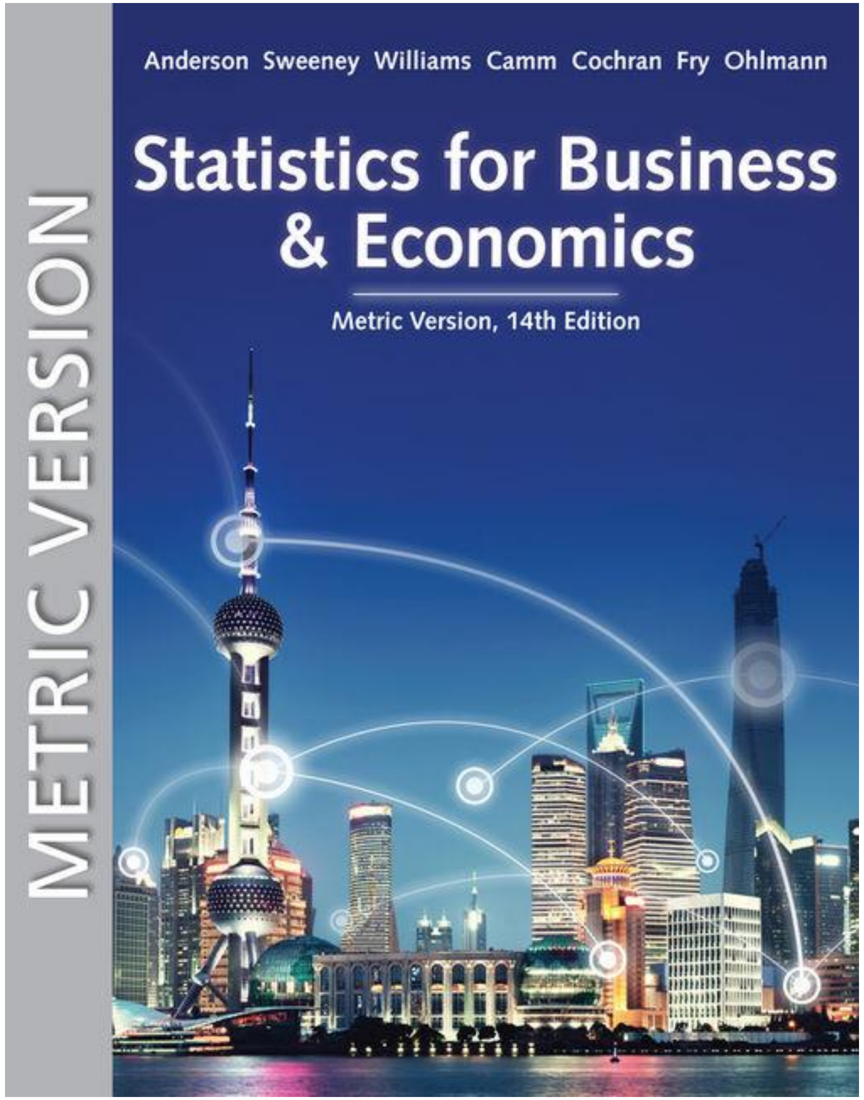
Statistics for Business and Economics (14e) Metric Version

Chapter 21 （品質管制）



Chapter 21 - Statistical Methods for Quality Control

21.1 – Philosophies and Frameworks

21.2 – Statistical Process Control

21.3 – Acceptance Sampling

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Quality

- The American Society for Quality (ASQ) defines quality as:
  - *“the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs*.”
- Organizations recognize that they must strive for high levels of quality.
- They have increased the emphasis on methods for monitoring and maintaining quality.

Total Quality（全面品質）(1 of 2)

- Total Quality (TQ) is a people-focused management system that aims at continual increase in customer satisfaction at continually lower real cost.
- TQ is a total system approach (not a separate work program) and an integral part of high-level strategy.
- TQ works horizontally across functions, involves all employees, top to bottom, and extends backward and forward to include both the supply and customer chains.
- TQ stresses learning and adaptation to continual change as keys to organization success.

Total Quality (2 of 2)

Regardless of how it is implemented in different organizations, Total Quality is based on three fundamental principles:

- a focus on customers and stakeholders
- participation and teamwork throughout the organization
- a focus on continuous improvement and learning

◆全面品質管理可用三個Q（Quality）表示：

1. 人的品質
2. 系統及流程（Process）的品質
3. 產品及服務的品質

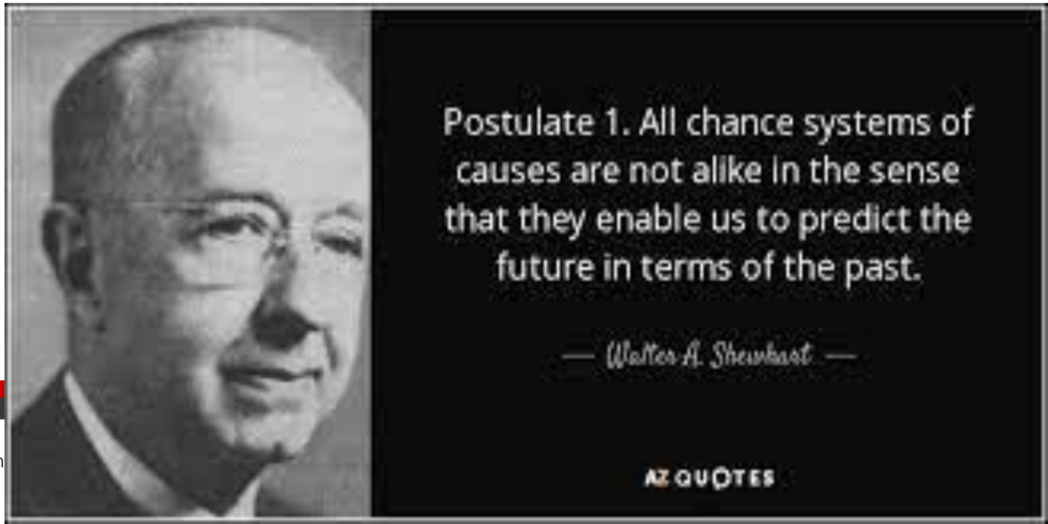
Quality Philosophies (1 of 4)

Dr. Walter A. Shewhart

- Developed a set of principles that are the basis for what is known today as process control (製程控制)
- Constructed a diagram that would now be recognized as a statistical control chart
- Brought together the disciplines of statistics, engineering, and economics and changed the course of industrial history
- Recognized as the father of statistical quality control
- First honorary member of ASQ

