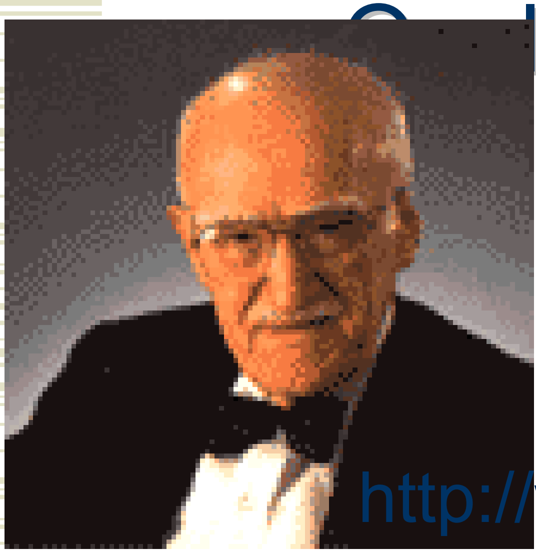
Meaning of Quality

- Webster's Dictionary
  - degree of excellence of a thing
- American Society for Quality
  - totality of features and characteristics that satisfy needs
- Consumer's and producer's perspective

http://www.deming.org/deminghtml/wedi.html

- 1950's: Deming and Juran's introduction to Japan of Statistical Quality Control Techniques



http://www.juran.com/drjuran.html

More quality gurus

Philip Crosby	Quality is free - the optimum is zero defects.
W. Edwards Deming	Deming's 14 points. How to use statistics.
Armand Feigenbaum	Total quality control.
Kaoru Ishikawa	Quality circles and cause and effect diagrams
Joseph Juran	Quality as fitness for use, rather than conformance to specification.
Genichi Taguchi	Loss function. Minimize variation.

Historie řízení jakosti a ISO 9000

1900 Výrobková normalizace, vojenský průmysl

1920 Organizovaná kontrola, členění kontroly na vstupní, mezioperační a výstupní

1930 Shewart vytváří principy řízení kvality, regulace procesů pomocí SPC

1940 Kontrola pomocí zkušebních nástrojů, kontrola výrobních prostředků, plánování kontroly, určování příčin a následků

1950 Japonský průmysl se snaží v kvalitě výrobků dostihnout USA pomocí nových metod řízení kvality procesů

1970 Integrované zabezpečování kvality, zabezpečování kvality nejen ve výrobě ale i ve vývoji a přípravě výroby, analýza plánů konstrukce, testů, nedostatků, reklamací, certifikace výrobků

1979 Vydání normy BS 5750 (vzorem byly vojenské normy AQAP-1, 4 a 9) - 3.části (1.specifikace systému kvality 2.-3.specifikace kontrolního systému)

1987 Organizace ISO vydává poprvé normy ISO řady 9000

1994 První revize norem řady ISO 9000

2000 Druhá „velká“ revize norem řady ISO 9000

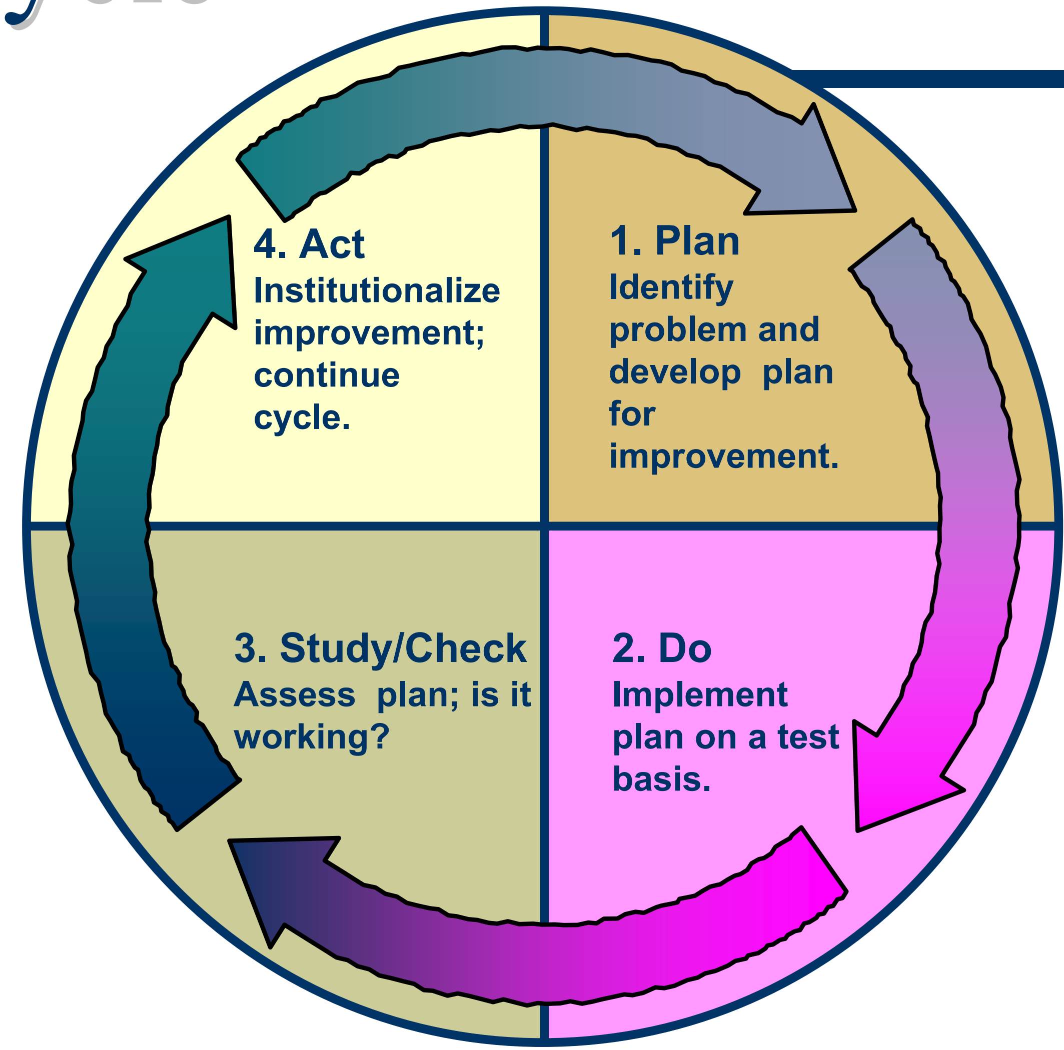
Quality Gurus

- Walter Shewart
  - In 1920s, developed control charts
  - Introduced term "*quality assurance*"
- W. Edwards Deming
  - Developed courses during World War II to teach statistical quality-control techniques to engineers and executives of companies that were military suppliers
  - After war, began teaching statistical quality control to Japanese companies
- Joseph M. Juran
  - Followed Deming to Japan in 1954
  - Focused on strategic quality planning

Quality Gurus (cont.)

- Armand V. Feigenbaum
  - In 1951, introduced concepts of total quality control and continuous quality improvement
- Philip Crosby
  - In 1979, emphasized that costs of poor quality far outweigh cost of preventing poor quality
  - In 1984, defined absolutes of quality management—conformance to requirements, prevention, and “zero defects”
- Kaoru Ishikawa
  - Promoted use of quality circles
  - Developed “fishbone” diagram
  - Emphasized importance of internal customer

Deming Wheel: PDCA Cycle



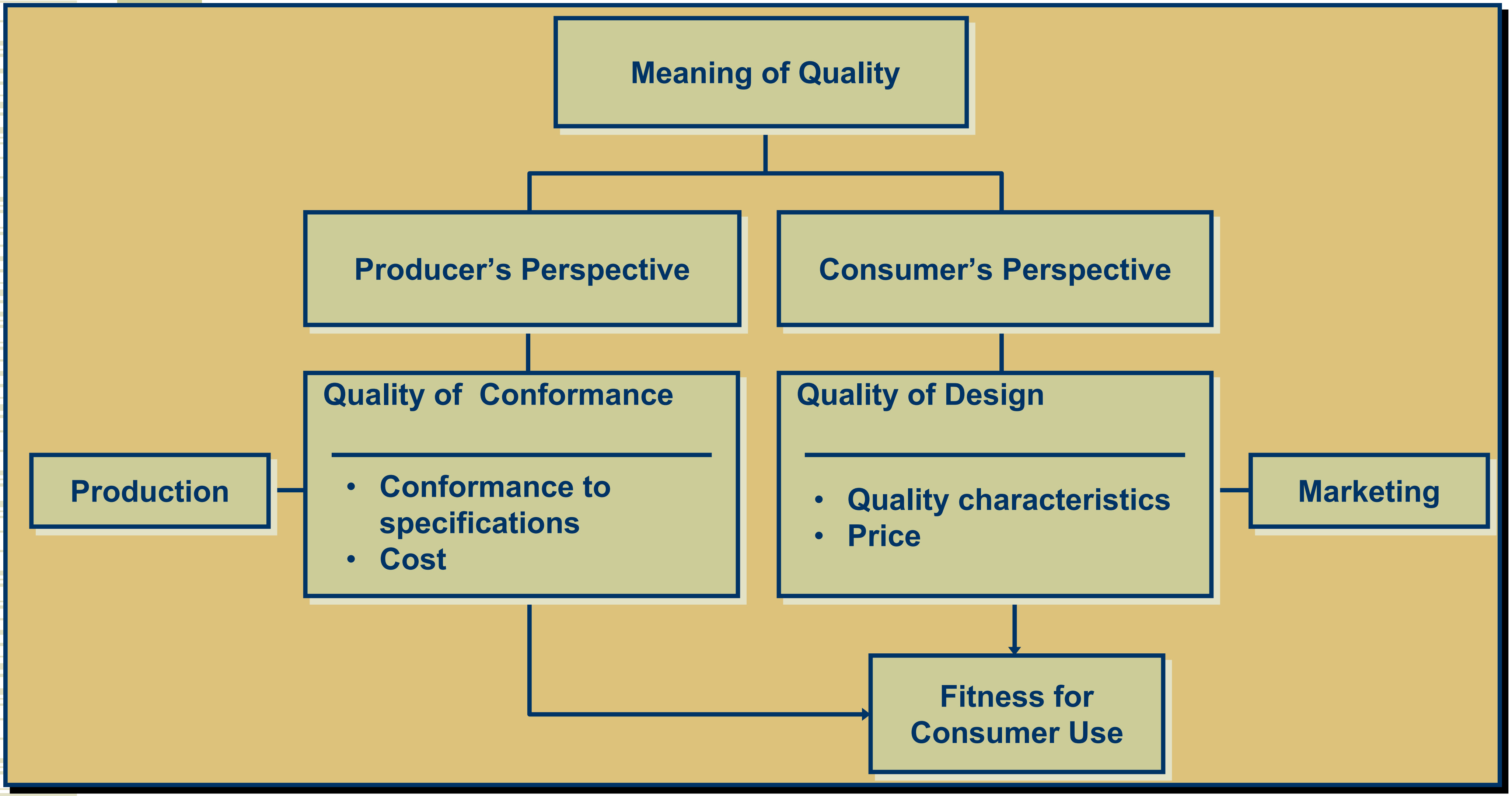
Jestliže jsou požadavky kapitoly „Odpovědnost managementu“ realizovány v praxi, dochází k plánování zdrojů a prostředků organizace **(Plan).**

Splnění požadavků z kapitoly „Řízení zdrojů“ zajišťuje, že „realizace produktu a/nebo služby“ může proběhnout efektivně a účinně **(Do).**

Výsledkem realizace produktu jsou produkty a služby. Výkon procesů a kvalita produktu jsou při tom průběžně měřeny **(Check).**

Požadavky kapitoly „Měření, analýza a zlepšení“ se cyklus k „Odpovědnosti managementu“ opět uzavírá **(Act).**

Meaning of Quality



Total Quality Management

- Commitment to quality throughout organization

- Principles of TQM
  - Customer-oriented
  - Leadership
  - Strategic planning
  - Employee responsibility
  - Continuous improvement
  - Cooperation
  - Statistical methods
  - Training and education

Basic Economic Quality Level Model

Princip 1 – Orientace na zákazníka

Organizace závisí na svých zákaznících, a proto mají porozumět současných i budoucím potřebám zákazníků, splňovat jejich požadavky a snažit se překonat jejich očekávání.

Princip 2 – Vedení

Vedoucí pracovníci vytvářejí shodu účelu a zaměření organizace. Mají vytvářet a zachovávat interní prostředí, v kterém se lidé mohou zcela zasazovat za dosažení cílů organizace.

Princip 3 – Zapojení osob

Na všech úrovních určují lidé charakter organizace a jejich úplné zapojení umožňuje nasadit své schopnosti k užitku organizace.

Princip 4 – Procesně orientovaný koncept

Požadovaného výsledku lze dosáhnout efektivněji tehdy, když jsou činnosti a příslušné zdroje vedeny a řízeny jako proces.

Princip 5 – Systémově orientovaný koncept řízení

Identifikace, pochopení, vedení a řízení procesů, které jsou vzájemně propojeny jako systém, přispívá k účinnosti a efektivitě organizace při dosahování svých cílů.

Princip 6 – Neustálé zlepšování

Neustálé zlepšování celkového výkonu organizace představuje trvalý cíl organizace.

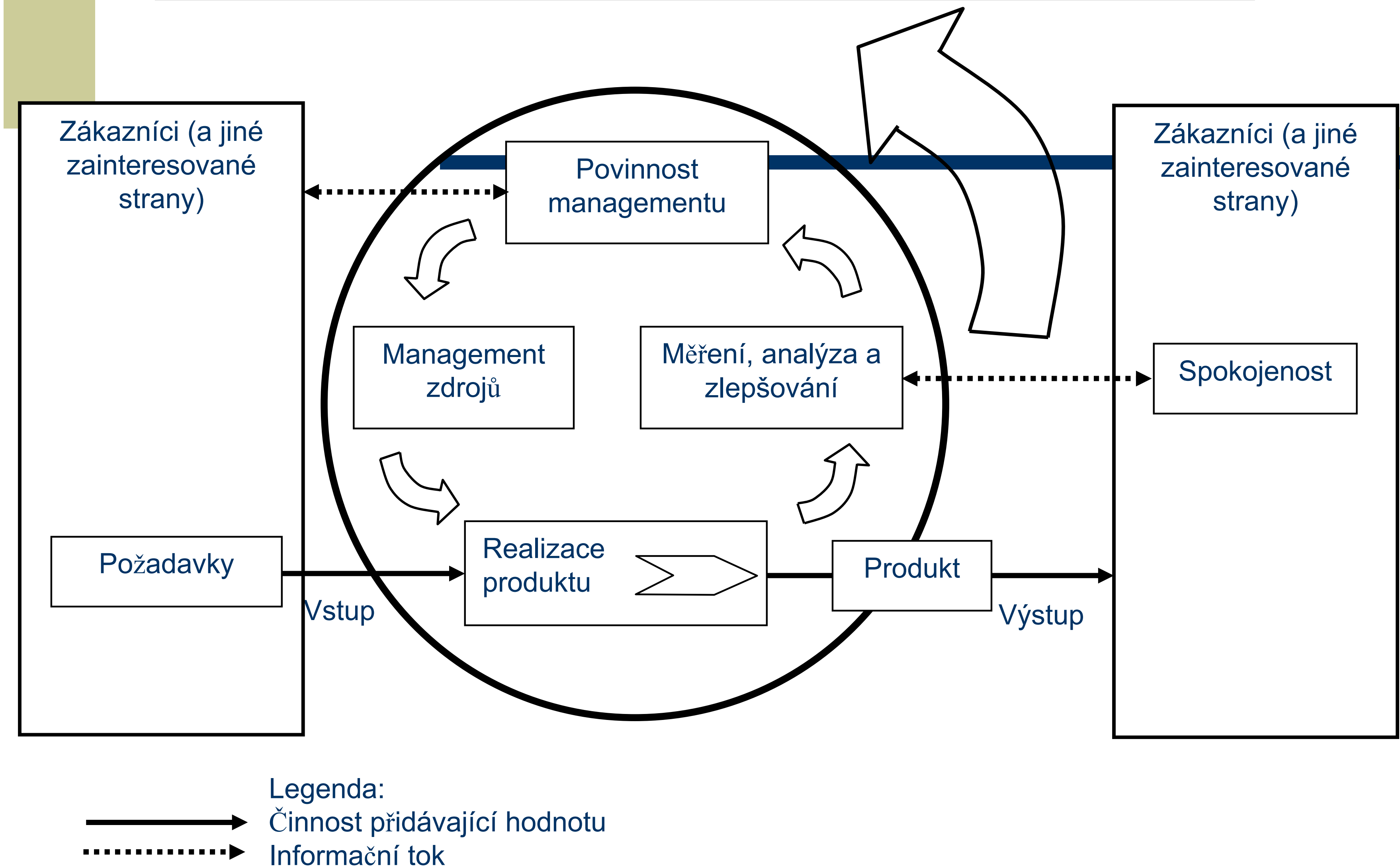
Princip 7 – Věcný koncept pro rozhodování

Účinná rozhodnutí se zakládají na analýze dat a informací.

