4-19 Cause-and-effect diagram for the tank defect problem.

How to Construct a Cause-and-Effect Diagram

1. Define the problem or effect to be analyzed.
2. Form the team to perform the analysis. Often the team will uncover potential causes through brainstorming.
3. Draw the effect box and the center line.
4. Specify the major potential cause categories and join them as boxes connected to the center line.
5. Identify the possible causes and classify them into the categories in step 4. Create new categories, if necessary.
6. Rank order the causes to identify those that seem most likely to impact the problem.
7. Take corrective action.

Defect Concentration Diagram

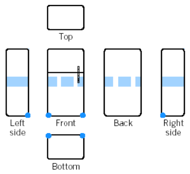


Figure 4-20 Surface-finish defects on a refrigerator.

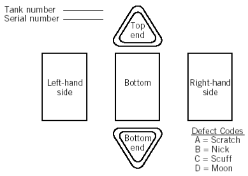


Figure 4-21 Defect concentration diagram for the tank.

Scatter Diagram

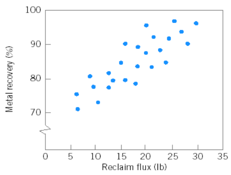


Figure 4-22 A scatter diagram.

4-5 IMPLEMENTING SPC

Elements of a Successful SPC Program

1. Management leadership
2. A team approach
3. Education of employees at all levels
4. Emphasis on reducing variability
5. Measuring success in quantitative (economic) terms
6. A mechanism for communicating successful results throughout the organization

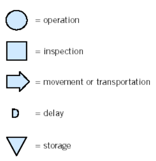
4-7 NONMANUFACTURING APPLICATIONS OF STATISTICAL PROCESS CONTROL

- Nonmanufacturing applications do not differ substantially from industrial applications, but sometimes require ingenuity
  1. Most nonmanufacturing operations do not have a natural measurement system
  2. The observability of the process may be fairly low
- **Flow charts** and **operation process charts** are particularly useful in developing process definition and process understanding. This is sometimes called **process mapping**.
  – Used to identify **value-added** versus **nonvalue-added** activity

Ways to Eliminate Nonvalue-Add Activities

1. Rearranging the sequence of worksteps
2. Rearranging the physical location of the operator in the system
3. Changing work methods
4. Changing the type of equipment used in the process
5. Redesigning forms and documents for more efficient use
6. Improving operator training
7. Improving supervision
8. Identifying more clearly the function of the process to all employees
9. Trying to eliminate unnecessary steps
10. Trying to consolidate process steps

Operation Process Chart Symbols



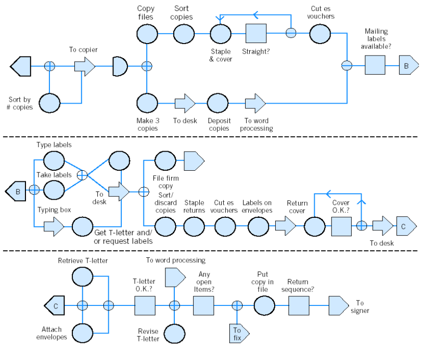


Figure 4-31 Flow chart of the assembly portion of the Form 1040 tax return process.

IMPORTANT TERMS AND CONCEPTS

- Assignable causes of variation
- Average run length (ARL)
- Average time to signal
- Cause-and-effect diagram
- Chance causes of variation
- Control chart
- Control limits
- Defect concentration diagram
- Designed experiments
- Flow charts and operations process charts
- Histogram
- In-control process
- "Magnificent seven"
- Out-of-control-action plan (OCAP)
- Out-of-control process
- Pareto chart
- Patterns on control charts
- Phase I and phase II application of control charts
- Rational subgroups
- Sample size for control charts
- Sampling frequency for control charts
- Scatter diagram
- Sensitizing rules for control charts
- Shewhart control charts
- Statistical control of a process
- Statistical process control (SPC)
- Stem-and-leaf plot
- Three-sigma control limits
- Warning limits

LEARNING OBJECTIVES

1. Understand chance and assignable causes of variability in a process
2. Explain the statistical basis of the Shewhart control chart, including choice of sample size, control limits, and sampling interval
3. Explain the rational subgroup concept
4. Understand the basic tools of SPC: the histogram or stem-and-leaf plot, the check sheet, the Pareto chart, the cause-and-effect diagram, the defect concentration diagram, the scatter diagram, and the control chart
5. Explain phase I and phase II use of control charts
6. Explain how average run length is used as a performance measure for a control chart
7. Explain how sensitizing rules and pattern recognition are used in conjunction with control charts