(American Society for Quality)

https://qualityleadershipblog.com/2020/08/02/dr-walter-shewhart-references/



Quality Philosophies (2 of 4)

Dr. W. Edwards Deming

- Helped educate the Japanese on quality management shortly after World War II
- Stressed that the focus on quality must be led by managers
- Developed a list of 14 points he believed represent the key responsibilities of managers
- *Japan named its national quality award the Deming Prize* in his honor

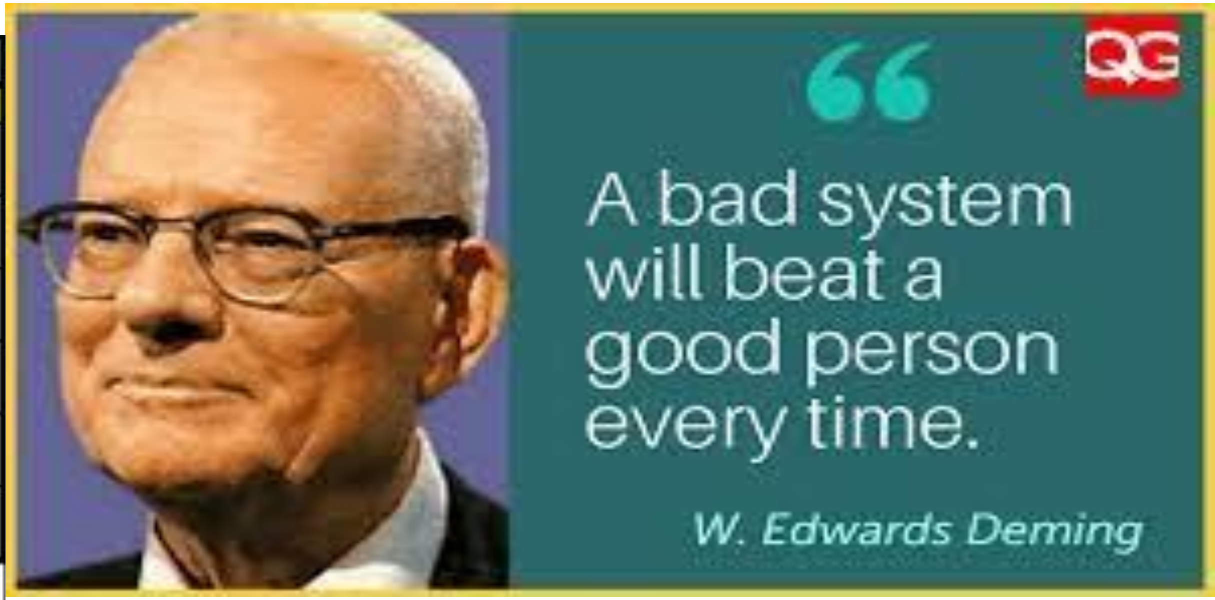
https://www.qualitygurus.com/w-edwards-deming/

https://kaizeninstituteindia.files.wordpress.com/2013/10/14-points_demingresize1.jpg?w=487

Deming's 14 Points

1	Create constancy of purpose .	8	Drive out fear.
2	Adopt the new philosophy and take on leadership .	9	Break down barriers. Work as a team.
3	Eliminate inspection. Build in quality.	10	Eliminate slogans. Fix the system.
4	Minimize total cost of by improving quality of supplies.	11	Eliminate quotas. Substitute Leadership
5	Constantly improve quality and productivity to decrease costs.	12	Remove barriers to pride of workmanship.
6	Institute training on the job.	13	Institute a vigorous program of education and self-improvement.
7	Supervision should be to help people.	14	The transformation is everybody's job.

Deming, *Out of the Crisis*, (p23-24)



Quality Philosophies (3 of 4)

Joseph Juran

- Helped educate the Japanese on quality management shortly after World War II
- Proposed a simple definition of quality: *fitness for use*
- His approach to quality focused on three quality processes: quality planning, quality control, and quality improvement

Quality Philosophies (4 of 4)