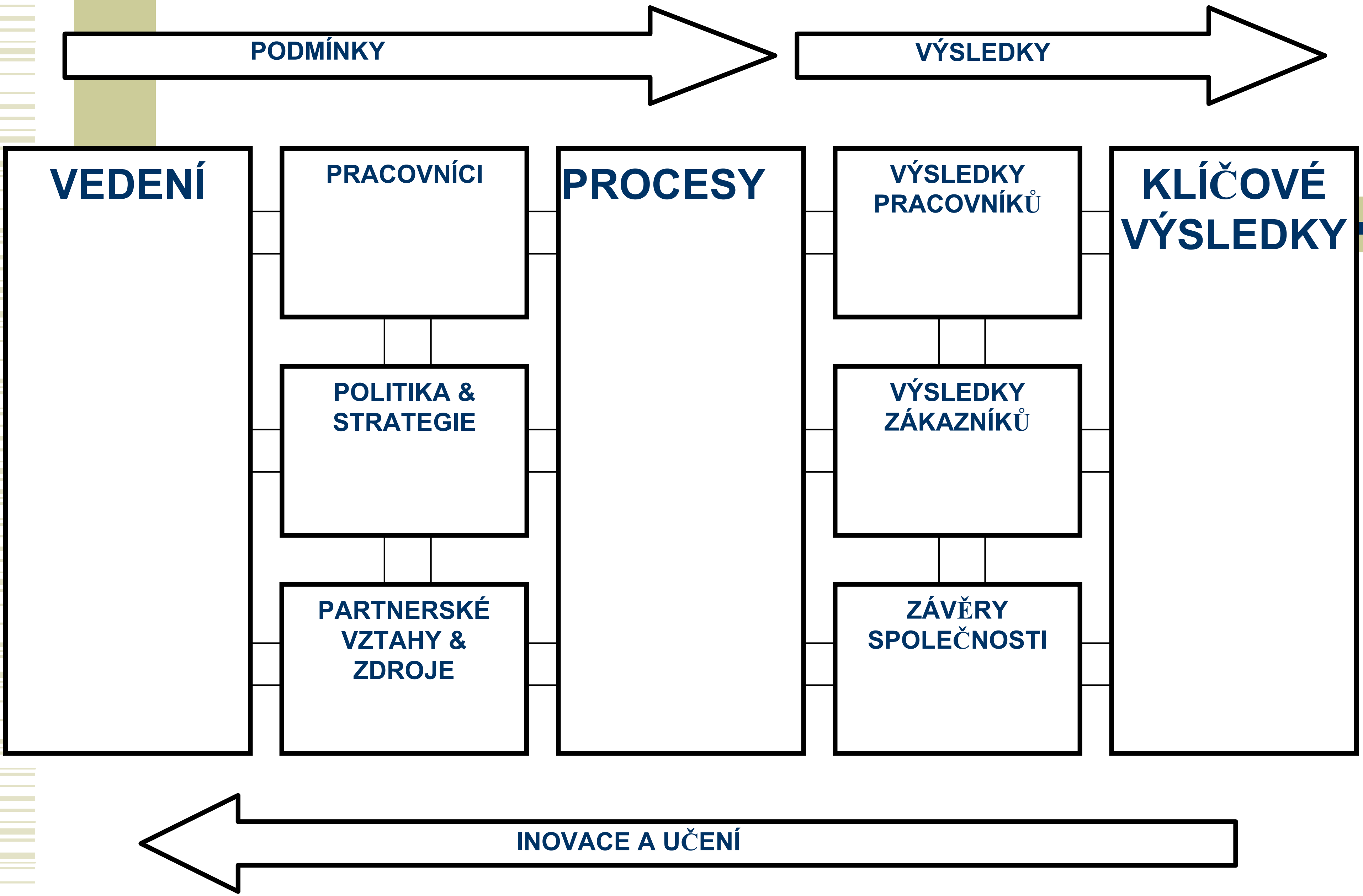
Princip 8 – Dodavatelské vztahy k vzájemnému užitku

Organizace a její dodavatelé jsou na sobě závislí. Vztahy sloužící k vzájemnému užitku zvyšují schopnost tvorby hodnot obou stran.

Neustálé zlepšování systému managementu jakosti



POZNÁMKA: Text v závorkách neplatí pro ISO 9001
Model procesně orientovaného systému managementu jakosti



Model excelence EFQM

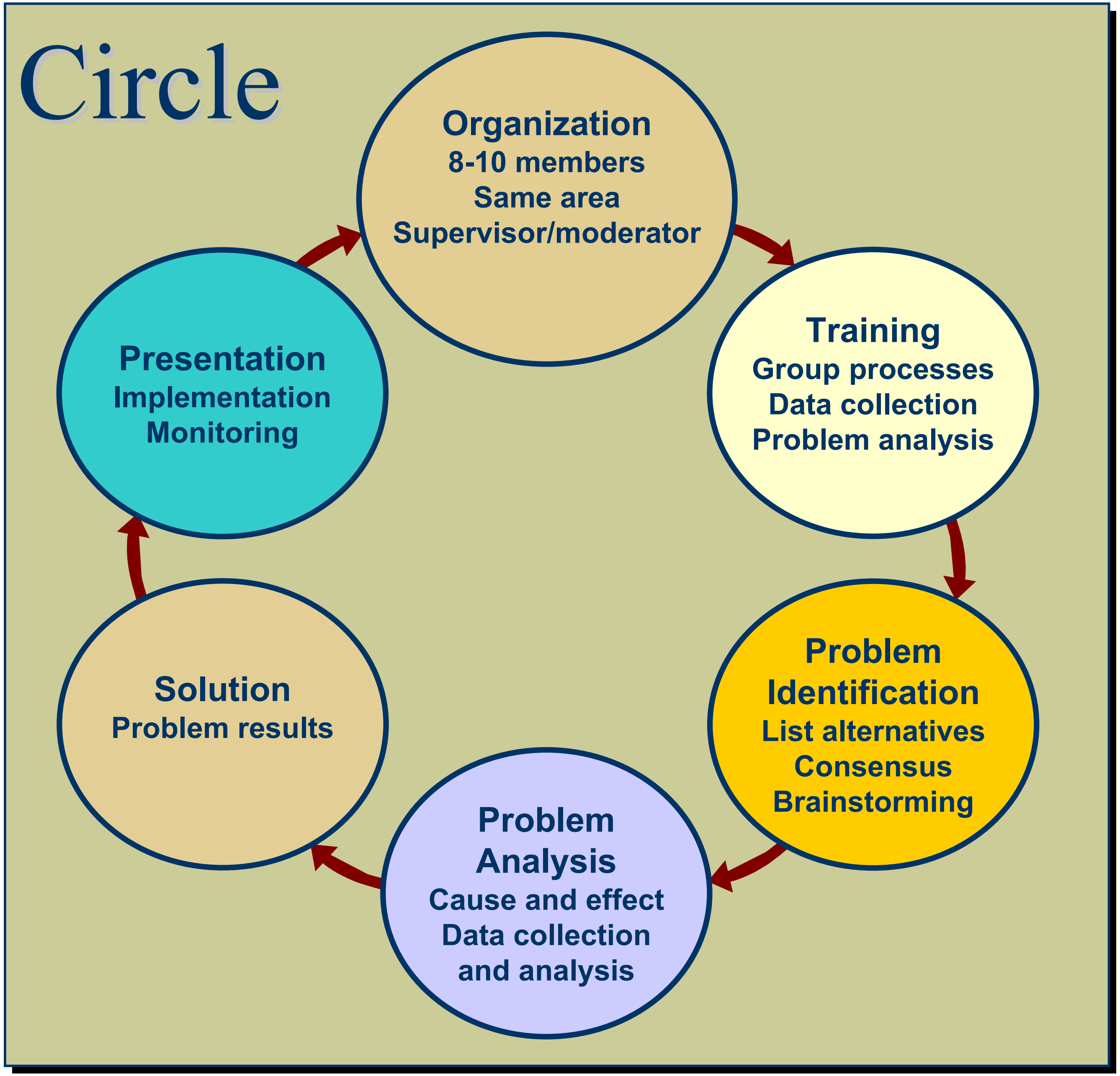
TQM and…

- … **Partnering**
  - a relationship between a company and its supplier based on mutual quality standards
- … **Customers**
  - system must measure customer satisfaction
- … **Information Technology**
  - infrastructure of hardware, networks, and software necessary to support a quality program

Quality Improvement and Role of Employees

- **Participative problem solving**
  - employees involved in quality management
  - every employee has undergone extensive training to provide quality service to Disney's guests

Quality Circle



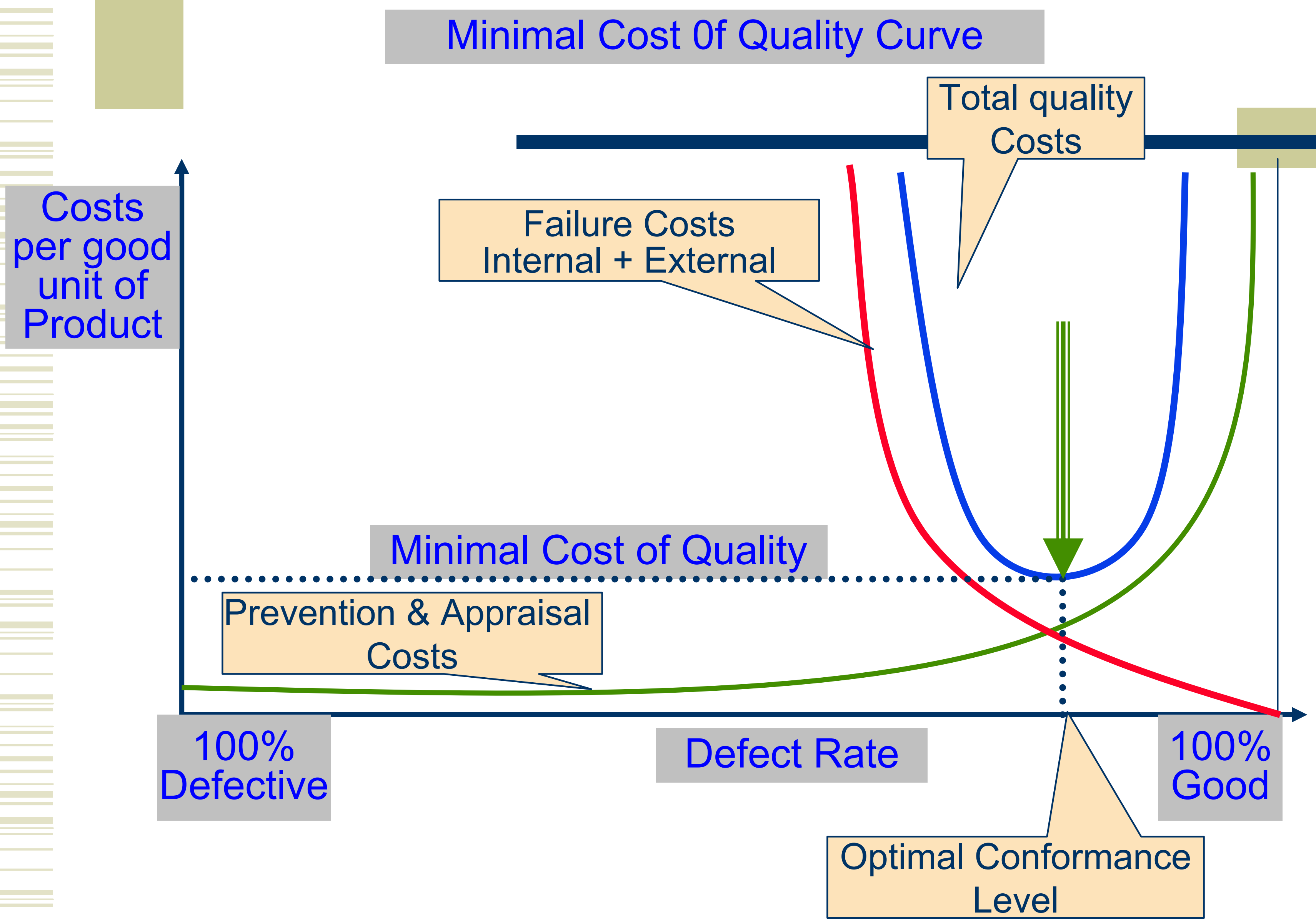
TQM in Service Companies

- **Principles of TQM apply equally well to services and manufacturing**
- **Services and manufacturing companies have similar inputs but different processes and outputs**
- **Services tend to be labor intensive**
- **Service defects are not always easy to measure because service output is not usually a tangible item**

Cost of Quality

- Cost of Achieving Good Quality
  - Prevention costs
    - costs incurred during product design
  - Appraisal costs
    - costs of measuring, testing, and analyzing
- Cost of Poor Quality
  - Internal failure costs
    - include scrap, rework, process failure, downtime, and price reductions
  - External failure costs
    - include complaints, returns, warranty claims, liability, and lost sales

Juran, J.M., "Planning for Quality"



Prevention Costs

- Quality planning costs
  - costs of developing and implementing quality management program
- Product-design costs
  - costs of designing products with quality characteristics
- Process costs
  - costs expended to make sure productive process conforms to quality specifications
- Training costs
  - costs of developing and putting on quality training programs for employees and management
- Information costs
  - costs of acquiring and maintaining data related to quality, and development of reports on quality performance

Appraisal Costs

- Inspection and testing
  - costs of testing and inspecting materials, parts, and product at various stages and at end of process
- Test equipment costs
  - costs of maintaining equipment used in testing quality characteristics of products
- Operator costs
  - costs of time spent by operators to gar data for testing product quality, to make equipment adjustments to maintain quality, and to stop work to assess quality

