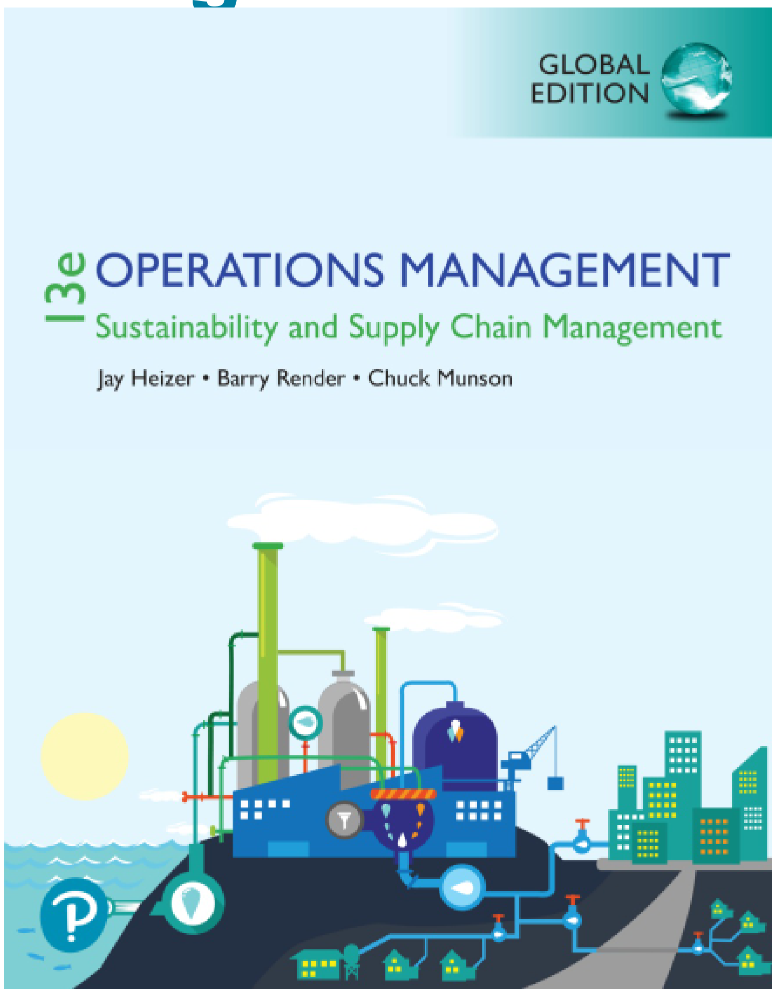
Operations Management: Sustainability and Supply Chain Management

Thirteenth Edition, Global Edition



Chapter 1

Operations and Productivity

Pearson

Outline (1 of 2)

- Global Company Profile: *Hard Rock Cafe*
- What Is Operations Management?
- Organizing to Produce Goods and Services
- The Supply Chain
- Why Study OM?
- What Operations Managers Do

Outline (2 of 2)

- The Heritage of Operations Management
- Operations for Goods and Services
- The Productivity Challenge
- Current Challenges in Operations Management
- Ethics, Social Responsibility, and Sustainability

Operations Management at Hard Rock Cafe

- First opened in 1971
  - Now - 23 hotels and 168 restaurants in over 68 countries
- Rock music memorabilia
- Creates value in the form of good food and entertainment
- 3,500+ custom meals per day in Orlando
- How does an item get on the menu?
- Role of the Operations Manager

Learning Objectives (1 of 2)

When you complete this chapter you should be able to:

1.1 ***Define*** operations management

1.2 ***Identify*** the 10 strategic decisions of operations management

1.3 ***Identify*** career opportunities in operations management

1.4 ***Explain*** the distinction between goods and services

Learning Objectives (2 of 2)

When you complete this chapter you should be able to:

1.5 ***Explain*** the difference between production and productivity

1.6 ***Compute*** single-factor productivity

1.7 ***Compute*** multifactor productivity

1.8 ***Identify*** the critical variables in enhancing productivity

What Is Operations Management?

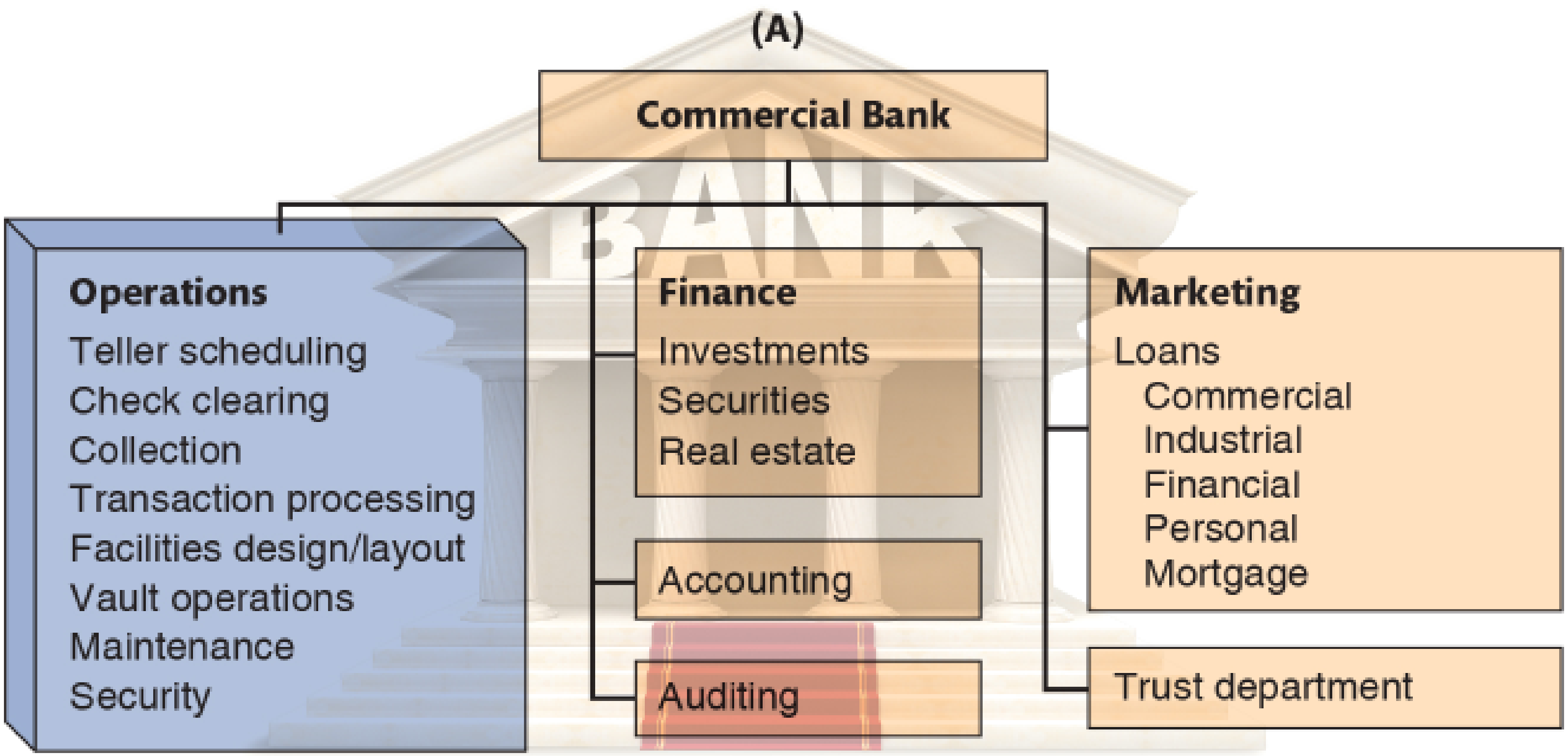
- **Production** is the creation of goods and services
- **Operations management (OM)** is the set of activities that creates value in the form of goods and services by transforming inputs into outputs

Organizing to Produce Goods and Services

- Essential functions:
  1. ***Marketing*** – generates demand
  2. ***Production/operations*** – creates the product
  3. ***Finance/accounting*** – tracks how well the organization is doing, pays bills, collects the money

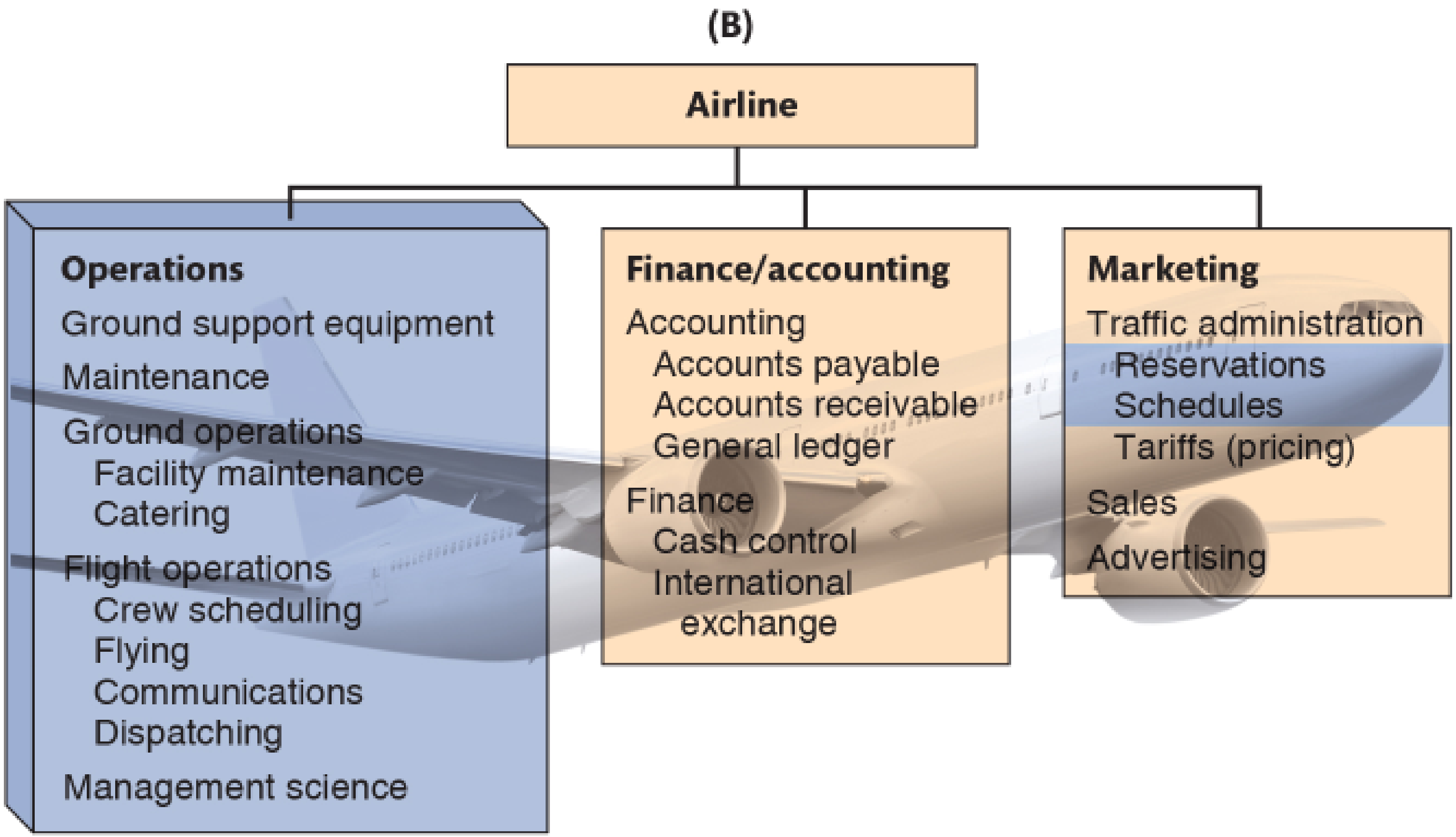
Organization Charts (1 of 3)

Figure 1.1



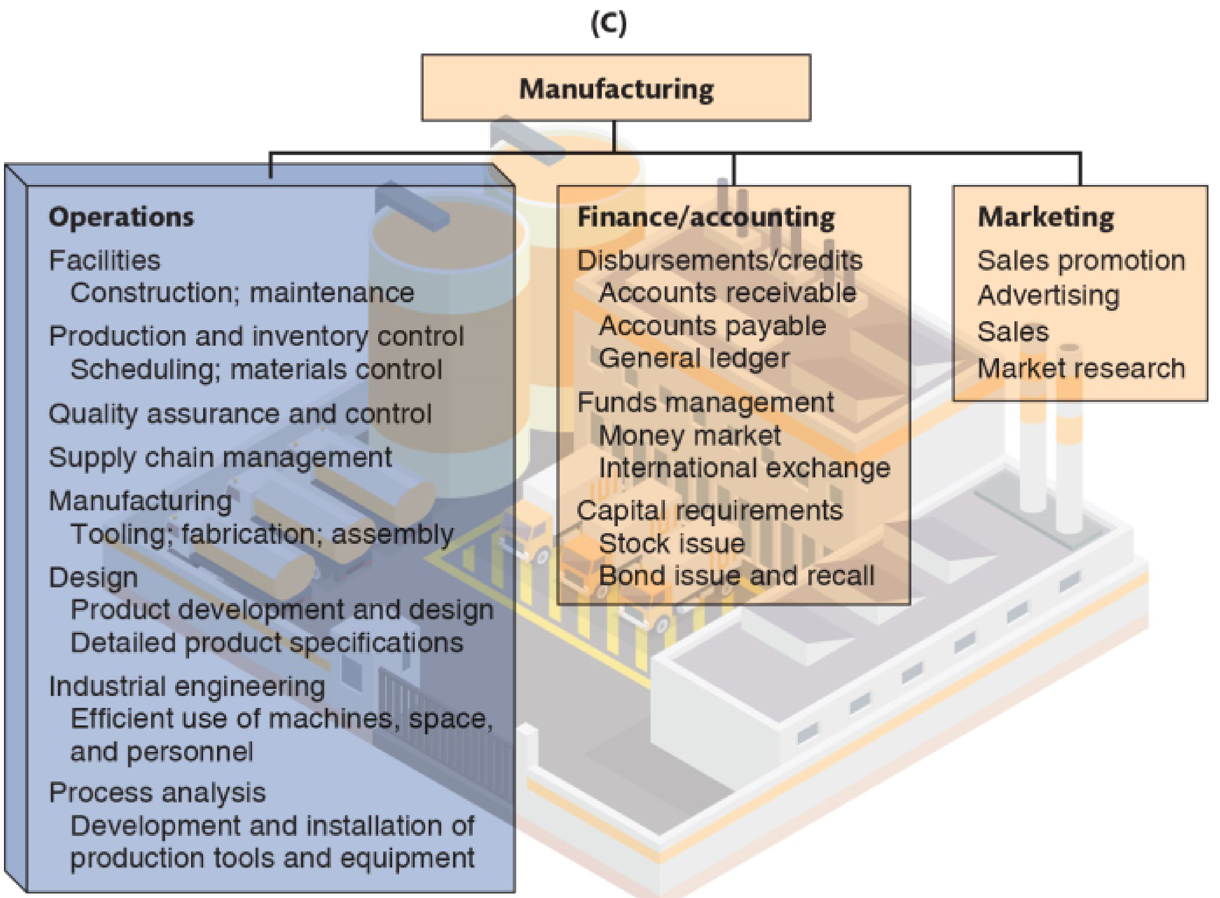
Organization Charts (2 of 3)

Figure 1.1



Organization Charts (3 of 3)

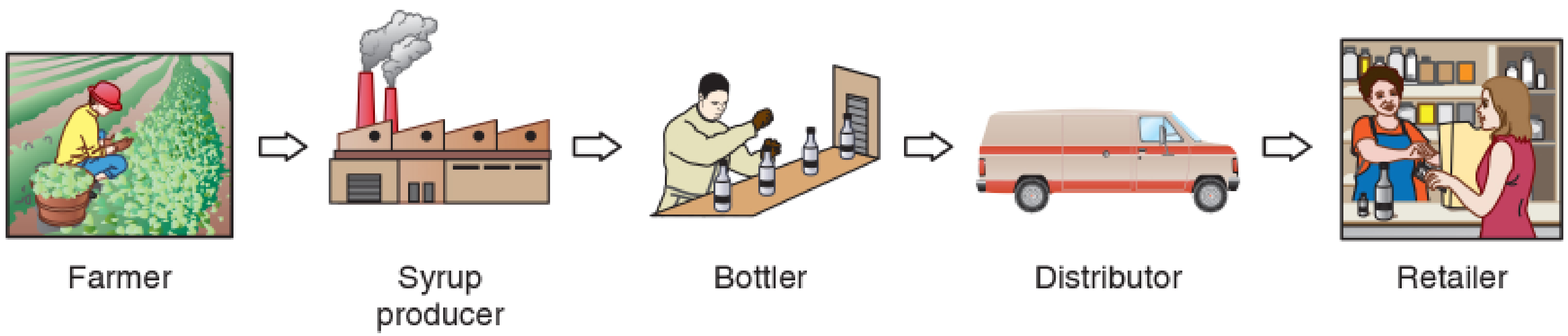
Figure 1.1



The Supply Chain

- A global network of organizations and activities that supplies a firm with goods and services
- Members of the supply chain collaborate to achieve high levels of customer satisfaction, efficiency, and competitive advantage

Figure 1.2



Why Study OM?

1. OM is one of three major functions of any organization; we want to study *how people organize themselves for productive enterprise*
2. We want (*and need*) to know *how goods and services are produced*
3. We want to *understand what operations managers do*
4. OM *is such a costly part of an organization*

Options for Increasing Contribution

Table 1.1

		MARKETING OPTION	FINANCE/ ACCOUNTING OPTION	OM OPTION
	CURRENT	INCREASE SALES REVENUE 50%	REDUCE FINANCE COSTS 50%	REDUCE PRODUCTION COSTS 20%
Sales	$100,000	$150,000	$100,000	$100,000
Cost of goods	–80,000	–120,000	–80,000	–64,000
Gross margin	20,000	30,000	20,000	36,000
Finance costs	–6,000	–6,000	–3,000	–6,000
Subtotal	14,000	24,000	17,000	30,000
Taxes at 25%	–3,500	–6,000	–4,250	–7,500
Contribution	$ 10,500	$ 18,000	$ 12,750	$ 22,500

What Operations Managers Do

Basic Management Functions

- Planning
- Organizing
- Staffing
- Leading
- Controlling

Ten Strategic Decisions

Table 1.2

DECISION	CHAPTER(S)
1. *Design of goods and services*	5, Supplement 5
2. *Managing quality*	6, Supplement 6
3. *Process and capacity strategy*	7, Supplement 7
4. *Location strategy*	8
5. *Layout strategy*	9
6. *Human resources and job design*	10
7. *Supply-chain management*	11, Supplement 11
8. *Inventory management*	12, 14, 16
9. *Scheduling*	13, 15
10. *Maintenance*	17

The Strategic Decisions (1 of 5)

1. **Design of goods and services**
   – Defines what is required of operations
   – Product design determines cost, quality, sustainability and human resources
2. **Managing quality**
   – Determine the customer’s quality expectations
   – Establish policies and procedures to identify and achieve that quality

The Strategic Decisions (2 of 5)

3. **Process and capacity design**
   - How is a good or service produced?
   - Commits management to specific technology, quality, human resources, and investments
4. **Location strategy**
   - Nearness to customers, suppliers, and talent
   - Considering costs, infrastructure, logistics, and government

The Strategic Decisions (3 of 5)

5. **Layout strategy**
   – Integrate capacity needs, personnel levels, technology, and inventory
   – Determine the efficient flow of materials, people, and information
6. **Human resources and job design**
   – Recruit, motivate, and retain personnel with the required talent and skills
   – Integral and expensive part of the total system design

The Strategic Decisions (4 of 5)

7. **Supply chain management**
   - Integrate supply chain into the firm's strategy
   - Determine what is to be purchased, from whom, and under what conditions
8. **Inventory management**
   - Inventory ordering and holding decisions
   - Optimize considering customer satisfaction, supplier capability, and production schedules

The Strategic Decisions (5 of 5)

9. **Scheduling**
   – Determine and implement intermediate- and short-term schedules
   – Utilize personnel and facilities while meeting customer demands
10. **Maintenance**
   – Consider facility capacity, production demands, and personnel
   – Maintain a reliable and stable process

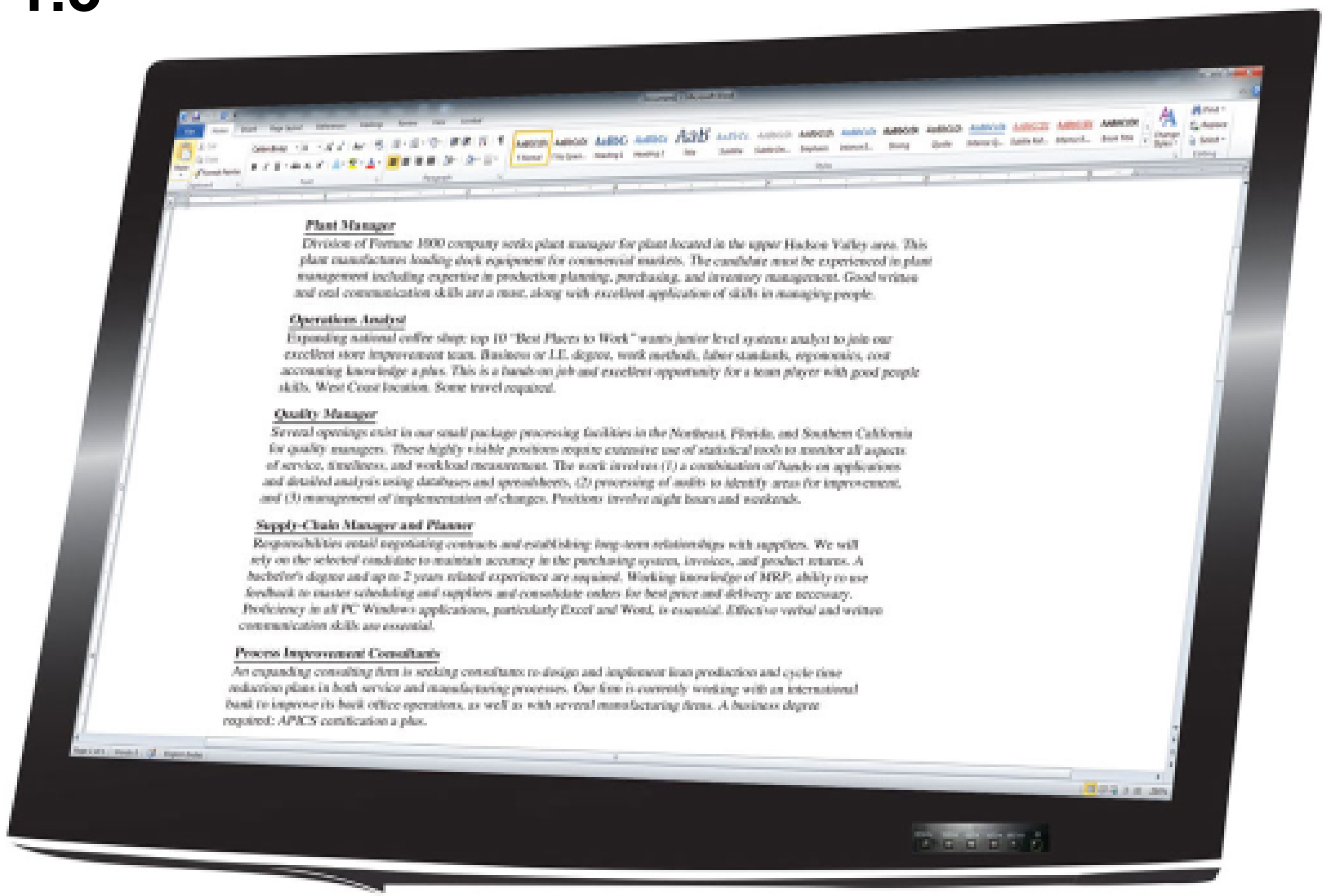
Pearson

Where are the OM Jobs?

- Introducing new technologies and methods
- Improving facility location and space utilization
- Defining and implementing operations strategy
- Improving response time
- Developing people and teams
- Improving customer service
- Managing quality
- Managing and controlling inventory
- Enhancing productivity

Opportunities

Figure 1.3



Plant Manager

Division of Fortune 1000 company seeks plant manager for plant located in the upper Hudson Valley area. This plant manufactures loading dock equipment for commercial markets. The candidate must be experienced in plant management including expertise in production planning, purchasing, and inventory management. Good written and oral communication skills are a must, along with excellent application of skills in managing people.

Operations Analyst

Expanding national coffee shop: top 10 "Best Places to Work" wants junior level systems analyst to join our excellent store improvement team. Business or I.E. degree, work methods, labor standards, ergonomics, cost accounting knowledge a plus. This is a hands-on job and excellent opportunity for a team player with good people skills. West Coast location. Some travel required.

Quality Manager

Several openings exist in our small package processing facilities in the Northeast, Florida, and Southern California for quality managers. These highly visible positions require extensive use of statistical tools to monitor all aspects of service, timeliness, and workload measurement. The work involves (1) a combination of hands-on applications and detailed analysis using databases and spreadsheets, (2) processing of audits to identify areas for improvement, and (3) management of implementation of changes. Positions involve night hours and weekends.

Supply-Chain Manager and Planner

Responsibilities entail negotiating contracts and establishing long-term relationships with suppliers. We will rely on the selected candidate to maintain accuracy in the purchasing system, invoices, and product returns. A bachelor's degree and up to 2 years related experience are required. Working knowledge of MRP, ability to use feedback to master scheduling and suppliers and consolidate orders for best price and delivery are necessary. Proficiency in all PC Windows applications, particularly Excel and Word, is essential. Effective verbal and written communication skills are essential.

Process Improvement Consultants

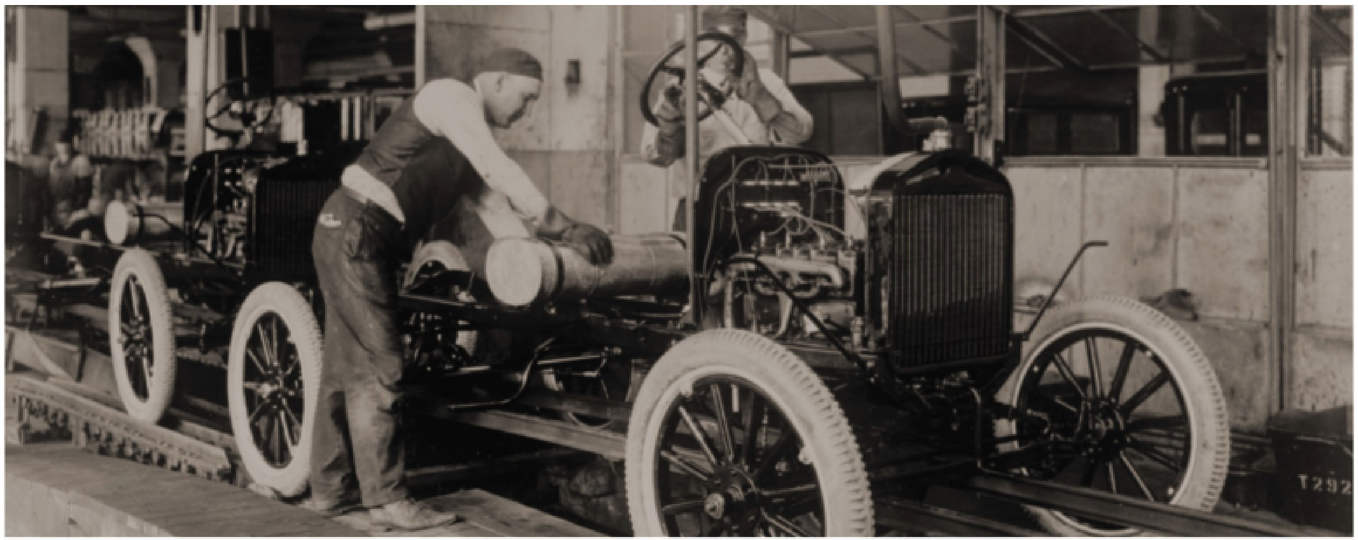
An expanding consulting firm is seeking consultants to design and implement lean production and cycle time reduction plans in both service and manufacturing processes. Our firm is currently working with an international bank to improve its back office operations, as well as with several manufacturing firms. A business degree required; APICS certification a plus.

Certifications

- APICS, the Association for Operations Management
- American Society for Quality (ASQ)
- Institute for Supply Management (ISM)
- Project Management Institute (PMI)
- Council of Supply Chain Management Professionals
- Chartered Institute of Procurement and Supply (CIPS)

Significant Events in OM

Figure 1.4



Cost Focus

Early Concepts
1776–1880
Labor Specialization
(Smith, Babbage)
Standardized Parts (Whitney)

Scientific Management Era
1880–1910
Gantt Charts (Gantt)
Motion & Time Studies
(Gilbreth)
Process Analysis (Taylor)
Queuing Theory (Erlang)

Mass Production Era
1910–1980
Moving Assembly Line
(Ford/Sorensen)
Statistical Sampling
(Shewhart)
Economic Order
Quantity (Harris)
Linear Programming
(Dantzig)
Material Requirements
Planning (MRP)

Quality Focus

Lean Production Era
1980–1995
Just-in-Time (JIT)
Computer-Aided Design
(CAD)
Electronic Data Interchange
(EDI)
Total Quality Management
(TQM)
Baldrige Award
Empowerment
Kanbans

Customization Focus

Mass Customization Era
1995–2005
Internet/E-Commerce
Enterprise Resource Planning
International Quality Standards
(ISO)
Finite Scheduling
Supply Chain Management
Mass Customization
Build-to-Order
Radio Frequency Identification
(RFID)

Globalization Focus

Globalization Era
2005–2025
Global Supply Chains
and Logistics
Growth of Transnational
Organizations
Sustainability
Ethics in the Global Workplace
Internet of Things (IoT)
Digital Operations
Industry 4.0

Eli Whitney

- Born 1765; died 1825
- In 1798, received government contract to make 10,000 muskets
- Showed that machine tools could make standardized parts to exact specifications
  - Musket parts could be used in any musket

Frederick W. Taylor

- Born 1856; died 1915
- Known as 'father of scientific management'
- In 1881, as chief engineer for Midvale Steel, studied how tasks were done
  - Began first motion and time studies
- Created efficiency principles

Taylor's Principles

Management Should Take More Responsibility for:

1. Matching employees to right job
2. Providing the proper training
3. Providing proper work methods and tools
4. Establishing legitimate incentives for work to be accomplished

Frank and Lillian Gilbreth

- Frank (1868-1924); Lillian (1878-1972)
- Husband and wife engineering team
- Further developed work measurement methods
- Applied efficiency methods to their home and 12 children!
- Book and Movie: “Cheaper by the Dozen,” “Bells on Their Toes”

Henry Ford

- Born 1863; died 1947
- In 1903, created Ford Motor Company
- In 1913, first used moving assembly line to make Model T
  - Unfinished product moved by conveyor past work station
- Paid workers very well for 1911 ($5/day!)