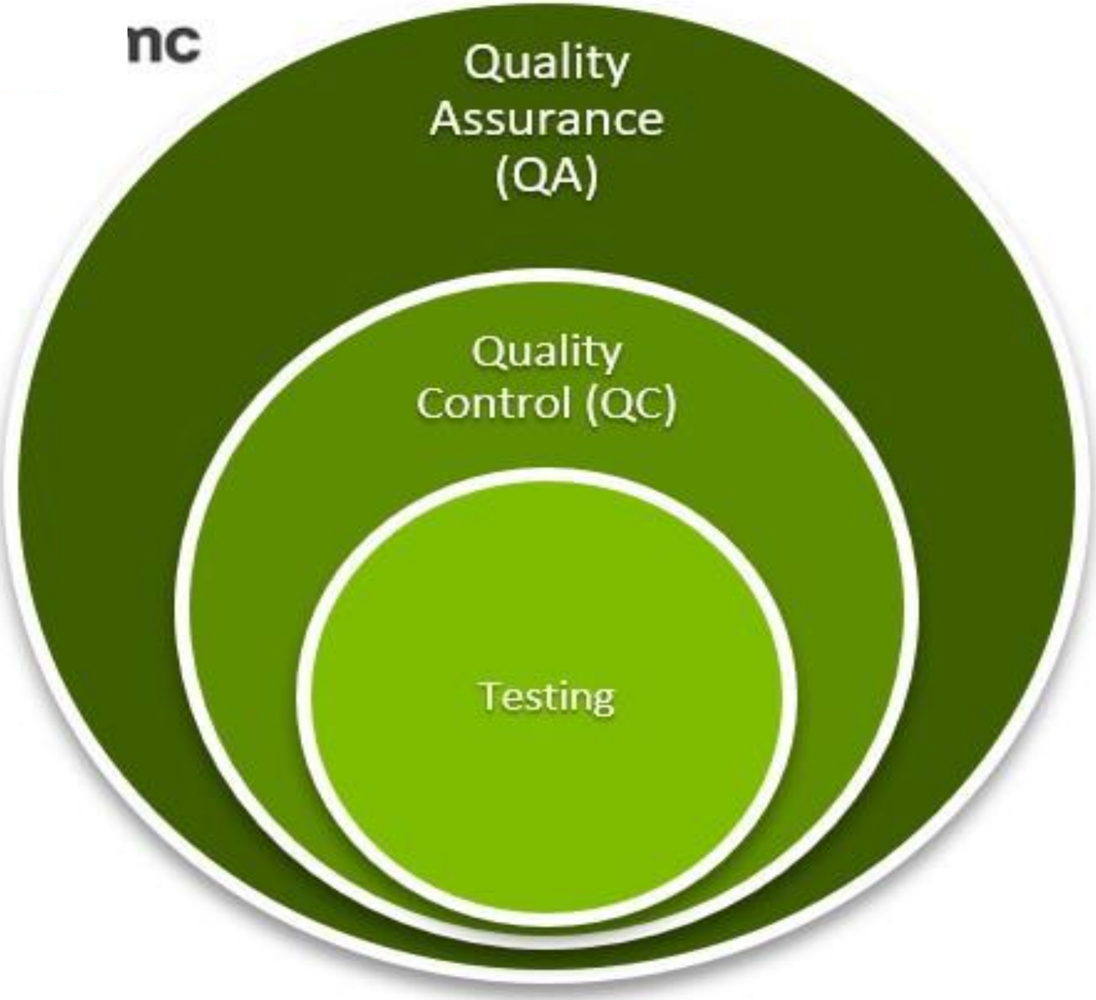
Other Significant Individuals

- Philip B. Crosby
- A. V. Feigenbaum
- Karou Ishikawa
- Genichi Taguchi (田口玄一)

https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTV6x0WkkM6uMHxX_SBCoDmr4ZeWarxU8NWDgn-xeZYoO0lLRl4vP10IGF4Qf8caGQbU-Q&usqp=CAU

Quality Assurance vs. **Quality Control**

（品質保證）　（品質管制）



https://s7280.pcdn.co/wp-content/uploads/2021/04/quality-assurance.jpg.optimal.jpg

Quality Frameworks (1 of 8)

Malcolm Baldrige National Quality Award

Established in 1987 and given by the U.S. president to organizations that judged to be outstanding in:

1. Leadership
2. Strategic Planning
3. Customer and Market Focus
4. Measurement, Analysis and Knowledge Management
5. Human Resource Focus
6. Process Management
7. Business Results

https://www.alamo.edu/siteassets/district/news/2018/november/bldrg-400x.jpg

https://cdn.firespring.com/images/017fe8f7-b0e0-4fbd-8668-577564cb9c09.jpg

BALDRIGE FOUNDATION

BALDRIGE - America's Best Investment

Quality Frameworks (2 of 8)

Malcolm Baldrige National Quality Award (continued)

- The first awards were presented in 1988.
- The Award is named for Malcolm Baldrige, who was U.S. Secretary of Commerce from 1981-1987.
- The U.S. Commerce Department’s National Institute of Standards and Technology (NIST) manages the Award.
- In 2003, the “Baldrige Index” (a hypothetical stock index comprised of Baldrige Award winning companies) outperformed the S&P 500 by 4.4 to 1.

Quality Frameworks (3 of 8)

ISO 9000

- A series of five standards published in 1987 by the **International Organization for Standardization** in Geneva, Switzerland.
- The standards describe the need for:
  - an effective quality system,
  - ensuring that measuring and testing equipment is calibrated regularly,
  - maintaining an adequate record-keeping system.
- ISO 9000 registration determines whether a company complies with its own quality system.

Quality Frameworks (4 of 8)

Six Sigma

- Six sigma level of quality means that for every million opportunities no more than 3.4 defects will occur.
- The methodology created to reach this quality goal is referred to as Six Sigma.
- Six Sigma is a major tool in helping organizations achieve Baldrige levels of business performance and process quality.

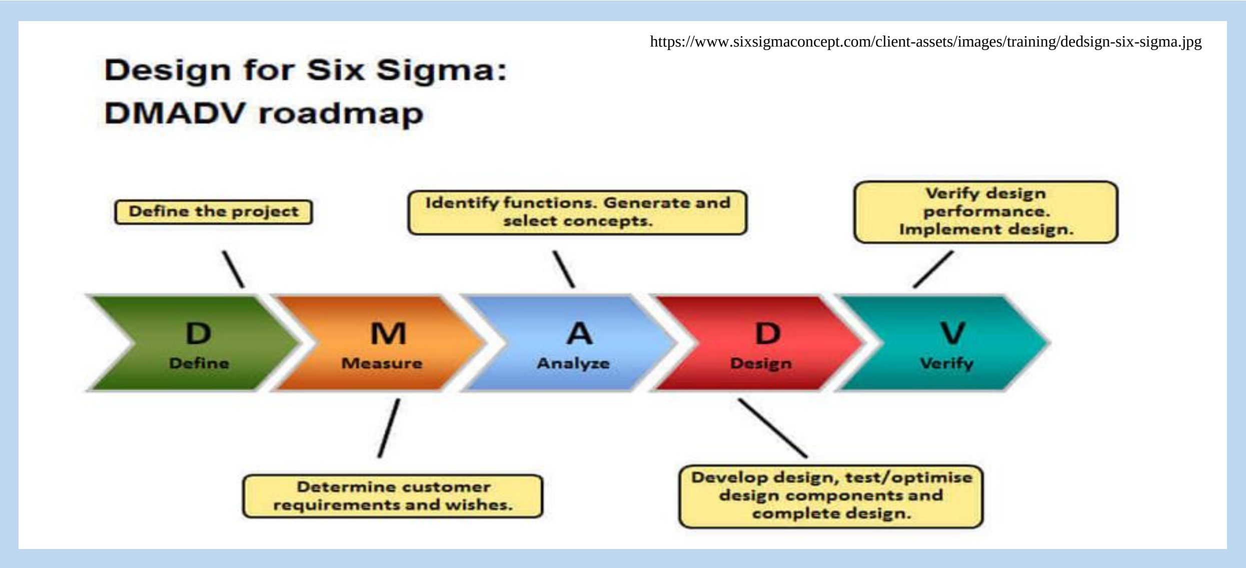
Quality Frameworks (5 of 8)

Six Sigma (continued)