Internal Failure Costs

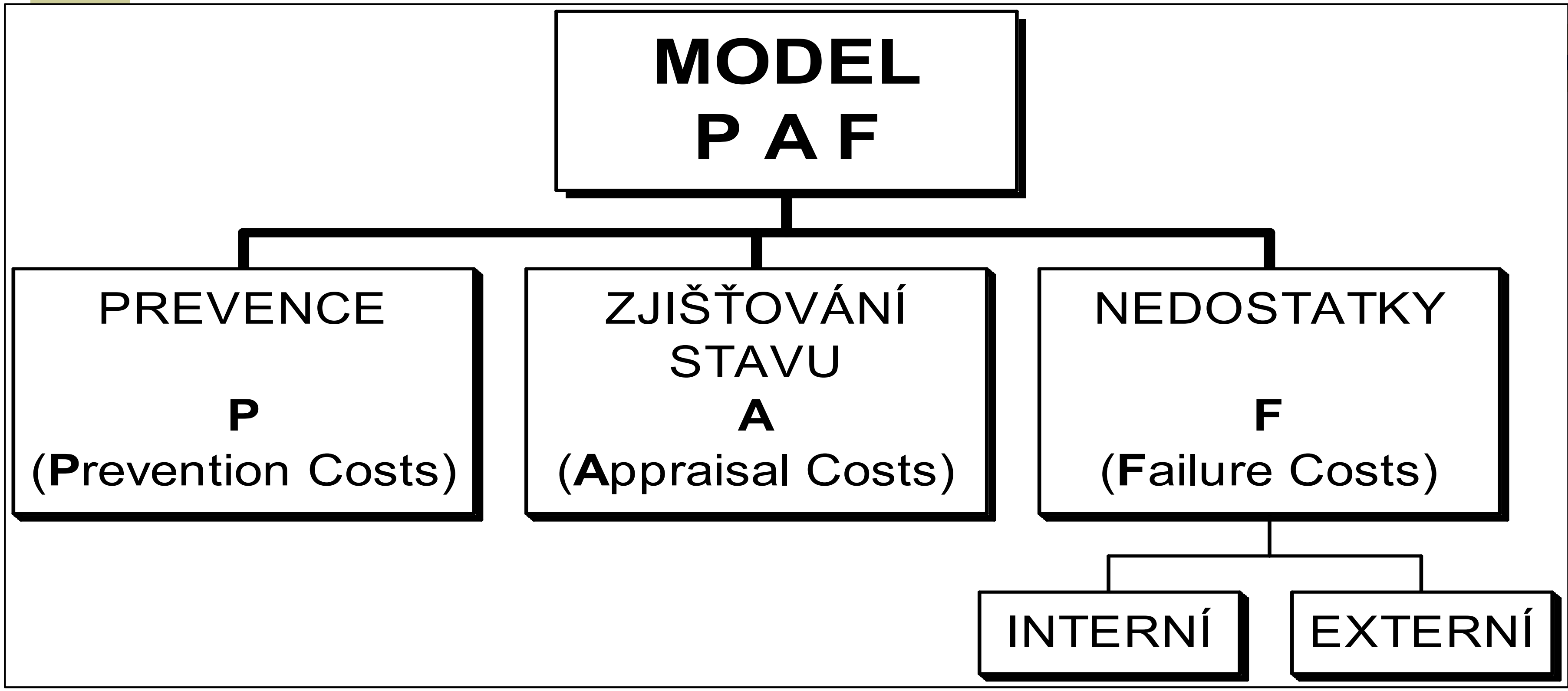
- *Scrap costs*
  - costs of poor-quality products that must be discarded, including labor, material, and indirect costs
- *Rework costs*
  - costs of fixing defective products to conform to quality specifications
- *Process failure costs*
  - costs of determining why production process is producing poor-quality products
- *Process downtime costs*
  - costs of shutting down productive process to fix problem
- *Price-downgrading costs*
  - costs of discounting poor-quality products—that is, selling products as “seconds”

External Failure Costs

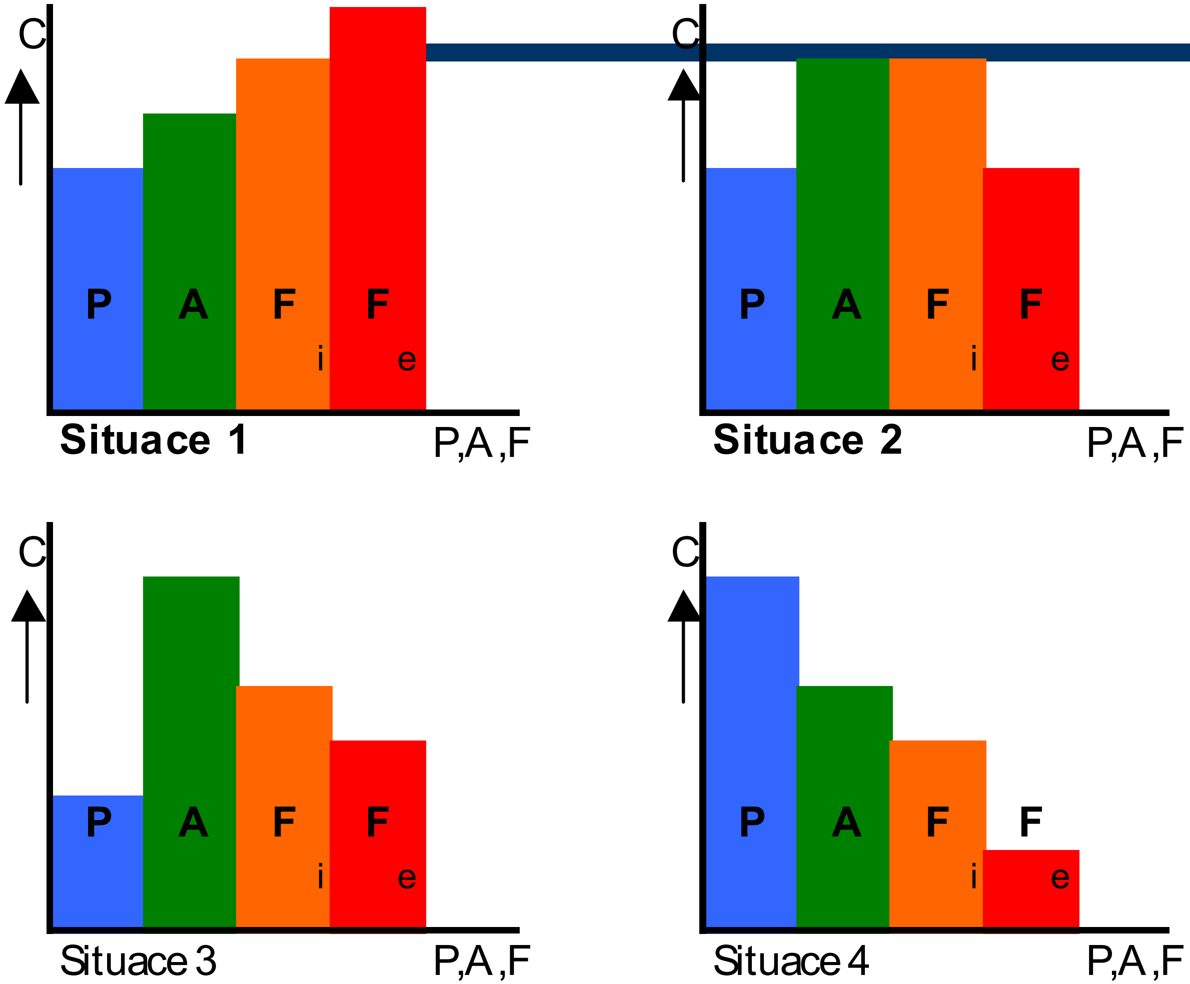
- Customer complaint costs
  - costs of investigating and satisfactorily responding to a customer complaint resulting from a poor-quality product
- Product return costs
  - costs of handling and replacing poor-quality products returned by customer
- Warranty claims costs
  - costs of complying with product warranties
- Product liability costs
  - litigation costs resulting from product liability and customer injury
- Lost sales costs
  - costs incurred because customers are dissatisfied with poor quality products and do not make additional purchases

Measuring and Reporting Quality Costs

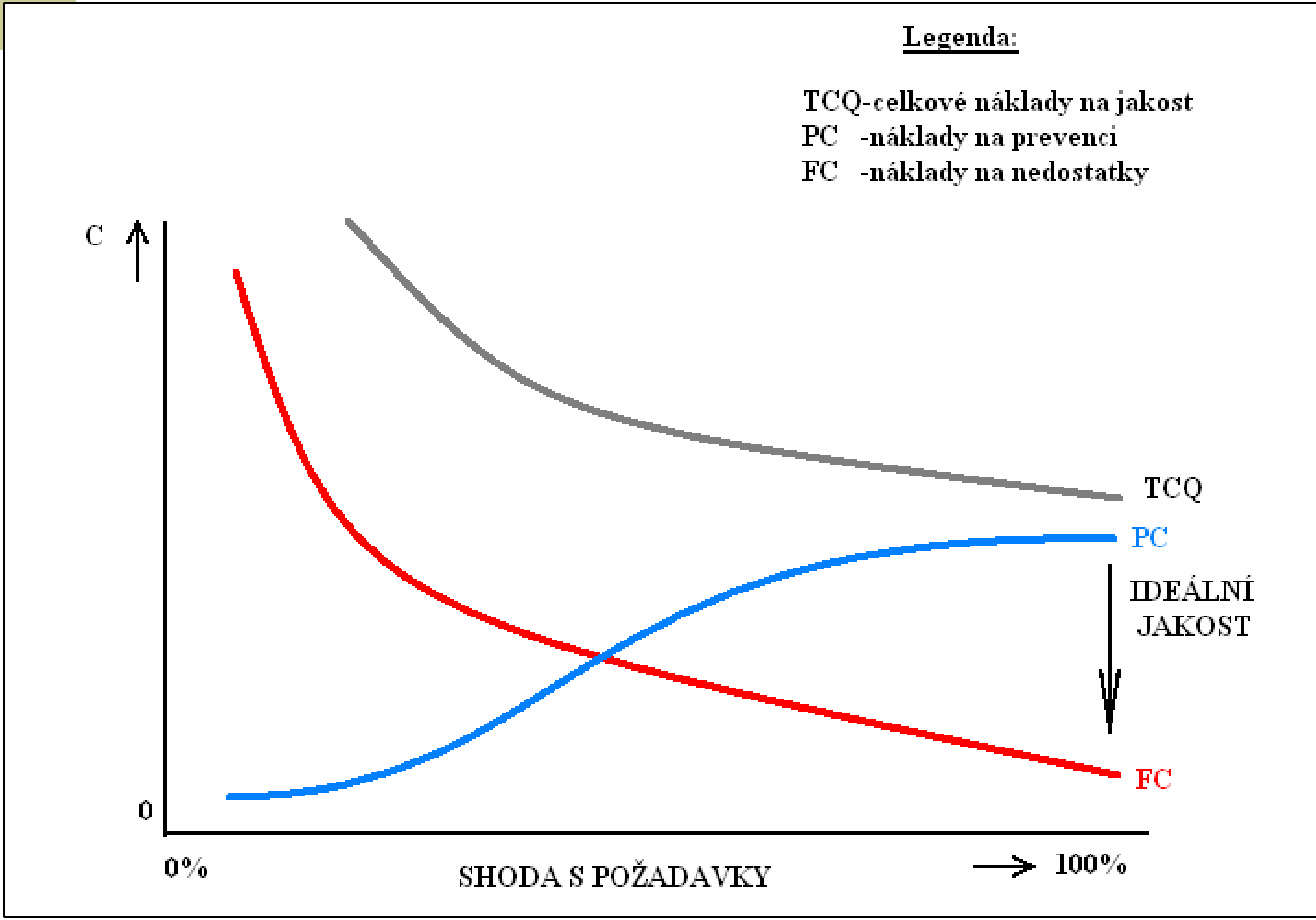
- **Index numbers**
  - ratios that measure quality costs against a base value
  - **labor index**
    - ratio of quality cost to labor hours
  - **cost index**
    - ratio of quality cost to manufacturing cost
  - **sales index**
    - ratio of quality cost to sales
  - **production index**
    - ratio of quality cost to units of final product


MODEL
P A F
PREVENCE
P
(Prevention Costs)
ZJIŠŤOVÁNÍ
STAVU
A
(Appraisal Costs)
NEDOSTATKY
F
(Failure Costs)
INTERNÍ
EXTERNÍ

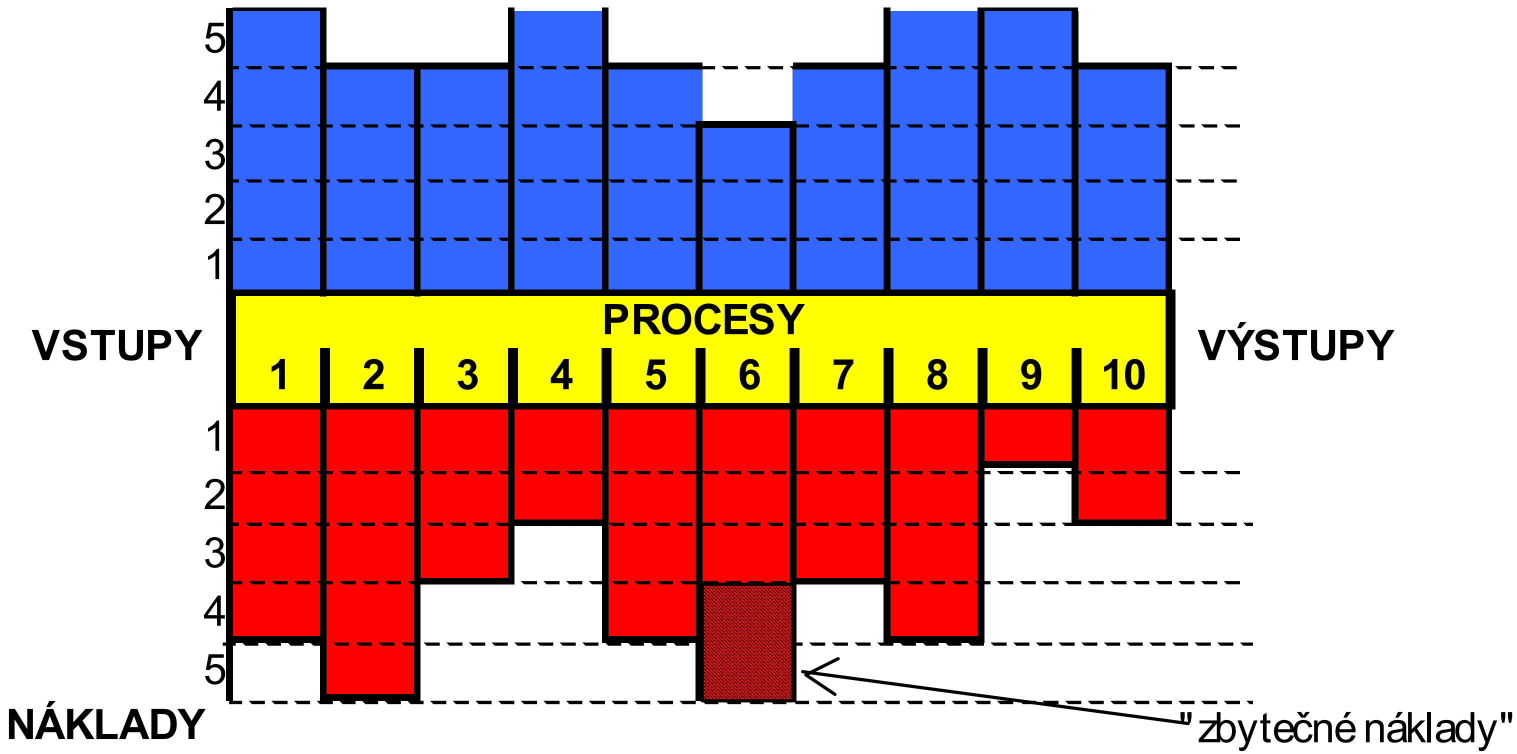
Možné struktury nákladů v modelu PAF



Trendy v modelu PAF



Grafické znázornění monitorování nákladů na proces



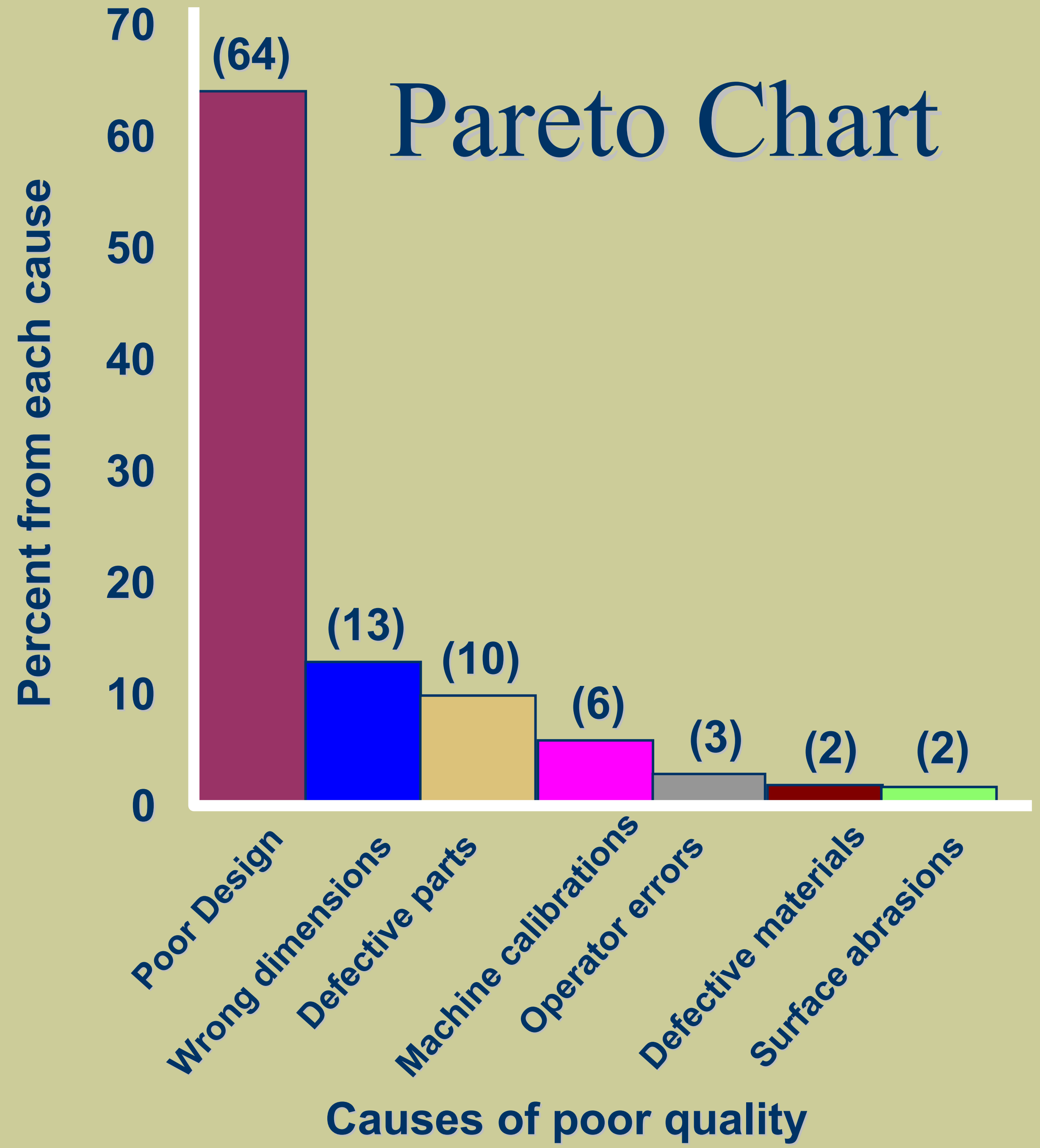
Seven Quality Control Tools

- Pareto Analysis
- Flow Chart
- Check Sheet
- Histogram
- Scatter Diagram
- SPC Chart
- Cause-and-Effect Diagram