W. Edwards Deming

- Born 1900; died 1993
- Engineer and physicist
- Credited with teaching Japan quality control methods in post-WW2
- Used statistics to analyze process
- His methods involve workers in decisions

OM Relies on Contributions From

- Industrial engineering
- Statistics
- Management
- Analytics
- Economics
- Physical sciences
- Information technology

Operations for Goods and Services (1 of 2)

Services – Economic activities that typically produce an intangible product (such as education, entertainment, lodging, government, financial, and health services)

Operations for Goods and Services (2 of 2)

- Manufacturers produce tangible product, services often intangible
- Operations activities are performed in both manufacturing and services
- Distinction not always clear
- Few pure services

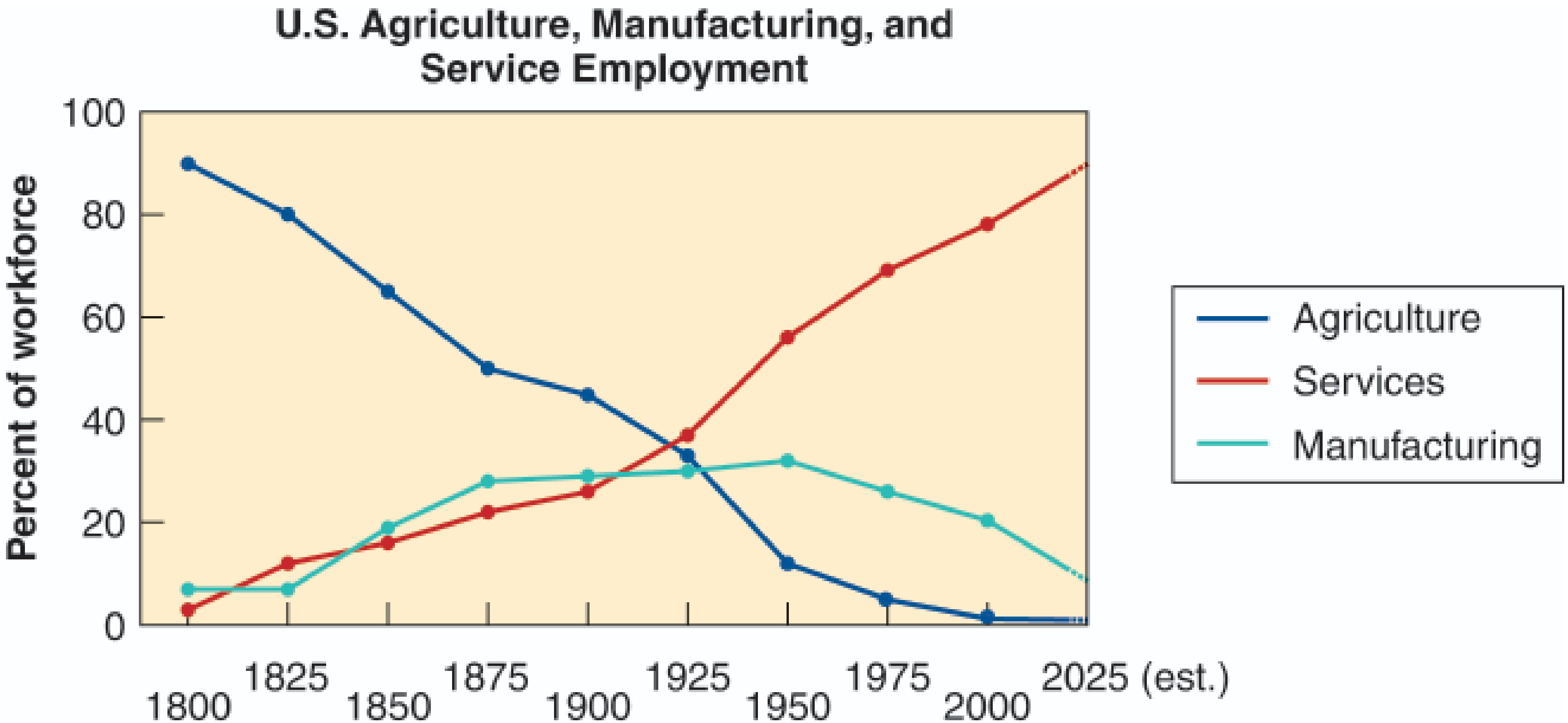
Differences Between Goods and Services

Table 1.3

CHARACTERISTICS OF SERVICES	CHARACTERISTICS OF GOODS
Intangible: Ride in an airline seat	Tangible: The seat itself
Produced and consumed simultaneously: Beauty salon produces a haircut that is consumed as it is produced	Product can usually be kept in inventory (beauty care products)
Unique: Your investments and medical care are unique	Similar products produced (iPods)
High customer interaction: Often what the customer is paying for (consulting, education)	Limited customer involvement in production
Inconsistent product definition: Auto Insurance changes with age and type of car	Product standardized (iPhone)
Often knowledge based: Legal, education, and medical services are hard to automate	Standard tangible product tends to make automation feasible
Services dispersed: Service may occur at retail store, local office, house call, or via Internet	Product typically produced at a fixed facility
Quality may be hard to evaluate: Consulting, education, and medical services	Many aspects of quality for tangible products are easy to evaluate (strength of a bolt)
Reselling is unusual: Musical concert or medical care	Product often has some residual value

U.S. Agriculture, Manufacturing, and Service Employment

Figure 1.5



Organizations in Each Sector

Table 1.4

SECTOR	EXAMPLE	PERCENT OF ALL JOBS	
Service Sector			
Education, Medical, Other	San Diego State University, Arnold Palmer Hospital	16.2	
Trade (retail, wholesale), Transportation	Walgreen's, Walmart, Nordstrom, Alaska Airlines	17.1	
Information, Publishers, Broadcast	IBM, Bloomberg, Pearson, ESPN	1.8	
Professional, Legal, Business Services, Associations	Snelling and Snelling, Waste Management, Inc., American Medical Association, Ernst & Young	17.0	85.9
Finance, Insurance, Real Estate	Citicorp, American Express, Prudential, Aetna	9.6	
Food, Lodging, Entertainment	Olive Garden, Motel 6, Walt Disney	10.0	
Public Administration	U.S., State of Alabama, Cook County	14.2	
Manufacturing Sector	General Electric, Ford, U.S. Steel, Intel		7.9
Construction Sector	Bechtel, McDermott		4.3
Agriculture	King Ranch		1.5
Mining Sector	Homestake Mining		.4
Grand Total			100.0

Service Pay

- Perception that services are low-paying
- 42% of service workers receive above average wages
- 14 of 33 service industries pay below average
- Retail trade pays only 61% of national average
- Overall average wage is 96% of the average

Productivity Challenge

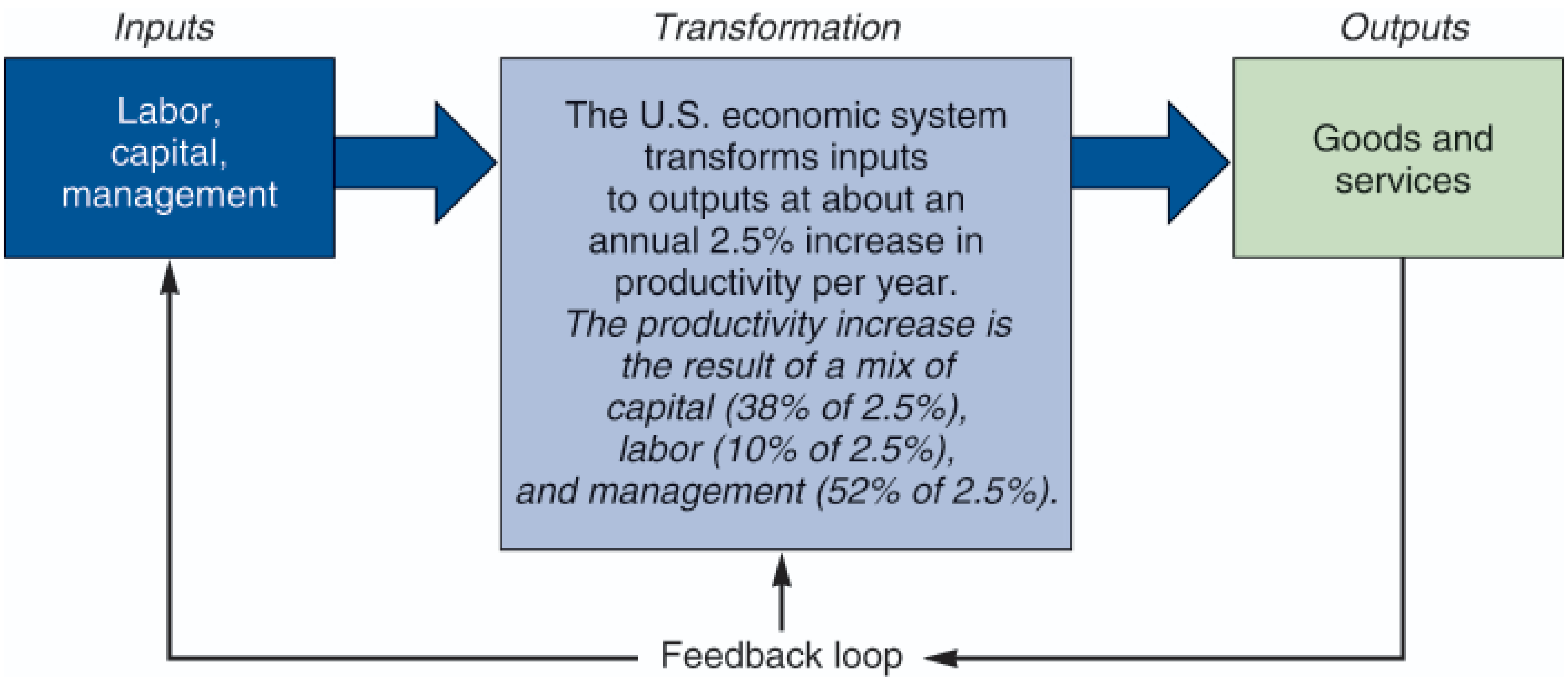
Productivity is the ratio of outputs (goods and services) divided by the inputs (resources such as labor and capital)

The objective is to improve productivity!

Important Note!
Production is a measure of output only and not a measure of efficiency

The Economic System

Figure 1.6



Improving Productivity at Starbucks (1 of 2)

A team of 10 analysts continually look for ways to shave time. Some improvements:

Stop requiring signatures on credit card purchases under $25	→	Saved 8 seconds per transaction
Change the size of the ice scoop	→	Saved 14 seconds per drink
New espresso machines	→	Saved 12 seconds per shot

Improving Productivity at Starbucks (2 of 2)

A team of 10 analysts continually look for ways to shave time. Some improvements:

Stop requiring signatures on credit card purchases under $25	➡	Saved 8 seconds per transaction
Change the size of the ice scoop	➡	Saved 14 seconds per drink
New espresso machines	➡	Saved 12 seconds per shot

Operations improvements have helped Starbucks increase yearly revenue per outlet by $250,000 to $1,000,000.

Productivity has improved by 27%, or about 4.5% per year.

Productivity

$$\text{Productivity} = \frac{\text{Units produced}}{\text{Input used}}$$

- Measure of process improvement
- Represents output relative to input
- Only through productivity increases can our standard of living improve

Productivity Calculations

Labor Productivity

$$\text{Productivity} = \frac{\text{Units produced}}{\text{Labor-hours used}}$$

$$= \frac{1{,}000}{250} = 4 \text{ units/labor-hour}$$

One resource input ⇨ single-factor productivity

Multi-Factor Productivity

$$\text{Multifactor} = \frac{\text{Output}}{\text{Labor + Material + Energy + Capital + Miscellaneous}}$$

- Also known as total factor productivity
- Output and inputs are often expressed in dollars

Multiple resource inputs ⇨ *multi-factor productivity*

Pearson

Collins Title Productivity (1 of 4)

Old System:

Staff of 4 works 8 hrs/day
Payroll cost = \$640/day

8 titles/day
Overhead = \$400/day

$$\text{Old labor productivity} = \frac{8 \text{ titles/day}}{32 \text{ labor-hrs}} = .25 \text{ titles/labor-hr}$$

Collins Title Productivity (2 of 4)

Old System:

Staff of 4 works 8 hrs/day — 8 titles/day

Payroll cost = $640/day — Overhead = $400/day

New System:

14 titles/day — Overhead = $800/day

$$\text{Old labor productivity} = \frac{8 \text{ titles/day}}{32 \text{ labor-hrs}} = .25 \text{ titles/labor-hr}$$

$$\text{New labor productivity} = \frac{14 \text{ titles/day}}{32 \text{ labor-hrs}} = .4375 \text{ titles/labor-hr}$$

Collins Title Productivity (3 of 4)

Old System:

Staff of 4 works 8 hrs/day
Payroll cost = $640/day

8 titles/day
Overhead = $400/day

New System:

14 titles/day

Overhead = $800/day

$$\text{Old multifactor productivity} = \frac{8 \text{ titles/day}}{\$640 + 400} = .0077 \text{ titles/dollar}$$

Pearson

Collins Title Productivity (4 of 4)

Old System:

Staff of 4 works 8 hrs/day
Payroll cost = $640/day

8 titles/day
Overhead = $400/day

New System:

14 titles/day

Overhead = $800/day

$$\text{Old multifactor productivity} = \frac{8 \text{ titles/day}}{\$640 + 400} = .0077 \text{ titles/dollar}$$

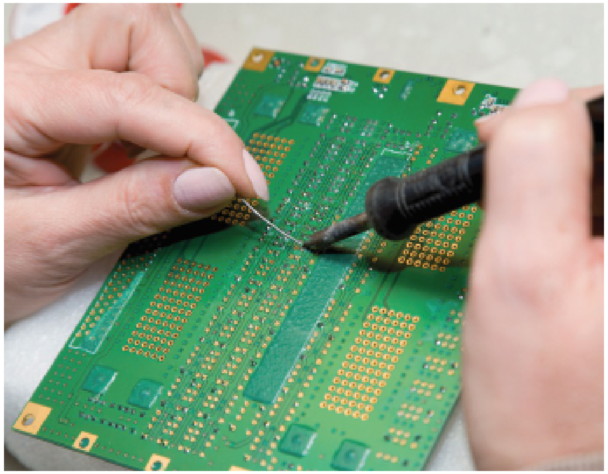
$$\text{New multifactor productivity} = \frac{14 \text{ titles/day}}{\$640 + 800} = .0097 \text{ titles/dollar}$$

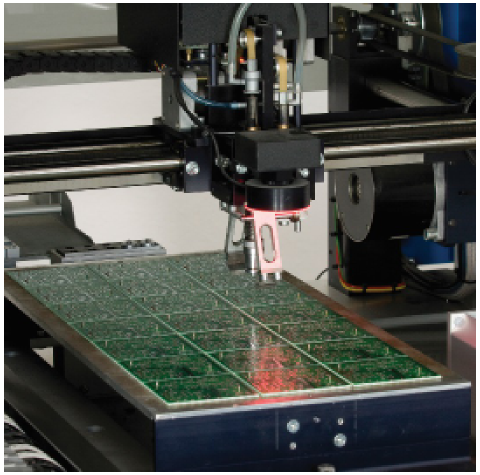
Measurement Problems

- ***Quality*** may change while the quantity of inputs and outputs remains constant
- ***External elements*** may cause an increase or decrease in productivity
- ***Precise units of measure*** may be lacking

Productivity Variables

1. ***Labor*** - contributes about 10% of the annual increase
2. ***Capital*** - contributes about 38% of the annual increase
3. ***Management*** - contributes about 52% of the annual increase





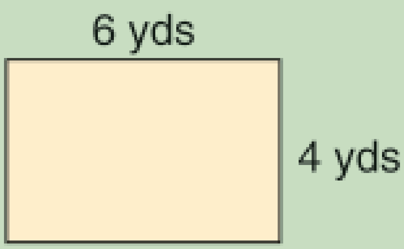
Key Variables for Improved Labor Productivity

1. Basic education appropriate for the labor force
2. Diet of the labor force
3. Social overhead that makes labor available
   – Challenge is in maintaining and enhancing skills in the midst of rapidly changing technology and knowledge

Labor Skills

About half of the 17-year-olds in the U.S. cannot correctly answer questions of this type

Figure 1.7



What is the area of this rectangle?

_______ 4 square yds
_______ 6 square yds
_______ 10 square yds
_______ 20 square yds
_______ 24 square yds

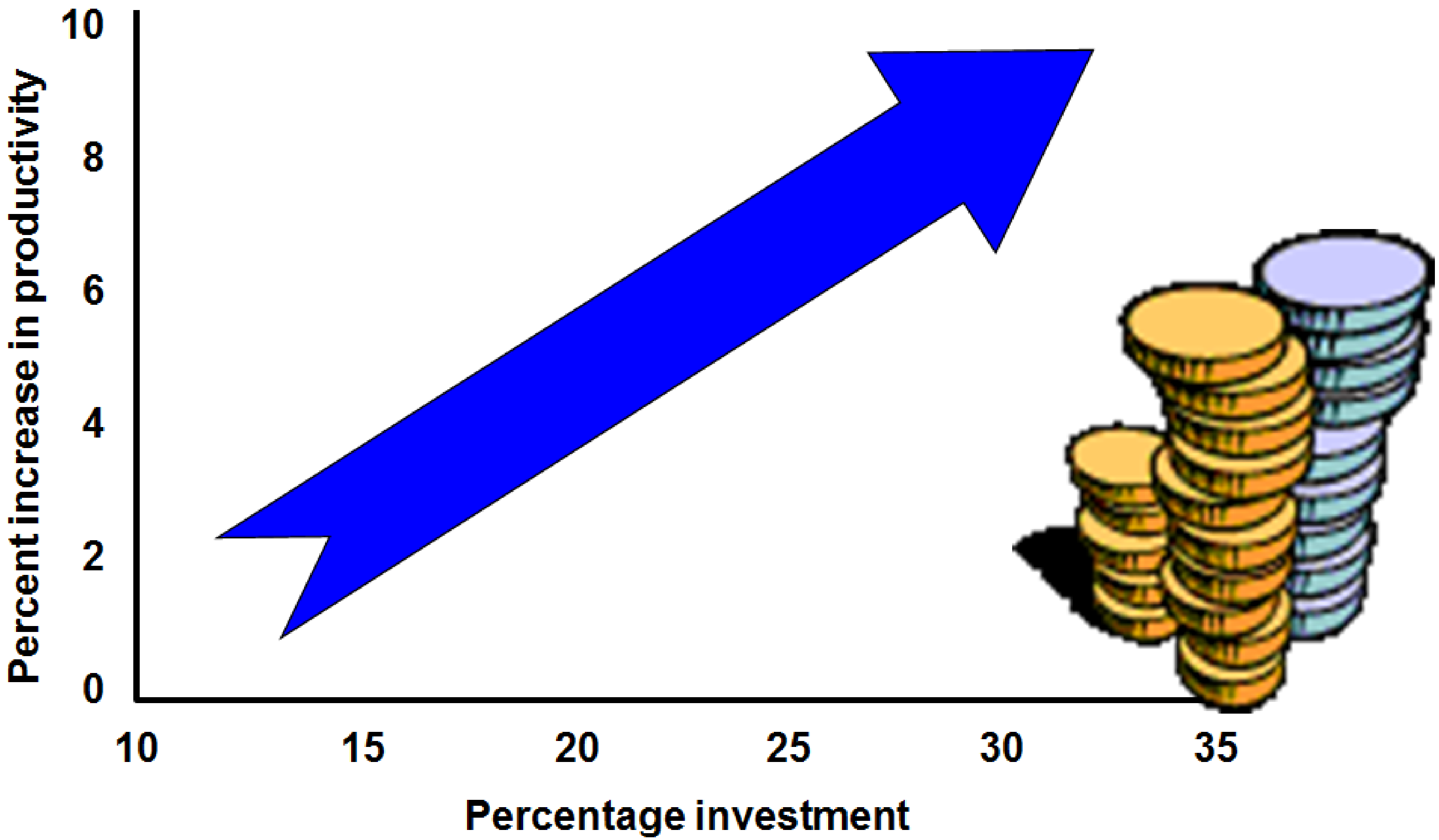
If $9y + 3 = 6y + 15$ then $y =$

_______ 1 _______ 4
_______ 2 _______ 6

Which of the following is true about 84% of 100?

_______ It is greater than 100
_______ It is less than 100
_______ It is equal to 100

Capital



10
8
6
4
2
0
Percent increase in productivity
10
15
20
25
30
35
Percentage investment

Management

- Ensures labor and capital are effectively used to increase productivity
  - Use of knowledge
  - Application of technologies
- Knowledge societies
  - Labor has migrated from manual work to technical and information-processing tasks
- More effective use of technology, knowledge, and capital

Productivity in the Service Sector

- Productivity improvement in services is difficult because:

1. Typically labor intensive
2. Frequently focused on unique individual attributes or desires
3. Often an intellectual task performed by professionals
4. Often difficult to mechanize and automate
5. Often difficult to evaluate for quality

Productivity at Taco Bell (1 of 2)

Improvements:

- Revised the menu
- Designed meals for easy preparation
- Shifted some preparation to suppliers
- Efficient layout and automation
- Training and employee empowerment
- New water and energy saving grills

Productivity at Taco Bell (2 of 2)

Results:

- Preparation time cut to 8 seconds
- Management span of control increased from 5 to 30
- In-store labor cut by 15 hours/day
- Floor space reduced by more than 50%
- Stores average 164 seconds/customer from drive-up to pull-out
- Water- and energy-savings grills conserve 300 million gallons of water and 200 million KwH of electricity each year
- Green-inspired cooking method saves 5,800 restaurants $17 million per year

Current Challenges in OM

- Globalization
- Supply-chain partnering
- Sustainability
- Rapid product development
- Mass customization
- Lean operations

Ethics, Social Responsibility, and Sustainability (1 of 2)

Challenges facing operations managers:

- Develop and produce safe, high-quality green products
- Train, retrain, and motivate employees in a safe workplace
- Honor stakeholder commitments

Ethics, Social Responsibility, and Sustainability (2 of 2)

Stakeholders

Those with a vested interest in an organization, including customers, distributors, suppliers, owners, lenders, employees, and community members.

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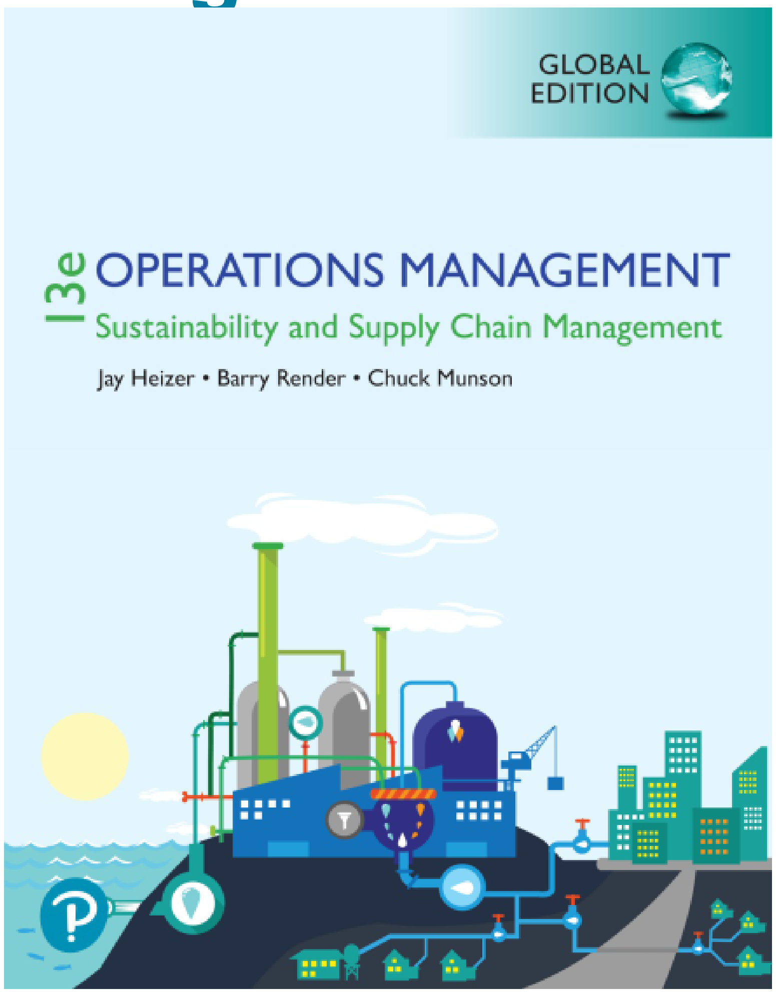


Chapter 2

Operations Strategy in a Global Environment

Outline (1 of 2)

- Global Company Profile: *Boeing*
- A Global View of Operations and Supply Chains
- Developing Missions and Strategies
- Achieving Competitive Advantage Through Operations
- Issues in Operations Strategy

Outline (2 of 2)

- Strategy Development and Implementation
- Strategic Planning, Core Competencies, and Outsourcing
- Global Operations Strategy Options

Boeing's Global Supply-Chain Strategy (1 of 3)

Some of the International Suppliers of Boeing 787 Components

SUPPLIER	HEADQUARTERS COUNTRY	COMPONENT
Latecoere	France	Passenger doors
Labinel	France	Wiring
Dassault	France	Design and PLM software
Messier-Bugatti	France	Electric brakes
Thales	France	Electrical power conversion system
Messier-Dowty	France	Landing gear structure
Diehl	Germany	Interior lighting

Boeing's Global Supply-Chain Strategy (2 of 3)

Some of the International Suppliers of Boeing 787 Components

SUPPLIER	HEADQUARTERS COUNTRY	COMPONENT
Cobham	UK	Fuel pumps and valves
Rolls-Royce	UK	Engines
Smiths Aerospace	UK	Central computer system
BAE Systems	UK	Electronics
Alenia Aeronautica	Italy	Upper center fuselage
Toray Industries	Japan	Carbon fiber for wing and tail units
Fuji Heavy Industries	Japan	Center wing box

Boeing's Global Supply-Chain Strategy (3 of 3)

Some of the International Suppliers of Boeing 787 Components

SUPPLIER	HEADQUARTERS COUNTRY	COMPONENT
Kawasaki Heavy Industries	Japan	Forward fuselage, fixed sections of wing
Teijin Seiki	Japan	Hydraulic actuators
Mitsubishi Heavy Industries	Japan	Wing box
Chengdu Aircraft	China	Rudder
Hafei Aviation	China	Parts
Korean Airlines	South Korea	Wingtips
Saab	Sweden	Cargo and access doors

Learning Objectives (1 of 2)

When you complete this chapter you should be able to:

2.1 ***Define*** mission and strategy

2.2 ***Identify*** and explain three strategic approaches to competitive advantage

2.3 ***Understand*** the significant key success factors and core competencies

Learning Objectives (2 of 2)

When you complete this chapter you should be able to:

2.4 ***Use*** factor rating to evaluate both country and provider outsources

2.5 ***Identify*** and explain four global operations strategy options

Global Strategies (1 of 2)

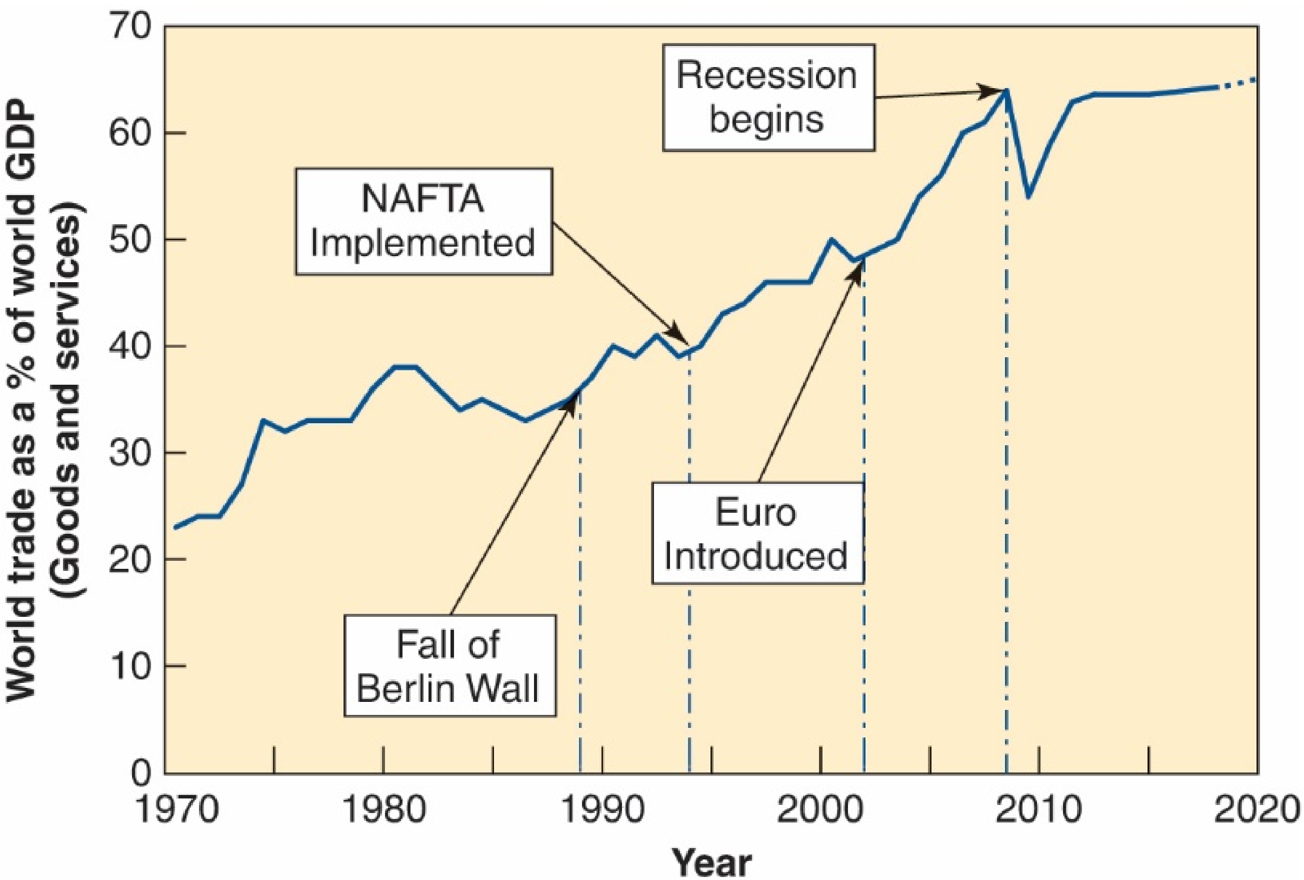
- Boeing – sales and supply chain are worldwide
- Benetton – moves inventory to stores around the world faster than its competition by building flexibility into design, production, and distribution
- Sony – purchases components from suppliers in Thailand, Malaysia, and around the world

Global Strategies (2 of 2)

- Volvo – considered a Swedish company, purchased by a Chinese company, Geely. The current Volvo S40 is assembled in Belgium and Malaysia on a platform shared with the Mazda 3 (built in Japan) and the Ford Focus (built in six countries including the U.S.).
- Haier – A Chinese company, produces compact refrigerators (it has one-third of the U.S. market) and wine cabinets (it has half of the U.S. market) in South Carolina and other appliances in Kentucky.

Growth of World Trade

Figure 2.1



Reasons to Globalize

1. Improve the supply chain
2. Reduce costs and exchange rate risks
3. Improve operations
4. Understand markets
5. Improve products
6. Attract and retain global talent

Improve the Supply Chain

- Locating facilities closer to unique resources
  - Auto design to California
  - Perfume manufacturing in France

Reduce Costs

- Risks associated with currency exchange rates
- Reduce direct and indirect costs
- Trade agreements can lower tariffs
  - Maquiladoras
  - World Trade Organization (WTO)
  - North American Free Trade Agreement (NAFTA)
  - APEC, SEATO, MERCOSUR, CAFTA
  - European Union (EU)

Improve Operations

- Understand differences between how business is handled in other countries
  - Japanese – inventory management
  - Germans – robots
  - Scandinavians – ergonomics
- International operations can improve response time and customer service

Understand Markets

- Interacting with foreign customers, suppliers, competition can lead to new opportunities
  - Cell phone design moved from Europe to Japan and India
  - Extend the product *life cycle*

Improve Products

- Remain open to free flow of ideas
- Toyota and BMW manage joint research and development
  - Reduced risk, state-of-the-art design, lower costs
- Samsung and Bosch jointly produce batteries

Attract and Retain Global Talent

- Offer better employment opportunities
  - Better growth opportunities and insulation against unemployment
  - Relocate unneeded personnel to more prosperous locations

Cultural and Ethical Issues

- Social and cultural behavior differs
- International laws, agreements, codes of conduct for ethical behaviors
- Despite cultural and ethical differences, we observe extraordinary mobility of capital, information, goods, and people

Companies Want To Consider

- National literacy rate
- Rate of innovation
- Rate of technology change
- Number of skilled workers
- Political stability
- Product liability laws
- Export restrictions
- Variations in language
- Work ethic
- Tax rates
- Inflation
- Availability of raw materials
- Interest rates
- Population
- Transportation infrastructure
- Communication system

Match Product and Parent

- Braun Household Appliances
- Firestone Tires
- Godiva Chocolate
- Haagen-Dazs Ice Cream
- Jaguar Autos
- GE Appliances
- Lamborghini Autos
- Alpo Petfoods

1. Volkswagen
2. Bridgestone
3. Campbell Soup
4. Tta Motors Limited
5. Proctor & Gamble
6. Nestlé
7. Pillsbury
8. Haier

Match Product and Country

- Braun Household Appliances
- Firestone Tires
- Godiva Chocolate
- Haagen-Dazs Ice Cream
- Jaguar Autos
- GE Appliances
- Lamborghini Autos
- Alpo Petfoods

1. Great Britain
2. Germany
3. China
4. United States
5. Switzerland
6. India

Developing Missions and Strategies

Mission statements tell an organization where it is going

The **Strategy** tells the organization how to get there

Mission (1 of 4)

- **Mission** - where is the organization going?
  - Organization’s purpose for being
  - Answers “What do we contribute to society?”
  - Provides boundaries and focus

Mission (2 of 4)

Figure 2.2

Merck
The mission of Merck is to provide society with superior products and services—innovations and solutions that improve the quality of life and satisfy customer needs—to provide employees with meaningful work and advancement opportunities and investors with a superior rate of return.