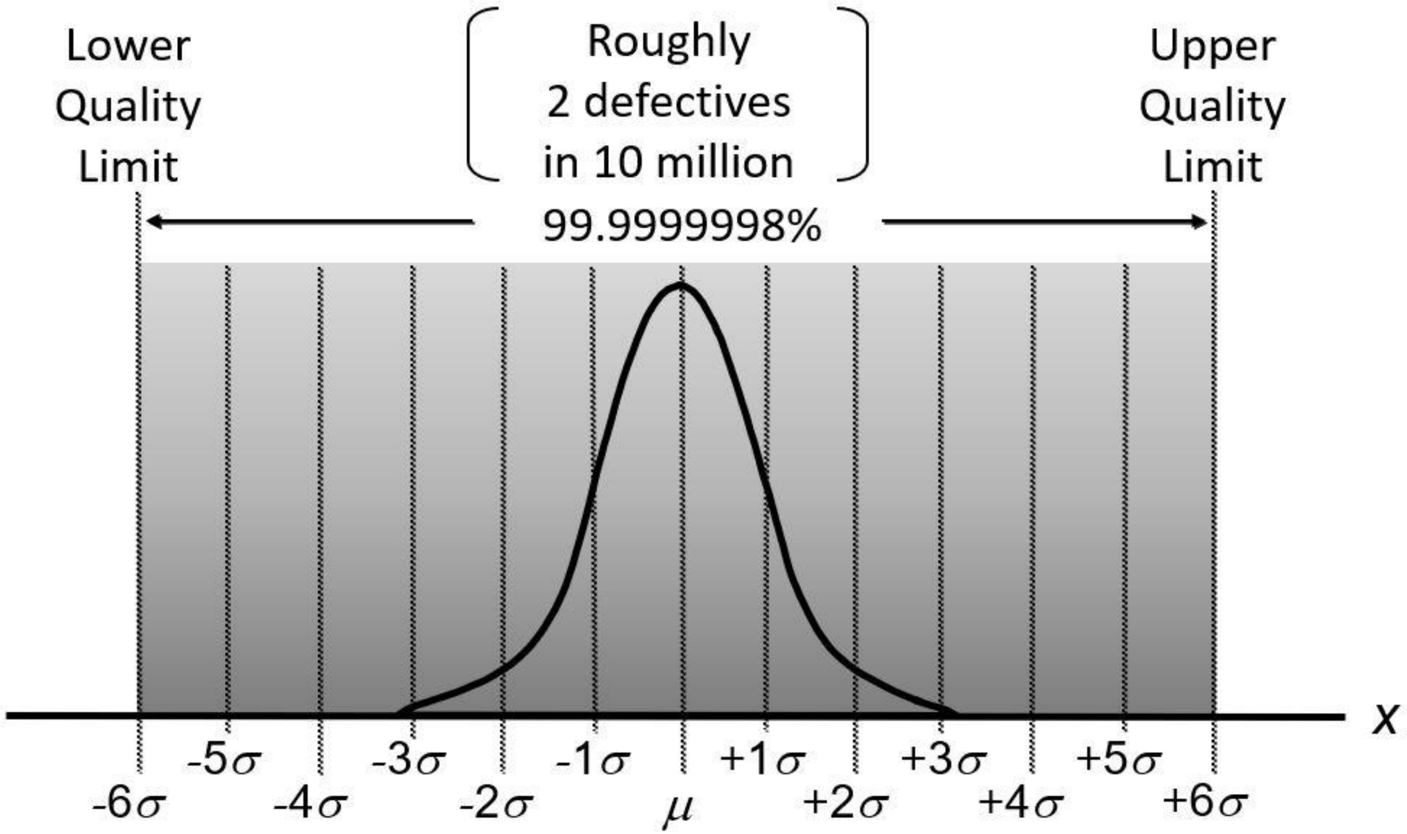
- Two kinds of Six Sigma projects can be undertaken:
    - **DMAIC** (Define, Measure, Analyze, Improve, and Control)
    - **DFSS** (Design for Six Sigma)

https://www.researchgate.net/profile/Tanvir-Ahmed-39/publication/340666189/figure/fig2/AS:880918352900100@1587038710868/Six-Sigma-DMAIC-define-measure-analyze-improve-control-methodology-Resources-2015b_Q640.jpg

- Six Sigma is a major tool in helping organizations achieve Baldrige levels of business performance.
- Six Sigma places a heavy emphasis on statistical analysis and careful measurement.



Quality Frameworks (6 of 8)



Quality Frameworks (7 of 8)

Six Sigma (continued)

- 99.9999998% of the process output will be within ± 3 standard deviations of the mean. Using Excel:

NORM.S.DIST(6,TRUE) – NORM.S.DIST(–6,TRUE)

= 0.999999998

- If the process mean shifts by 1.5 standard deviations, there will be approximately 3.4 defects per million opportunities. Using Excel:

1 – NORM.S.DIST(4.5,TRUE) = 0.0000034

Quality Frameworks (8 of 8)

Quality in the Service Sector

- Quality control is also very important to businesses that focus primarily on providing services (e.g., law firms, hotels, airlines, restaurants and banks).
- Quality efforts in the service sector focus on ensuring customer satisfaction and improving the customer experience.
- Services provided are often intangible, and thus customer satisfaction is subjective. So, measuring quality can be challenging.

Quality Terminology

- **Quality assurance** refers to the entire system of policies, procedures, and guidelines established by an organization to achieve and maintain quality.

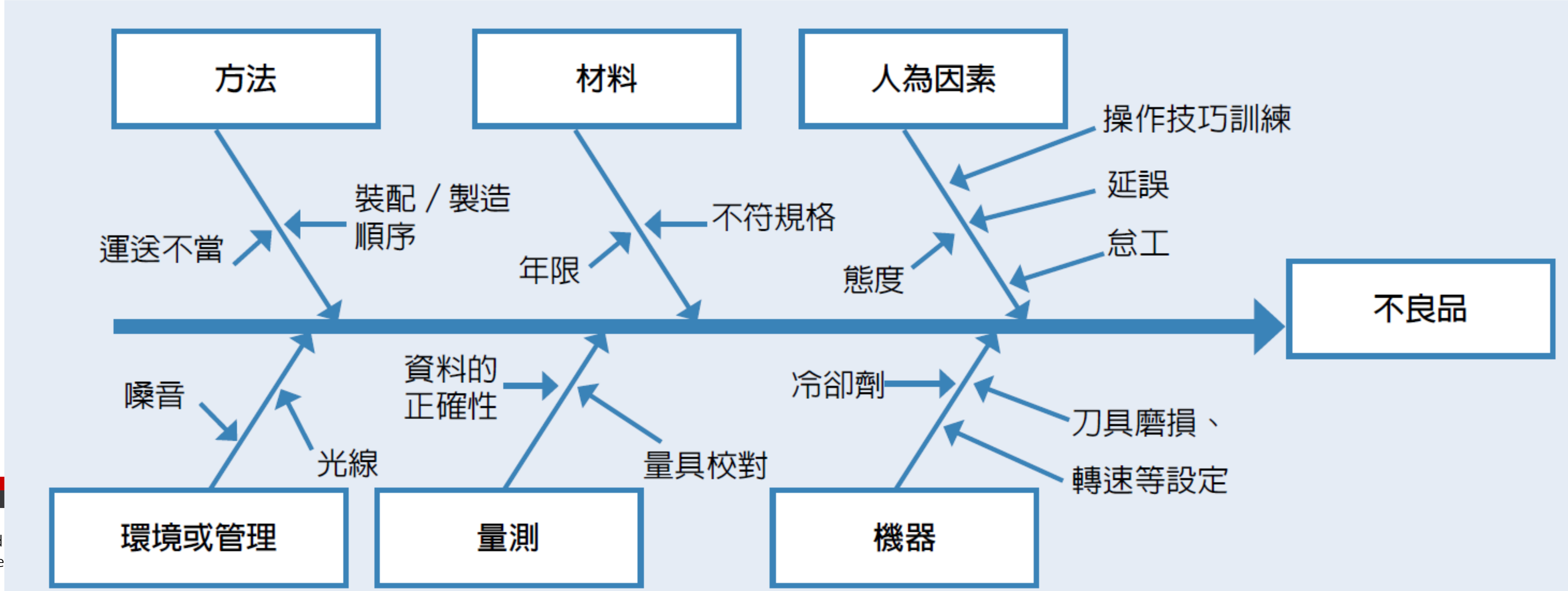
- Quality assurance consists of two functions:

→**Quality engineering** - its objective is to include quality in the design of products and processes and to identify potential quality problems prior to production.

→**Quality control** consists of making a series of inspections and measurements to determine whether quality standards are being met.

Statistical Process Control (SPC)

- Output of the production process is sampled and inspected.
- Using SPC methods, it can be determined whether variations in output are due to common causes or assignable causes.
- The goal is to decide whether the process can be continued or if it should be adjusted to achieve a desired quality level.



Causes of Process Output Variation (1 of 2)

Common Causes

- randomly occurring variations in materials, humidity, temperature, etc.
- variations the producer cannot control
- process is *in statistical control*
- process does not need to be adjusted

Causes of Process Output Variation (2 of 2)

Assignable Causes

- non-random variations in output due to tools wearing out, operator error, incorrect machine settings, poor quality raw material, etc.
- variations the producer can control
- process is *out of control*
- corrective action should be taken

SPC Hypotheses

- SPC procedures are based on hypothesis-testing methodology.
- Null hypothesis, H_0, is formulated in terms of the production process being in control.
- Alternative hypothesis, H_a, is formulated in terms of the production process being out of control.

Decisions and State of the Process

Type I and Type II Errors

Decision	State of Production Process: H_0 True In-Control	State of Production Process: H_0 False Out-of-Control
Accept H_0 Continue Process	Correct Decision	Type II Error Allow out-of-control process to continue
Reject H_0 Adjust Process	Type I Error Adjust in-control process	Correct Decision

Control Charts

- SPC uses graphical displays known as control charts to monitor a production process.
- Control charts provide a basis for deciding whether the variation in the output is due to common causes (in control) or assignable causes (out of control).
- Two important lines on a control chart are the upper control limit (UCL) and lower control limit (LCL).
- These lines are chosen so that when the process is in control, there will be a high probability that the sample finding will be between the two lines.
- Values outside of the control limits provide strong evidence that the process is out of control.

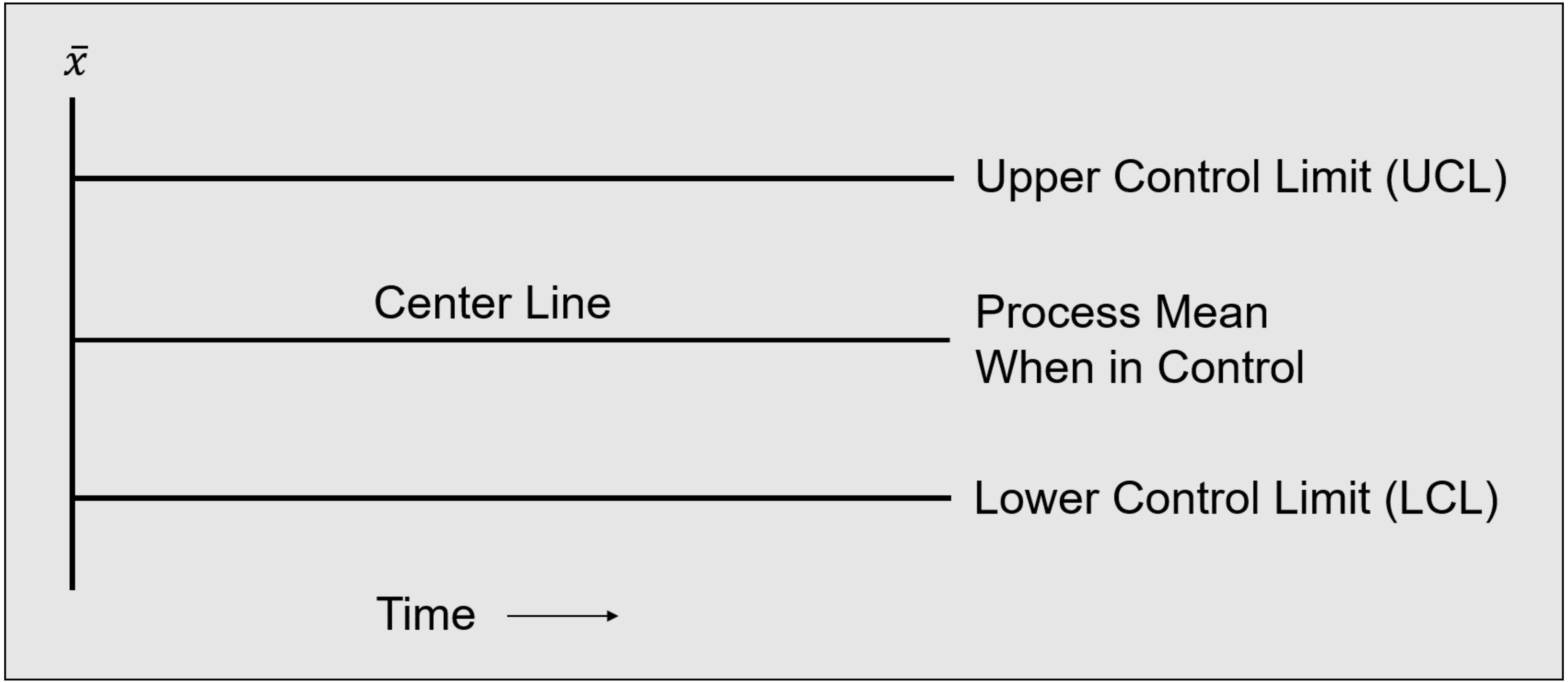
Variables Control Charts

- An $\bar{x}$ Chart is used if the quality of the output is measured in terms of a variable such as length, weight, temperature, and so on.
- An $\bar{x}$ Chart is used to monitor the mean value found in a sample of the output.
- An *R* Chart is used to monitor the range of the measurements in the sample.