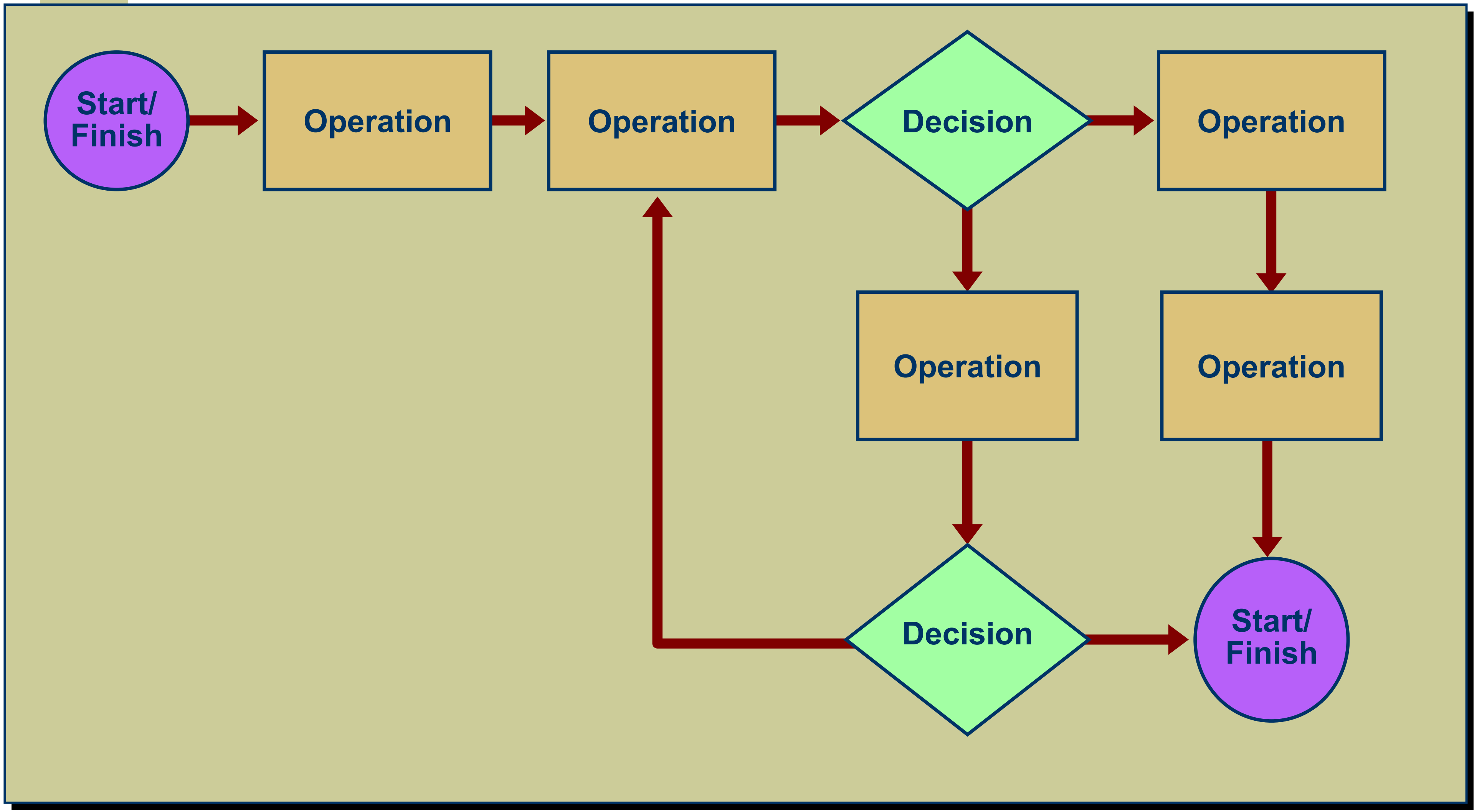
Pareto Analysis

CAUSE	NUMBER OF DEFECTS	PERCENTAGE
Poor design	80	64 %
Wrong part dimensions	16	13
Defective parts	12	10
Incorrect machine calibration	7	6
Operator errors	4	3
Defective material	3	2
Surface abrasions	3	2
	125	100 %

Pareto Chart



Flow Chart


Start/ Finish
Operation
Operation
Decision
Operation
Operation
Operation
Decision
Start/ Finish

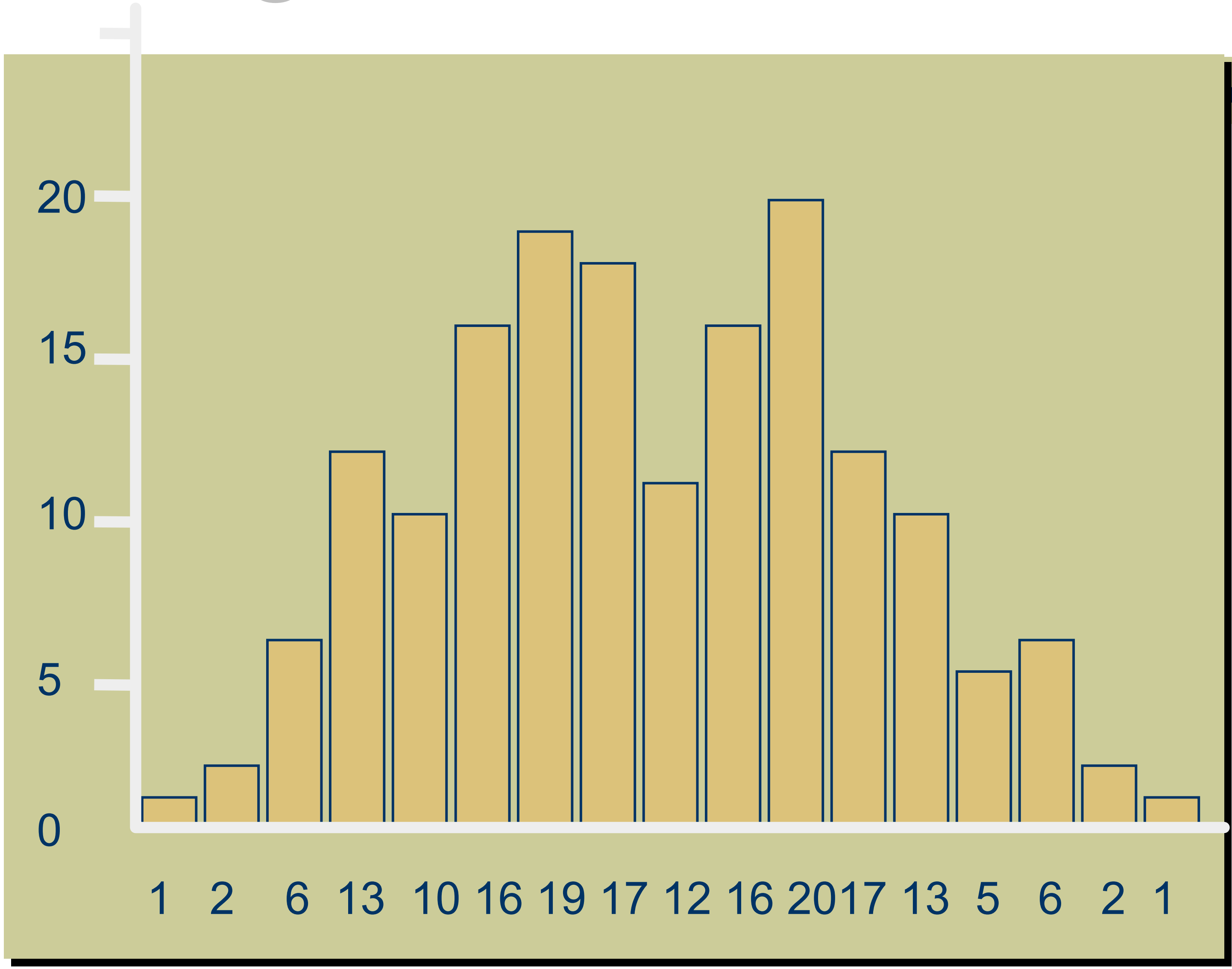
Check Sheet

COMPONENTS REPLACED BY LAB
TIME PERIOD: 22 Feb to 27 Feb 2002
REPAIR TECHNICIAN: Bob

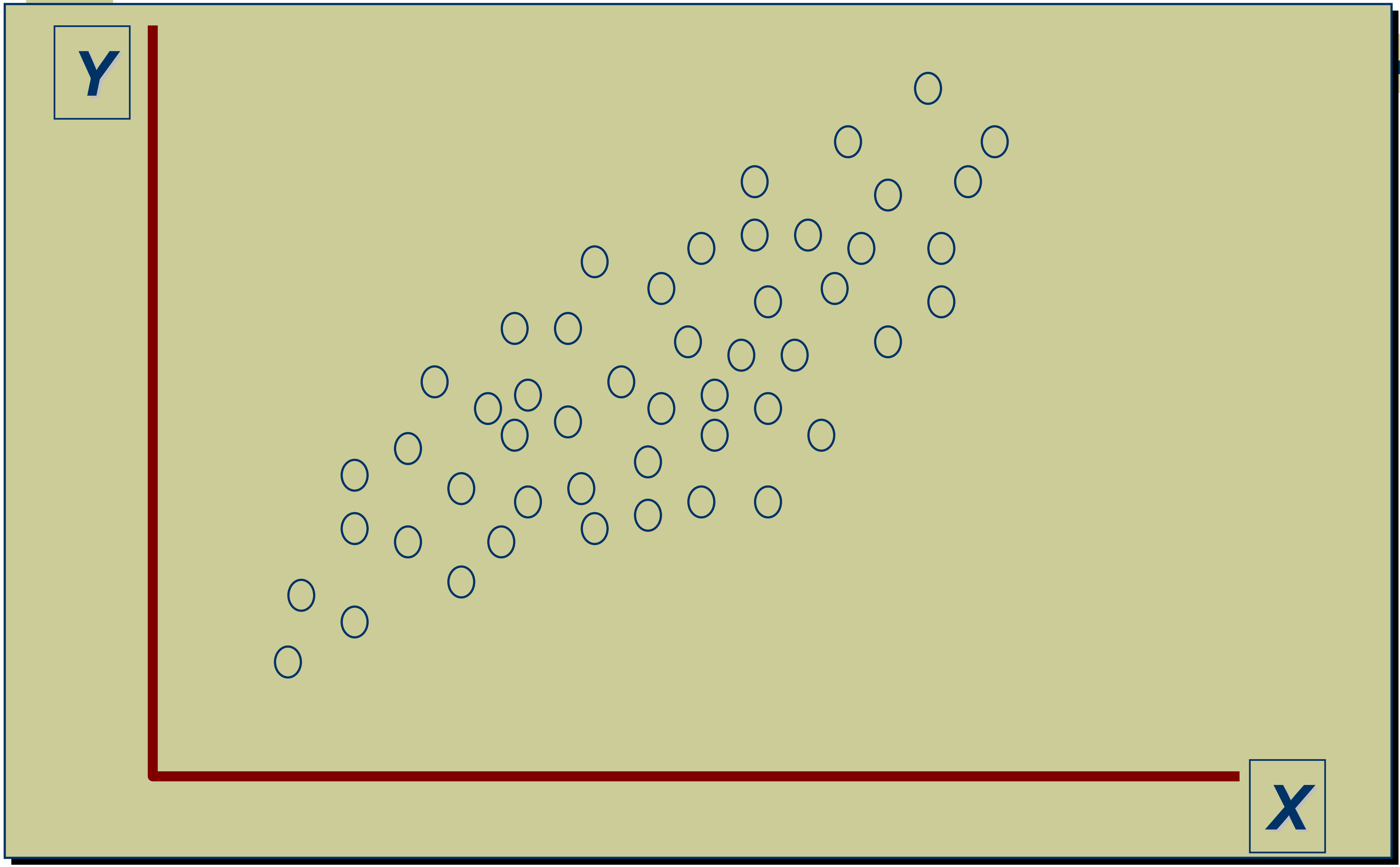
TV SET MODEL 1013

Integrated Circuits	𝍸
Capacitors	𝍸 𝍸 𝍸 𝍸 𝍸 ||
Resistors	||
Transformers	𝍸
Commands	
CRT	|