Mission (3 of 4)

Figure 2.2

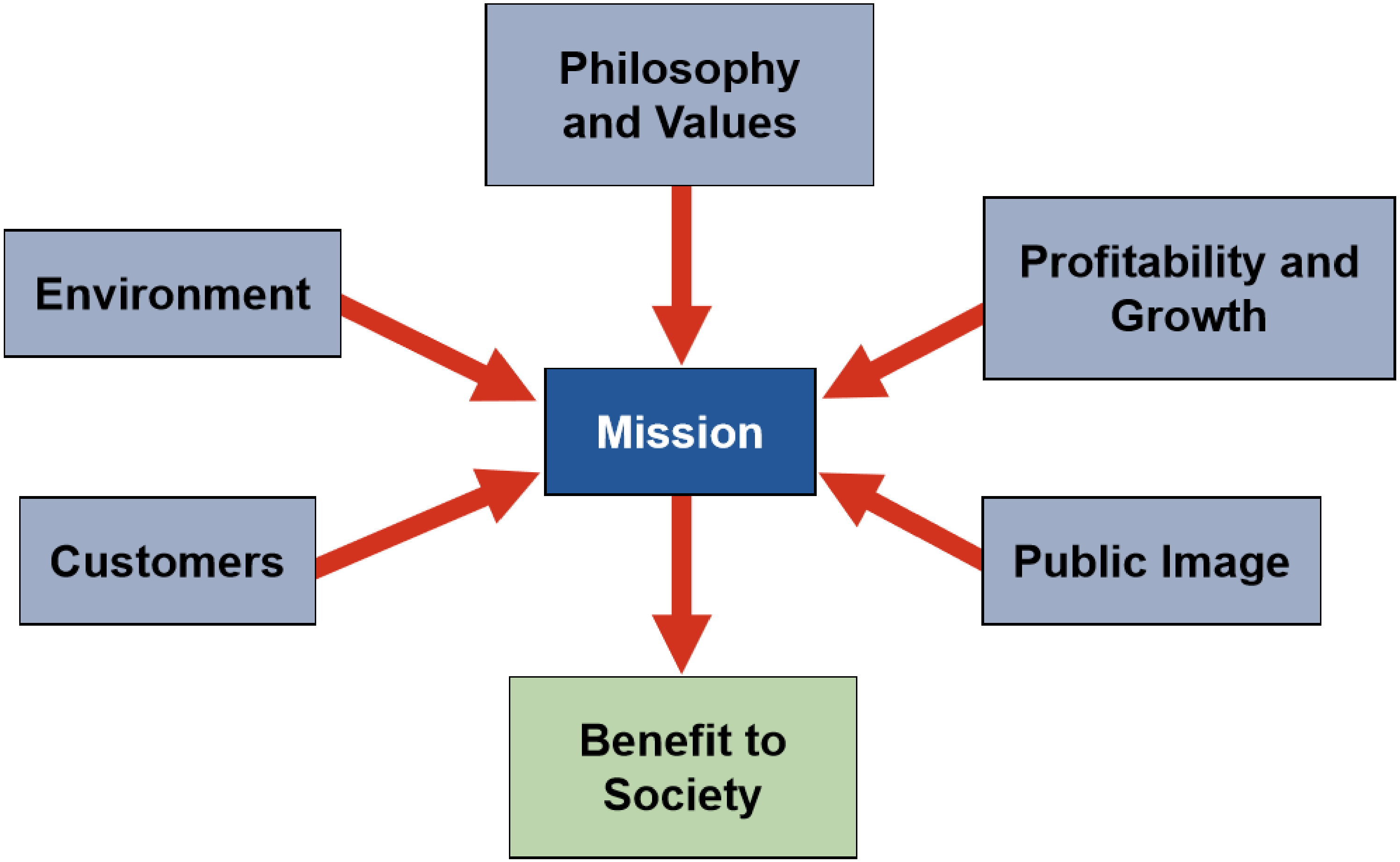
PespsiCo
Our mission is to be the world's premier consumer products company focused on convenient foods and beverages. We seek to produce financial rewards to investors as we provide opportunities for growth and enrichment to our employees, our business partners and the communities in which we operate. And in everything we do, we strive for honesty, fairness and integrity.

Mission (4 of 4)

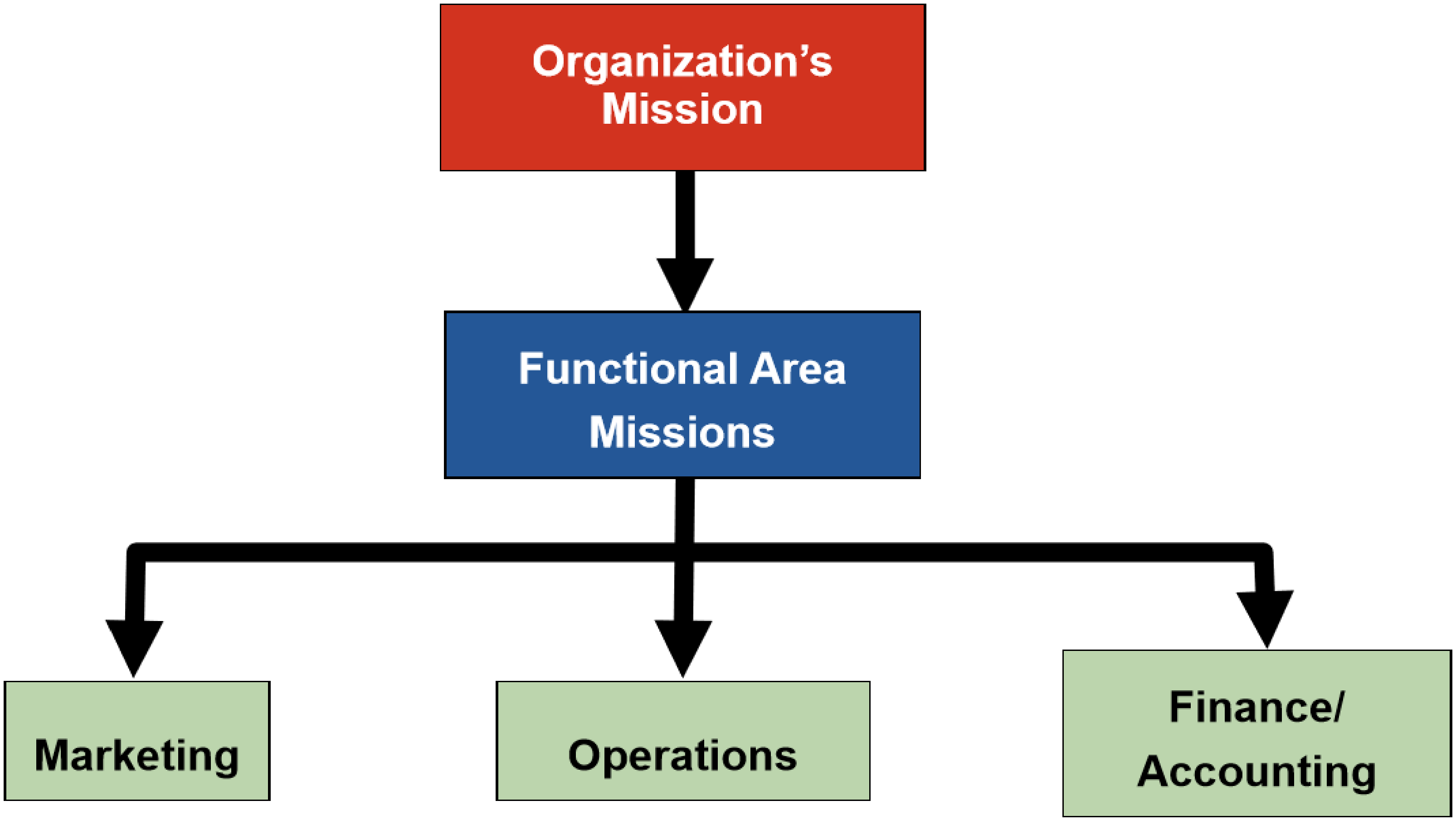
Figure 2.2

Arnold Palmer Hospital
Arnold Palmer Hospital for Children provides state of the art, family-centered healthcare focused on restoring the joy of childhood in an environment of compassion, healing, and hope.

Factors Affecting Mission



Strategic Process



Sample Missions

Figure 2.3

Sample Company Mission	
To manufacture and service an innovative, growing, and profitable worldwide microwave communications business that exceeds our customers' expectations.	
Sample Operations Management Mission	
To produce products consistent with the company's mission as the worldwide low-cost manufacturer.	
Sample OM Department Missions	
Product design	To design and produce products and services with outstanding quality and inherent customer value.
Quality management	To attain the exceptional value that is consistent with our company mission and marketing objectives by close attention to design, supply chain, production, and field service opportunities.
Process design	To determine, design, and develop the production process and equipment that will be compatible with low-cost product, high quality, and a good quality of work life.
Location	To locate, design, and build efficient and economical facilities that will yield high value to the company, its employees, and the community.
Layout design	To achieve, through skill, imagination, and resourcefulness in layout and work methods, production effectiveness and efficiency while supporting a high quality of work life.
Human resources	To provide a good quality of work life, with well-designed, safe, rewarding jobs, stable employment, and equitable pay, in exchange for outstanding individual contribution from employees at all levels.
Supply chain management	To collaborate with suppliers to develop innovative products from stable, effective, and efficient sources of supply.
Inventory	To achieve low investment in inventory consistent with high customer service levels and high facility utilization.
Scheduling	To achieve high levels of throughput and timely customer delivery through effective scheduling.
Maintenance	To achieve high utilization of facilities and equipment by effective preventive maintenance and prompt repair of facilities and equipment.

Strategy

Strategies require managers to

- Develop action plan to achieve mission
- Ensure functional areas have supporting strategies
- Exploit opportunities and strengths, neutralize threats, and avoid weaknesses

Strategies for Competitive Advantage

1. Differentiation – *better*, or at least different
2. Cost leadership – *cheaper*
3. Response – more *responsive*

Competing on Differentiation

Uniqueness can go beyond both the physical characteristics and service attributes to encompass everything that impacts customer's perception of value

- Safeskin gloves – leading edge products
- Walt Disney Magic Kingdom – experience differentiation
- Hard Rock Cafe – dining experience

Experience Differentiation

Engaging a customer with a product through imaginative use of the five senses, so the customer "experiences" the product

- Theme parks use sight, sound, smell, and participation
- Movie theatres use sight, sound, moving seats, smells, and mists of rain
- Restaurants use music, smell, and open kitchens

Competing on Cost

Provide the maximum value as perceived by customer.
Does not imply low quality.

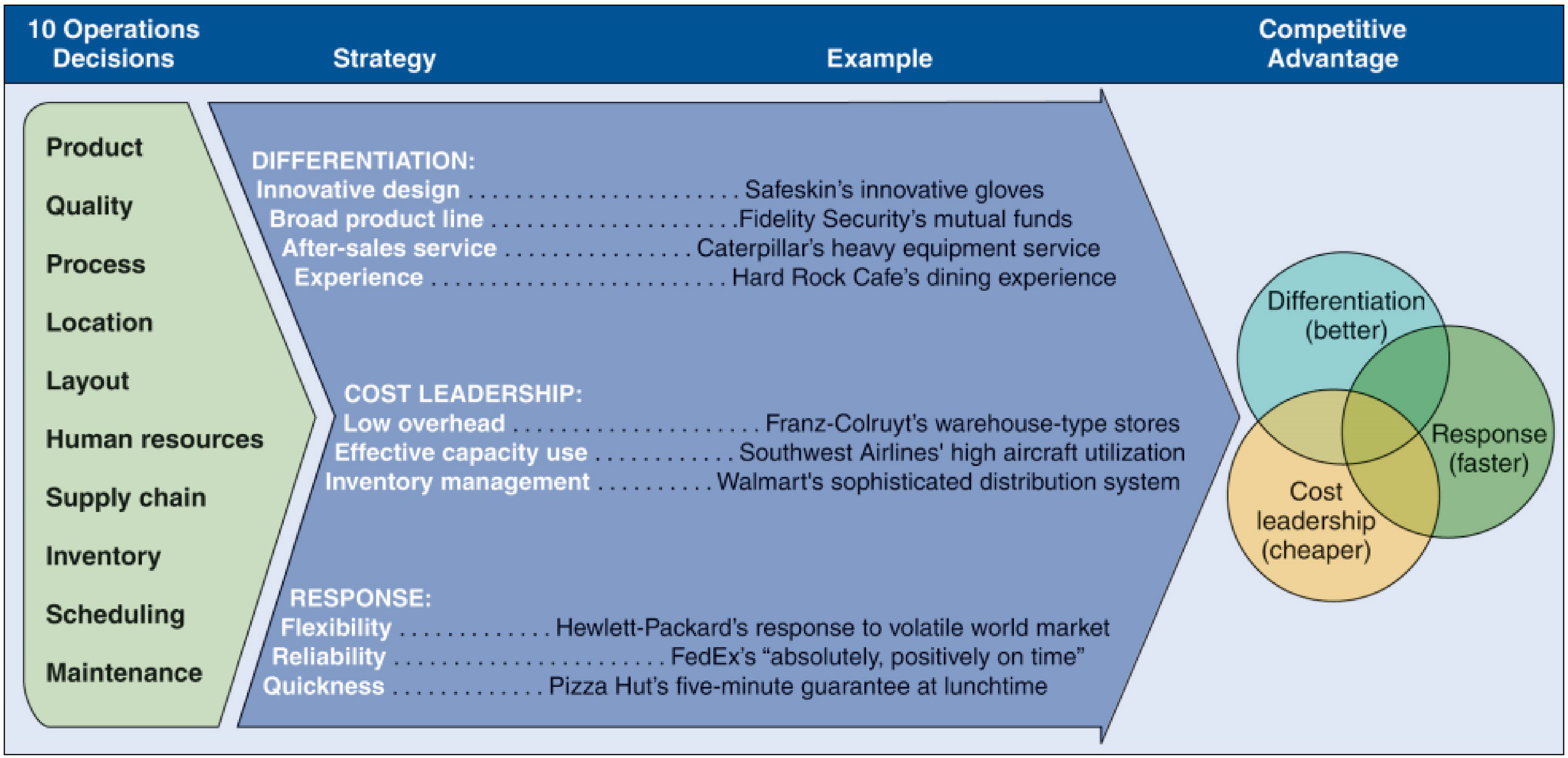
- Southwest Airlines – secondary airports, no frills service, efficient utilization of equipment
- Walmart – small overhead, shrinkage, and distribution costs
- Franz Colruyt – no bags, no bright lights, no music

Competing on Response

- Flexibility is matching market changes in design innovation and volumes
  - A way of life at Hewlett-Packard
- Reliability is meeting schedules
  - German machine industry
- Quickness in design, production, and delivery
  - Johnson Electric, Pizza Hut

OM's Contribution to Strategy

Figure 2.4

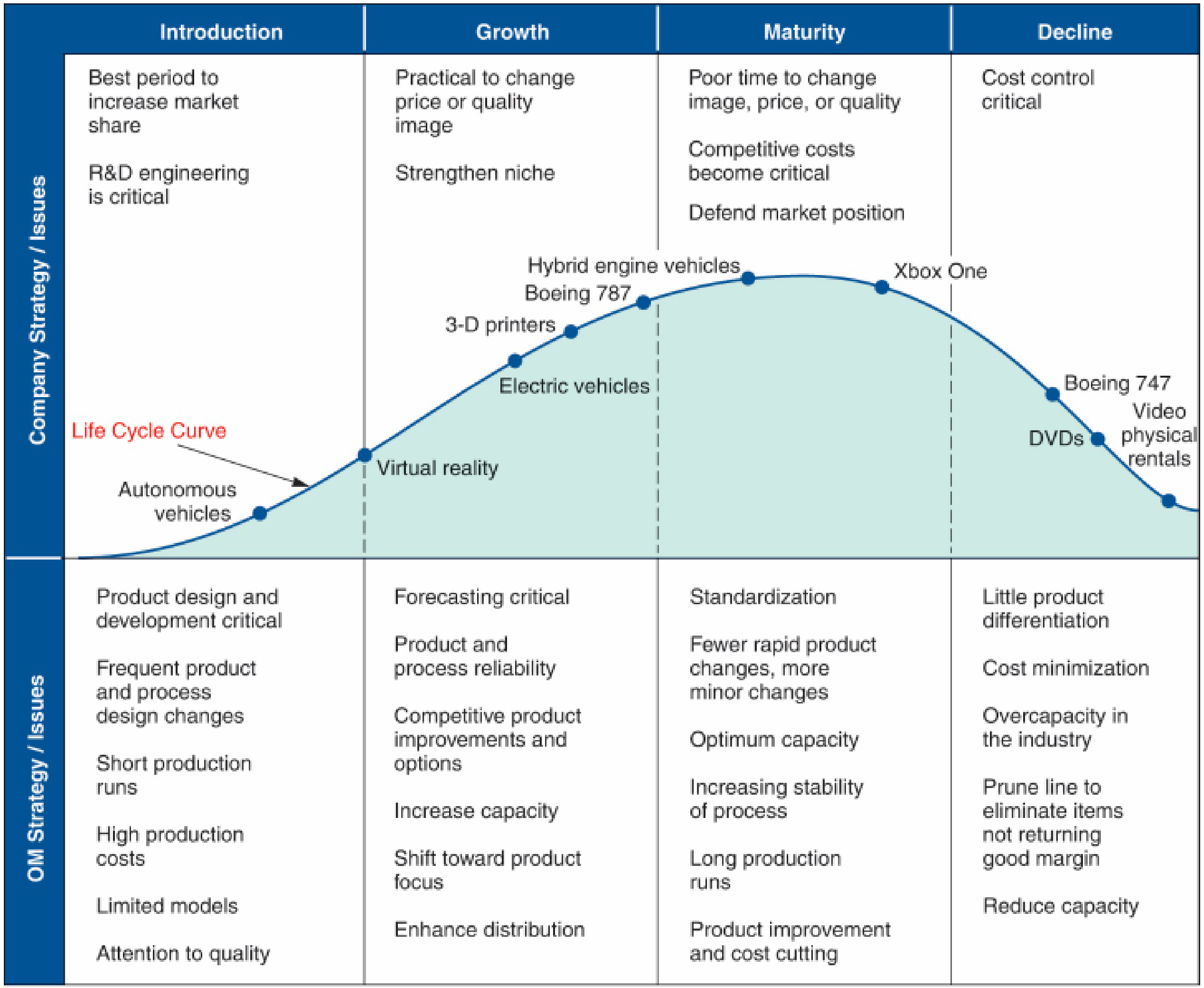


Issues In Operations Strategy

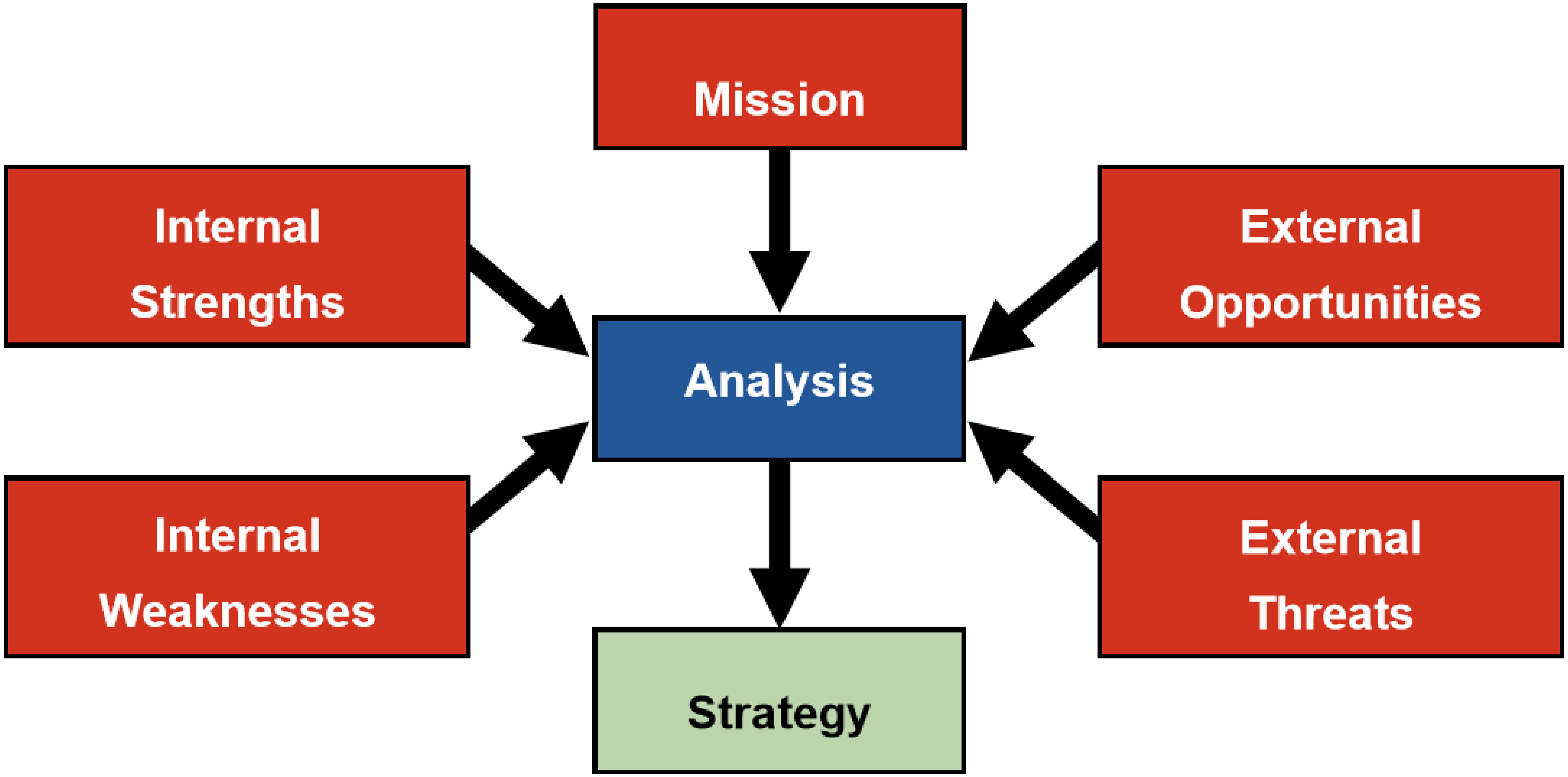
- Resources view
- Value-chain analysis
- Porter's Five Forces model
- Operating in a system with many external factors
- Constant change

Product Life Cycle

Figure 2.5

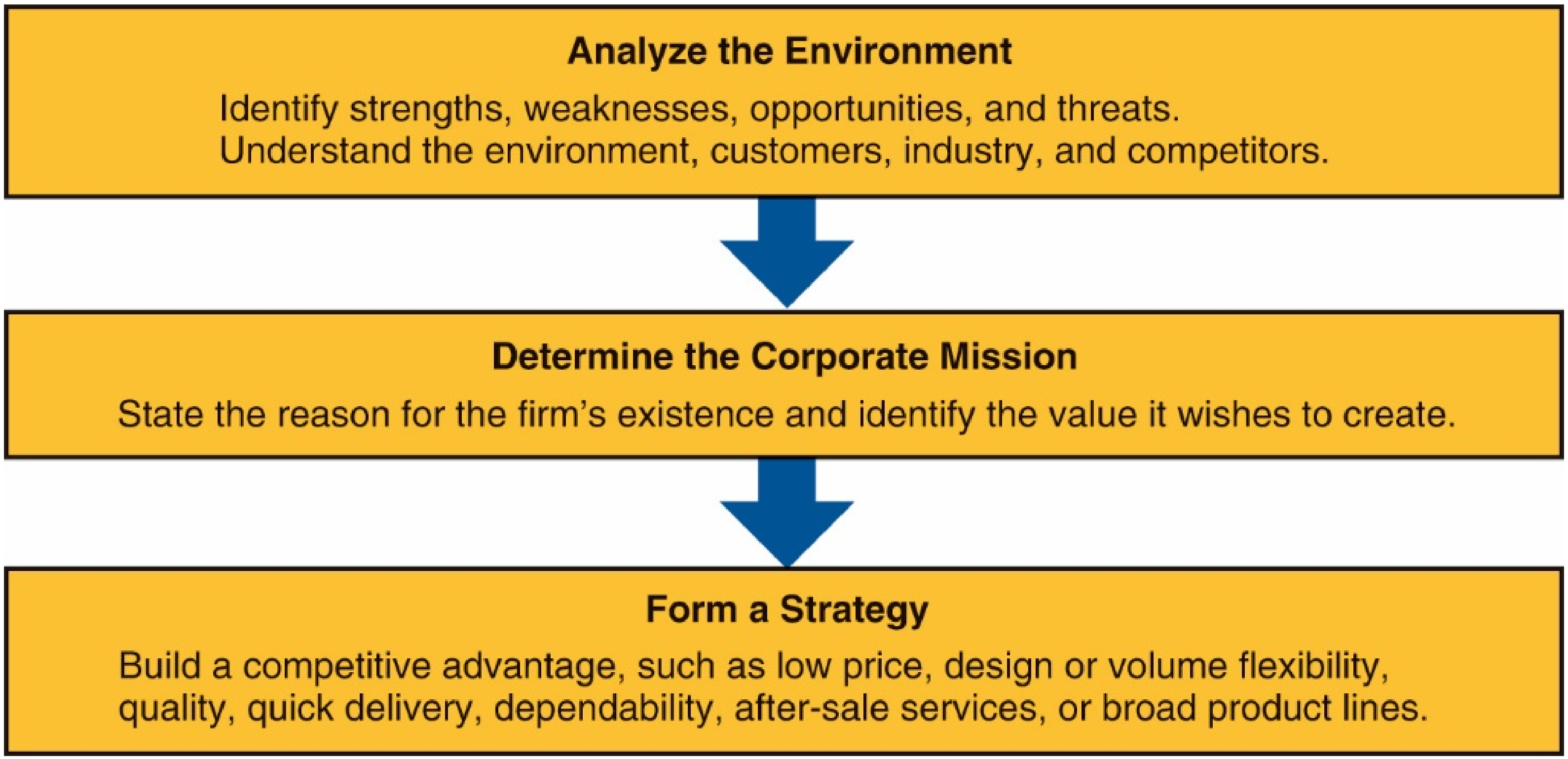


SWOT Analysis



Strategy Development Process

Figure 2.6



Strategy Development and Implementation

- Identify key success factors
- Integrate OM with other activities
- Build and staff the organization

The operations manager's job is to implement an OM strategy, provide competitive advantage, and increase productivity

Key Success Factors

Figure 2.7

Support a Core Competency and Implement Strategy by Identifying and Executing the Key Success Factors in the Functional Areas

Marketing

- Service
- Distribution
- Promotion
- Price
- Channels of distribution
- Product positioning (image, functions)

Finance/Accounting

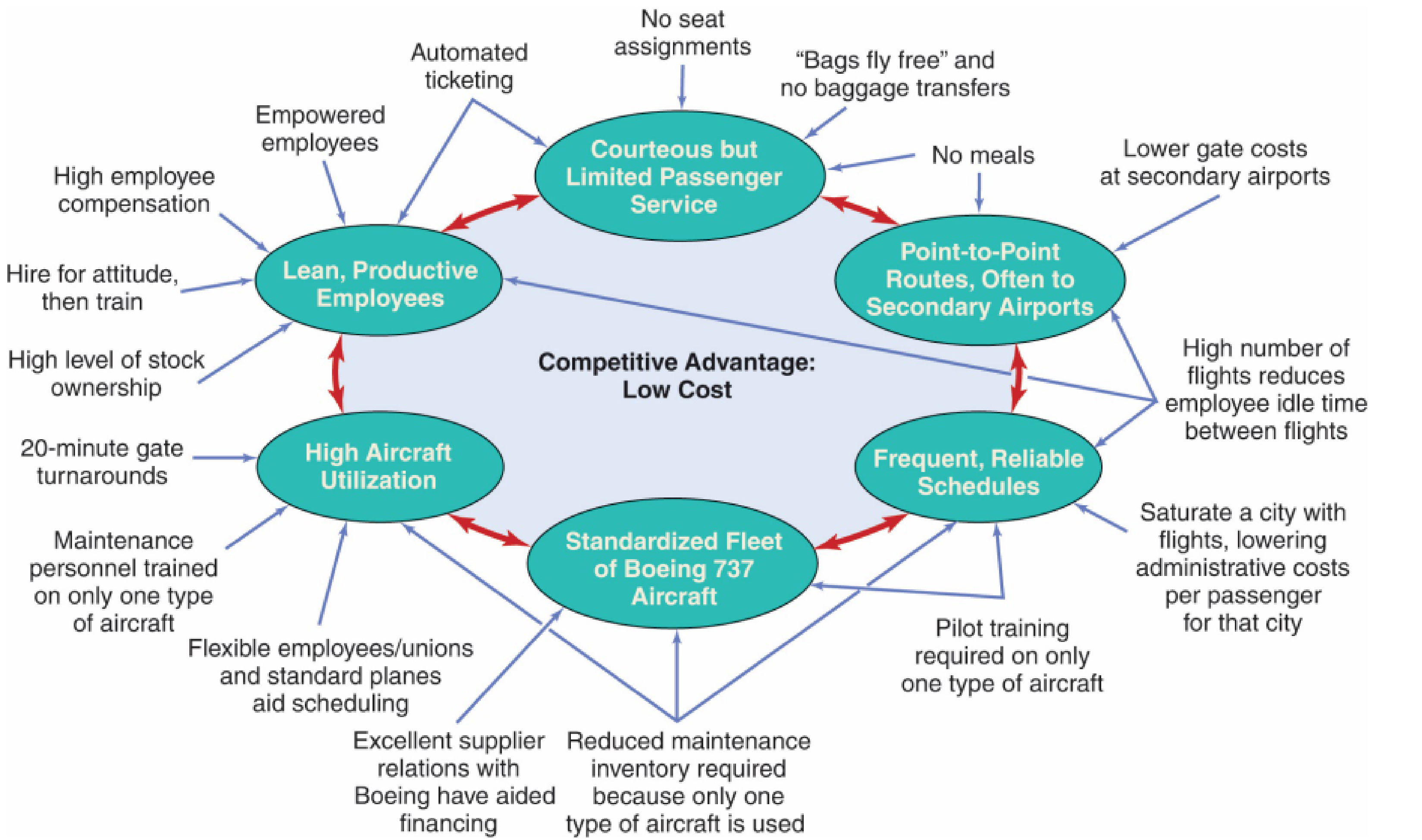
- Leverage
- Cost of capital
- Working capital
- Receivables
- Payables
- Financial control
- Lines of credit

Operations

10 OM Decisions	Sample Options	Chapter
Product	Customized or standardized; sustainability	5,S5
Quality	Define customer quality expectations and how to achieve them	6,S6
Process	Facility design, capacity, how much automation	7,S7
Location	Near supplier or near customer	8
Layout	Work cells or assembly line	9
Human resources	Specialized or enriched jobs	10
Supply chain	Single or multiple suppliers	11, S11
Inventory	When to reorder; how much to keep on hand	12,14,16
Schedule	Stable or fluctuating production rate	13,15
Maintenance	Repair as required or preventive maintenance	17

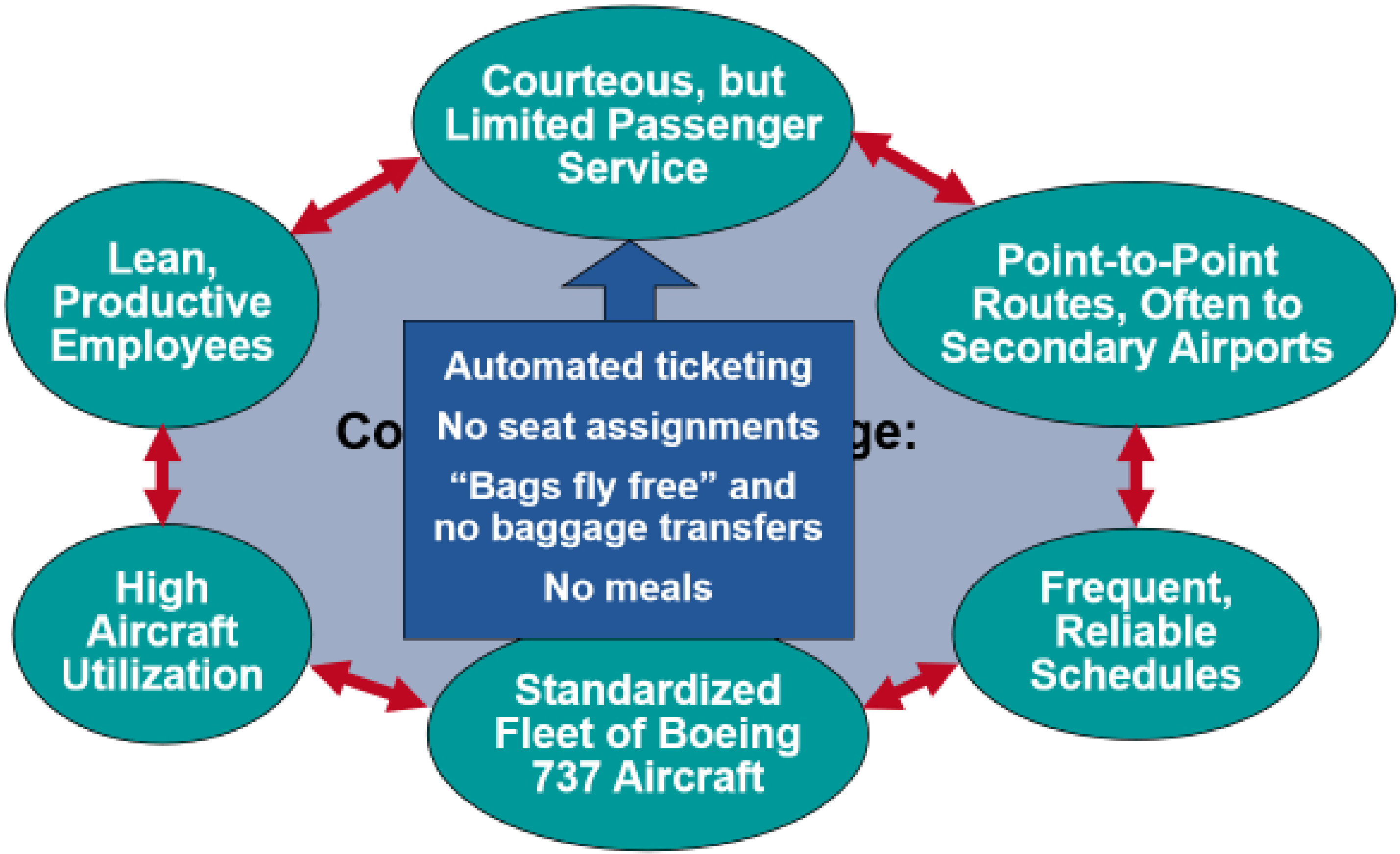
Activity Mapping at Southwest Airlines (1 of 7)