Attributes Control Charts

- A *p* Chart is used to monitor the proportion defective in the sample.
- An *np* Chart is used to monitor the number of defective items in the sample.

$\bar{x}$ Chart Structure



Control Limits for an $\bar{x}$ Chart

Process Mean μ and Standard Deviation σ Known

$$\text{UCL} = \mu + 3\sigma_{\bar{x}}$$
$$\text{LCL} = \mu - 3\sigma_{\bar{x}}$$

where: n = sample size

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

Control Limits for an $\bar{x}$ Chart: Process Mean and Standard Deviation Known

(1 of 2)

Example: Granite Rock Co.

When Granite Rock's packaging process is in control, the weight of bags of cement filled by the process is normally distributed with a mean of 50 kg and a standard deviation of 1.5 kg.

What should be the control limits for samples of 9 bags?

Control Limits for an $\bar{x}$ Chart: Process Mean and Standard Deviation Known
(2 of 2)

$$\mu = 50, \quad \sigma = 1.5, \quad n = 9$$

$$\sigma_{\bar{x}} = {}^{\sigma}/_{\sqrt{n}} = {}^{1.5}/_{\sqrt{9}} = 0.5$$

UCL = 50 + 3(0.5) = **51.5**

CL = **50**

LCL = 50 – 3(0.5) = **48.5**

Control Limits for an $\bar{x}$ Chart

Process Mean and Standard Deviation Unknown

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

where:

$\bar{\bar{x}}$ = overall sample mean

$\bar{R}$ = average range

A_2 = constant that depends on *n*; taken from "Factors for Control Charts" table

Factors for $\bar{x}$ Control Chart

"Factors for Control Charts" Table (Partial)

n	d_2	A_2	d_3	D_3	D_4
5	2.326	0.577	0.864	0	2.114
6	2.534	0.483	0.848	0	2.004
7	2.704	0.419	0.833	0.076	1.924
8	2.847	0.373	0.820	0.136	1.864
9	2.970	0.337	0.808	0.184	1.816
10	3.078	0.308	0.797	0.223	1.777
.	.	.	.	.	.
.	.	.	.	.	.

Control Limits for an *R* Chart

Process Mean and Standard Deviation Unknown

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

where:

$\bar{R}$ = average range

D_3, D_4 = constants that depend on n; taken from “Factors for Control Charts” table

Factors for *R* Control Chart

"Factors for Control Charts" Table (Partial)

n	d_2	A_2	d_3	D_3	D_4
5	2.326	0.577	0.864	0	2.114
6	2.534	0.483	0.848	0	2.004
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9	2.970	0.337	0.808	0.184	1.816
10	3.078	0.308	0.797	0.223	1.777
.	.	.	.	.	.
.	.	.	.	.	.

R Chart

- Because the control limits for the $\bar{x}$ chart depend on the value of the average range, these limits will not have much meaning unless the process variability is in control.
- In practice, the *R* chart is usually constructed before the $\bar{x}$ chart.
- If the *R* chart indicates that the process variability is in control, then the $\bar{x}$ chart is constructed.

Control Limits for an *R* Chart: Process Mean and Standard Deviation Unknown (1 of 5)

Example: Granite Rock Co.

Suppose Granite does not know the true mean and standard deviation for its bag filling process. It wants to develop $\bar{x}$ and R charts based on twenty samples of 5 bags each.

The twenty samples, collected when the process was in control, resulted in an overall sample mean of 50.01 kg and an average range of .322 kg.

Control Limits for an *R* Chart: Process Mean and Standard Deviation Unknown

(2 of 5)

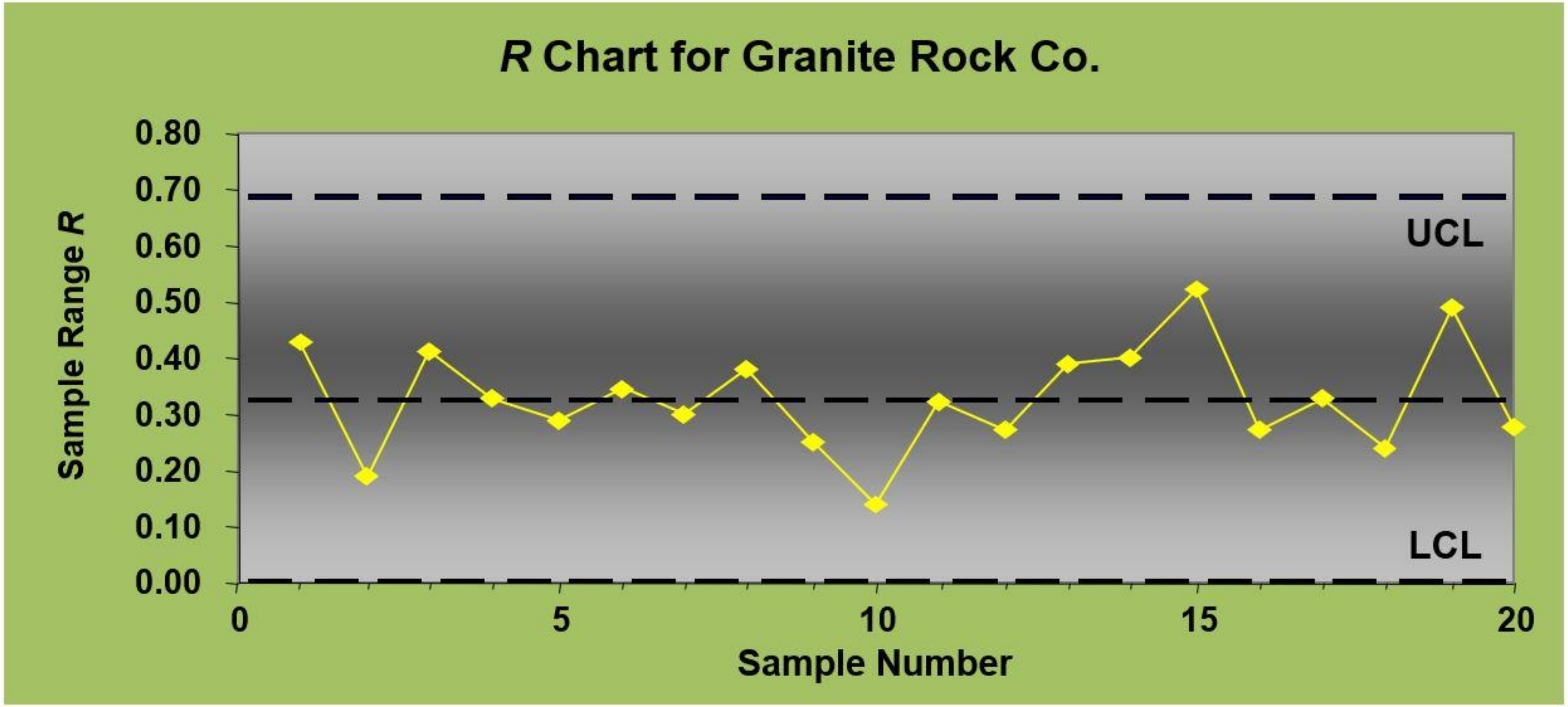
$\bar{\bar{x}} = 50.01, \quad \bar{R} = 0.322, \quad n = 5$