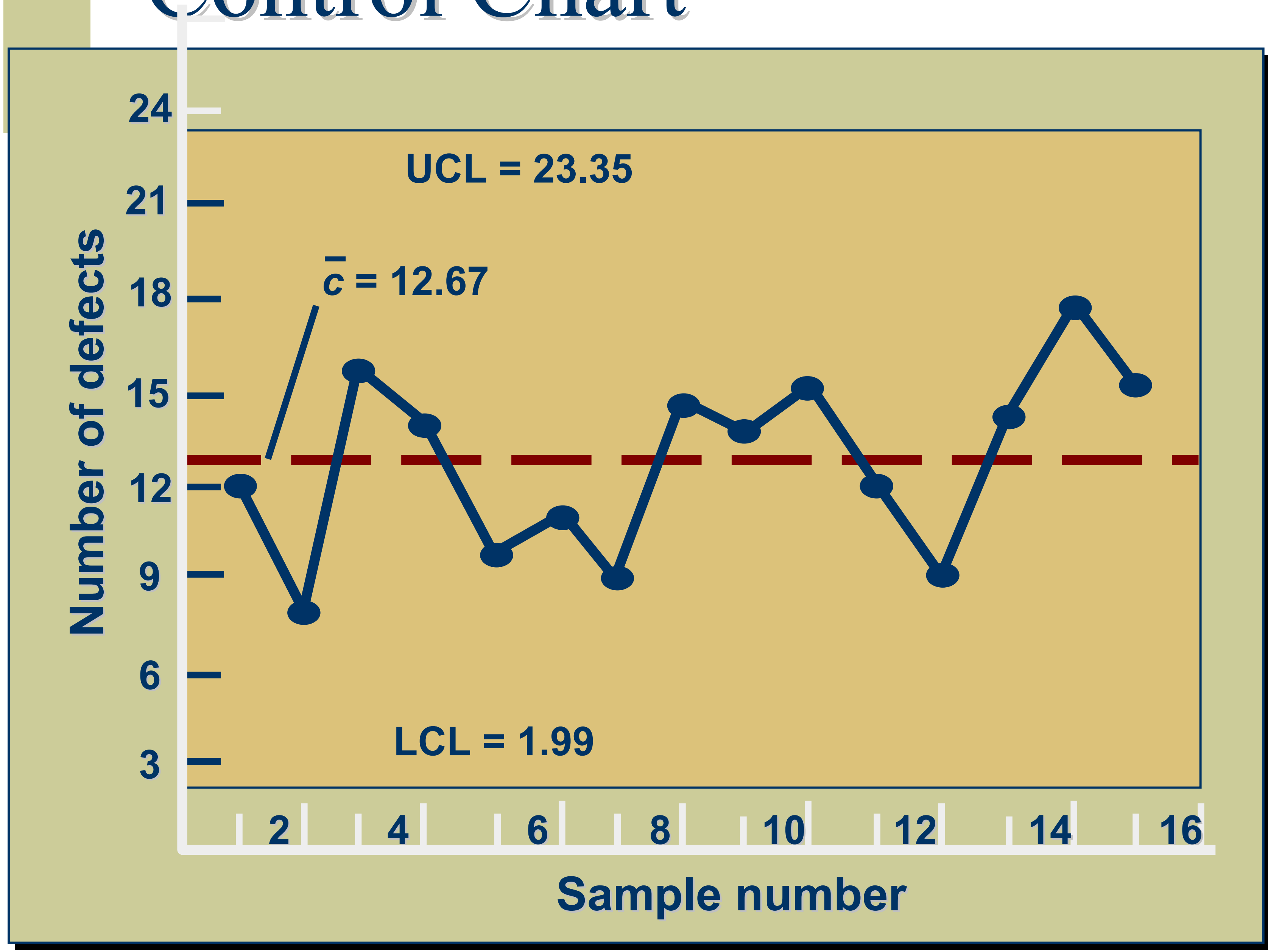
Histogram



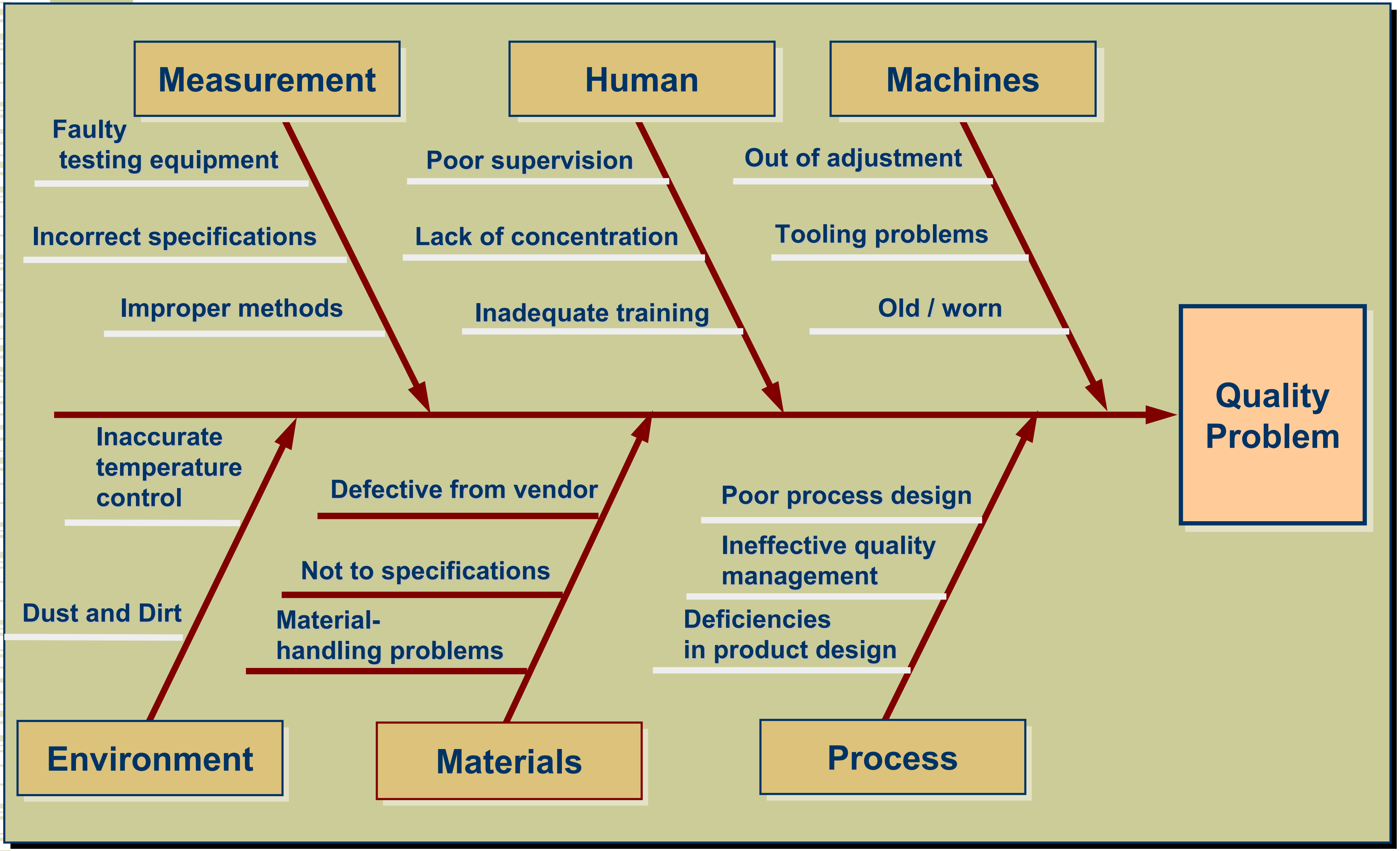
Scatter Diagram



Control Chart



Cause-and-Effect Diagram



Baldrige Award

- Created in 1987 to stimulate growth of quality management in United States
- Categories
  - Leadership
  - Information and analysis
  - Strategic planning
  - Human resource
  - Focus
  - Process management
  - Business results
  - Customer and market focus

Other Awards for Quality

- National individual awards
  - Armand V. Feigenbaum Medal
  - Deming Medal
  - E. Jack Lancaster Medal
  - Edwards Medal
  - Shewart Medal
  - Ishikawa Medal
- International awards
  - European Quality Award
  - Canadian Quality Award
  - Australian Business Excellence Award
  - Deming Prize from Japans

American Customer Satisfaction Index (ACSI)

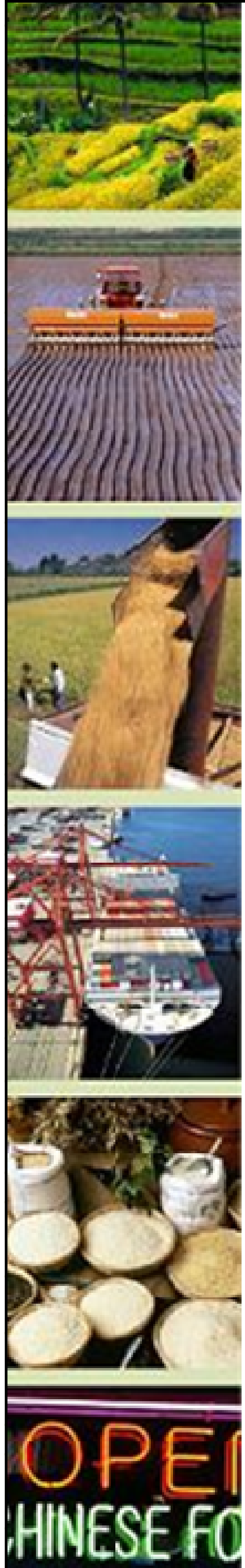
- Measures customer satisfaction
- Established in 1994
- Web site: www.acsi.org
  - Examples (in 2003)
    - Amazon.com scored 88 (highest in service)
    - Dell scored of 78 (highest in computer industry)
    - Cadillac scored 87 (highest in car industry)

ISO 9000

- A set of procedures and policies for international quality certification of suppliers
- Standards
  - ISO 9000:2000
    - *Quality Management Systems—Fundamentals and Vocabulary*
    - defines fundamental terms and definitions used in ISO 9000 family
- ISO 9001:2000
  - *Quality Management Systems—Requirements*
  - standard to assess ability to achieve customer satisfaction
- ISO 9004:2000
  - *Quality Management Systems—Guidelines for Performance Improvements*
  - guidance to a company for continual improvement of its quality-management system

Implications of ISO 9000 for U.S. Companies

- Many overseas companies will not do business with a supplier unless it has ISO 9000 certification
- ISO 9000 accreditation
- ISO registrars
- A total commitment to quality is required throughout an organization



Chapter 4

Statistical Process Control

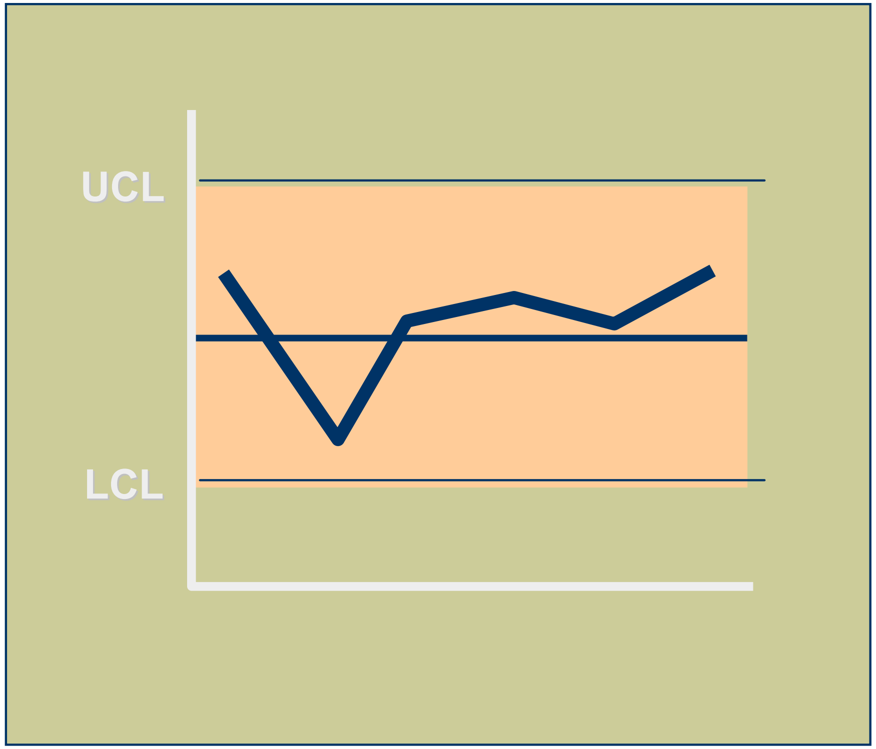
Operations Management - 5th Edition

Roberta Russell & Bernard W. Taylor, III

Beni Asllani
University of Tennessee at Chattanooga

Basics of Statistical Process Control

- Statistical Process Control (SPC)
  - monitoring production process to detect and prevent poor quality
- Sample
  - subset of items produced to use for inspection
- Control Charts
  - process is within statistical control limits



Variability

- Random
  - common causes
  - inherent in a process
  - can be eliminated only through improvements in the system
- Non-Random
  - special causes
  - due to identifiable factors
  - can be modified through operator or management action

SPC in TQM

- SPC
  - tool for identifying problems and make improvements
  - contributes to the TQM goal of continuous improvements

Quality Measures

- **Attribute**
  - a product characteristic that can be evaluated with a discrete response
  - good – bad; yes - no
- **Variable**
  - a product characteristic that is continuous and can be measured
  - weight - length

Applying SPC to Service

- Nature of defect is different in services
- Service defect is a failure to meet customer requirements
- Monitor times, customer satisfaction

Applying SPC to Service (cont.)

- Hospitals
  - timeliness and quickness of care, staff responses to requests, accuracy of lab tests, cleanliness, courtesy, accuracy of paperwork, speed of admittance and checkouts
- Grocery stores
  - waiting time to check out, frequency of out-of-stock items, quality of food items, cleanliness, customer complaints, checkout register errors
- Airlines
  - flight delays, lost luggage and luggage handling, waiting time at ticket counters and check-in, agent and flight attendant courtesy, accurate flight information, passenger cabin cleanliness and maintenance

Applying SPC to Service (cont.)

- Fast-food restaurants
  - waiting time for service, customer complaints, cleanliness, food quality, order accuracy, employee courtesy
- Catalogue-order companies
  - order accuracy, operator knowledge and courtesy, packaging, delivery time, phone order waiting time
- Insurance companies
  - billing accuracy, timeliness of claims processing, agent availability and response time

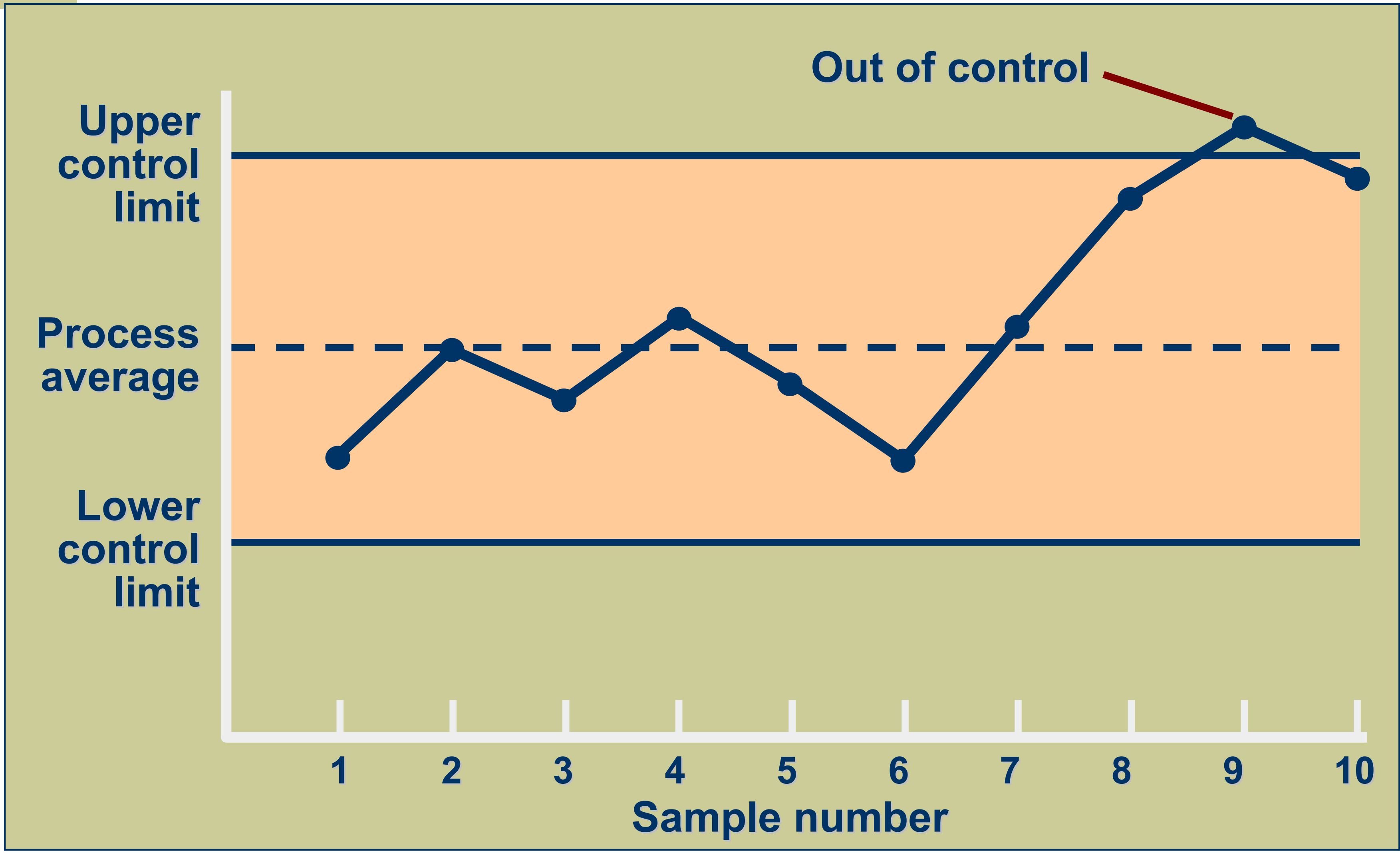
Where to Use Control Charts

- Process has a tendency to go out of control
- Process is particularly harmful and costly if it goes out of control
- Examples
  - at the beginning of a process because it is a waste of time and money to begin production process with bad supplies
  - before a costly or irreversible point, after which product is difficult to rework or correct
  - before and after assembly or painting operations that might cover defects
  - before the outgoing final product or service is delivered