Figure 2.8



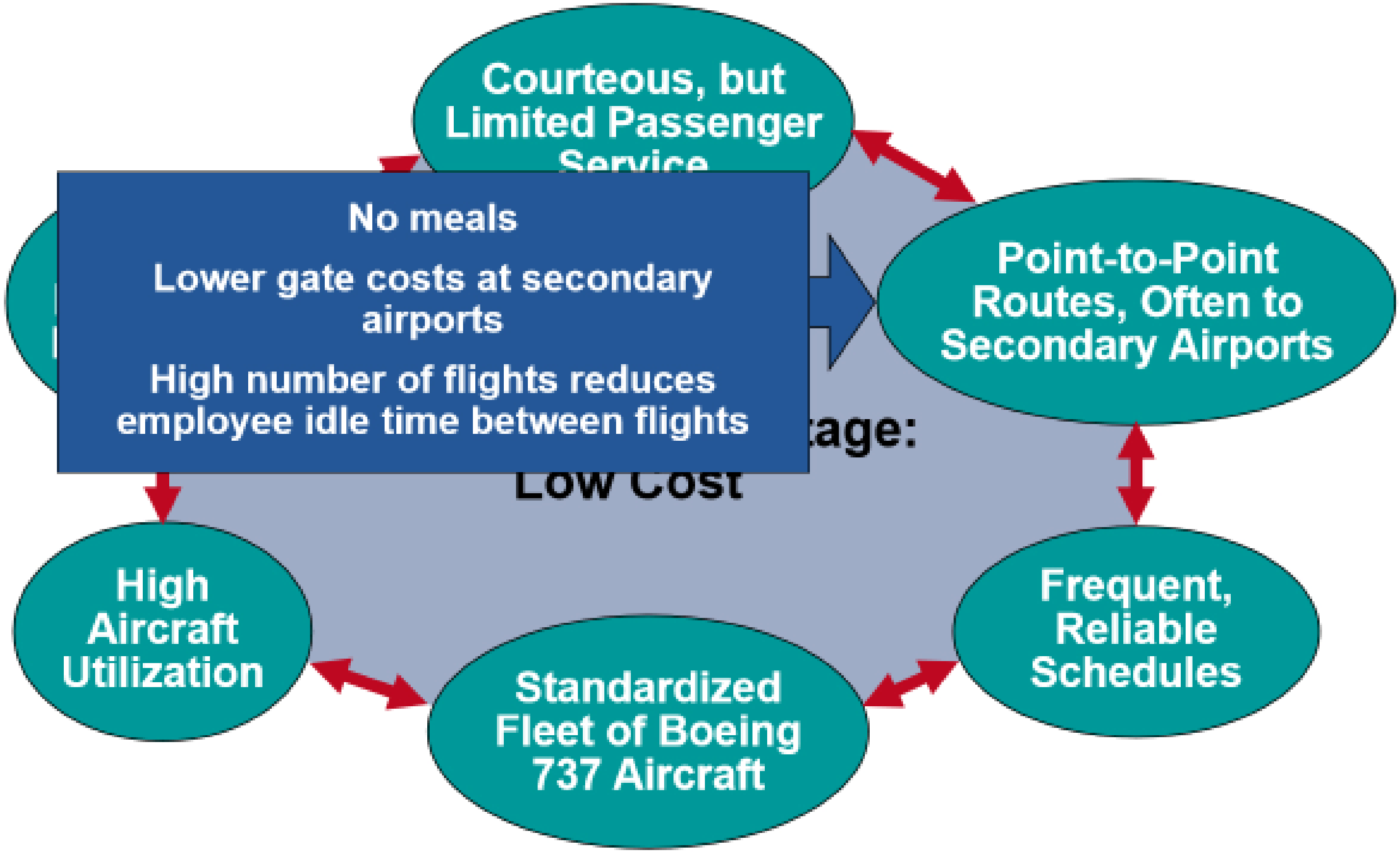
Activity Mapping at Southwest Airlines (2 of 7)

Figure 2.8



Activity Mapping at Southwest Airlines (3 of 7)

Figure 2.8



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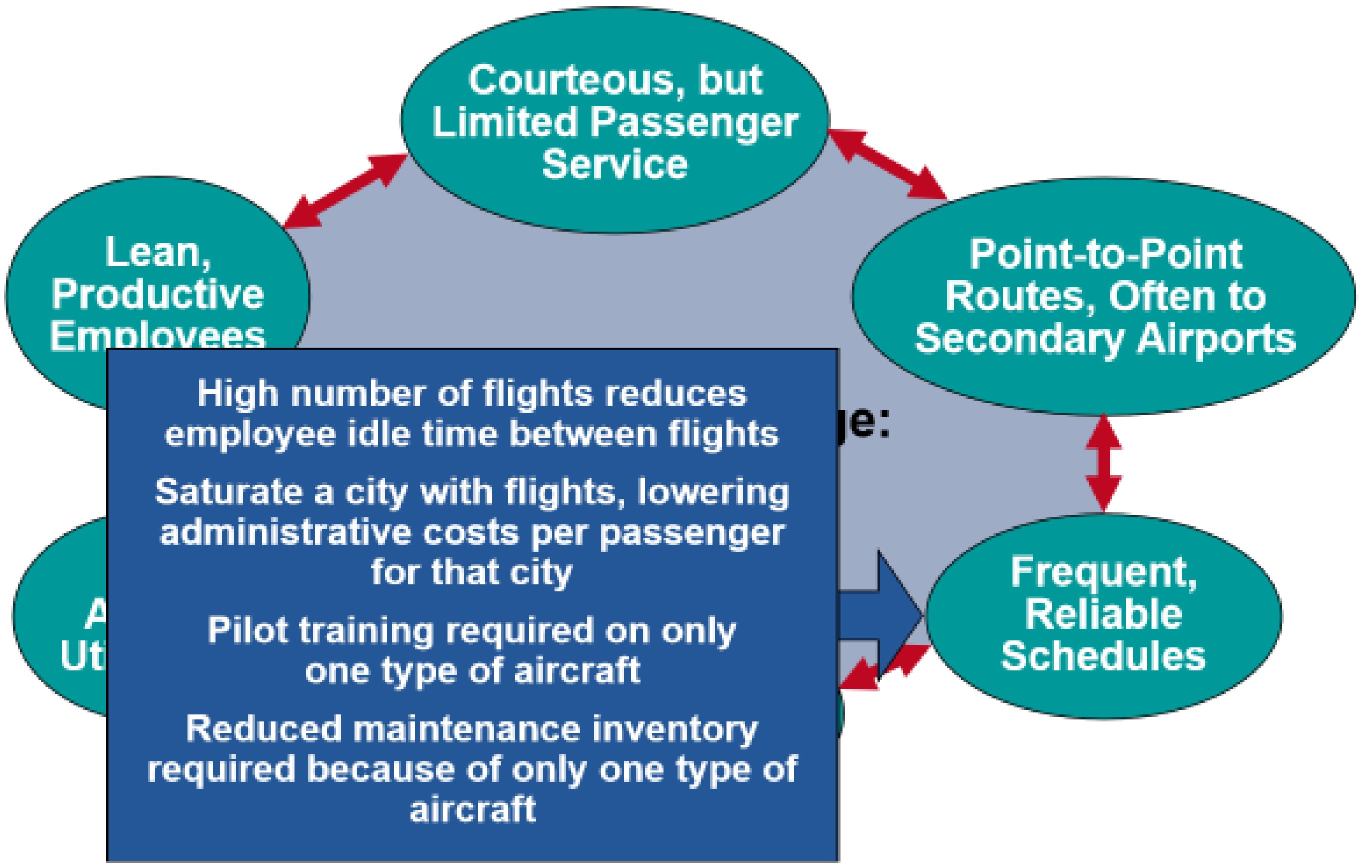
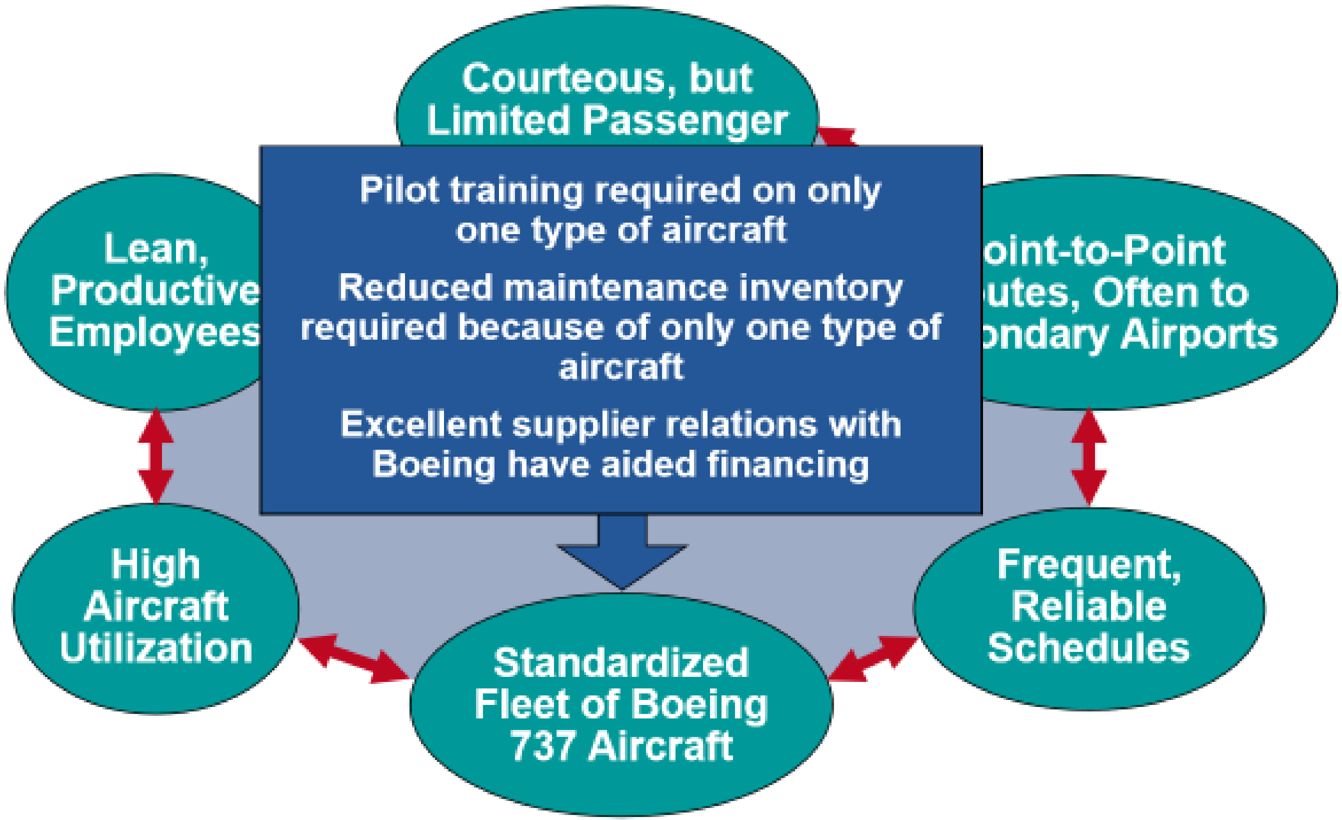
Activity Mapping at Southwest Airlines (4 of 7)

Figure 2.8



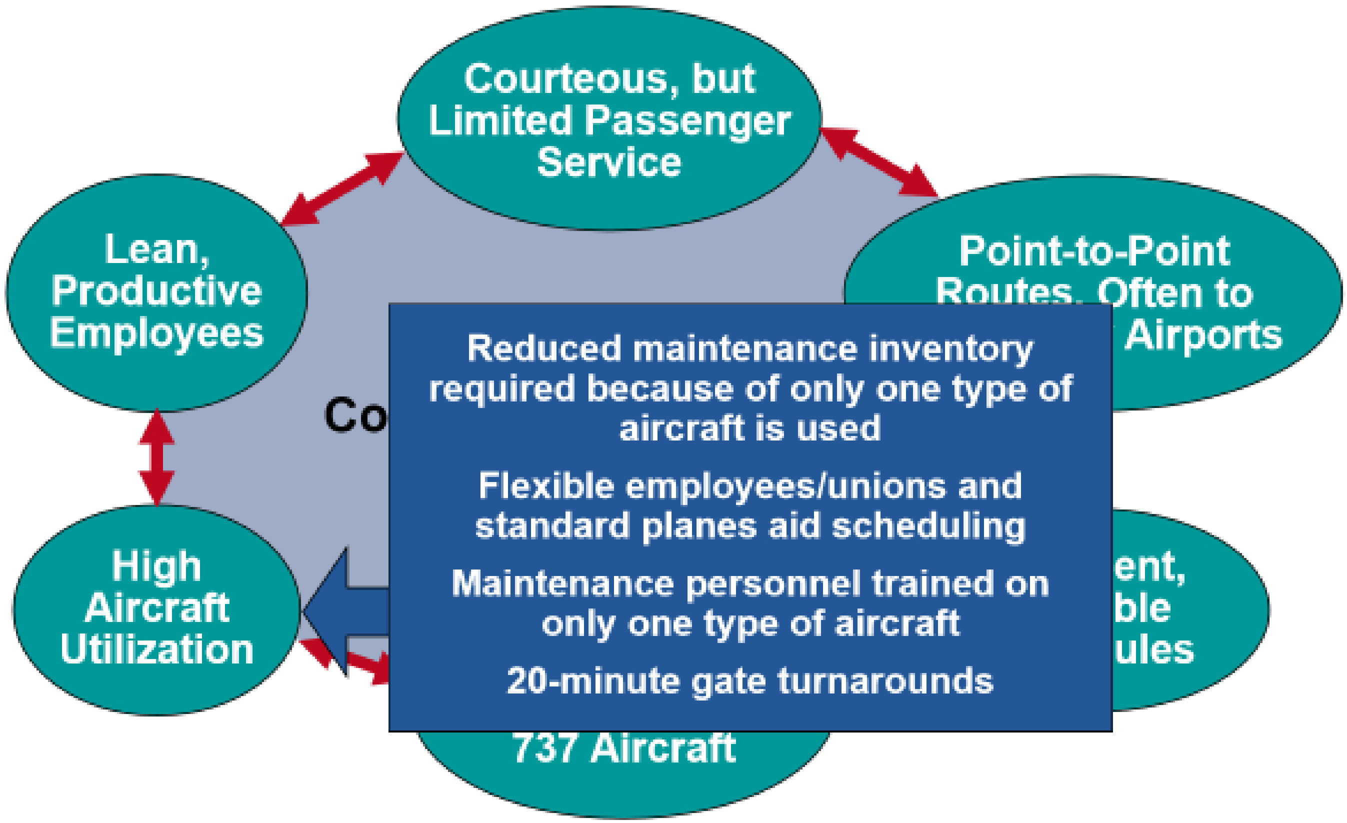
Activity Mapping at Southwest Airlines (5 of 7)

Figure 2.8



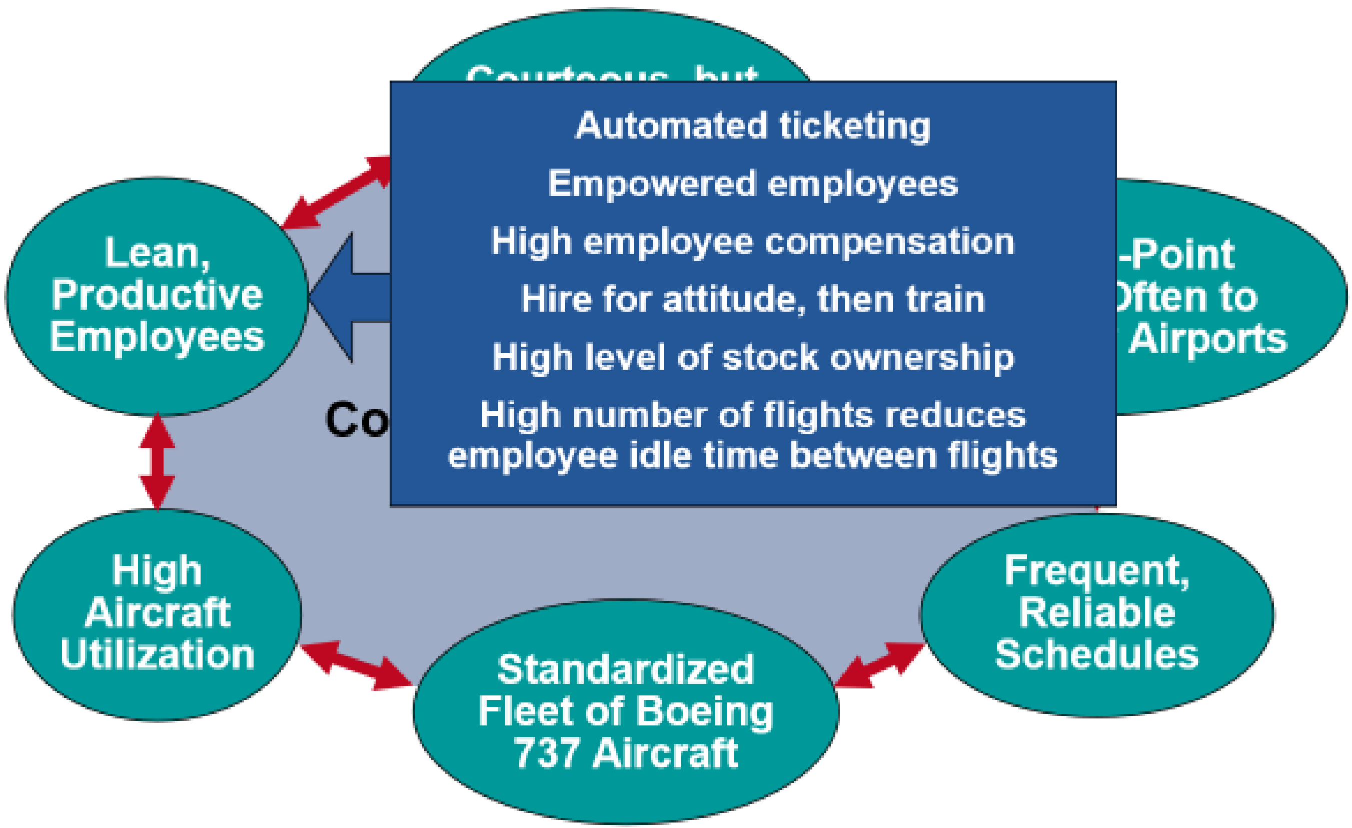
Activity Mapping at Southwest Airlines (6 of 7)

Figure 2.8



Activity Mapping at Southwest Airlines (7 of 7)

Figure 2.8



Implementing Strategic Decisions (1 of 2)

Table 2.1 Operations Strategies of Two Drug Companies

	BRAND NAME DRUGS, INC.	GENERIC DRUGS CORP.
COMPETITIVE ADVANTAGE	PRODUCT DIFFERENTIATION STRATEGY	LOW-COST STRATEGY
Product selection and design	Heavy R&D investment; extensive labs; focus on development in a broad range of drug categories	Low R&D investment; focus on development of generic drugs
Quality	Quality is major priority, standards exceed regulatory requirements	Meets regulatory requirements on a country-by-country basis, as necessary
Process	Product and modular production process; tries to have long product runs in specialized facilities; builds capacity ahead of demand	Process focused; general production processes; "job shop" approach, short-run production; focus on high utilization
Location	Still located in city where it was founded	Recently moved to low-tax, low-labor-cost environment

Implementing Strategic Decisions (2 of 2)

Table 2.1 Operations Strategies of Two Drug Companies

COMPETITIVE ADVANTAGE	BRAND NAME DRUGS, INC. PRODUCT DIFFERENTIATION STRATEGY	GENERIC DRUGS CORP. LOW-COST STRATEGY
Layout	Layout supports automated product-focused production	Layout supports process-focused "job shop" practices
Human resources	Hire the best; nationwide searches	Very experienced top executives provide direction; other personnel paid below industry average
Supply chain	Long-term supplier relationships	Tends to purchase competitively to find bargains
Inventory	Maintains high finished goods inventory primarily to ensure all demands are met	Process focus drives up work-in-process inventory; finished goods inventory tends to be low
Scheduling	Centralized production planning	Many short-run products complicate scheduling
Maintenance	Highly trained staff; extensive parts inventory	Highly trained staff to meet changing process and equipment demands

Strategic Planning, Core Competencies, and Outsourcing (1 of 2)

- **Outsourcing** – transferring activities that have traditionally been internal to external suppliers
- Accelerating due to
  1) Increased technological expertise
  2) More reliable and cheaper transportation
  3) Rapid development and deployment of advancements in telecommunications and computers

Strategic Planning, Core Competencies, and Outsourcing (2 of 2)

- Subcontracting - contract manufacturing
- Outsourced activities
  - Legal services
  - IT services
  - Travel services
  - Payroll
  - Production
  - Surgery

Theory of Comparative Advantage

- If an external provider can perform activities more productively than the purchasing firm, then the external provider should do the work
- Purchasing firm focuses on core competencies
- Drives outsourcing

Risks of Outsourcing

Table 2.2 Potential Advantages and Disadvantages of Outsourcing

ADVANTAGES	DISADVANTAGES
Cost savings	Increased logistics and inventory costs
Gaining outside expertise that comes with specialization	Loss of control (quality, delivery, etc.)
Improving operations and service	Potential creation of future competition
Maintaining a focus on core competencies	Negative impact on employees
Accessing outside technology	Risks may not manifest themselves for years

Rating Outsourcing Providers

- Insufficient analysis most common reason for failure
- *Factor-rating method*
- Points are assigned for each factor for each provider
- Weights are assigned to each factor

Rating Provider Selection Criteria

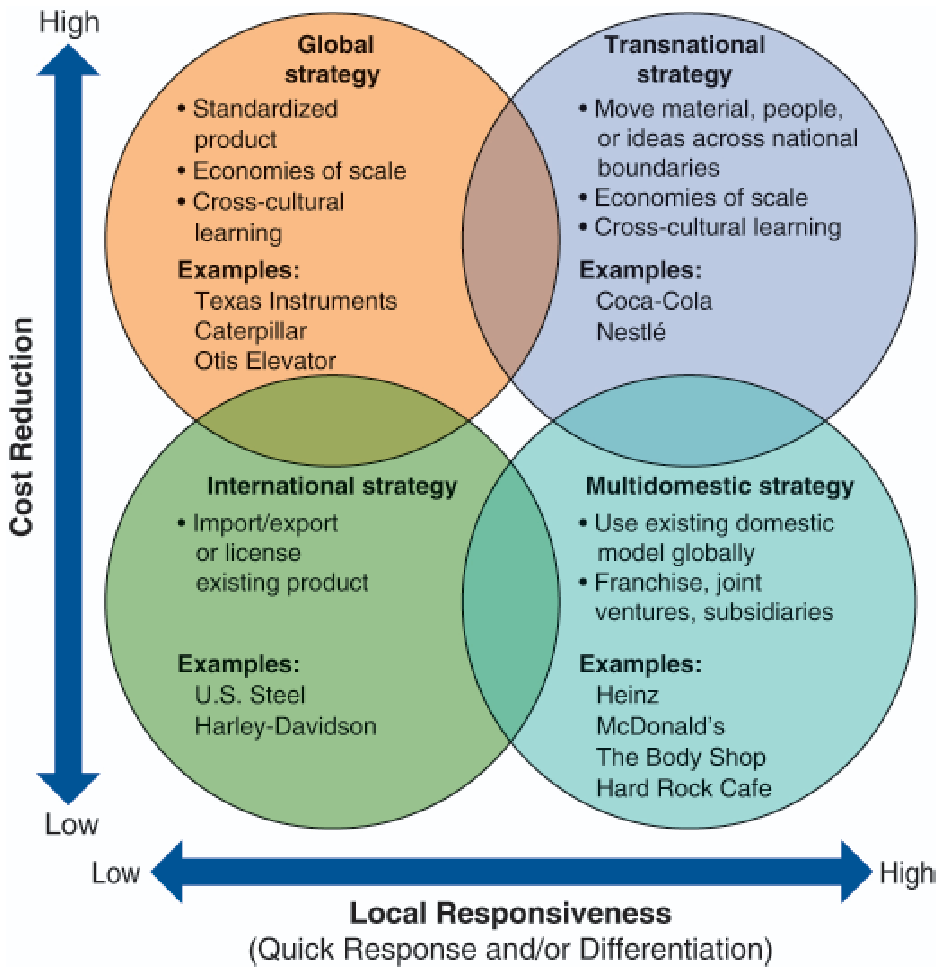
Table 2.3 Factor Ratings Applied to National Architects' Potential IT Outsourcing Providers

FACTOR (CRITERION)	IMPORTANCE WEIGHTS	OUTSOURCING PROVIDERS		
		BIM (U.S.)	S.P.C. (INDIA)	TELCO (ISRAEL)
1. Can reduce operating costs	.2	3	3	5
2. Can reduce capital investment	.2	4	3	3
3. Skilled personnel	.2	5	4	3
4. Can improve quality	.1	4	5	2
5. Can gain access to technology not in company	.1	5	3	5
6. Can create additional capacity	.1	4	2	4
7. Aligns with policy/philosophy/culture	.1	2	3	5
Total Weighted Score	1.0	3.9	3.3	3.8

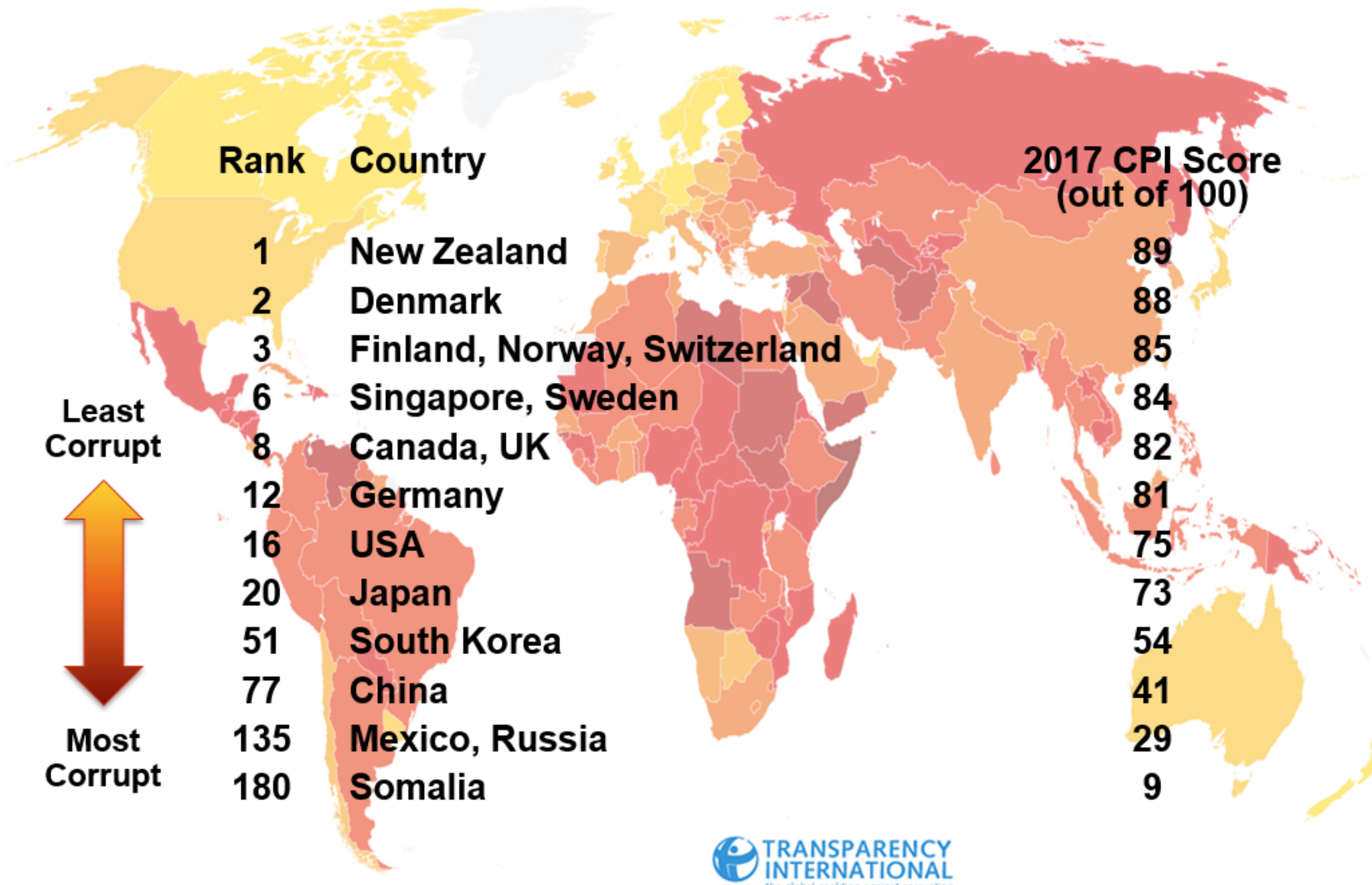
Score for BIM = (.2 * 3) + (.2 * 4) + (.2 * 5) + (.1 * 4) + (.1 * 5) + (.1 * 4) + (.1 * 2) = 3.9

Global Operations Strategy Options

Figure 2.9



Ranking Corruption



Least Corrupt

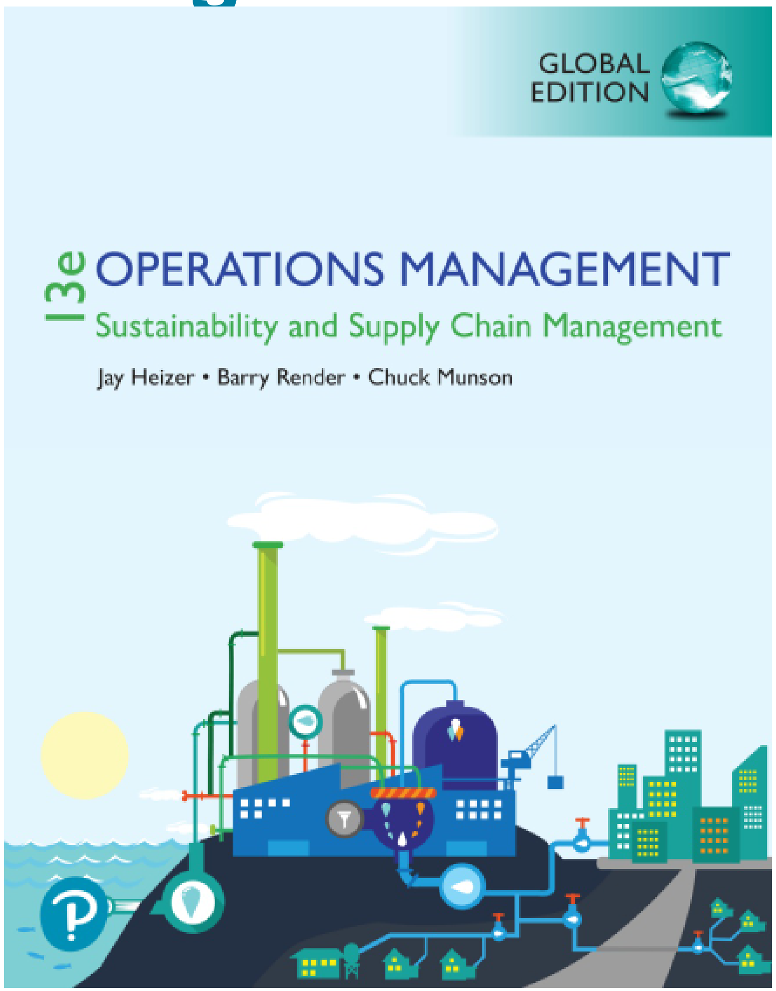
Most Corrupt

Rank	Country	2017 CPI Score (out of 100)
1	New Zealand	89
2	Denmark	88
3	Finland, Norway, Switzerland	85
6	Singapore, Sweden	84
8	Canada, UK	82
12	Germany	81
16	USA	75
20	Japan	73
51	South Korea	54
77	China	41
135	Mexico, Russia	29
180	Somalia	9

Copyright

Operations Management: Sustainability and Supply Chain Management

Thirteenth Edition, Global Edition



Chapter 3

Project Management

Pearson

Outline (1 of 3)

- Global Company Profile: *Bechtel Group*
- The Importance of Project Management
- Project Planning
- Project Scheduling
- Project Controlling

Outline (2 of 3)

- Project Management Techniques: PERT and CPM
- Determining the Project Schedule
- Variability in Activity Times
- Cost-Time Trade-offs and Project Crashing

Outline (3 of 3)

- A Critique of PERT and CPM
- Using Microsoft Project to Manage Projects

Bechtel Projects (1 of 2)

- Oil pipelines in Venezuela, from Saudi Arabia to Syria through Jordan, and Canada Trans Mountain Oil Pipeline
- Managing the Channel Tunnel project
- Constructing the Hoover Dam, the highest dam in the Western Hemisphere
- Nuclear power plants and nuclear cleanup projects including Three Mile Island

Bechtel Projects (2 of 2)

- Construction of Jubail, a complete city in Saudi Arabia
- Project management for the 1984 Summer Olympics in Los Angeles
- San Francisco's Bay Area Rapid Transit system (BART)
- Emergency response efforts following Hurricane Katrina and extinguishing oil well fires in Kuwait
- Boston's Central Artery/Tunnel Project and Washington D. C.'s Silver Line metro

Learning Objectives (1 of 2)

When you complete this chapter you should be able to:

3.1 ***Use*** a Gantt chart for scheduling

3.2 ***Draw*** AOA and AON networks

3.3 ***Complete*** forward and backward passes for a project

3.4 ***Determine*** a critical path

Learning Objectives (2 of 2)

When you complete this chapter you should be able to:

3.5 ***Calculate*** the variance of activity times

3.6 ***Crash*** a project

Importance of Project Management

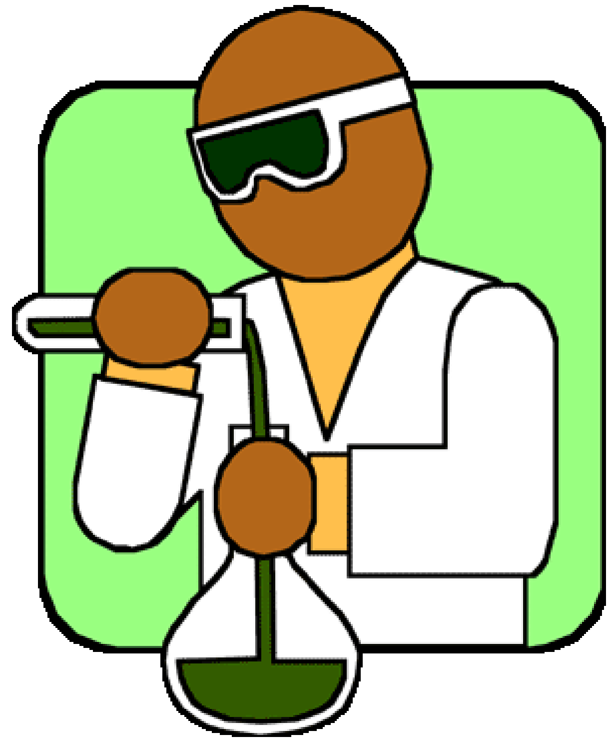
- Bechtel Project Management
  - International workforce, construction professionals, cooks, medical personnel, security
  - Strategic value of time-based competition
  - Quality mandate for continual improvement

Project Characteristics

- Single unit
- Many related activities
- Difficult production planning and inventory control
- General purpose equipment
- High labor skills

Examples of Projects

- Building Construction



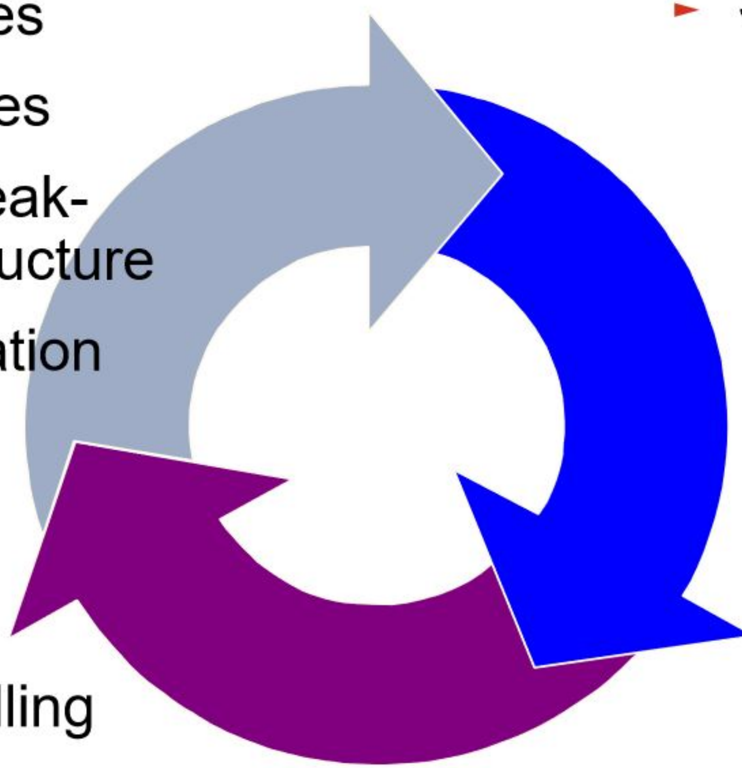
- Research Project

Management of Projects

1. *Planning* - goal setting, defining the project, team organization
2. *Scheduling* - relate people, money, and supplies to specific activities and activities to each other
3. *Controlling* - monitor resources, costs, quality, and budgets; revise plans and shift resources to meet time and cost demands

Project Management Activities

- Planning
  - Objectives
  - Resources
  - Work break-down structure
  - Organization

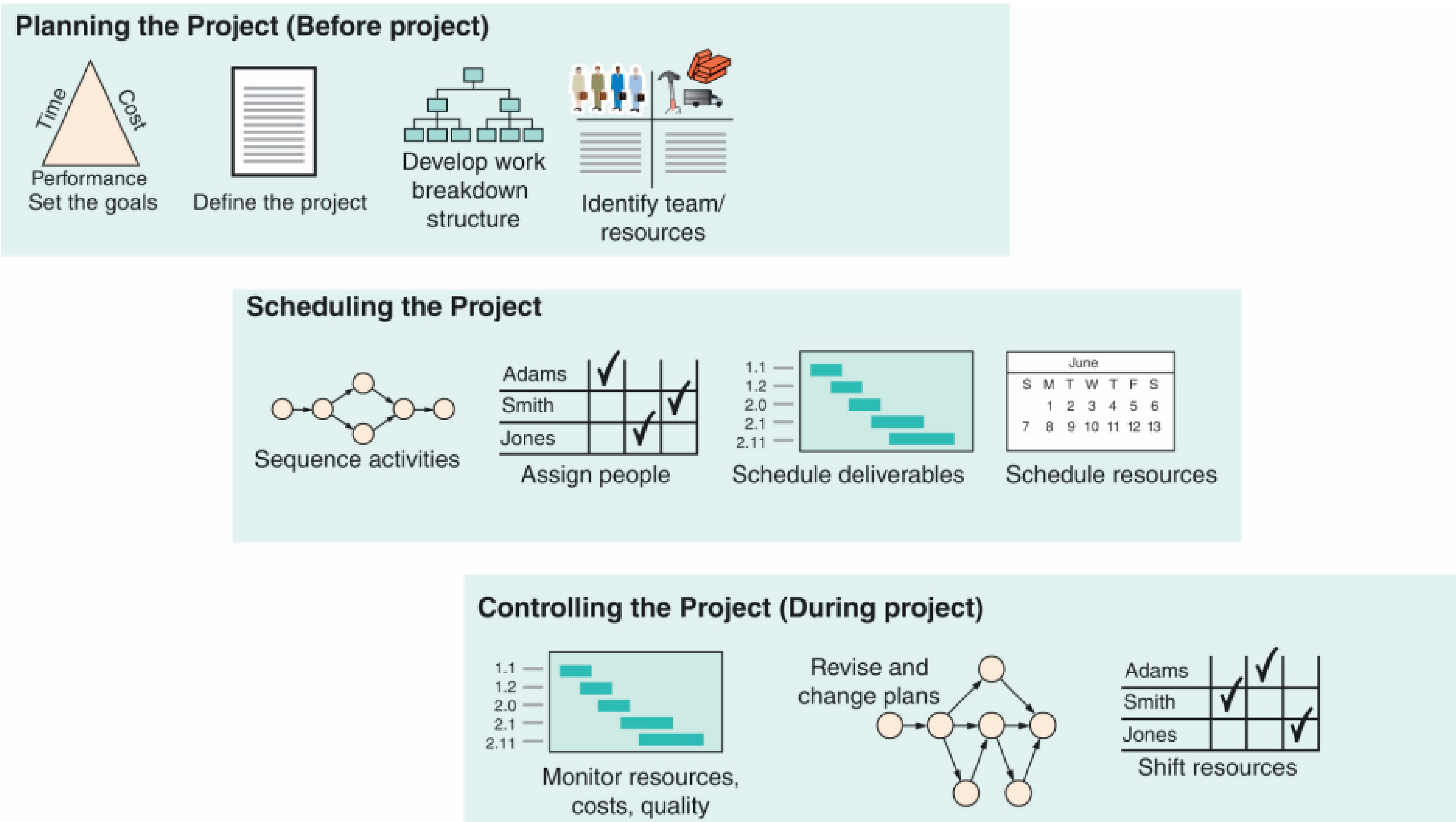


- Scheduling
  - Project activities
  - Start and end times
  - Network

- Controlling
  - Monitor, compare, revise, action

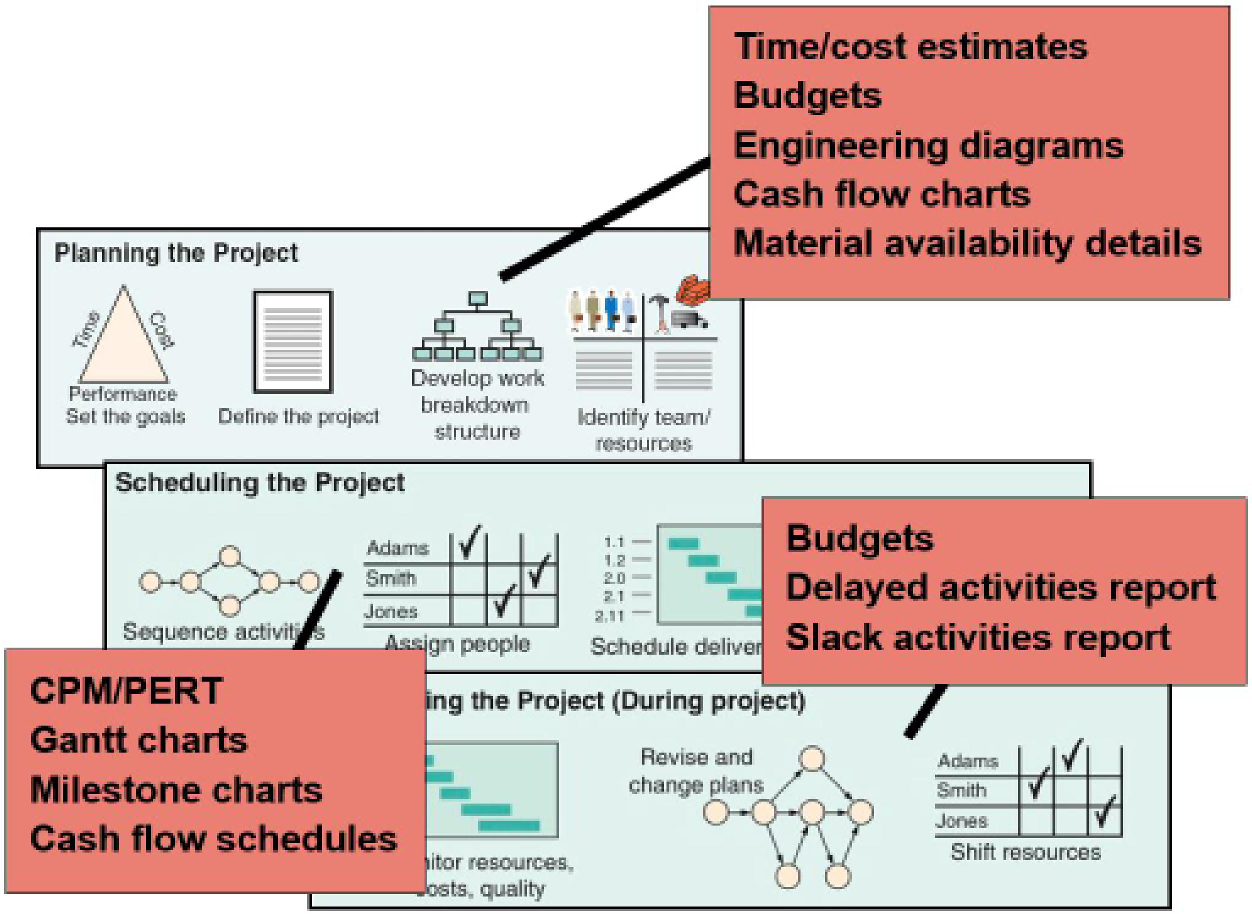
Project Planning, Scheduling, and Controlling (1 of 2)

Figure 3.1



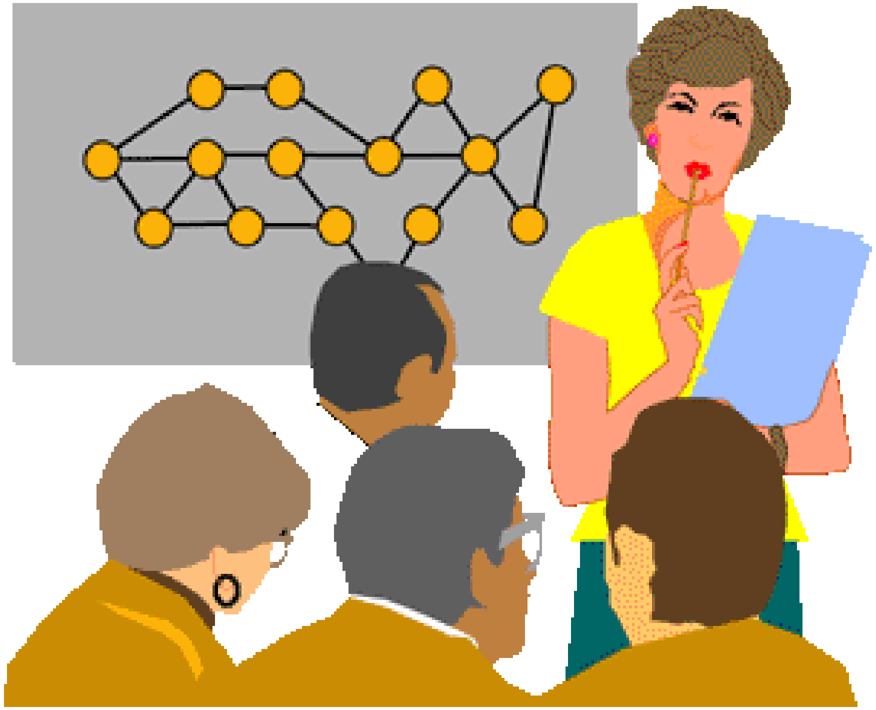
Project Planning, Scheduling, and Controlling (2 of 2)

Figure 3.1



Project Planning

- Establishing objectives
- Defining project
- Creating work breakdown structure
- Determining resources
- Forming organization



Project Organization

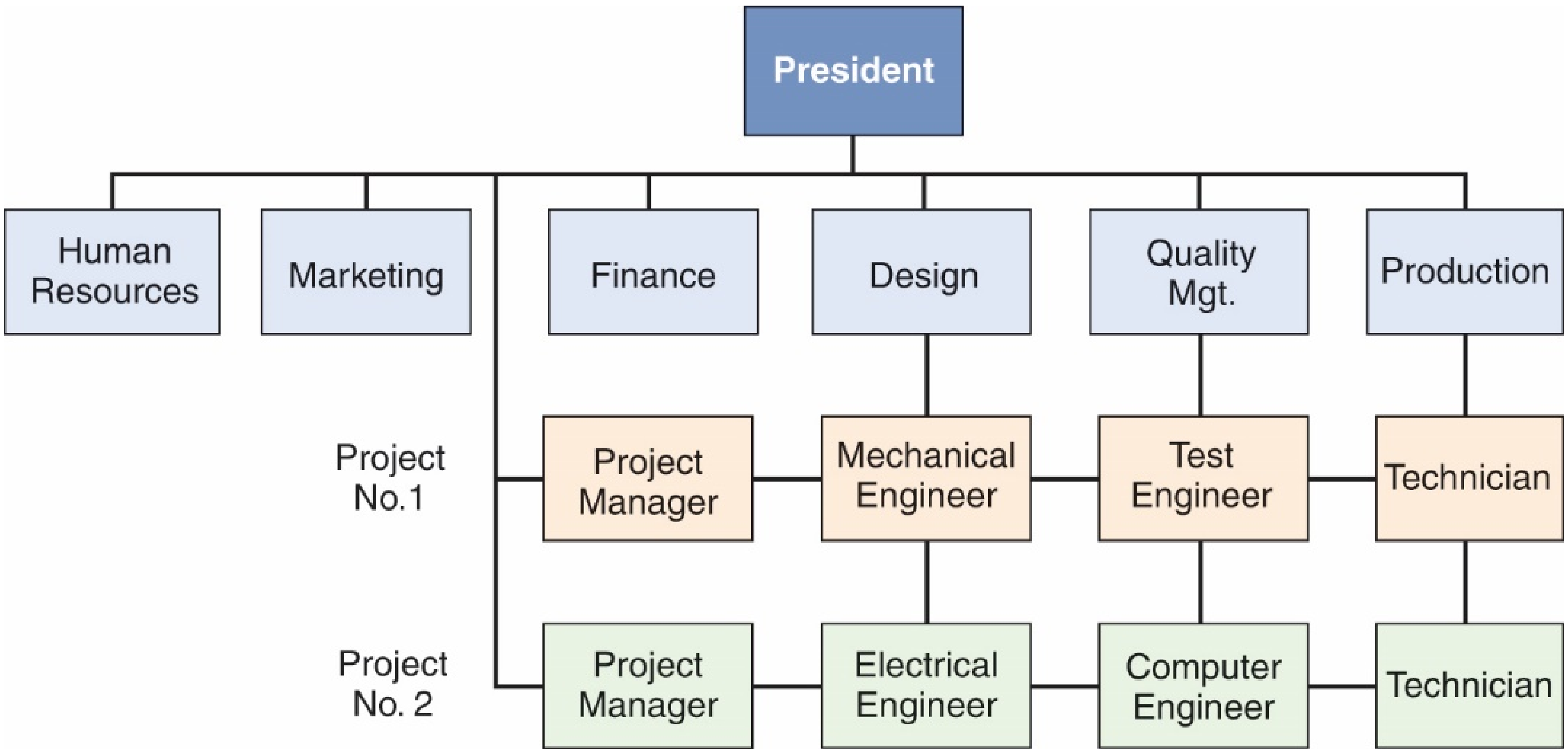
- Often temporary structure
- Uses specialists from entire company
- Headed by project manager
  - Coordinates activities
  - Monitors schedule and costs
- Permanent structure called ‘matrix organization’

Project Organization Most Helpful When:

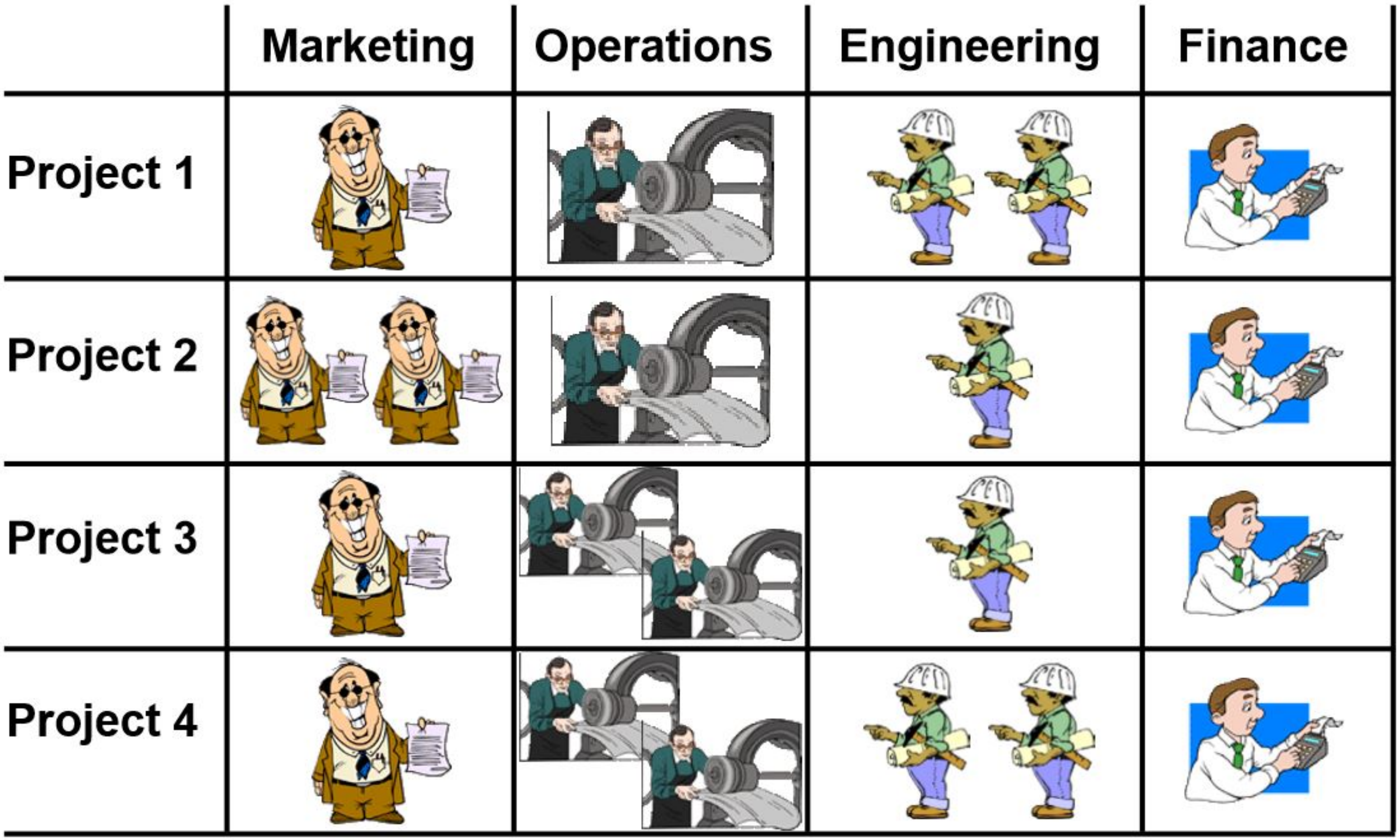
1. Work can be defined with a specific goal and deadline
2. The job is unique or somewhat unfamiliar to the existing organization
3. The work contains complex interrelated tasks requiring specialized skills
4. The project is temporary but critical to the organization
5. The project cuts across organizational lines

A Sample Project Organization

Figure 3.2



Matrix Organization



The Role of the Project Manager (1 of 2)

Highly visible, Responsible for making sure that:

1. All necessary activities are finished in order and on time
2. The project comes in within budget
3. The project meets quality goals
4. The people assigned to the project receive motivation, direction, and information

The Role of the Project Manager (2 of 2)

Highly visible, Responsible for making sure that:

1. All necessary activities are finished in order and on time
2. The project comes in within budget
3. The project meets quality goals
4. The people assigned to the project receive motivation, direction, and information

Project managers should be:

- **Good coaches**
- **Good communicators**
- **Able to organize activities from a variety of disciplines**

Ethical Issues

- Project managers face many ethical decisions on a daily basis
- The Project Management Institute has established an ethical code to deal with problems such as:
    1. Offers of gifts from contractors
    2. Pressure to alter status reports to mask delays
    3. False reports for charges of time and expenses
    4. Pressure to compromise quality to meet schedules

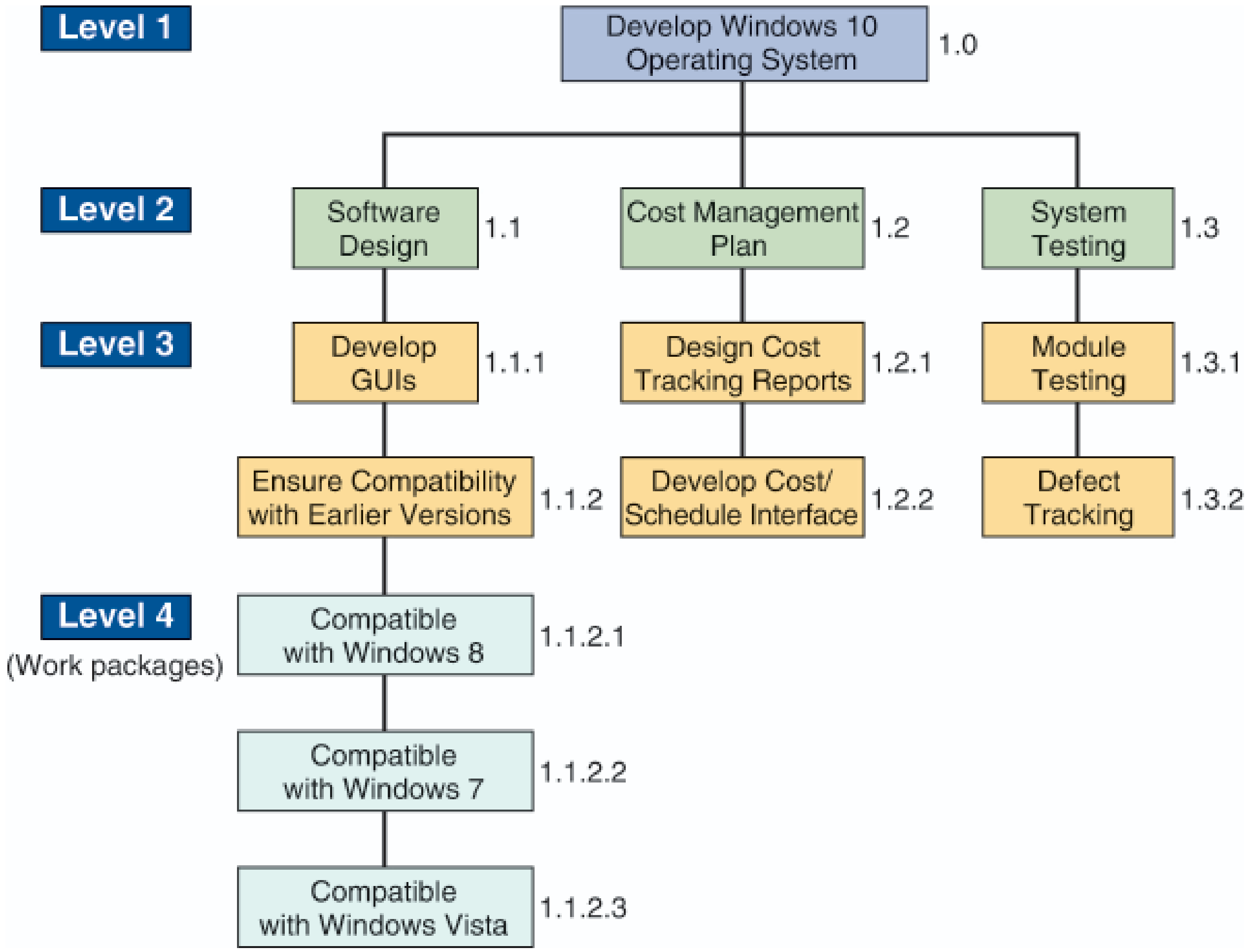
Work Breakdown Structure (1 of 2)

Level

1. Project
2. Major tasks in the project
3. Subtasks in the major tasks
4. Activities (or “work packages”) to be completed

Work Breakdown Structure (2 of 2)

Figure 3.3



Project Scheduling Techniques (1 of 2)

- Ensure that all activities are planned for
- Their order of performance is accounted for
- The activity time estimates are recorded
- The overall project time is developed

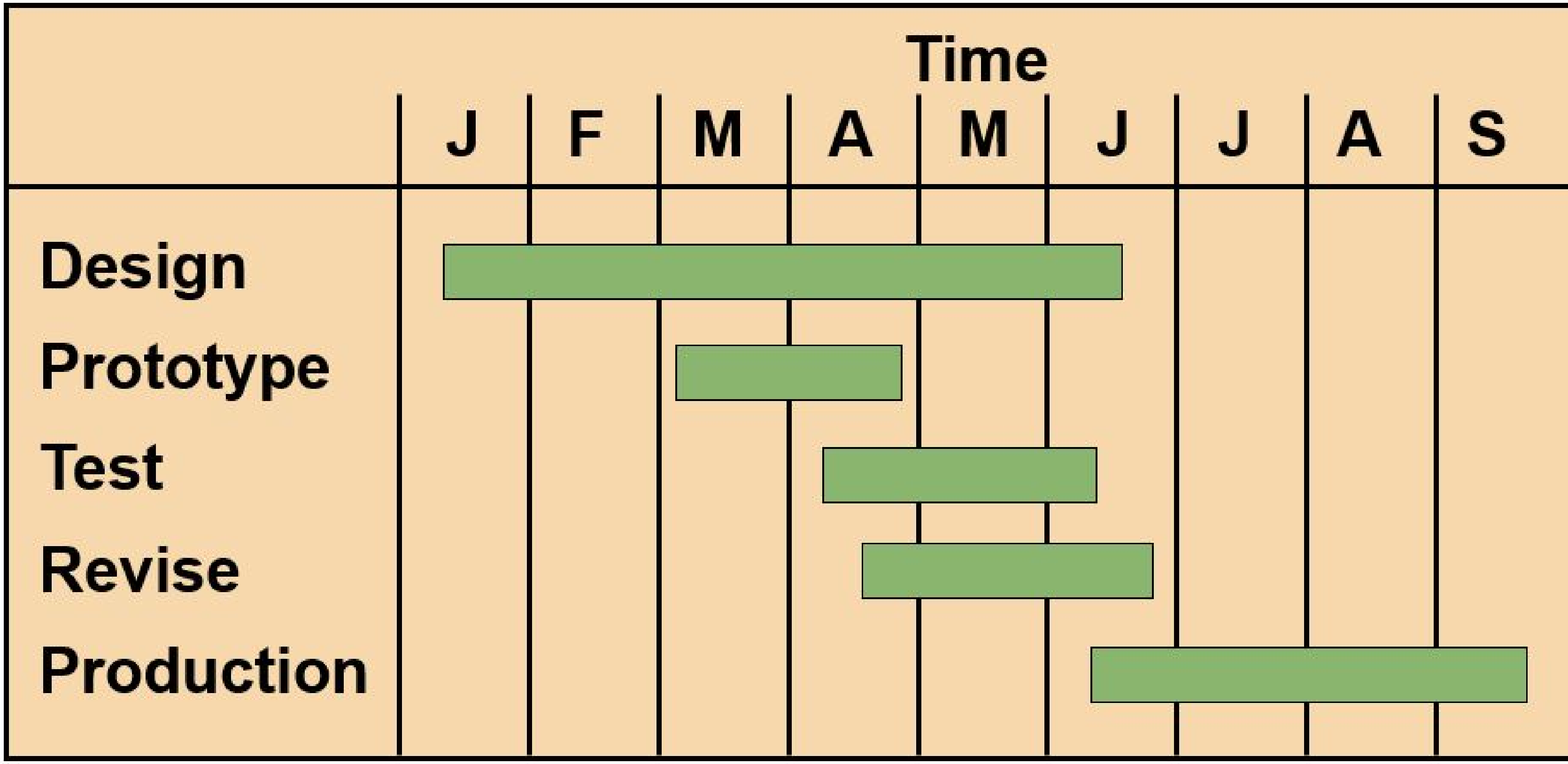
Purposes of Project Scheduling

1. Shows the relationship of each activity to others and to the whole project
2. Identifies the precedence relationships among activities
3. Encourages the setting of realistic time and cost estimates for each activity
4. Helps make better use of people, money, and material resources by identifying critical bottlenecks in the project

Project Scheduling Techniques (2 of 2)

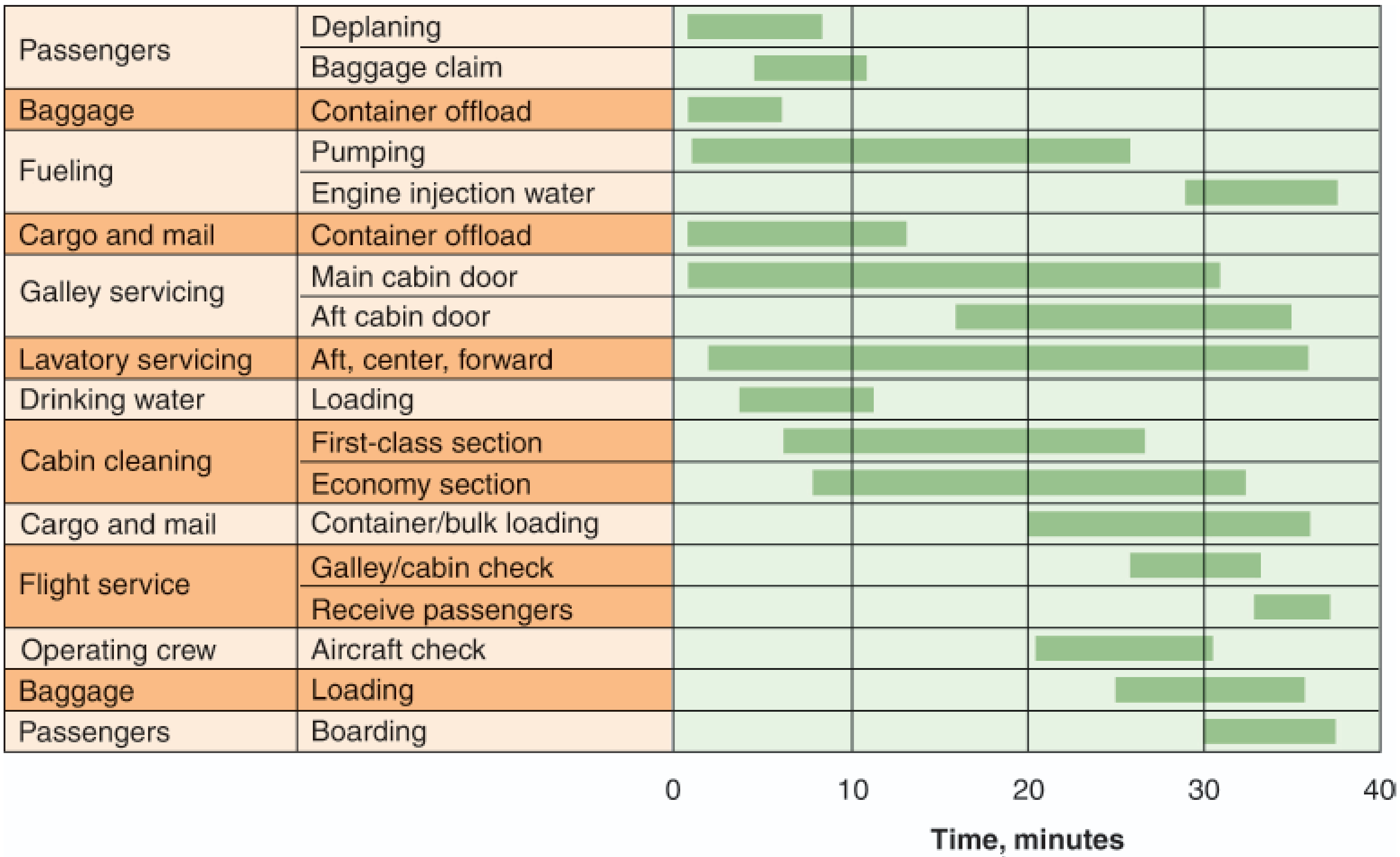
1. Gantt chart
2. Critical Path Method (CPM)
3. Program Evaluation and Review Technique (PERT)

A Simple Gantt Chart



Service For a Delta Jet

Figure 3.4



Project Controlling

- Close monitoring of resources, costs, quality, budgets
- Feedback enables revising the project plan and shift resources
- Computerized tools produce extensive reports

Project Management Software

- There are several popular packages for managing projects
  - Oracle Primavera
  - Mind View
  - HP Project
  - Fast Track
  - Microsoft Project

Project Control Reports

1. Detailed cost breakdowns for each task
2. Labor requirements
3. Cost and hour summaries
4. Raw material and expenditure forecasts
5. Variance reports
6. Time analysis reports
7. Work status reports

Project Control (1 of 2)

- Well-defined – Waterfall Projects
  - Extensive planning
  - Known constraints
  - Well-defined specifications

Project Control (2 of 2)

- Ill-defined – Agile Projects
  - Many unknowns
  - Evolving technology and specifications
  - Project developed iteratively and incrementally

PERT and CPM

- Network techniques
- Developed in 1950s
  - CPM by DuPont for chemical plants (1957)
  - PERT by Booz, Allen & Hamilton with the U.S. Navy, for Polaris missile (1958)
- Consider precedence relationships and interdependencies
- Each uses a different estimate of activity times

Six Steps PERT and CPM (1 of 2)

1. Define the project and prepare the work breakdown structure
2. Develop relationships among the activities – decide which activities must precede and which must follow others
3. Draw the network connecting all of the activities

Six Steps PERT and CPM (2 of 2)

4. Assign time and/or cost estimates to each activity
5. Compute the *longest* time path through the network – this is called the **critical path**
6. Use the network to help plan, schedule, monitor, and control the project

Pearson

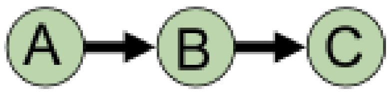
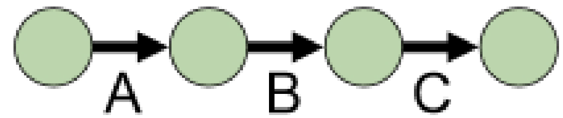
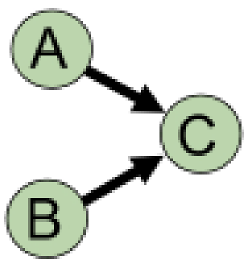
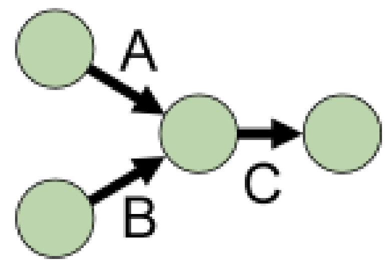
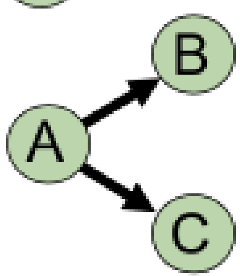
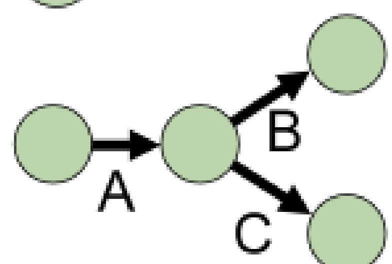
Questions PERT and CPM Can Answer (1 of 2)

1. When will the entire project be completed?
2. What are the critical activities or tasks in the project?
3. Which are the noncritical activities?
4. What is the probability the project will be completed by a specific date?