$$\text{UCL} = \bar{R}D_4 = 0.322(2.114) = \mathbf{0.681}$$

$$\text{CL} = \bar{R} = \mathbf{0.322}$$

$$\text{LCL} = \bar{R}D_3 = 0.322(0) = \mathbf{0}$$

Control Limits for an *R* Chart: Process Mean and Standard Deviation Unknown (3 of 5)



Control Limits for an *R* Chart: Process Mean and Standard Deviation Unknown
(4 of 5)

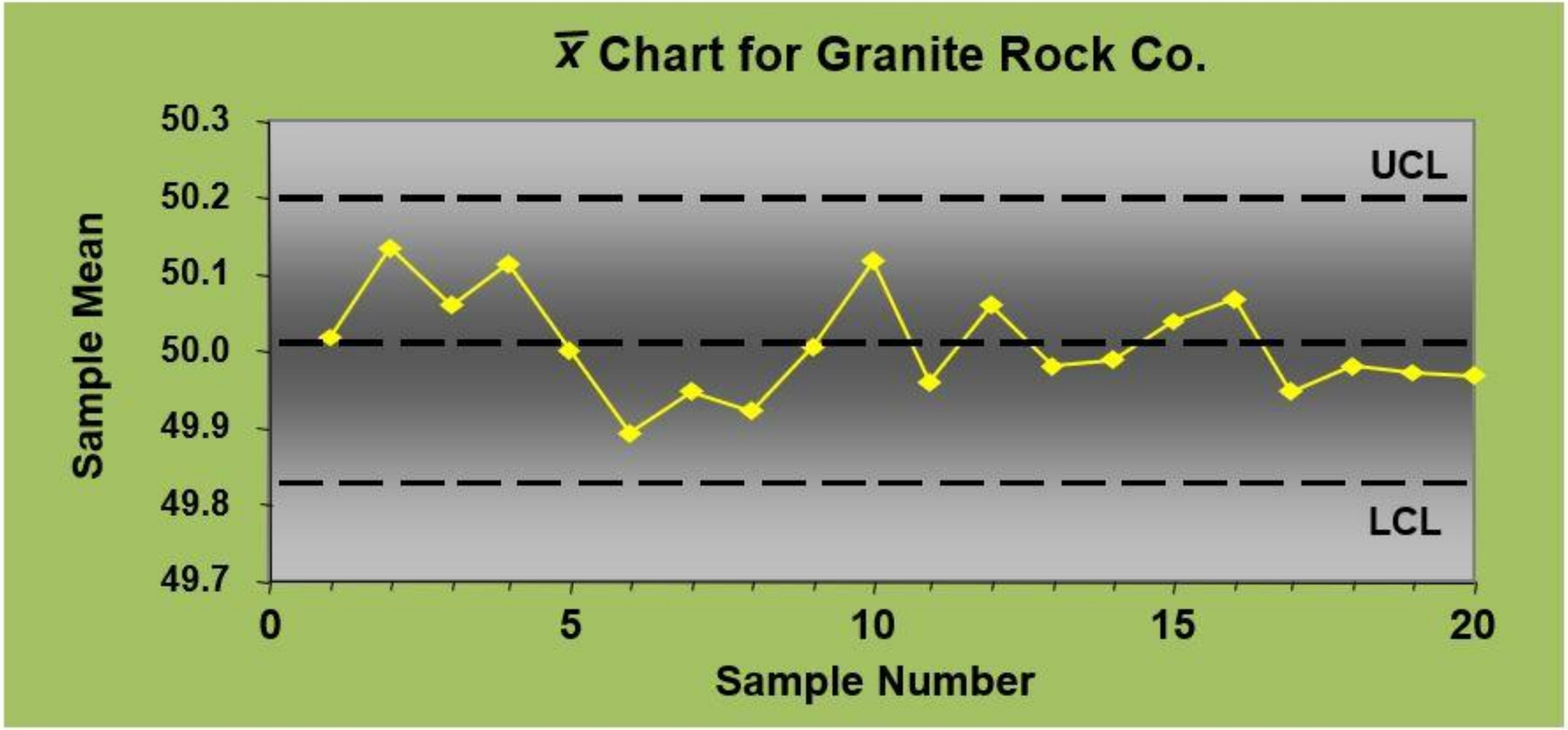
$$\bar{\bar{x}} = 50.01, \quad \bar{R} = .322, \quad n = 5$$

$$\text{UCL} = \bar{\bar{x}} + A_2\bar{R} = 50.01 + .577(.322) = \mathbf{50.196}$$

$$\text{CL} = \bar{\bar{x}} = \mathbf{50.01}$$

$$\text{LCL} = \bar{\bar{x}} - A_2\bar{R} = 50.01 - .577(.322) = \mathbf{49.824}$$

Control Limits for an *R* Chart: Process Mean and Standard Deviation Unknown (5 of 5)



Control Limits for a *p* Chart (1 of 5)

$$\text{UCL} = p + 3\sigma_{\bar{p}}$$
$$\text{LCL} = p - 3\sigma_{\bar{p}}$$

where: $$\sigma_{\bar{p}} = \sqrt{\frac{p(1-p)}{n}}$$

assuming: $np \geq 5$ and $n(1-p) \geq 5$

Note: If computed LCL is negative, set LCL = 0

Control Limits for a *p* Chart (2 of 5)

Every check cashed or deposited at Norwest Bank must be encoded with the amount of the check before it can begin the Federal Reserve clearing process.