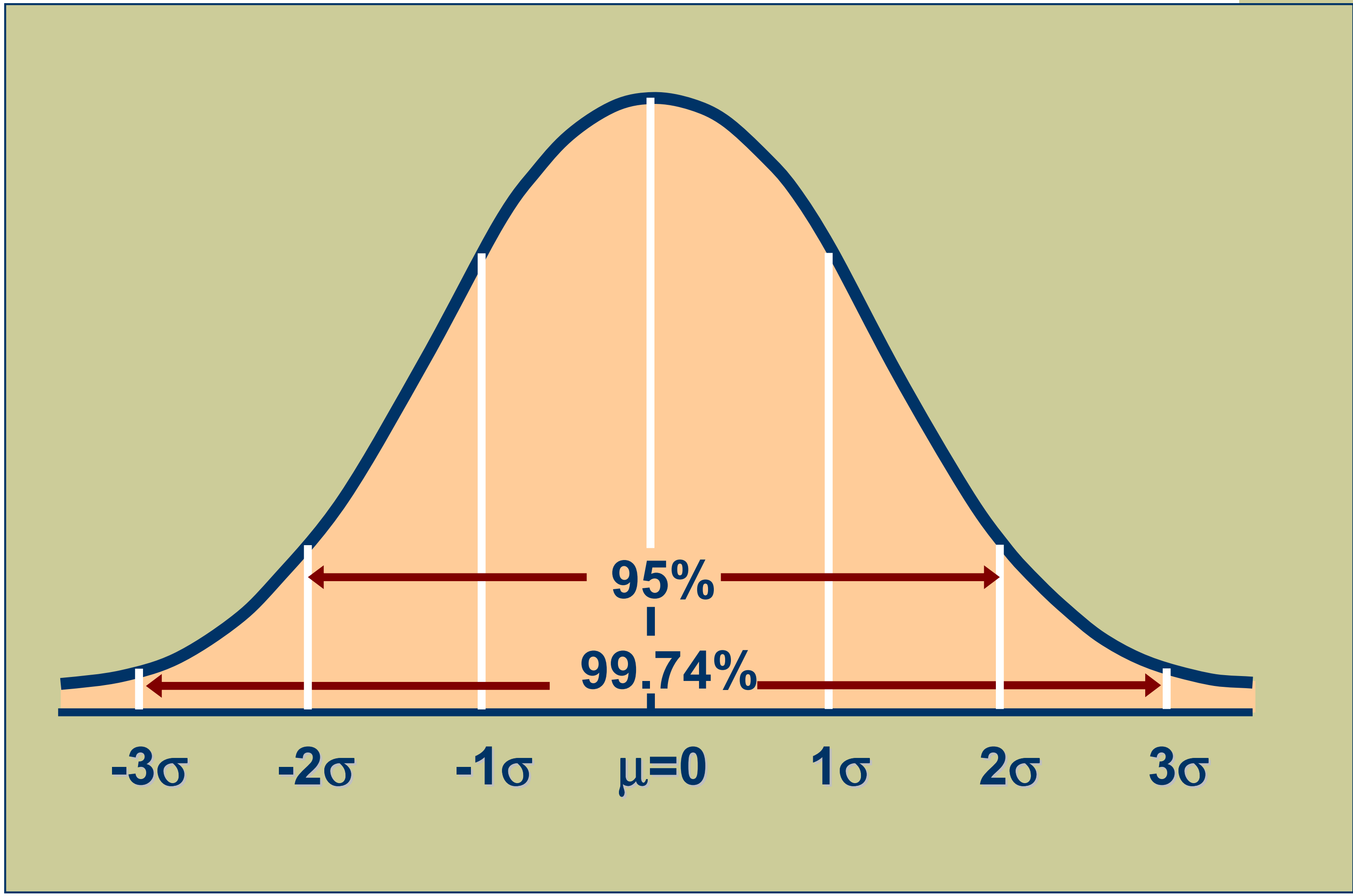
Control Charts

- A graph that establishes control limits of a process
- Control limits
  - upper and lower bands of a control chart
- Types of charts
  - Attributes
    - p-chart
    - c-chart
  - Variables
    - range (R-chart)
    - mean (x bar – chart)

Process Control Chart



Normal Distribution



A Process Is in Control If …

1. … no sample points outside limits
2. … most points near process average
3. … about equal number of points above and below centerline
4. … points appear randomly distributed

Control Charts for Attributes

- p-charts
  - uses portion defective in a sample
- c-charts
  - uses number of defects in an item

p-Chart

$$UCL = p + z\sigma_p$$

$$LCL = p - z\sigma_p$$

z = number of standard deviations from process average

$\bar{p}$ = sample proportion defective; an estimate of process average

σ_p = standard deviation of sample proportion

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

p-Chart Example

SAMPLE	NUMBER OF DEFECTIVES	PROPORTION DEFECTIVE
1	6	.06
2	0	.00
3	4	.04
:	:	:
:	:	:
20	18	.18
	200	

20 samples of 100 pairs of jeans

p-Chart Example (cont.)

$$\bar{p} = \frac{\text{total defectives}}{\text{total sample observations}} = 200 / 20(100) = 0.10$$

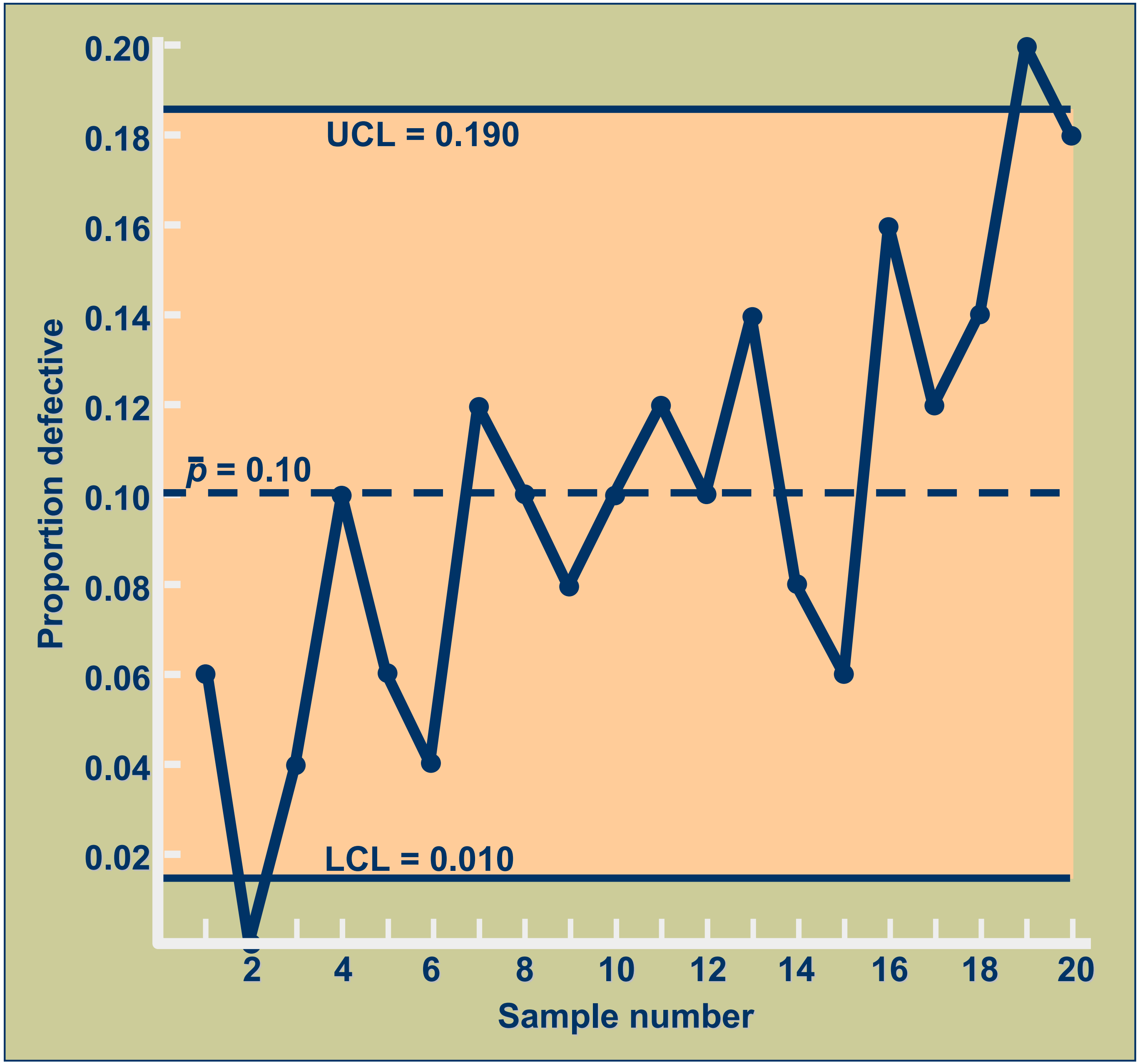
$$UCL = \bar{p} + z\sqrt{\frac{\bar{p}(1 - \bar{p})}{n}} = 0.10 + 3\sqrt{\frac{0.10(1 - 0.10)}{100}}$$

$$UCL = 0.190$$

$$LCL = \bar{p} - z\sqrt{\frac{\bar{p}(1 - \bar{p})}{n}} = 0.10 - 3\sqrt{\frac{0.10(1 - 0.10)}{100}}$$

$$LCL = 0.010$$

p-Chart Example (cont.)



c-Chart

$$UCL = \bar{c} + z\sigma_c$$

$$LCL = \bar{c} - z\sigma_c$$

$$\sigma_c = \sqrt{\bar{c}}$$

where

c = number of defects per sample

c-Chart (cont.)

Number of defects in 15 sample rooms

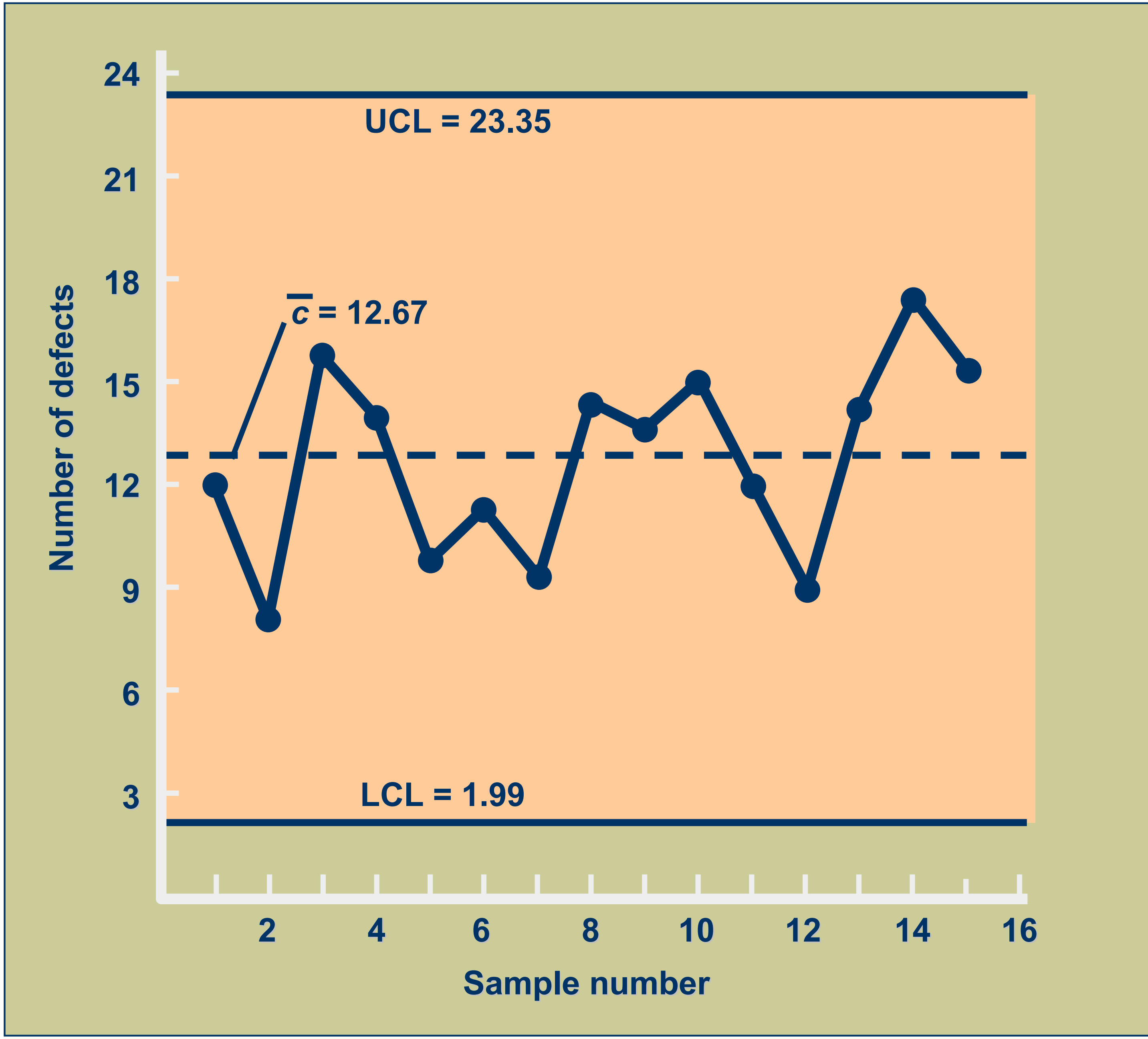
SAMPLE	NUMBER OF DEFECTS
1	12
2	8
3	16
:	:
:	:
15	15
	190

$$\bar{c} = \frac{190}{15} = 12.67$$

$$\text{UCL} = \bar{c} + z\sigma_c$$
$$= 12.67 + 3\sqrt{12.67}$$
$$= 23.35$$

$$\text{LCL} = \bar{c} + z\sigma_c$$
$$= 12.67 - 3\sqrt{12.67}$$
$$= 1.99$$

c-Chart (cont.)



24
21
18
15
12
9
6
3
UCL = 23.35
c̄ = 12.67
LCL = 1.99
Number of defects
2
4
6
8
10
12
14
16
Sample number

Control Charts for Variables

- Mean chart ($\bar{x}$ -Chart)
  - uses average of a sample
- Range chart (R-Chart)
  - uses amount of dispersion in a sample

x-bar Chart

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \ldots \bar{x}_k}{k}$$

$$UCL = \bar{\bar{x}} + A_2\bar{R} \qquad LCL = \bar{\bar{x}} - A_2\bar{R}$$

where

$\bar{\bar{x}}$ = average of sample means

x-bar Chart Example

	OBSERVATIONS (SLIP- RING DIAMETER, CM)						
SAMPLE *k*	*1*	*2*	*3*	*4*	*5*	$\bar{x}$	*R*
1	5.02	5.01	4.94	4.99	4.96	4.98	0.08
2	5.01	5.03	5.07	4.95	4.96	5.00	0.12
3	4.99	5.00	4.93	4.92	4.99	4.97	0.08
4	5.03	4.91	5.01	4.98	4.89	4.96	0.14
5	4.95	4.92	5.03	5.05	5.01	4.99	0.13
6	4.97	5.06	5.06	4.96	5.03	5.01	0.10
7	5.05	5.01	5.10	4.96	4.99	5.02	0.14
8	5.09	5.10	5.00	4.99	5.08	5.05	0.11
9	5.14	5.10	4.99	5.08	5.09	5.08	0.15
10	5.01	4.98	5.08	5.07	4.99	5.03	0.10
						50.09	1.15

Example 15.4

x- bar Chart Example (cont.)