Questions PERT and CPM Can Answer (2 of 2)

5. Is the project on schedule, behind schedule, or ahead of schedule?
6. Is the money spent equal to, less than, or greater than the budget?
7. Are there enough resources available to finish the project on time?
8. If the project must be finished in a shorter time, what is the way to accomplish this at least cost?

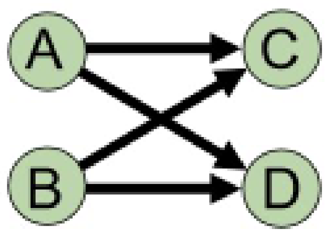
A Comparison of AON and AOA Network Conventions (1 of 3)

	Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
(a)		A comes before B, which comes before C	
(b)		A and B must both be completed before C can start	
(c)		B and C cannot begin until A is completed	

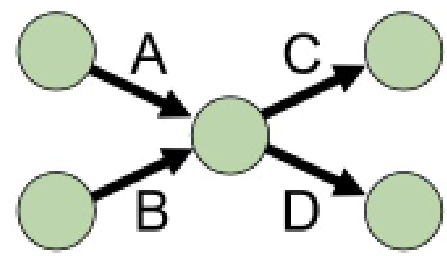
A Comparison of AON and AOA Network Conventions (2 of 3)

Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)

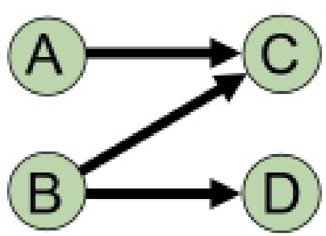
(d)



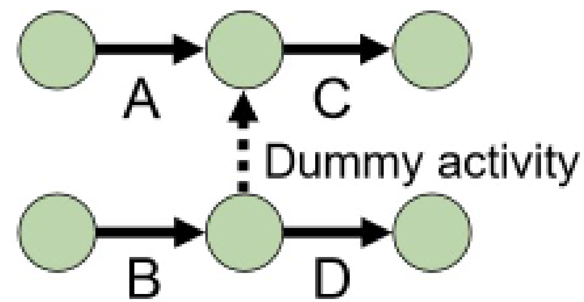
C and D cannot begin until both A and B are completed



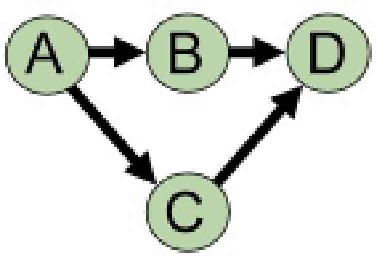
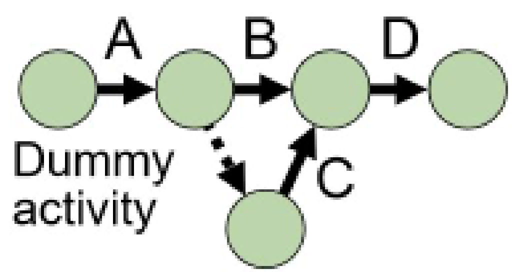
(e)



C cannot begin until both A and B are completed
D cannot begin until B is completed
A dummy activity is introduced in AOA



A Comparison of AON and AOA Network Conventions (3 of 3)

	Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
(f)		B and C cannot begin until A is completed D cannot begin until both B and C are completed A dummy activity is again introduced in AOA	

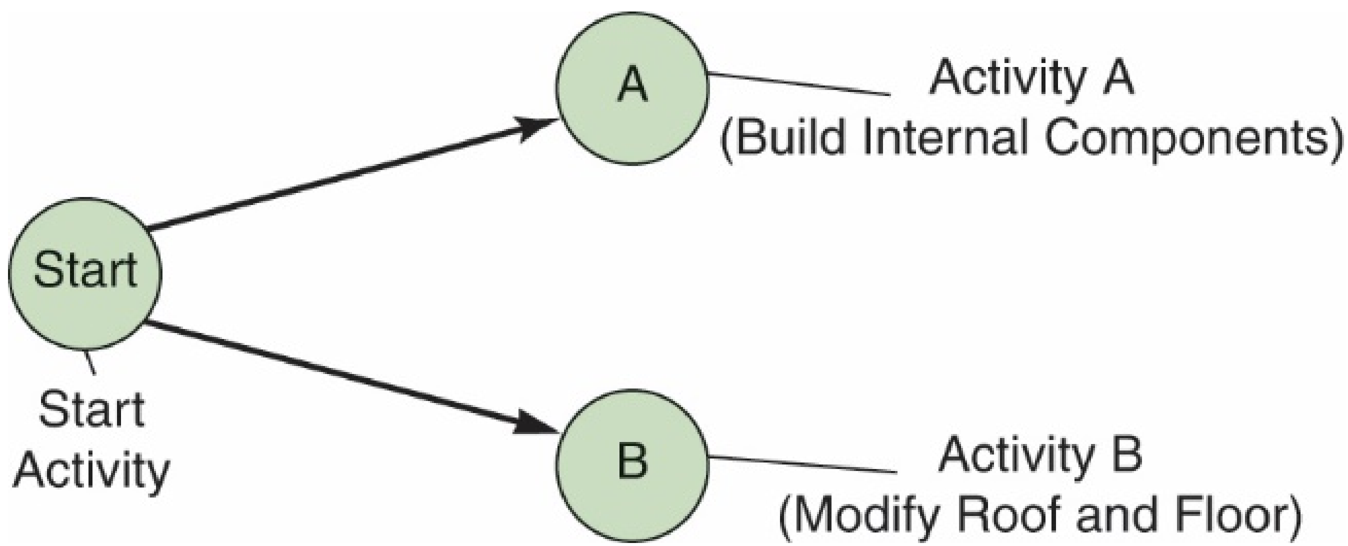
AON Example

Table 3.1 Milwaukee Paper Manufacturing's Activities and Predecessors

ACTIVITY	DESCRIPTION	IMMEDIATE PREDECESSORS
A	Build internal components	
B	Modify roof and floor	
C	Construct collection stack	A
D	Pour concrete and install frame	A, B
E	Build high-temperature burner	C
F	Install pollution control system	C
G	Install air pollution device	D, E
H	Inspect and test	F, G

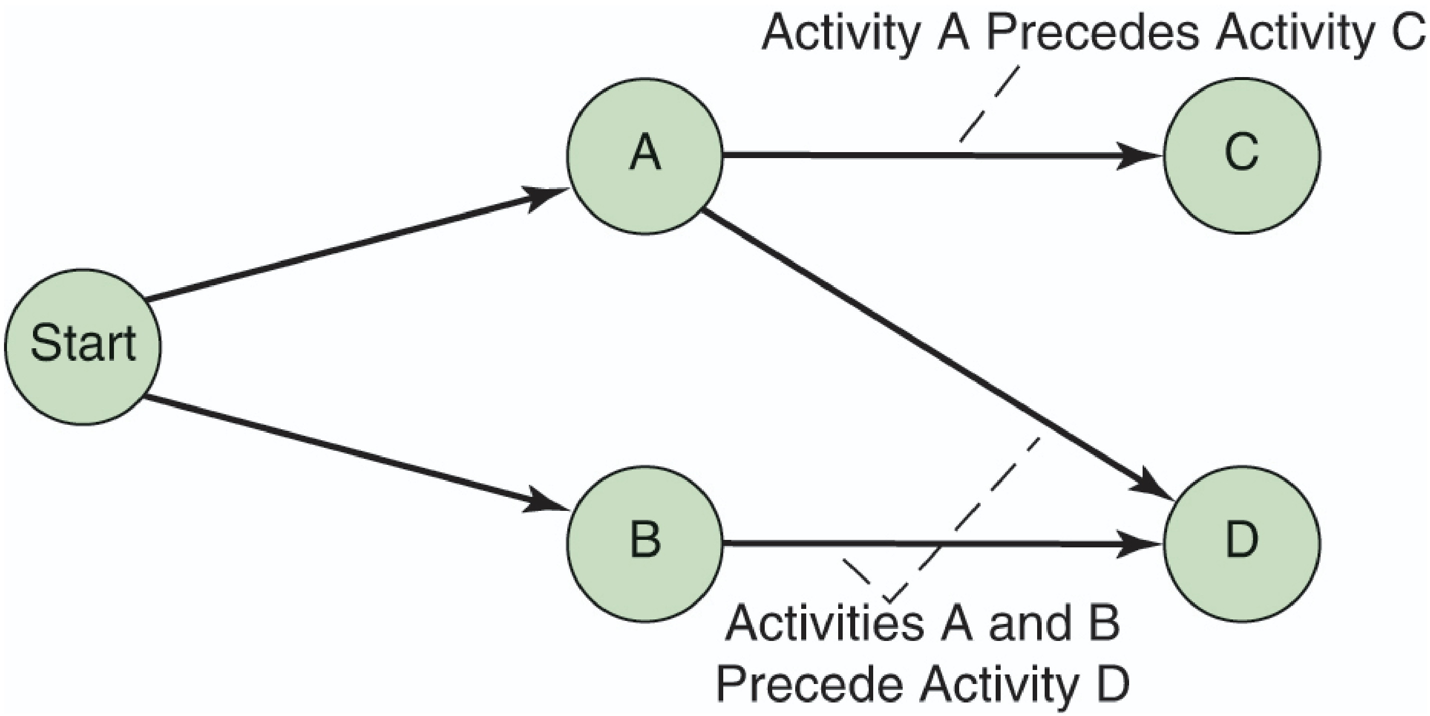
AON Network for Milwaukee Paper (1 of 3)

Figure 3.5



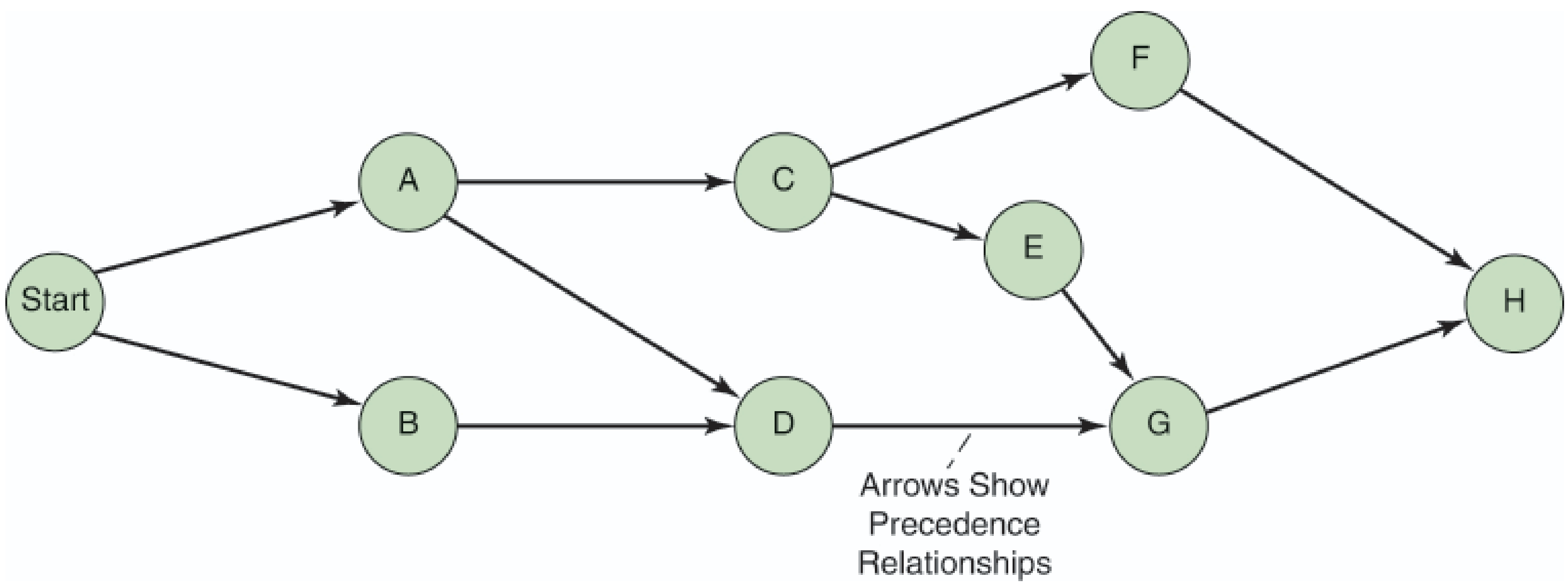
AON Network for Milwaukee Paper
(2 of 3)

Figure 3.6



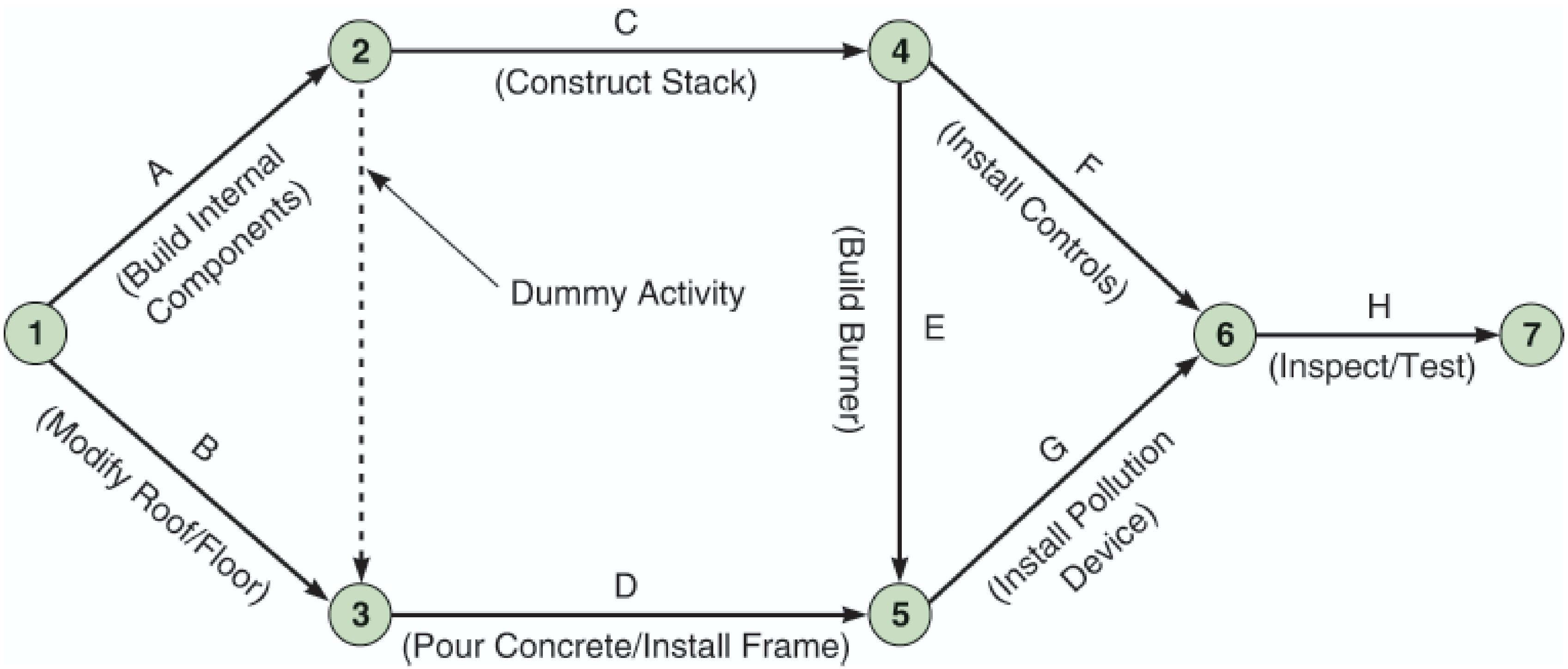
AON Network for Milwaukee Paper (3 of 3)

Figure 3.7



AOA Network for Milwaukee Paper

Figure 3.8



Pearson

Determining the Project Schedule (1 of 4)

Perform a Critical Path Analysis

- The critical path is the longest path through the network
- The critical path is the shortest time in which the project can be completed
- Any delay in critical path activities delays the project
- Critical path activities have no slack time

Determining the Project Schedule (2 of 4)

Table 3.2 Time Estimates for Milwaukee Paper Manufacturing

ACTIVITY	DESCRIPTION	TIME (WEEKS)
A	Build internal components	2
B	Modify roof and floor	3
C	Construct collection stack	2
D	Pour concrete and install frame	4
E	Build high-temperature burner	4
F	Install pollution control system	3
G	Install air pollution device	5
H	Inspect and test	2
	Total time (weeks)	25

Determining the Project Schedule (3 of 4)

Perform a Critical Path Analysis

Earliest start (ES) = earliest time at which an activity can start, assuming all predecessors have been completed

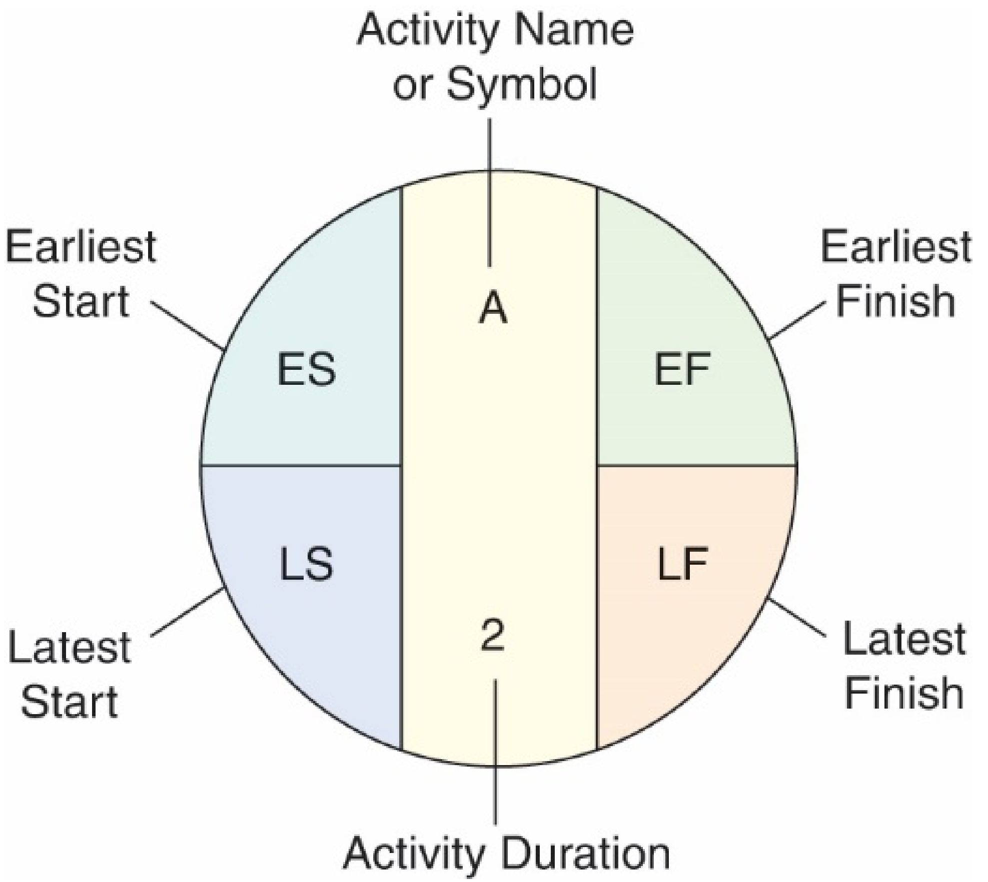
Earliest finish (EF) = earliest time at which an activity can be finished

Latest start (LS) = latest time at which an activity can start so as to not delay the completion time of the entire project

Latest finish (LF) = latest time by which an activity has to be finished so as to not delay the completion time of the entire project

Determining the Project Schedule (4 of 4)

Figure 3.9



Forward Pass (1 of 2)

Begin at starting event and work forward

Earliest Start Time Rule:

- If an activity has only a single immediate predecessor, its ES equals the EF of the predecessor
- If an activity has multiple immediate predecessors, its ES is the maximum of all the EF values of its predecessors

ES = Max {EF of all immediate predecessors}

Forward Pass (2 of 2)

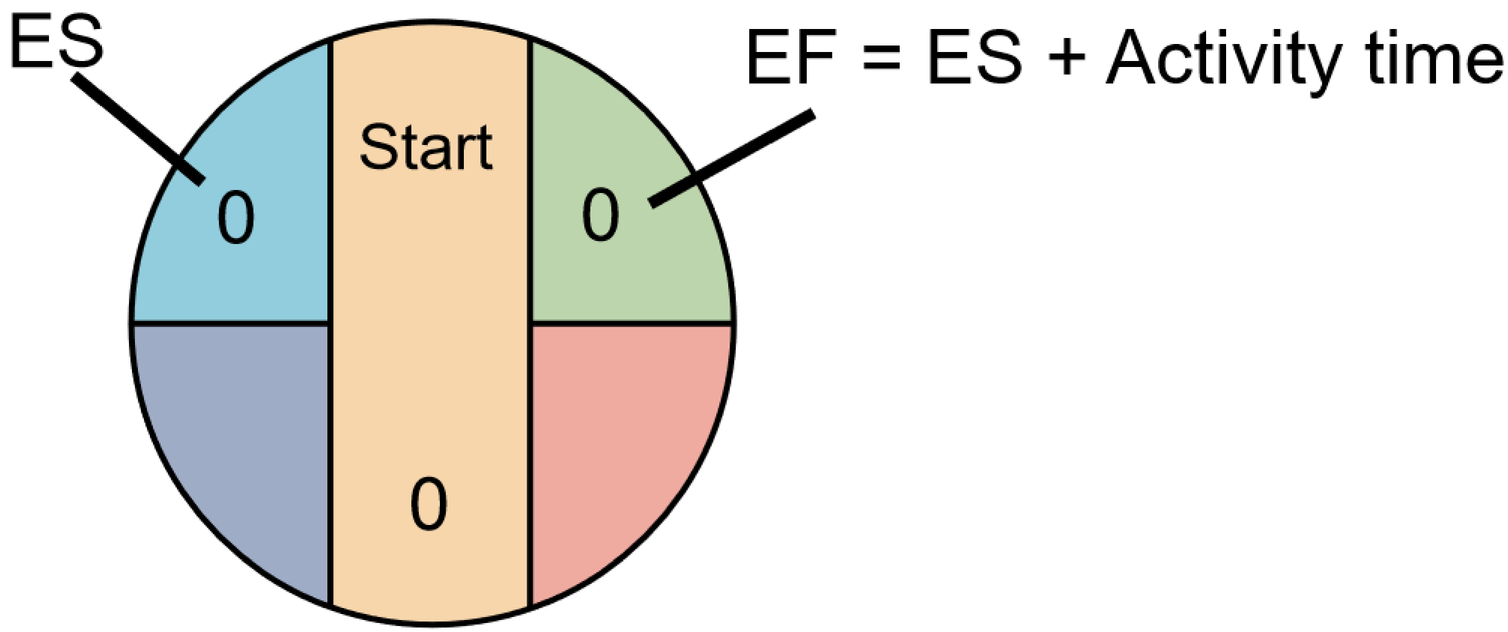
Begin at starting event and work forward

Earliest Finish Time Rule:

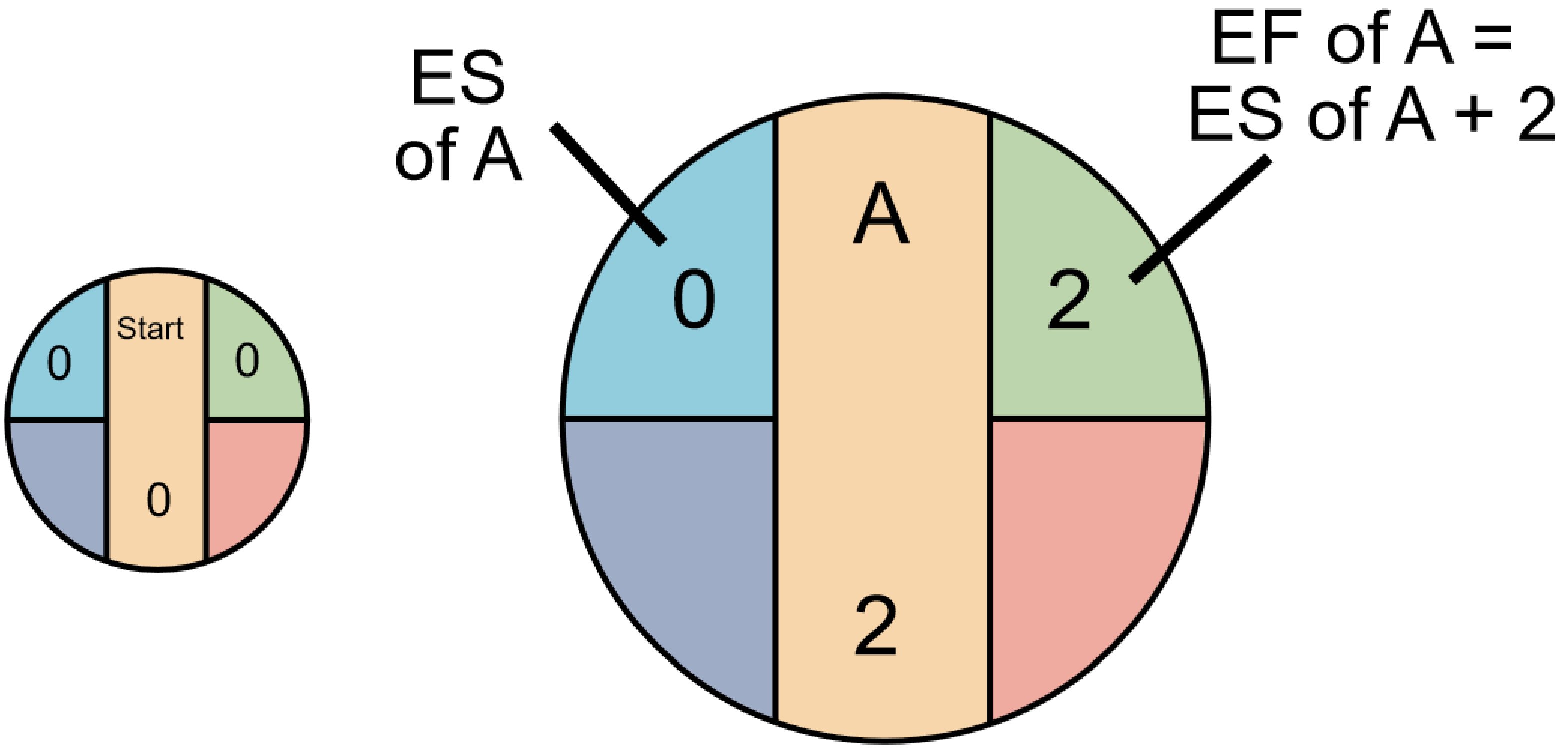
- The earliest finish time (EF) of an activity is the sum of its earliest start time (ES) and its activity time

EF = ES + Activity time

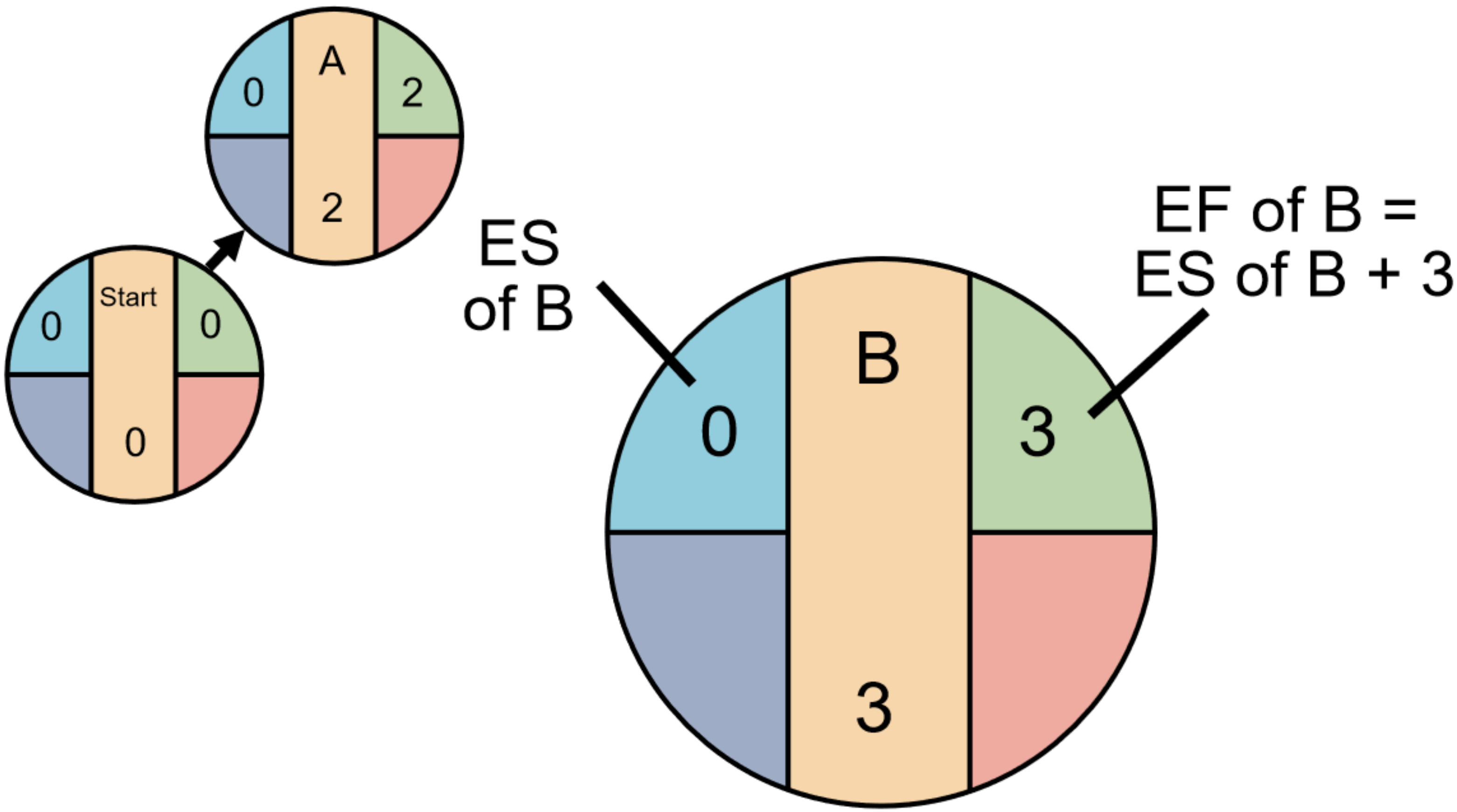
ES/EF Network for Milwaukee Paper (1 of 7)