The accuracy of the check encoding process is of utmost importance. If there is any discrepancy between the amount a check is made out for and the encoded amount, the check is defective.

Twenty samples, each consisting of 400 checks, were selected and examined when the encoding process was known to be operating correctly. The number of defective checks found in the 20 samples are listed below.

6	4	5	7	6	8	6	9	8	5
5	11	5	8	6	4	7	5	6	7

Control Limits for a *p* Chart (3 of 5)

- Suppose Norwest does not know the proportion of defective checks, *p*, for the encoding process when it is in control.
- We will treat the data (20 samples) collected as one large sample and compute the average number of defective checks for all the data. That value can then be used to estimate *p*.

Control Limits for a *p* Chart (4 of 5)

Estimated p = 128/(20 × 400) = 128/8000 = 0.016

np = 400(0.016) = 6.4 $\geq$ 5 and $n(1-p)$= 400(0.984) = 393.6 $\geq$ 5

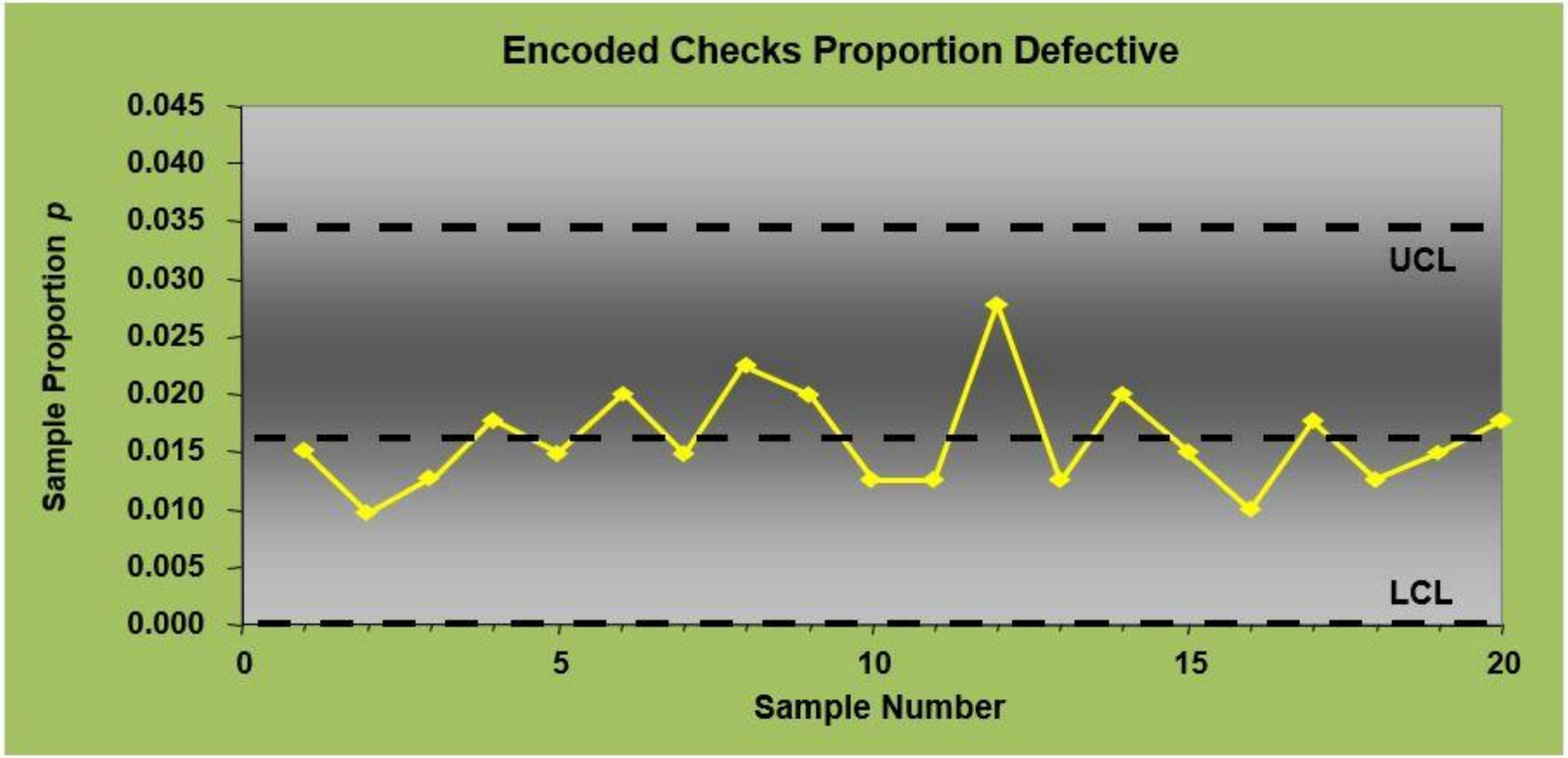
$$\sigma_{\bar{p}} = \sqrt{\frac{p(1-p)}{n}} = \sqrt{\frac{.016(1-.016)}{400}} = 0.006274$$

$$\text{UCL} = p + 3\sigma_{\bar{p}} = 0.016 + 3(0.006274) = \mathbf{0.0348}$$

$$\text{CL} = p = \mathbf{0.016}$$

$$\text{LCL} = p - 3\sigma_{\bar{p}} = 0.016 - 3(0.006274) = -0.0028 = \mathbf{0}$$

Control Limits for a *p* Chart (5 of 5)



Control Limits for an *np* Chart

$$\text{UCL} = np + 3\sqrt{np(1-p)}$$
$$\text{LCL} = np - 3\sqrt{np(1-p)}$$

assuming: $np \geq 5$ and $n(1-p) \geq 5$

Note: If computed LCL is negative, set LCL = 0

Interpretation of Control Charts

- The location and pattern of points in a control chart enable us to determine, with a small probability of error, whether a process is in statistical control.
- A primary indication that a process may be out of control is a data point outside the control limits.
- Certain patterns of points within the control limits can be warning signals of quality problems:
  - a large number of points on one side of the center line
  - six or seven points in a row that indicate either an increasing or decreasing trend