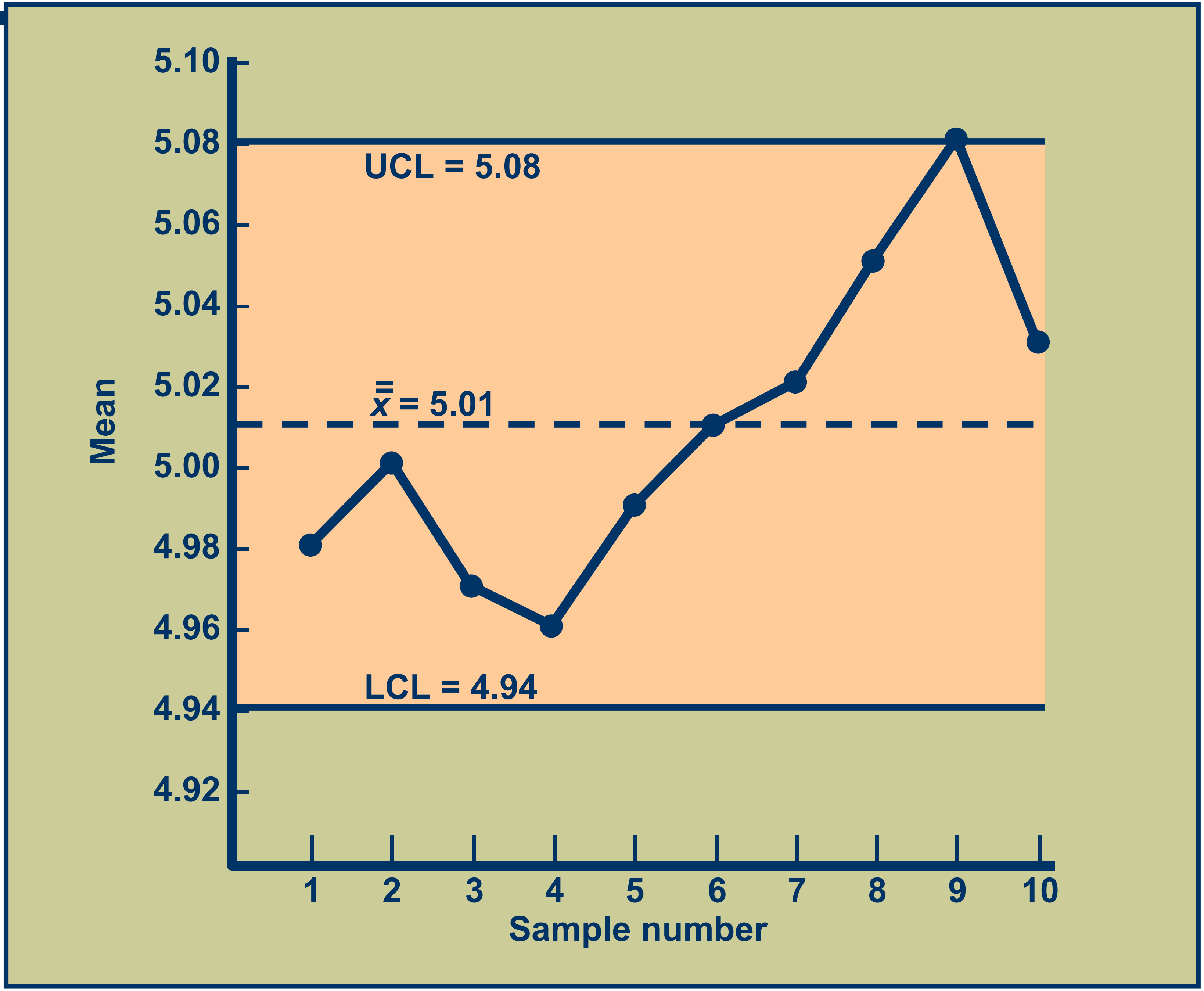
$$\bar{\bar{x}} = \frac{\sum \bar{x}}{k} = \frac{50.09}{10} = 5.01 \text{ cm}$$

$$UCL = \bar{\bar{x}} + A_2\bar{R} = 5.01 + (0.58)(0.115) = 5.08$$

$$LCL = \bar{\bar{x}} - A_2\bar{R} = 5.01 - (0.58)(0.115) = 4.94$$

Retrieve Factor Value A_2

x- bar Chart Example (cont.)



R- Chart

$$UCL = D_4\bar{R} \qquad LCL = D_3\bar{R}$$

$$\bar{R} = \frac{\sum R}{k}$$

where

$\bar{R}$ = range of each sample
k = number of samples

R-Chart Example

SAMPLE k	OBSERVATIONS (SLIP-RING DIAMETER, CM) 1	2	3	4	5	$\bar{x}$	R
1	5.02	5.01	4.94	4.99	4.96	4.98	0.08
2	5.01	5.03	5.07	4.95	4.96	5.00	0.12
3	4.99	5.00	4.93	4.92	4.99	4.97	0.08
4	5.03	4.91	5.01	4.98	4.89	4.96	0.14
5	4.95	4.92	5.03	5.05	5.01	4.99	0.13
6	4.97	5.06	5.06	4.96	5.03	5.01	0.10
7	5.05	5.01	5.10	4.96	4.99	5.02	0.14
8	5.09	5.10	5.00	4.99	5.08	5.05	0.11
9	5.14	5.10	4.99	5.08	5.09	5.08	0.15
10	5.01	4.98	5.08	5.07	4.99	5.03	0.10
						50.09	1.15

Example 15.3

R-Chart Example (cont.)

$$\bar{R} = \frac{\sum R}{k} = \frac{1.15}{10} = 0.115$$

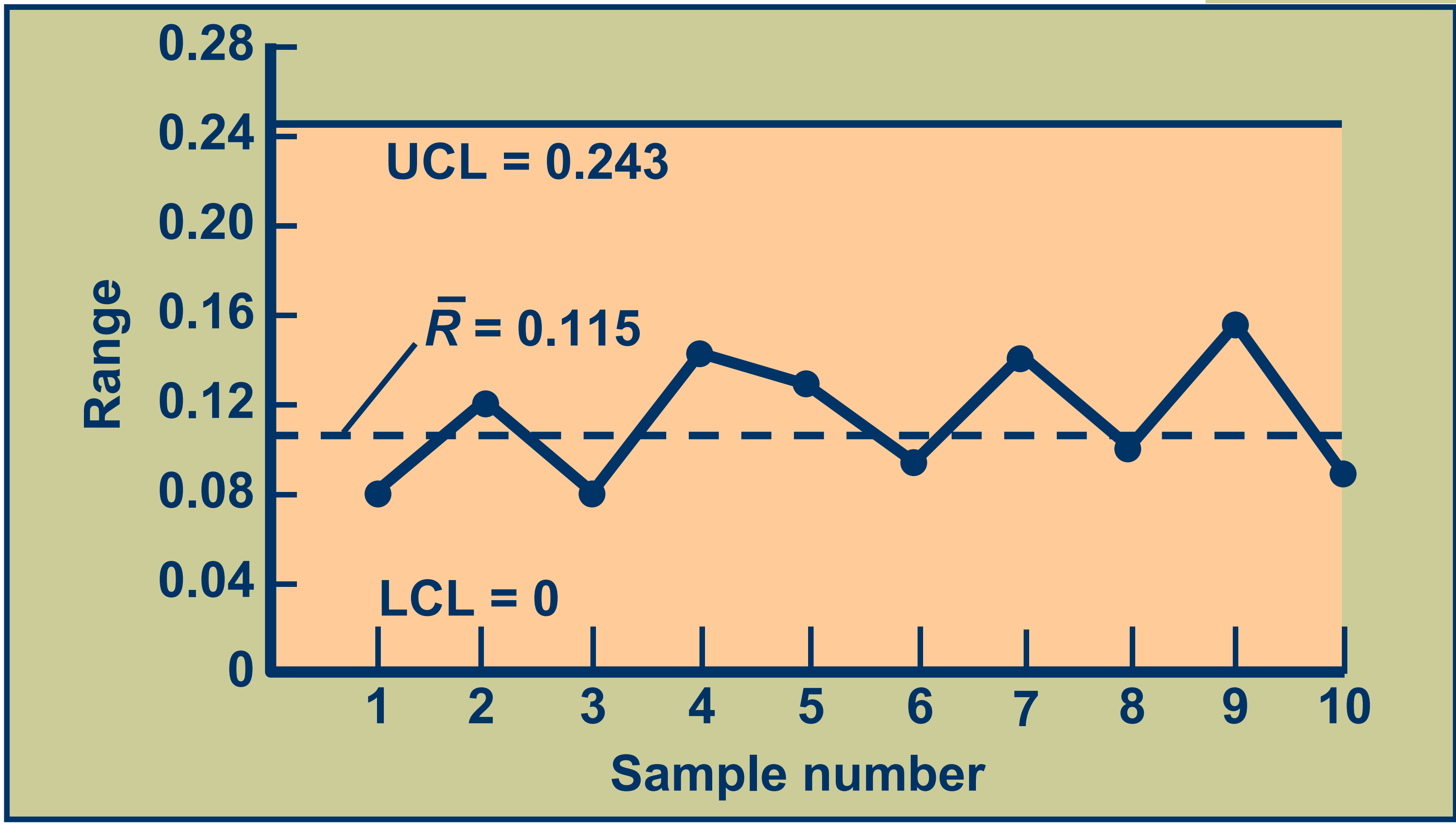
$$UCL = D_4\bar{R} = 2.11(0.115) = 0.243$$

$$LCL = D_3\bar{R} = 0(0.115) = 0$$

Retrieve Factor Values D_3 and D_4

Example 15.3

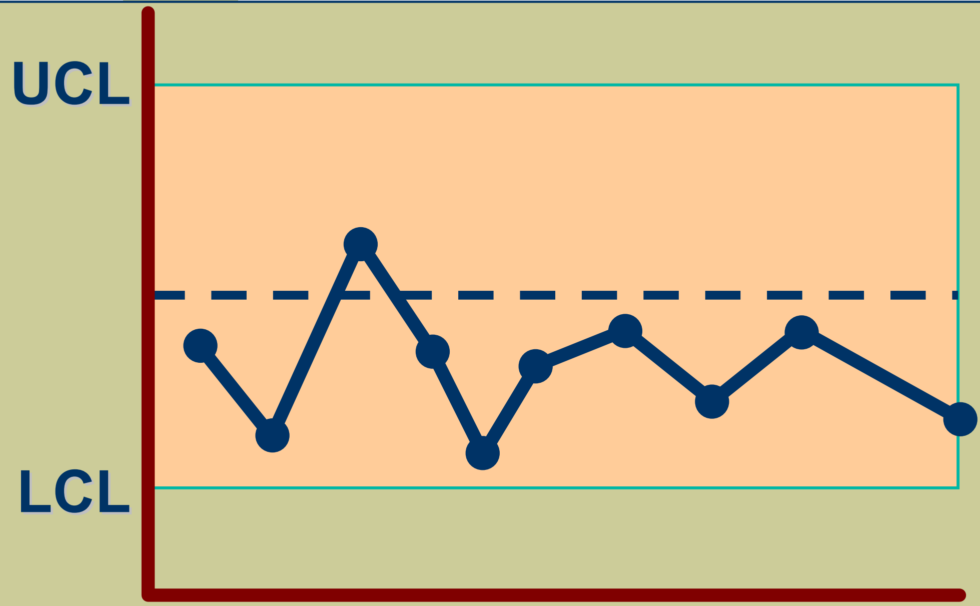
R-Chart Example (cont.)



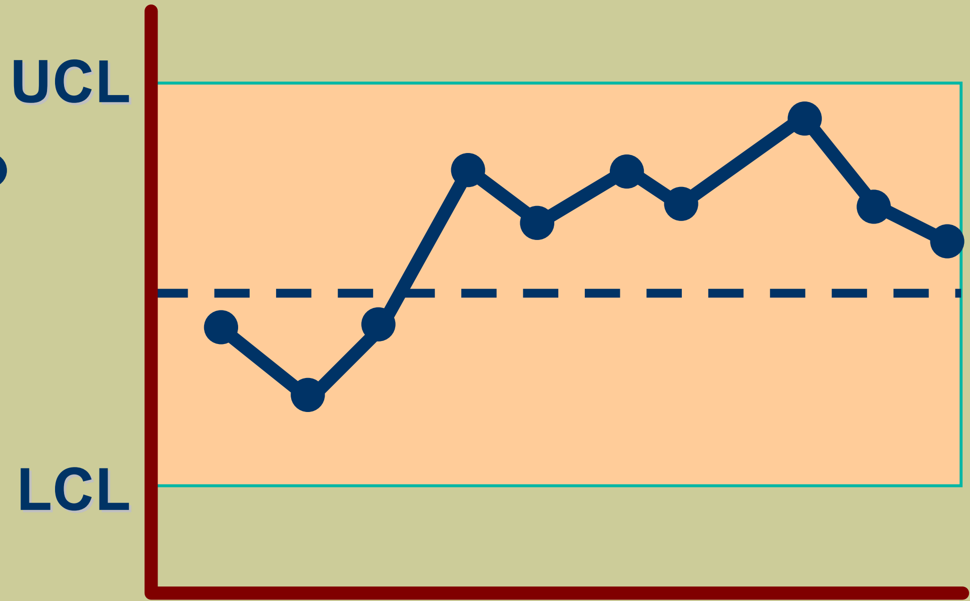
Using x- bar and R-Charts Together

- Process average and process variability must be in control
- It is possible for samples to have very narrow ranges, but their averages is beyond control limits
- It is possible for sample averages to be in control, but ranges might be very large

Control Chart Patterns

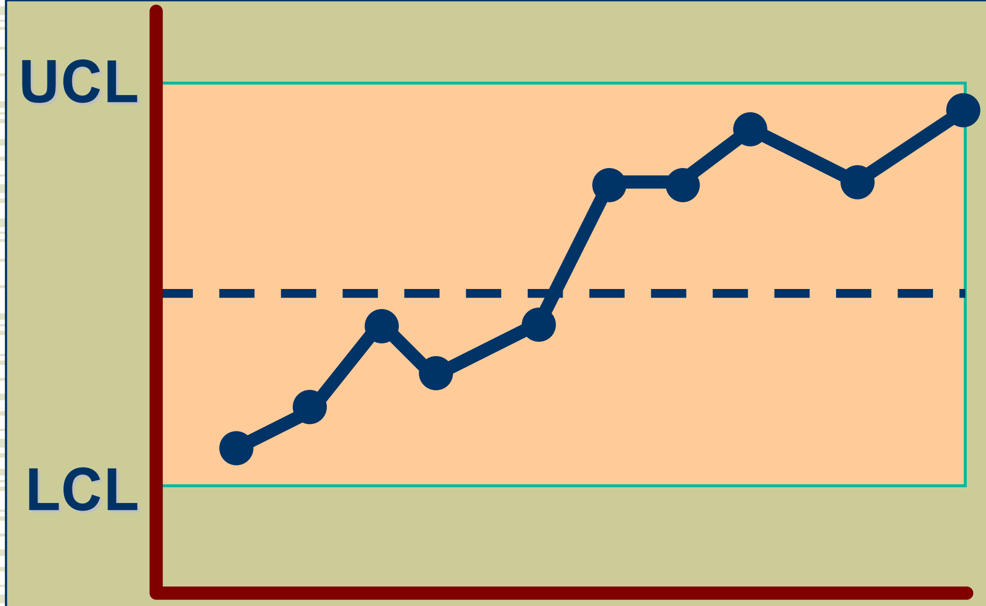


Sample observations consistently below the center line

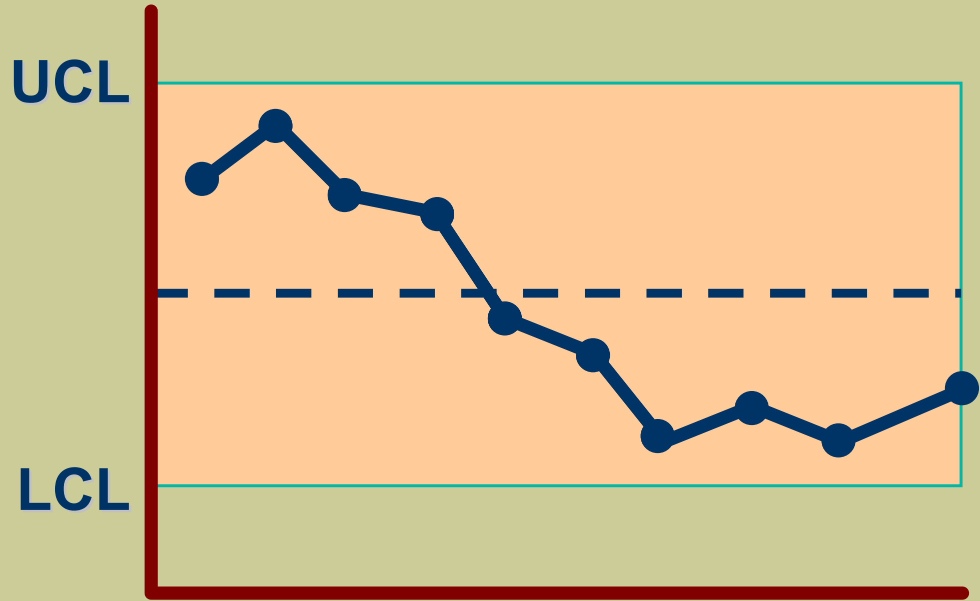


Sample observations consistently above the center line

Control Chart Patterns (cont.)