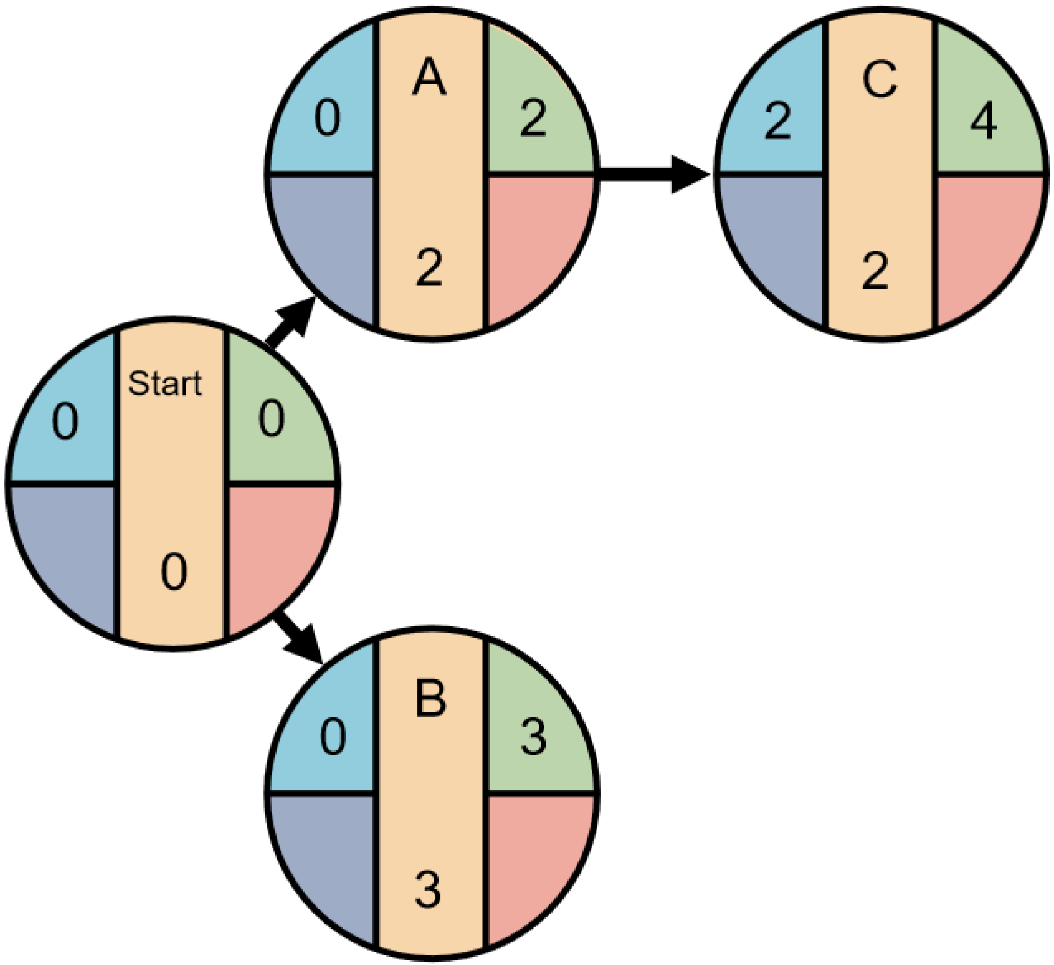
ES/EF Network for Milwaukee Paper (2 of 7)



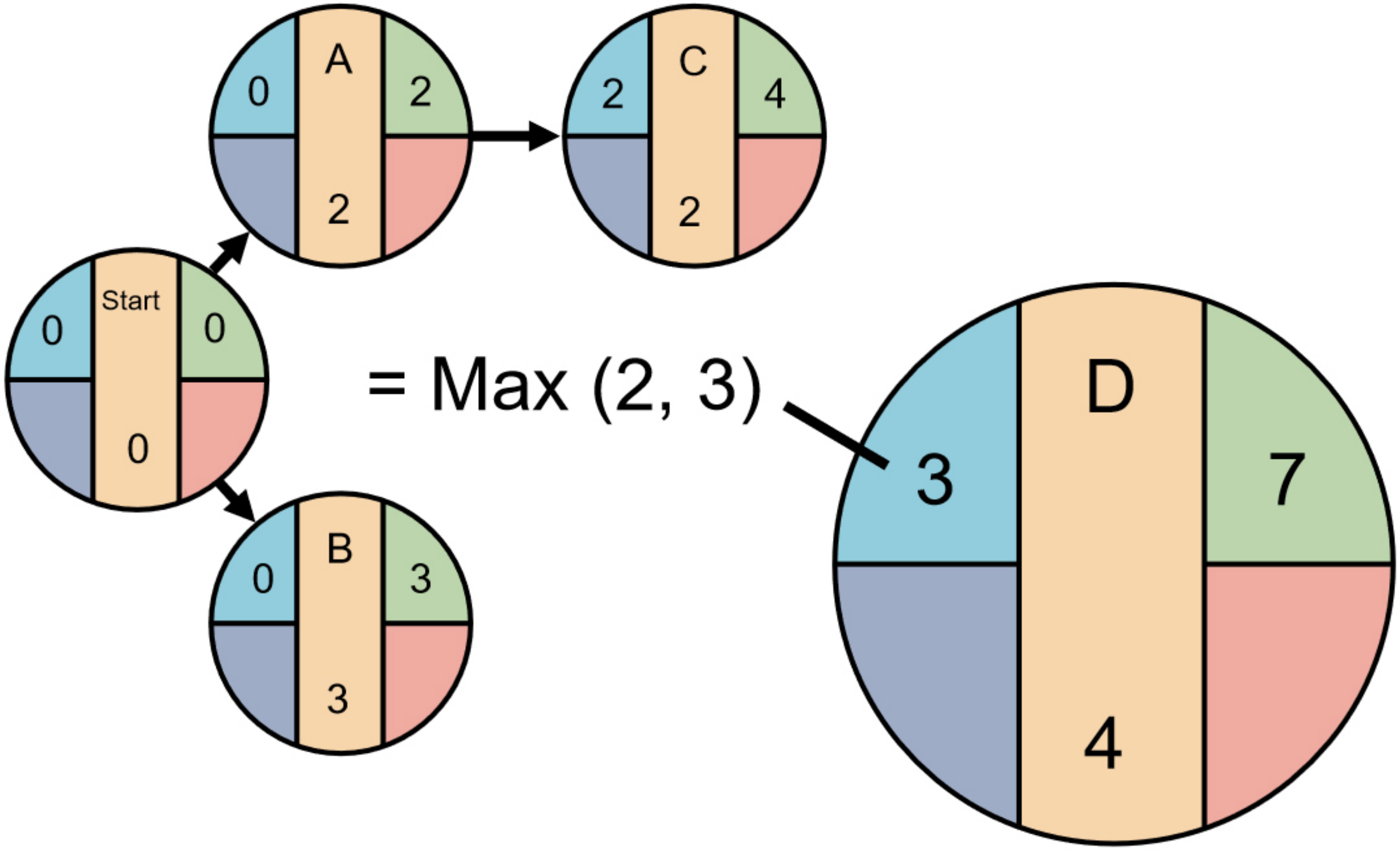
ES/EF Network for Milwaukee Paper
(3 of 7)



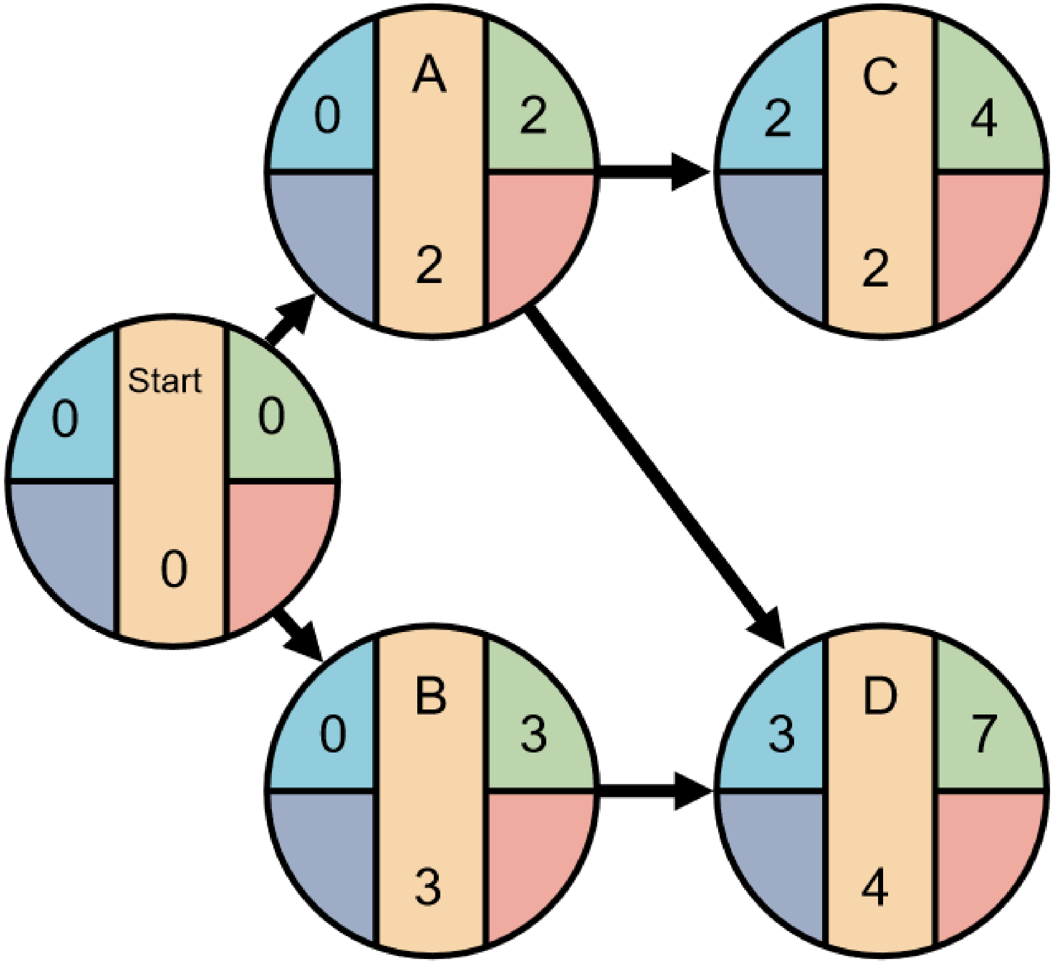
ES/EF Network for Milwaukee Paper (4 of 7)



ES/EF Network for Milwaukee Paper (5 of 7)



ES/EF Network for Milwaukee Paper (6 of 7)



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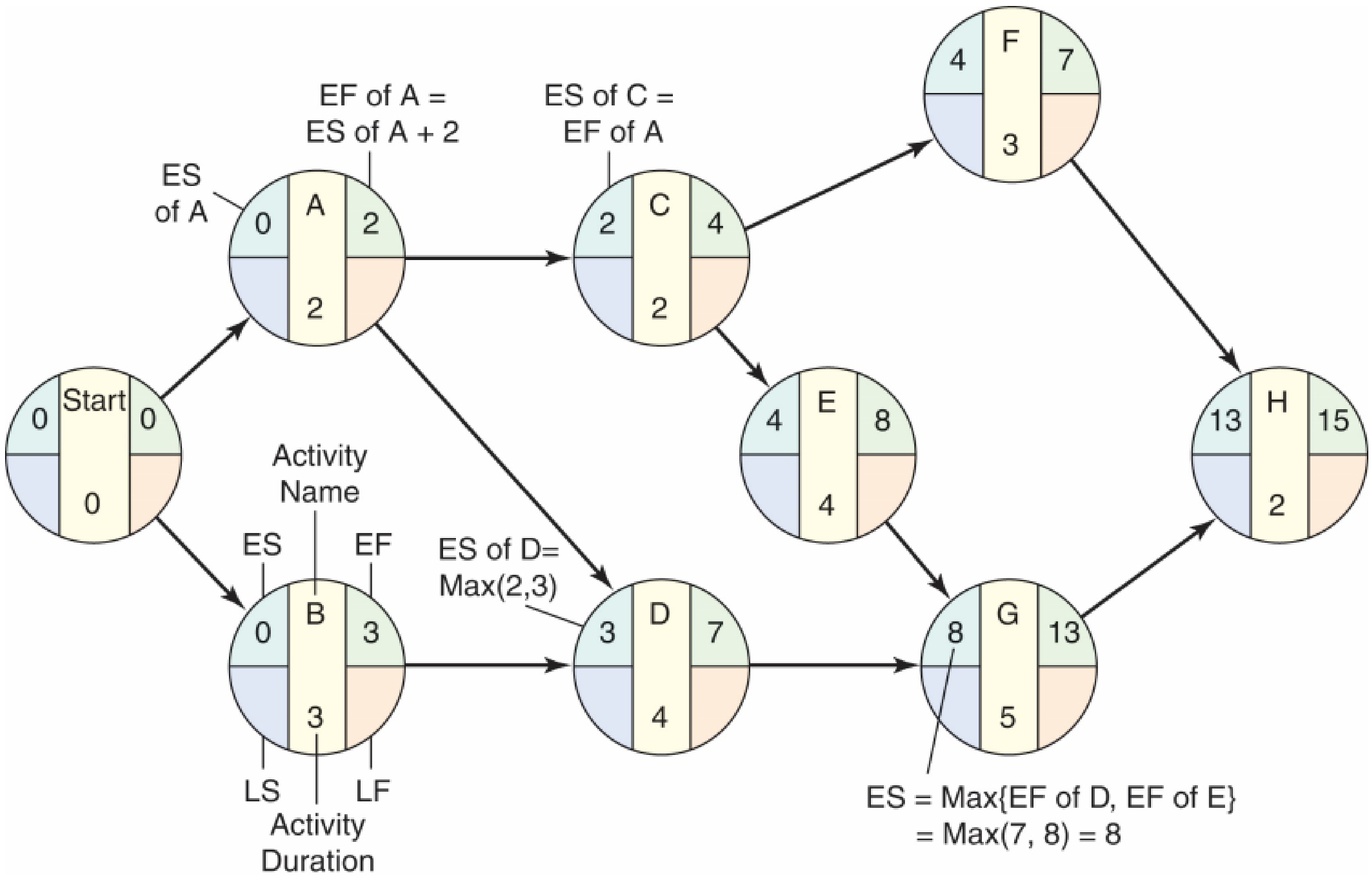
ES/EF Network for Milwaukee Paper (7 of 7)

Figure 3.10



Backward Pass (1 of 2)

Begin with the last event and work backwards

Latest Finish Time Rule:

- If an activity is an immediate predecessor for just a single activity, its LF equals the LS of the activity that immediately follows it
- If an activity is an immediate predecessor to more than one activity, its LF is the minimum of all LS values of all activities that immediately follow it

LF = Min {LS of all immediate following activities}

Backward Pass (2 of 2)

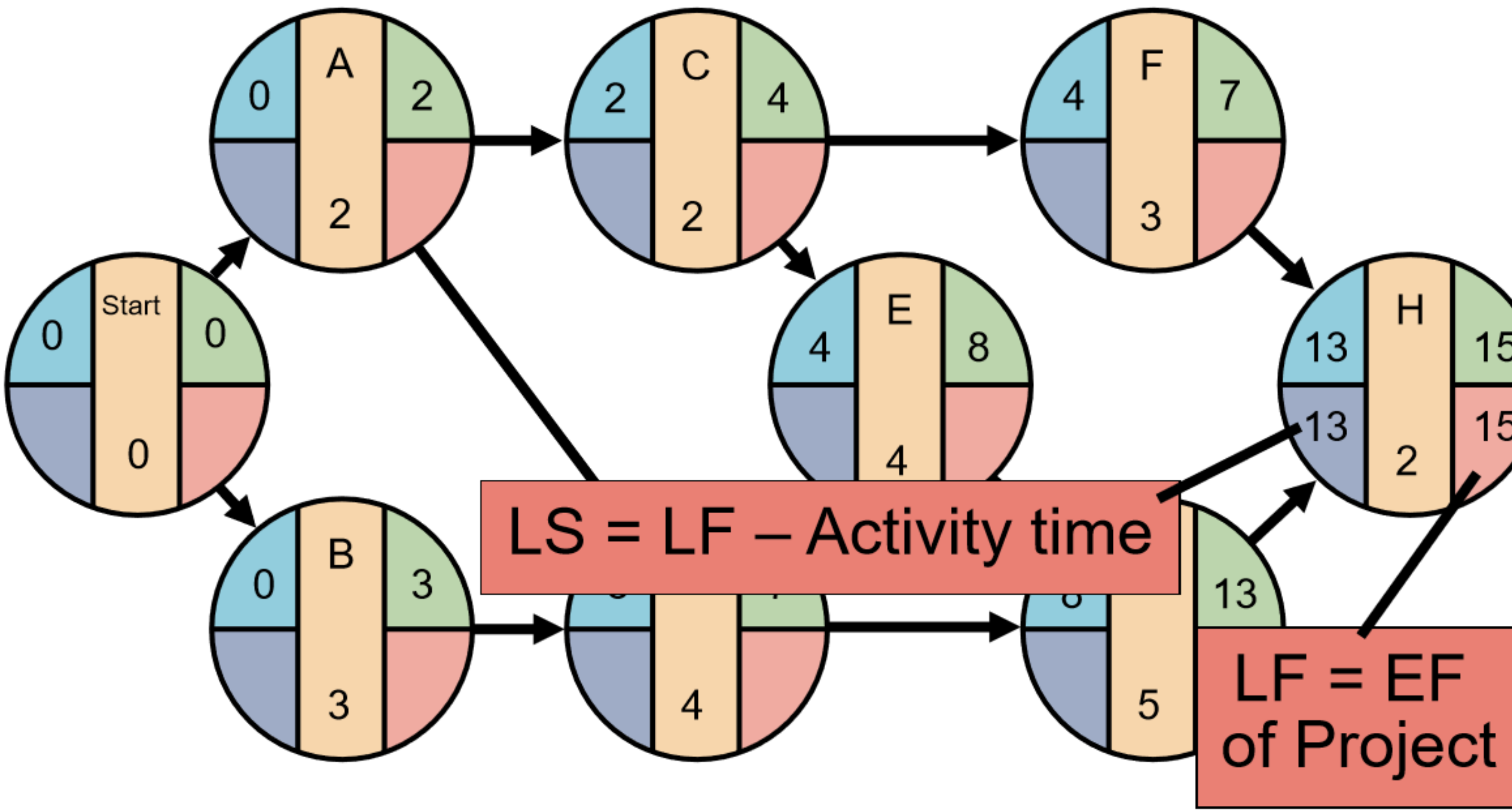
Begin with the last event and work backwards

Latest Start Time Rule:

- The latest start time (LS) of an activity is the difference of its latest finish time (LF) and its activity time

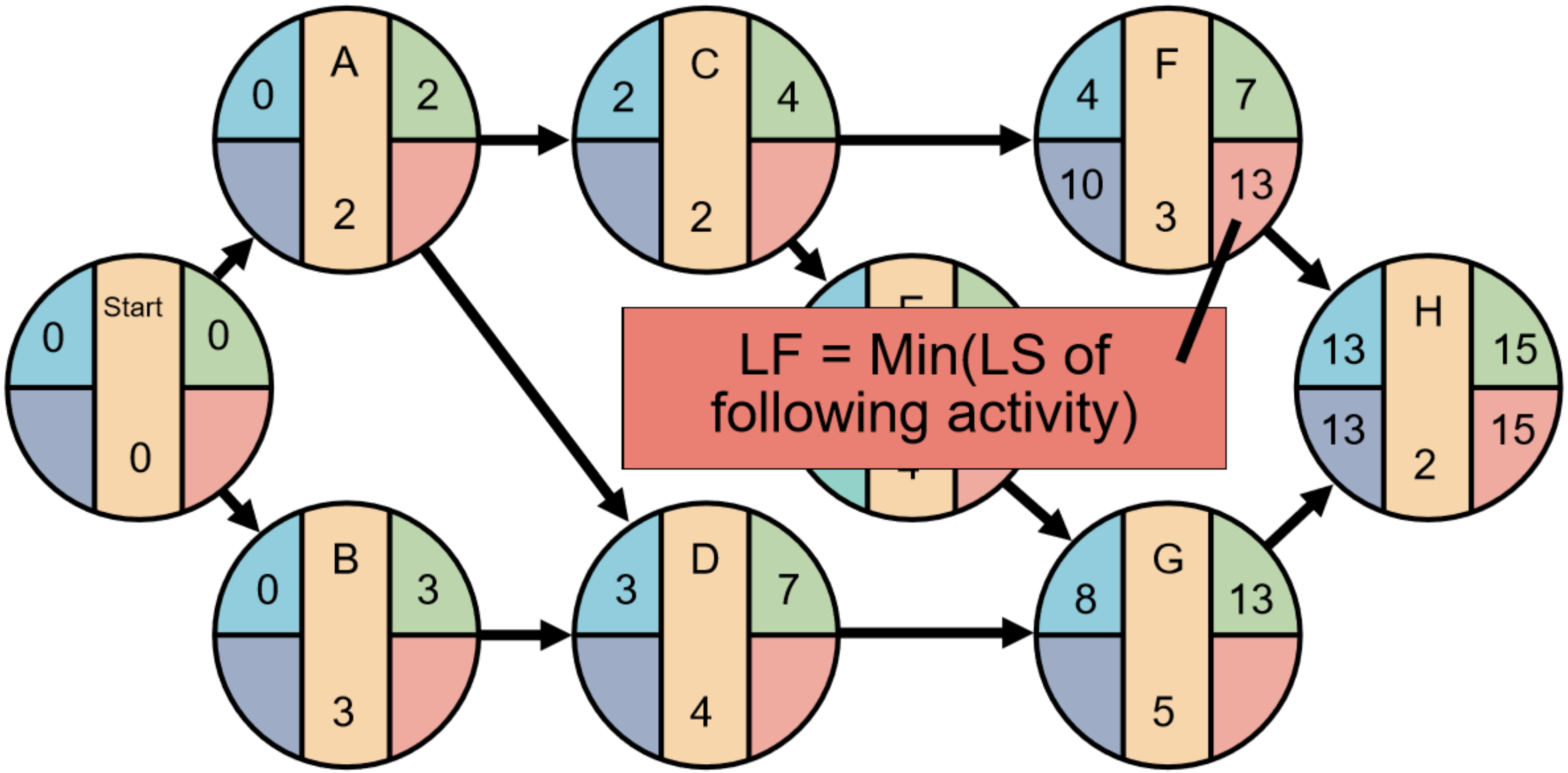
LS = LF − Activity time

LS/LF Times for Milwaukee Paper (1 of 4)

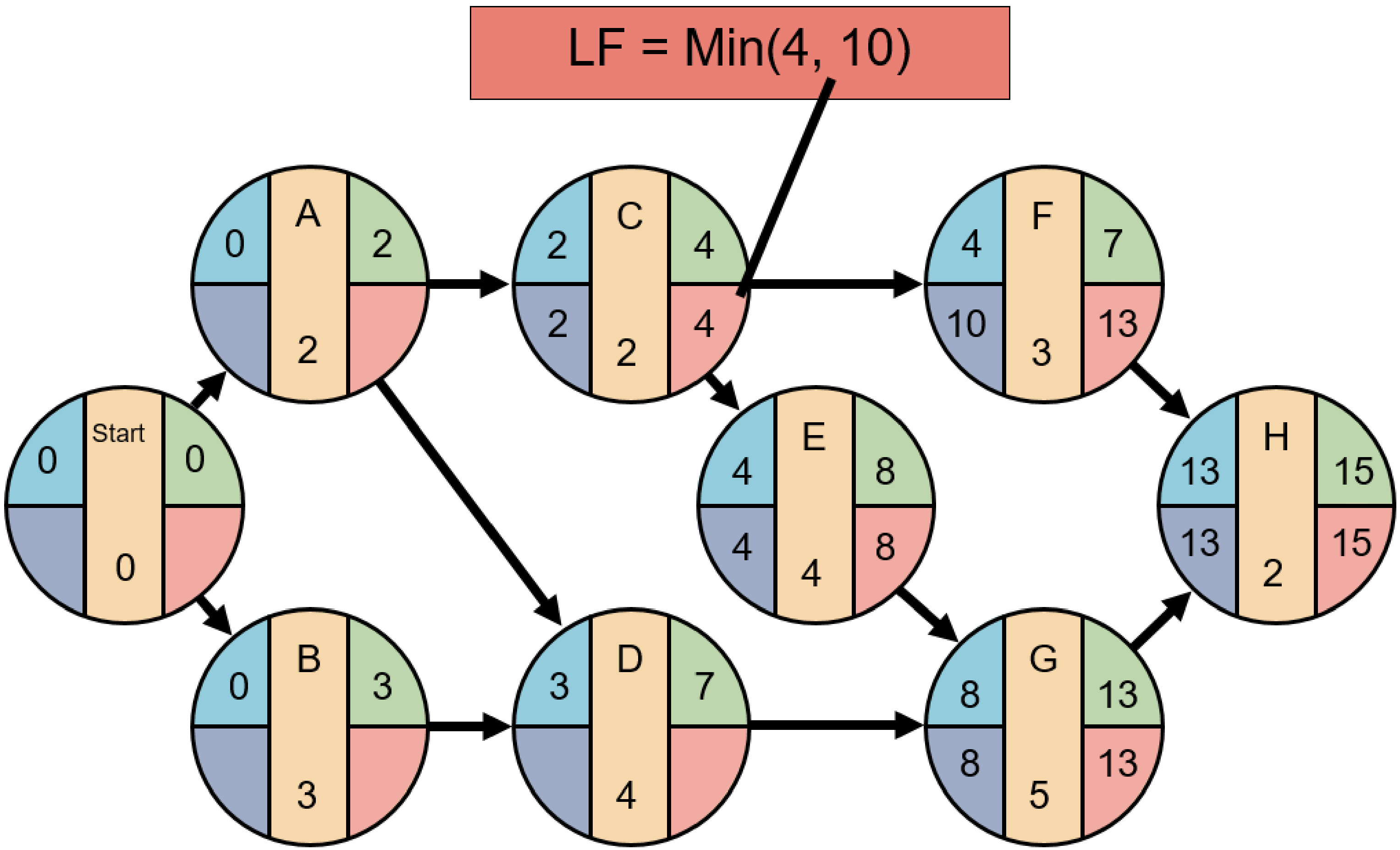


LS/LF Times for Milwaukee Paper

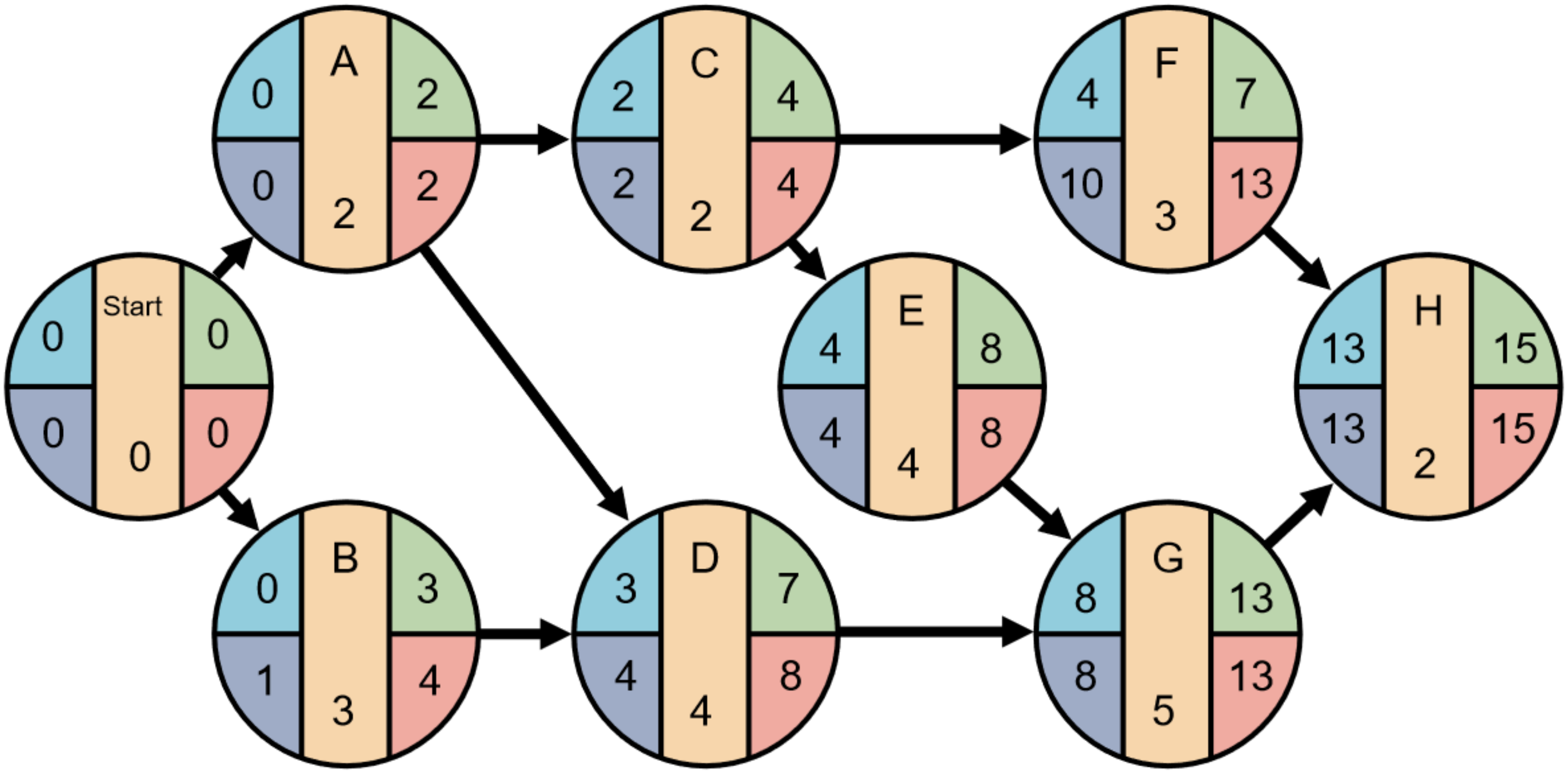
(2 of 4)



LS/LF Times for Milwaukee Paper
(3 of 4)



LS/LF Times for Milwaukee Paper
(4 of 4)



Computing Slack Time (1 of 3)

After computing the ES, EF, LS, and LF times for all activities, compute the slack or free time for each activity

- Slack is the length of time an activity can be delayed without delaying the entire project

Slack = LS − ES   or   Slack = LF − EF

Computing Slack Time (2 of 3)

Table 3.3 Milwaukee Paper's Schedule and Slack Times

ACTIVITY	EARLIEST START ES	EARLIEST FINISH EF	LATEST START LS	LATEST FINISH LF	SLACK LS − ES	ON CRITICAL PATH
A	0	2	0	2	0	Yes
B	0	3	1	4	1	No
C	2	4	2	4	0	Yes
D	3	7	4	8	1	No
E	4	8	4	8	0	Yes
F	4	7	10	13	6	No
G	8	13	8	13	0	Yes
H	13	15	13	15	0	Yes

Computing Slack Time (3 of 3)