Sample observations consistently increasing



Sample observations consistently decreasing

Sample Size

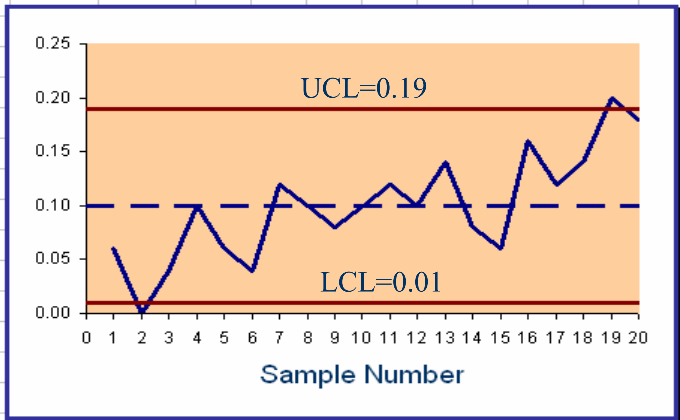
- Attribute charts require larger sample sizes
  - 50 to 100 parts in a sample
- Variable charts require smaller samples
  - 2 to 10 parts in a sample

SPC with Excel

Microsoft Excel - SPC_excel

Sample	Portion Defective	UCL	LCL	$\bar{p}$
0		0.190	0.010	0.100
1	0.06	0.190	0.010	0.100
2	0.00	0.190	0.010	0.100
3	0.04	0.190	0.010	0.100
4	0.10	0.190	0.010	0.100
5	0.06	0.190	0.010	0.100
6	0.04	0.190	0.010	0.100
7	0.12	0.190	0.010	0.100
8	0.10	0.190	0.010	0.100
9	0.08	0.190	0.010	0.100
10	0.10	0.190	0.010	0.100
11	0.12	0.190	0.010	0.100
12	0.10	0.190	0.010	0.100
13	0.14	0.190	0.010	0.100
14	0.08	0.190	0.010	0.100
15	0.06	0.190	0.010	0.100
16	0.16	0.190	0.010	0.100
17	0.12	0.190	0.010	0.100
18	0.14	0.190	0.010	0.100
19	0.20	0.190	0.010	0.100
20	0.18	0.190	0.010	0.100

$\bar{p}$ =	0.100
UCL=	0.190
LCL=	0.010

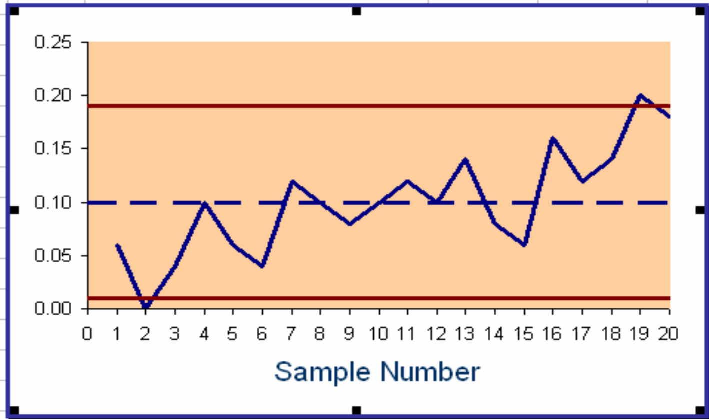


SPC with Excel: Formulas

Microsoft Excel - SPC_excel

Sample	Portion Defective	UCL	LCL	$\bar{p}$
0		=$H$3	=$H$4	=$H$2
1	0.06	=$H$3	=$H$4	=$H$2
2	0	=$H$3	=$H$4	=$H$2
3	0.04	=$H$3	=$H$4	=$H$2
4	0.1	=$H$3	=$H$4	=$H$2
5	0.06	=$H$3	=$H$4	=$H$2
6	0.04	=$H$3	=$H$4	=$H$2
7	0.12	=$H$3	=$H$4	=$H$2
8	0.1	=$H$3	=$H$4	=$H$2
9	0.08	=$H$3	=$H$4	=$H$2
10	0.1	=$H$3	=$H$4	=$H$2
11	0.12	=$H$3	=$H$4	=$H$2
12	0.1	=$H$3	=$H$4	=$H$2
13	0.14	=$H$3	=$H$4	=$H$2
14	0.08	=$H$3	=$H$4	=$H$2
15	0.06	=$H$3	=$H$4	=$H$2
16	0.16	=$H$3	=$H$4	=$H$2
17	0.12	=$H$3	=$H$4	=$H$2
18	0.14	=$H$3	=$H$4	=$H$2
19	0.2	=$H$3	=$H$4	=$H$2
20	0.18	=$H$3	=$H$4	=$H$2

$\bar{p}$ =	=AVERAGE(B3:B22)
UCL=	=H2+3*SQRT(H2*(1-H2)/100)
LCL=	=H2-3*SQRT(H2*(1-H2)/100)

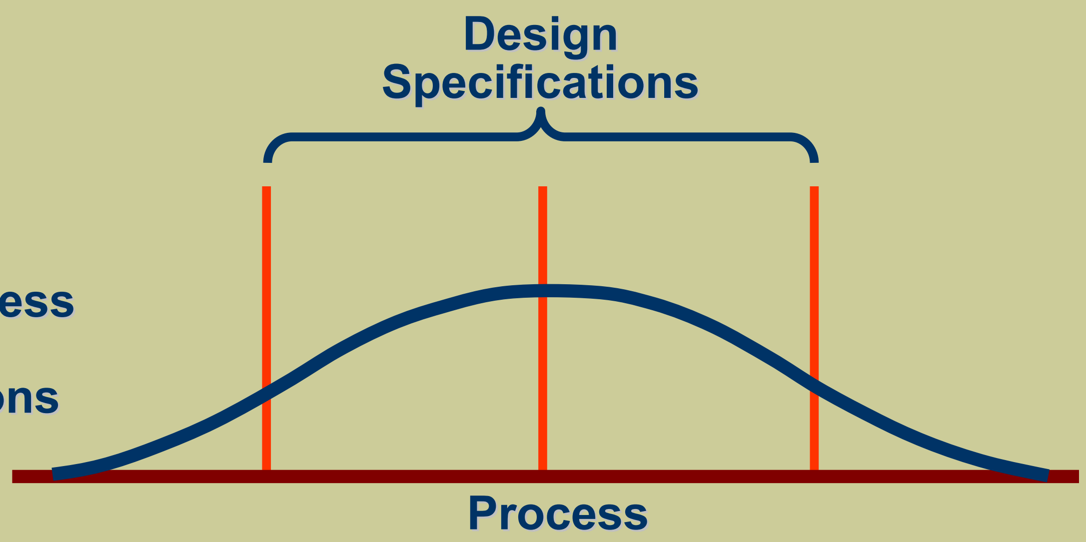


Process Capability

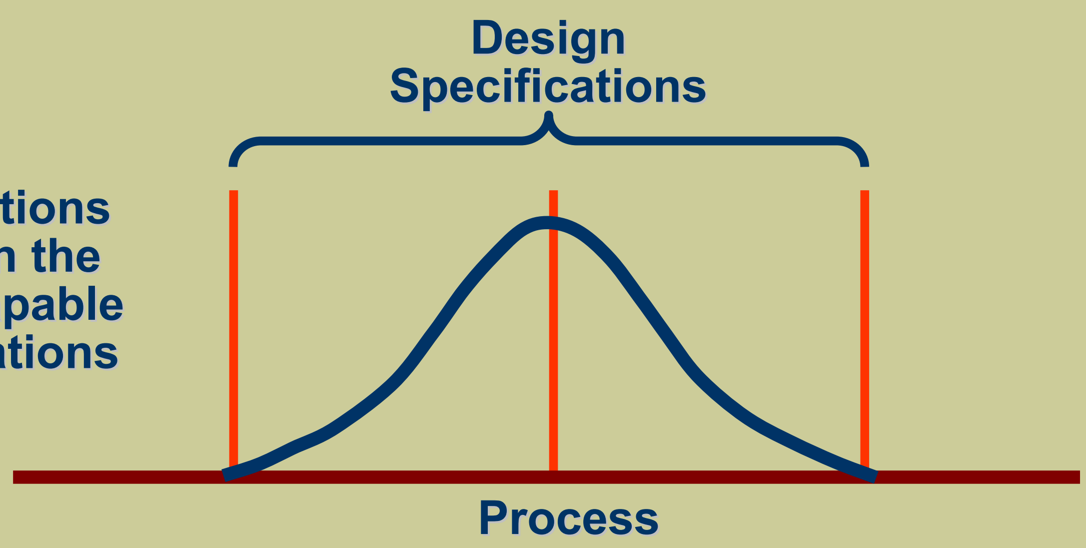
- Tolerances
  - design specifications reflecting product requirements
- Process capability
  - range of natural variability in a process what we measure with control charts

Process Capability

(a) Natural variation exceeds design specifications; process is not capable of meeting specifications all the time.

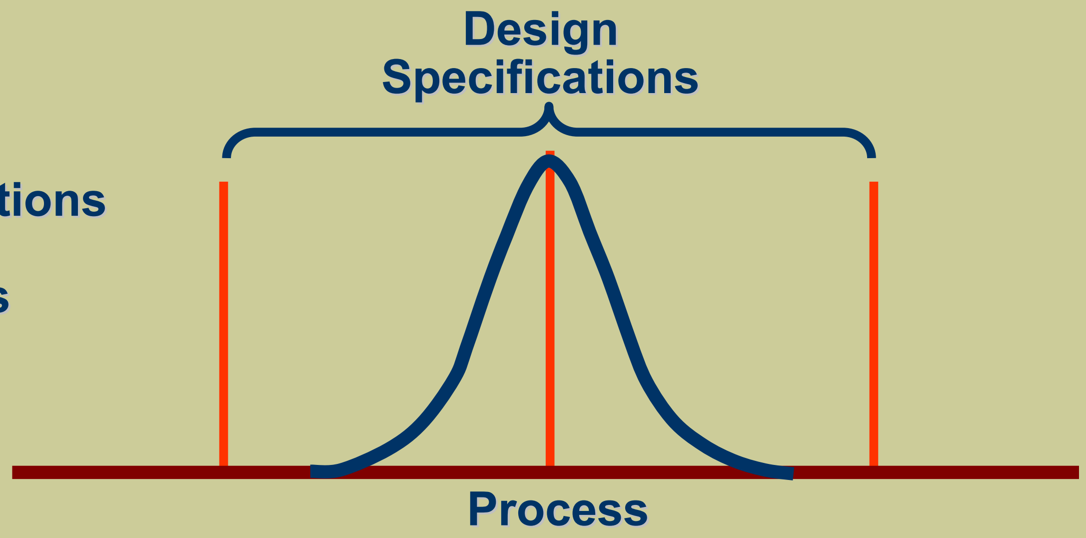


(b) Design specifications and natural variation the same; process is capable of meeting specifications most of the time.

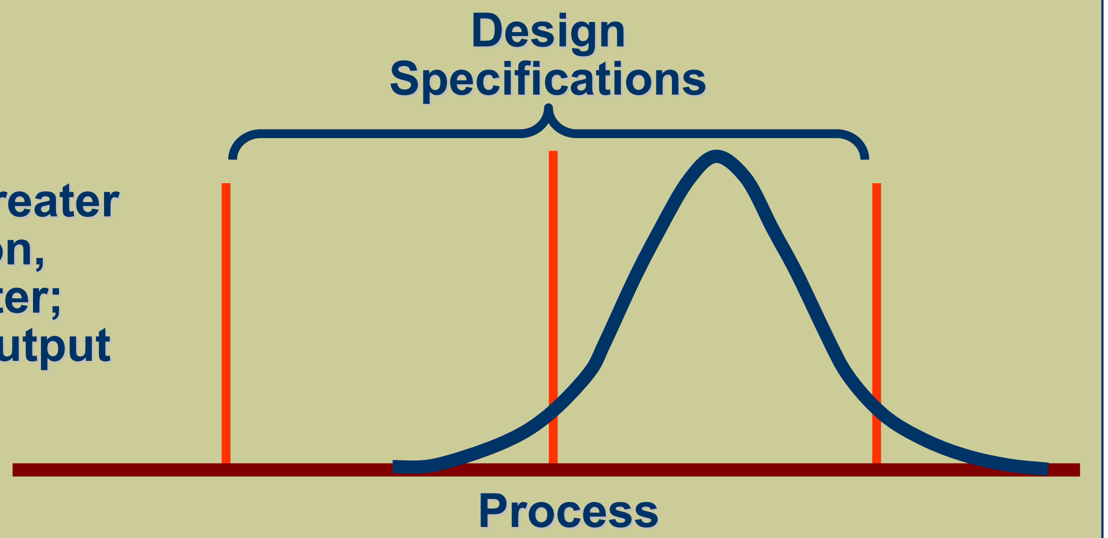


Process Capability (cont.)

(c) Design specifications greater than natural variation; process is capable of always conforming to specifications.



(d) Specifications greater than natural variation, but process off center; capable but some output will not meet upper specification.



Process Capability Measures

Process Capability Ratio

$$C_p = \frac{\text{tolerance range}}{\text{process range}}$$

$$= \frac{\text{upper specification limit - lower specification limit}}{6\sigma}$$

Computing C_p

Net weight specification = 9.0 oz ± 0.5 oz
Process mean = 8.80 oz
Process standard deviation = 0.12 oz

$$C_p = \frac{\text{upper specification limit - lower specification limit}}{6\sigma}$$

$$= \frac{9.5 - 8.5}{6(0.12)} = 1.39$$

Process Capability Measures

Process Capability Index

$$C_{pk} = \text{minimum}\left[\frac{\bar{\bar{x}} - \text{lower specification limit}}{3\sigma}, \frac{\text{upper specification limit} - \bar{\bar{x}}}{3\sigma}\right]$$

Computing C_{pk}

Net weight specification = 9.0 oz ± 0.5 oz
Process mean = 8.80 oz
Process standard deviation = 0.12 oz

$$C_{pk} = \text{minimum}\left[\frac{\bar{\bar{x}} - \text{lower specification limit}}{3\sigma}, \frac{\text{upper specification limit} - \bar{\bar{x}}}{3\sigma}\right]$$

$$= \text{minimum}\left[\frac{8.80 - 8.50}{3(0.12)}, \frac{9.50 - 8.80}{3(0.12)}\right] = 0.83$$

Appendix: Determining Control Limits for x-bar and R-Charts

SAMPLE SIZE n	FACTOR FOR $\bar{x}$-CHART A_2	FACTORS FOR R-CHART D_3	D_4
2	1.88	0.00	3.27
3	1.02	0.00	2.57
4	0.73	0.00	2.28
5	0.58	0.00	2.11
6	0.48	0.00	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.44	0.18	1.82
10	0.11	0.22	1.78
11	0.99	0.26	1.74
12	0.77	0.28	1.72
13	0.55	0.31	1.69
14	0.44	0.33	1.67
15	0.22	0.35	1.65
16	0.11	0.36	1.64
17	0.00	0.38	1.62
18	0.99	0.39	1.61
19	0.99	0.40	1.61
20	0.88	0.41	1.59

Return