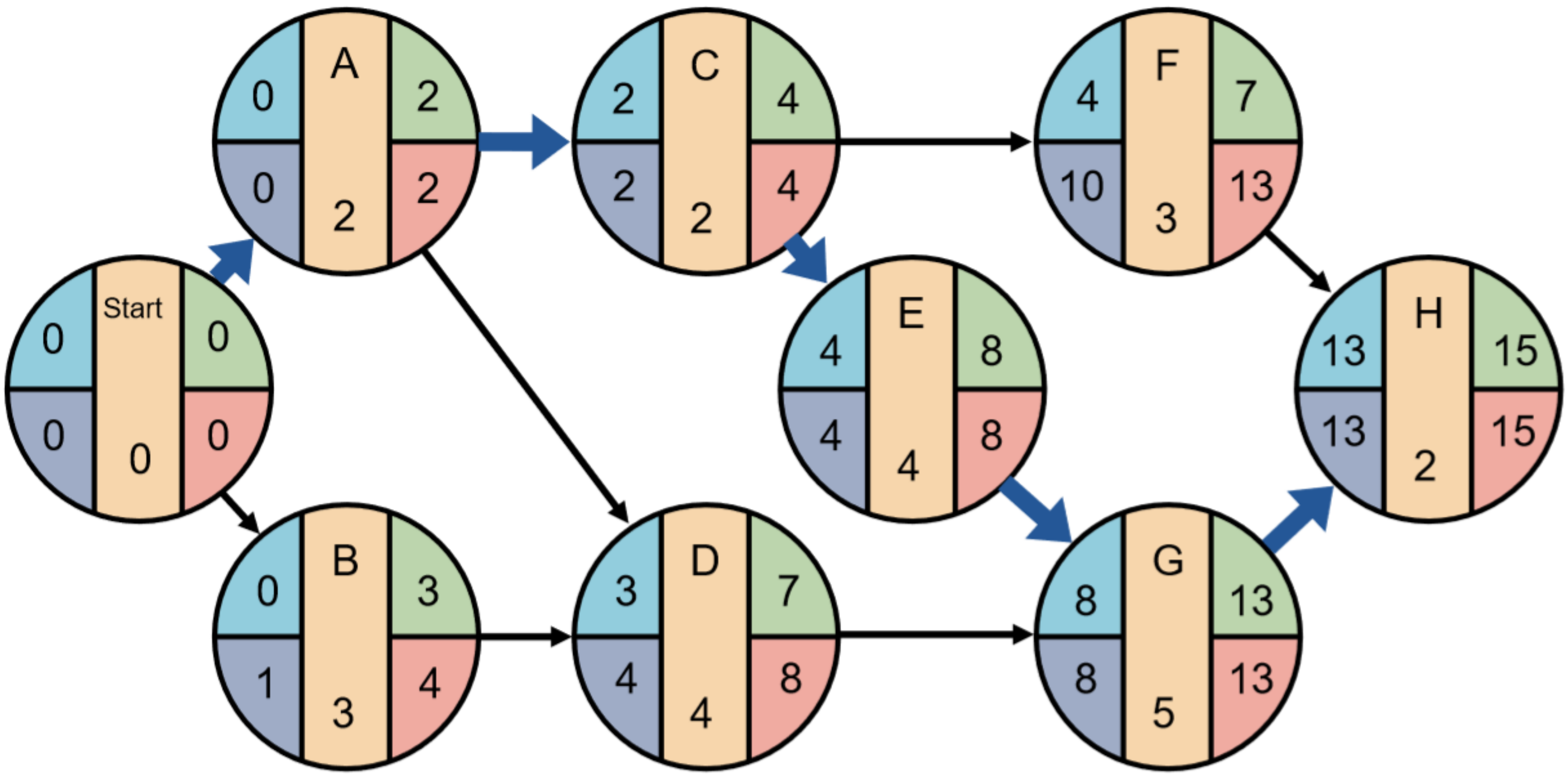
Table 3.3 Milwaukee Paper's Schedule and Slack Times

Activities with zero slack are on the critical path. It:

- Starts at the first activity in the project
- Terminates at the last activity in the project
- Includes only critical activities

ACTIVITY	EARLIEST START ES	EARLIEST FINISH EF	LATEST START LS	LATEST FINISH LF	SLACK LS – ES	ON CRITICAL PATH
A	0	2	0	2	0	Yes
B	0	3	1	4	1	No
C	2	4	2	4	0	Yes
D	3	7	4	8	1	No
E	4	8	4	8	0	Yes
F	4	7	10	13	6	No
G	8	13	8	13	0	Yes
H	13	15	13	15	0	Yes

Critical Path for Milwaukee Paper



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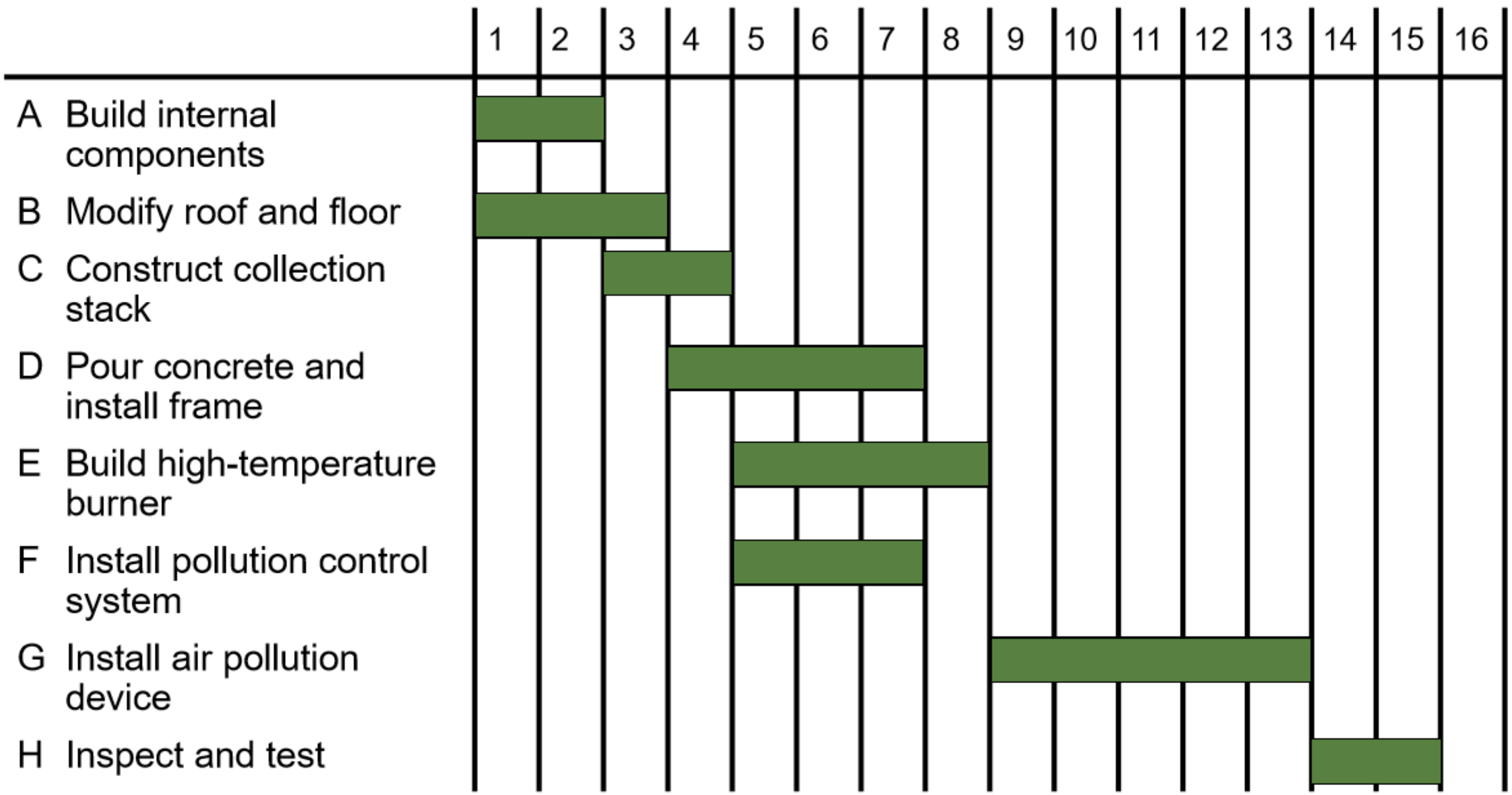
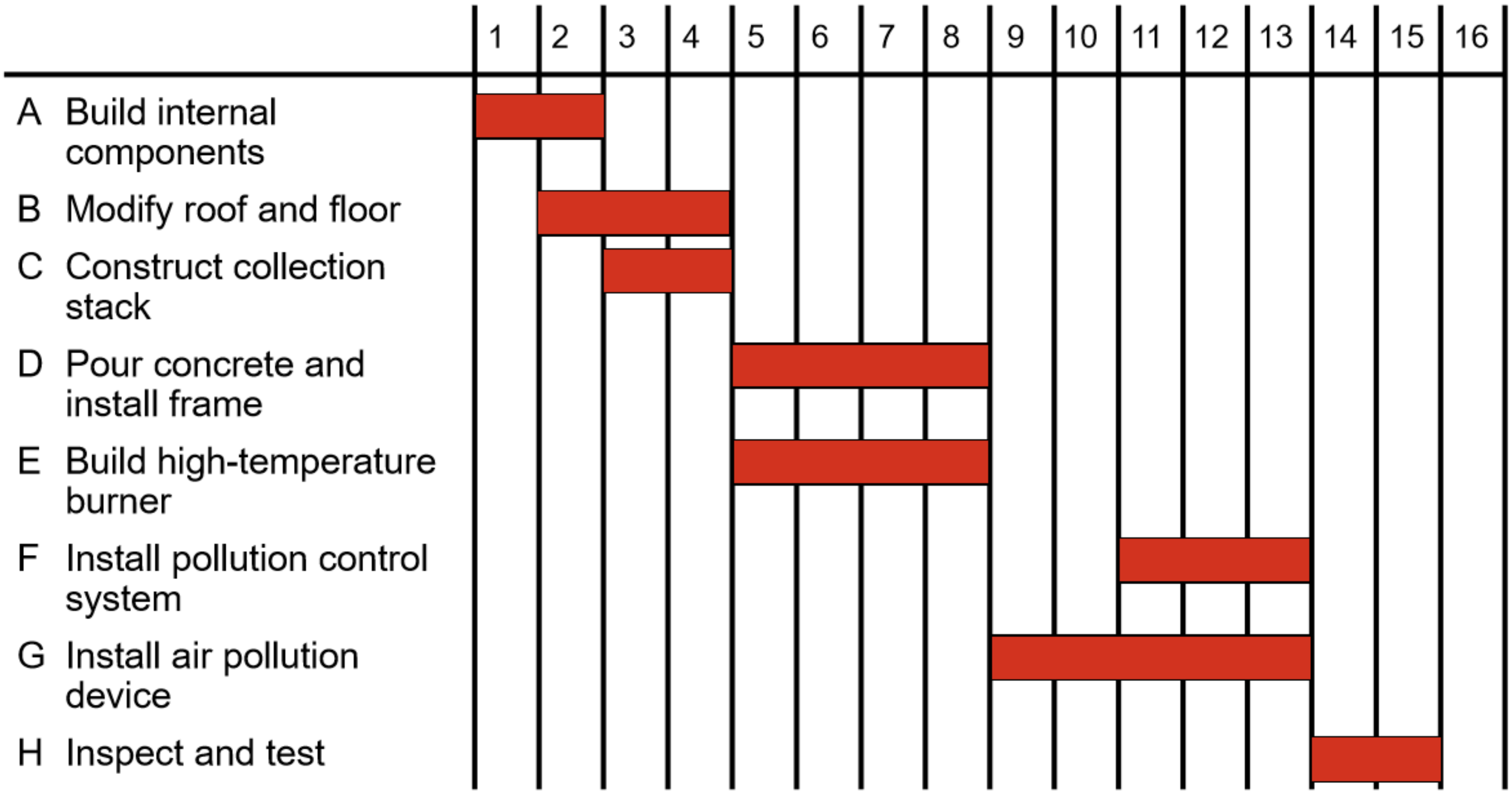
ES – EF Gantt Chart for Milwaukee Paper



LS – LF Gantt Chart for Milwaukee Paper



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Variability in Activity Times (1 of 4)

- CPM assumes we know a fixed time estimate for each activity and there is no variability in activity times
- PERT uses a probability distribution for activity times to allow for variability

Variability in Activity Times (2 of 4)

- Three time estimates are required
  - **Optimistic time** (*a*) – if everything goes according to plan
  - **Pessimistic time** (*b*) – assuming very unfavorable conditions
  - **Most likely time** (*m*) – most realistic estimate

Variability in Activity Times (3 of 4)

Estimate follows beta distribution

Expected activity time:

$$t = (a + 4m + b) / 6$$

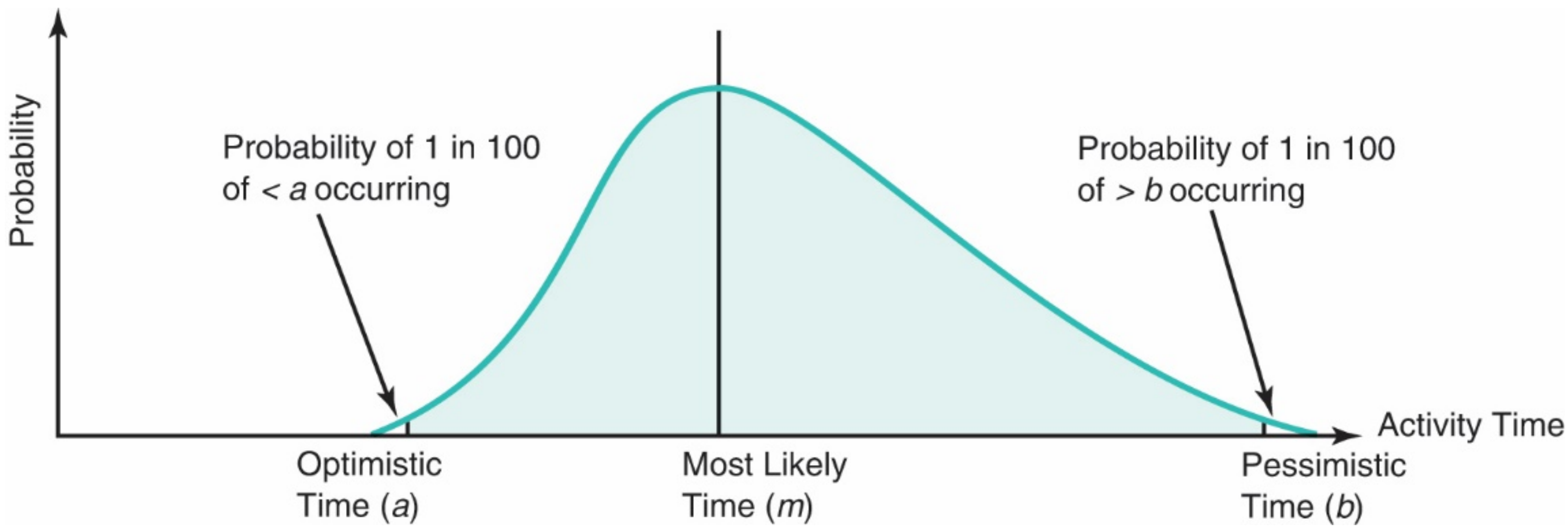
Variance of activity completion times:

$$v = [(b - a) / 6]^2$$

Variability in Activity Times (4 of 4)

Figure 3.11

Estimate follows beta distribution



Computing Variance

Table 3.4 Time Estimates (in weeks) for Milwaukee Paper's Project

ACTIVITY	OPTIMISTIC a	MOST LIKELY m	PESSIMISTIC b	EXPECTED TIME $t = (a + 4m + b)/6$	VARIANCE $[(b - a)/6]^2$
A	1	2	3	2	.11
B	2	3	4	3	.11
C	1	2	3	2	.11
D	2	4	6	4	.44
E	1	4	7	4	1.00
F	1	2	9	3	1.78
G	3	4	11	5	1.78
H	1	2	3	2	.11

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Probability of Project Completion (1 of 7)

Project variance is computed by summing the variances of critical activities

$$\sigma_p^2 = \text{Project variance}$$

$$= \Sigma(\text{variances of activities on critical path})$$

Probability of Project Completion (2 of 7)

Project variance is computed by summing the variances of critical activities

Project variance

$$\sigma_p^2 = .11 + .11 + 1.00 + 1.78 + .11 = 3.11$$

Project standard deviation

$$\sigma_p = \sqrt{\text{Project variance}}$$

$$= \sqrt{3.11} = 1.76 \text{ weeks}$$

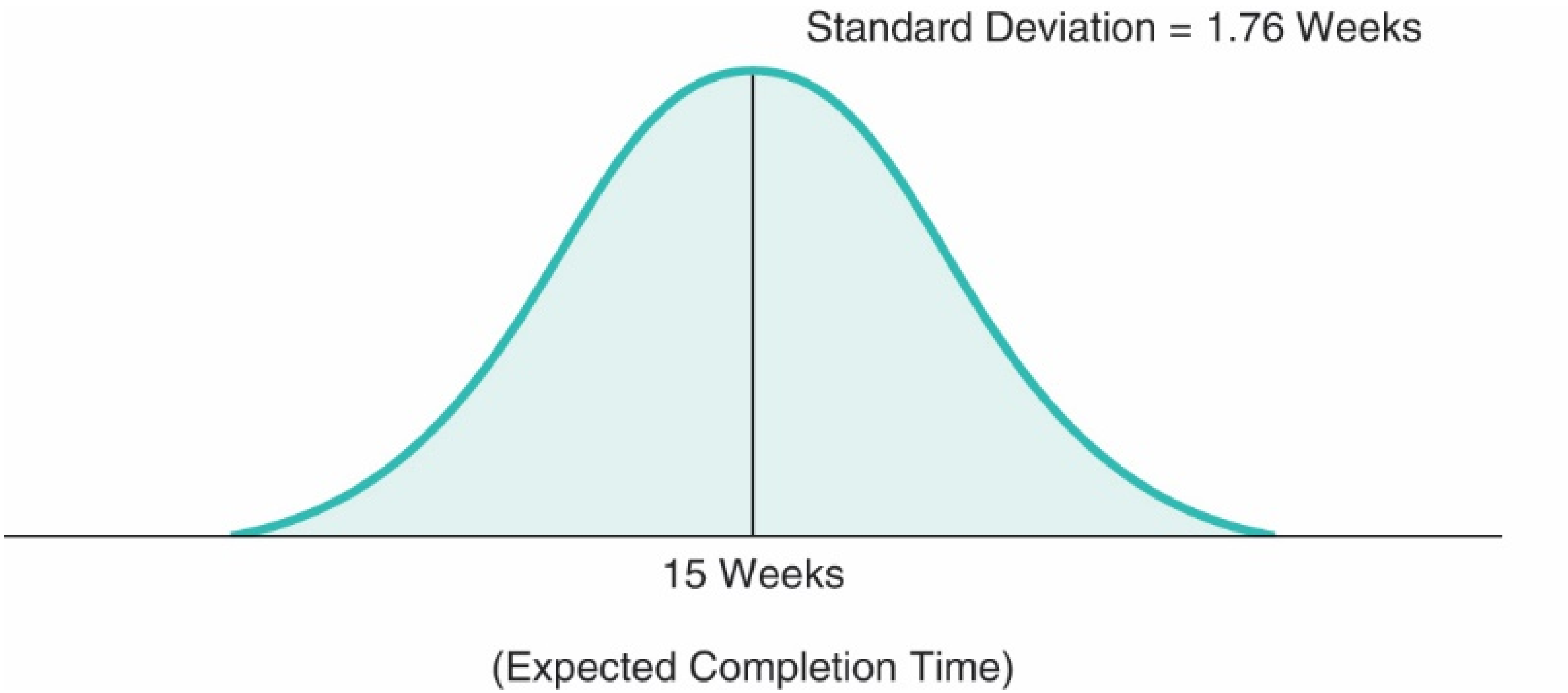
Probability of Project Completion (3 of 7)

PERT makes two more assumptions:

- Total project completion times follow a normal probability distribution
- Activity times are statistically independent

Probability of Project Completion (4 of 7)

Figure 3.12



Probability of Project Completion (5 of 7)

What is the probability this project can be completed on or before the 16-week deadline?

$$Z = (\text{Due date} - \text{Expected date of completion}) / \sigma_p$$
$$= (16 \text{ weeks} - 15 \text{ weeks}) / 1.76$$
$$= 0.57$$

Where Z is the number of standard deviations the due date or target date lies from the mean or expected date

Probability of Project Completion (6 of 7)

What is the probability this project can be completed on or before the 16-week deadline?

From Appendix I

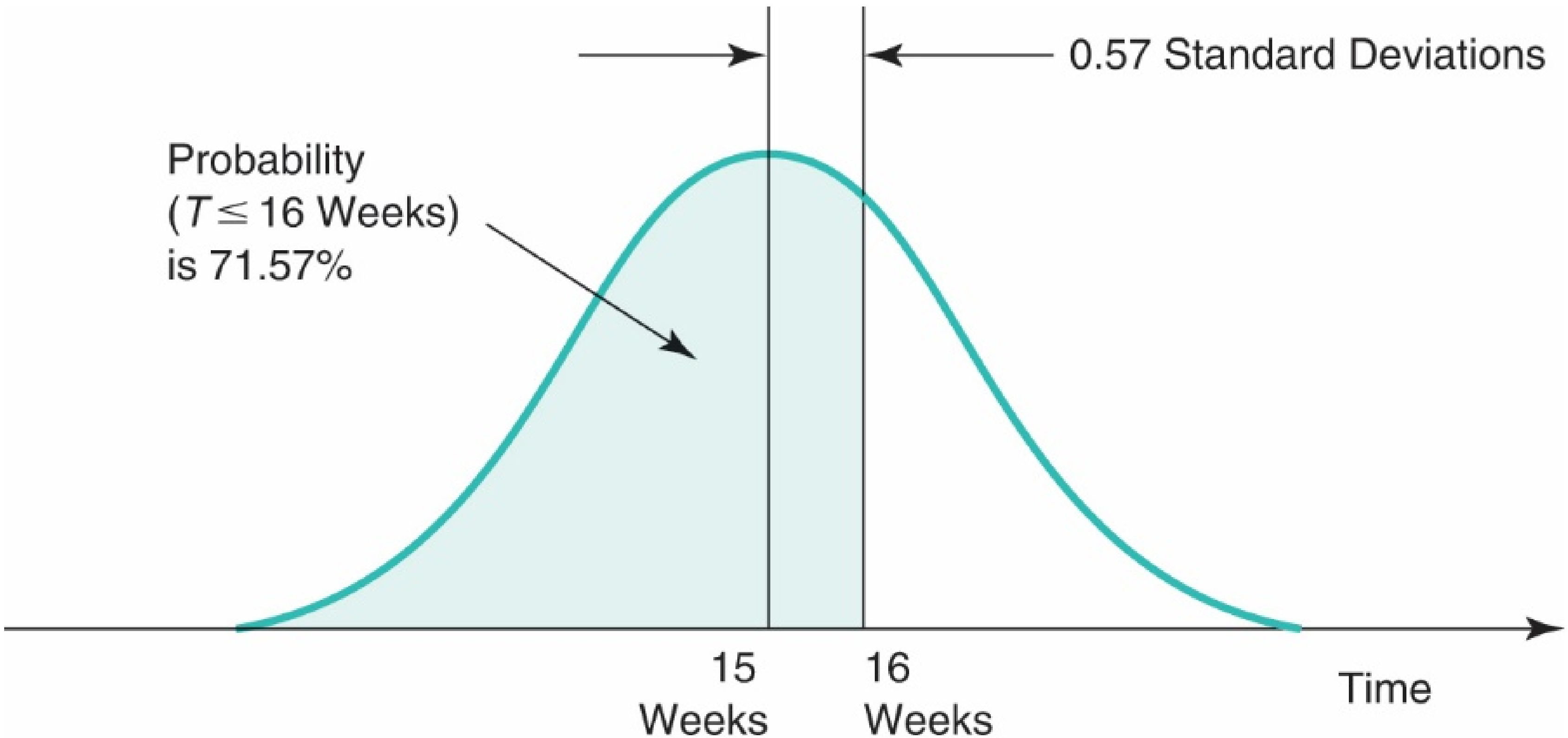
	.00	.01	.07	.08
.1	.50000	.50399	.52790	.53188
.2	.53983	.54380	.56749	.57142
.5	.69146	.69497	.71566	.71904
.6	.72575	.72907	.74857	.75175

= 0.57

Where Z is the number of standard deviations the due date or target date lies from the mean or expected date

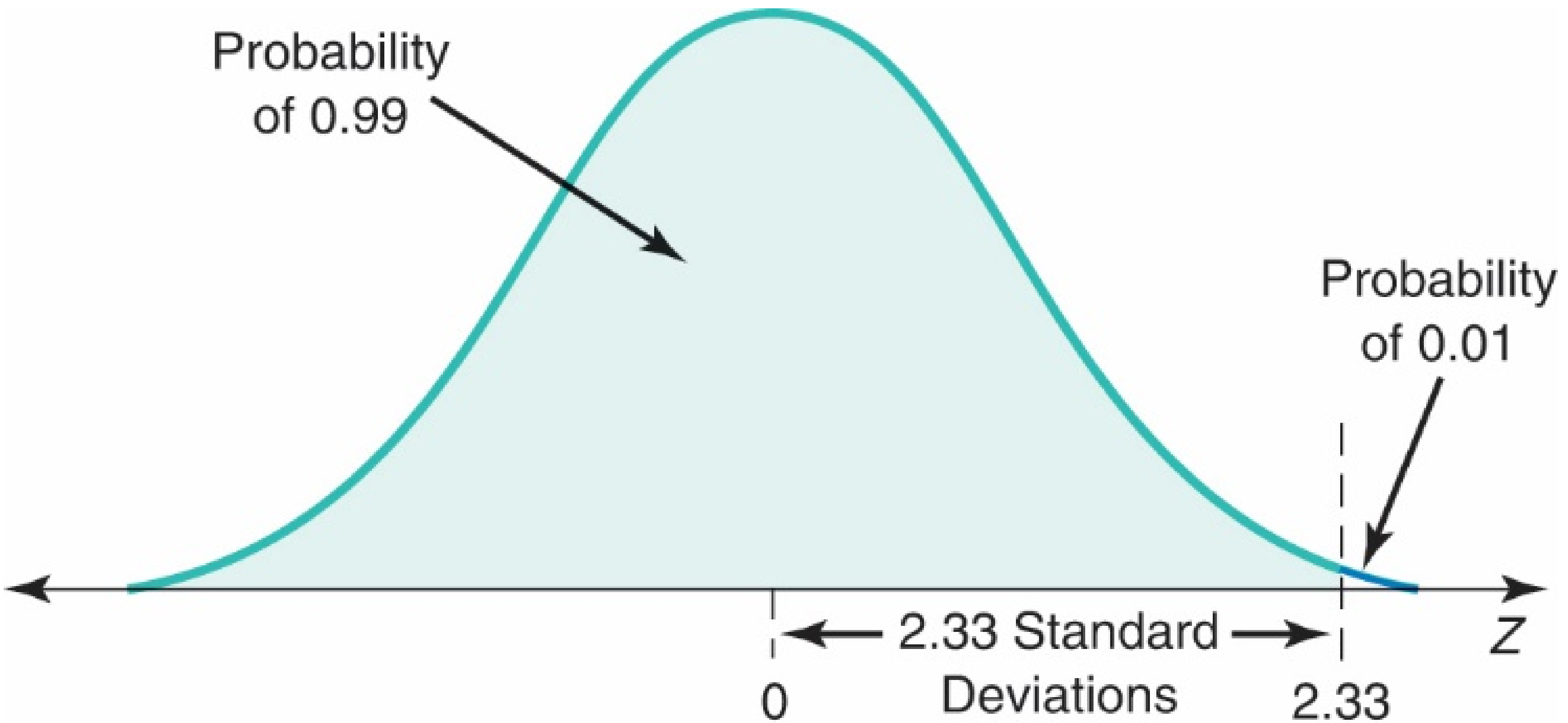
Probability of Project Completion (7 of 7)

Figure 3.13



Determining Project Completion Time

Figure 3.14



Variability of Completion Time for Noncritical Paths

- Variability of times for activities on noncritical paths must be considered when finding the probability of finishing in a specified time
- Variation in noncritical activity may cause change in critical path

What Project Management Has Provided So Far

1. The project's expected completion time is 15 weeks
2. There is a 71.57% chance the equipment will be in place by the 16-week deadline
3. Five activities (A, C, E, G, and H) are on the critical path
4. Three activities (B, D, F) are not on the critical path and have slack time
5. A detailed schedule is available

Cost–Time Trade-Offs and Project Crashing

It is not uncommon to face the following situations:

- The project is behind schedule
- The completion time has been moved forward

Shortening the duration of the project is called project crashing

Factors to Consider When Crashing a Project

- The amount by which an activity is crashed is, in fact, permissible
- Taken together, the shortened activity durations will enable us to finish the project by the due date
- The total cost of crashing is as small as possible

Steps in Project Crashing (1 of 3)

Step 1: Compute the crash cost per time period. If crash costs are linear over time:

$$\text{Crash cost per period} = \frac{(\text{Crash cost} - \text{Normal cost})}{(\text{Normal time} - \text{Crash time})}$$

Step 2: Using current activity times, find the critical path(s) and identify the critical activities

Steps in Project Crashing (2 of 3)

Step 3: If there is only one critical path, then select the activity on this critical path that (a) can still be crashed, and (b) has the smallest crash cost per period. If there is more than one critical path, then select one activity from each critical path such that (a) each selected activity can still be crashed, and (b) the total crash cost of all selected activities is the smallest. Crash each selected activity by one period.

Steps in Project Crashing (3 of 3)

Step 4: Update all activity times. If the desired due date has been reached, stop. If not, return to Step 2.

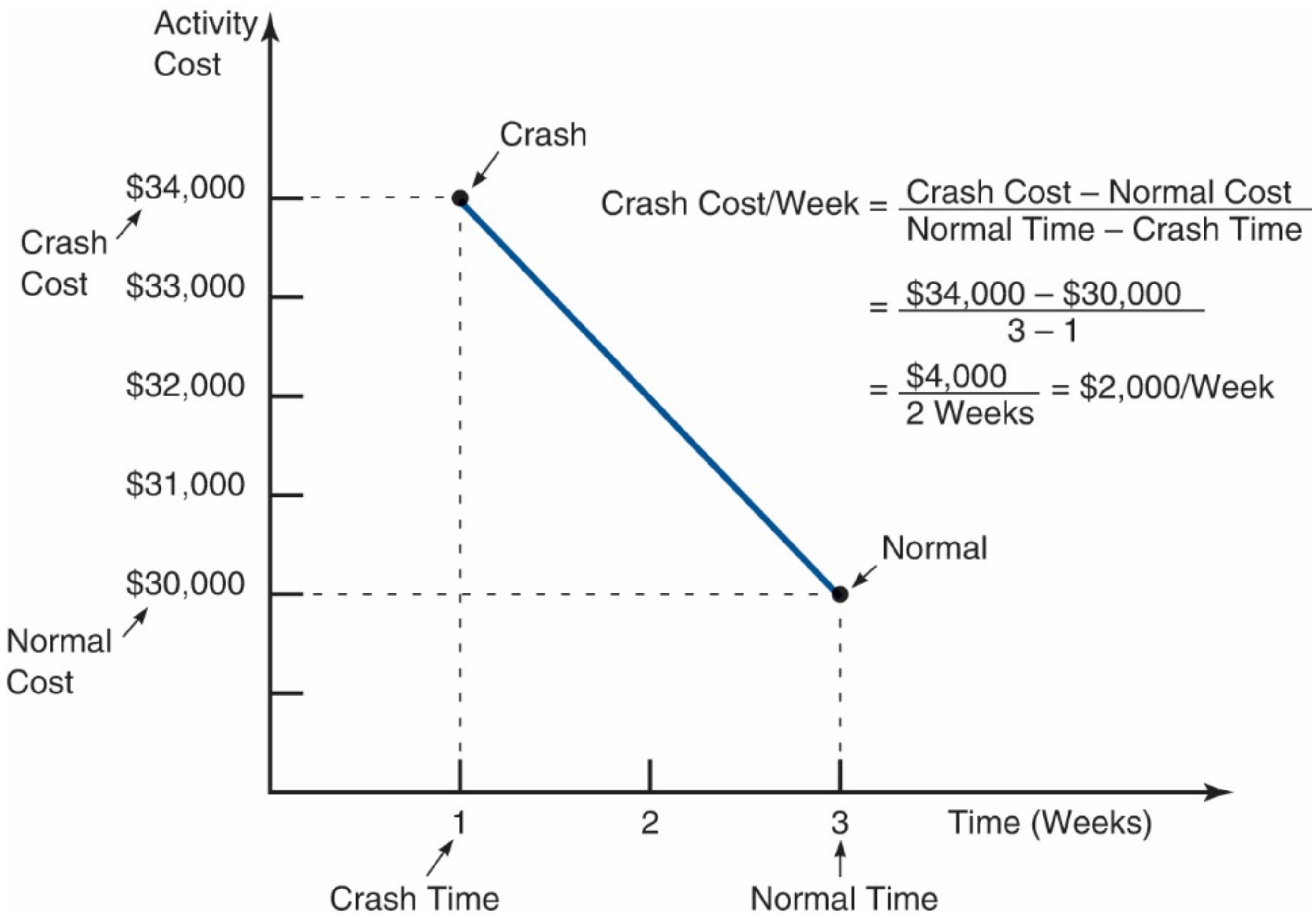
Crashing the Project

Table 3.5 Normal and Crash Data for Milwaukee Paper Manufacturing

ACTIVITY	TIME (WEEKS)		COST ($)		CRASH COST PER WEEK ($)	CRITICAL PATH ?
	NORMAL	CRASH	NORMAL	CRASH		
A	2	1	22,000	22,750	750	Yes
B	3	1	30,000	34,000	2,000	No
C	2	1	26,000	27,000	1,000	Yes
D	4	3	48,000	49,000	1,000	No
E	4	2	56,000	58,000	1,000	Yes
F	3	2	30,000	30,500	500	No
G	5	2	80,000	84,500	1,500	Yes
H	2	1	16,000	19,000	3,000	Yes

Crash and Normal Times and Costs for Activity B

Figure 3.15



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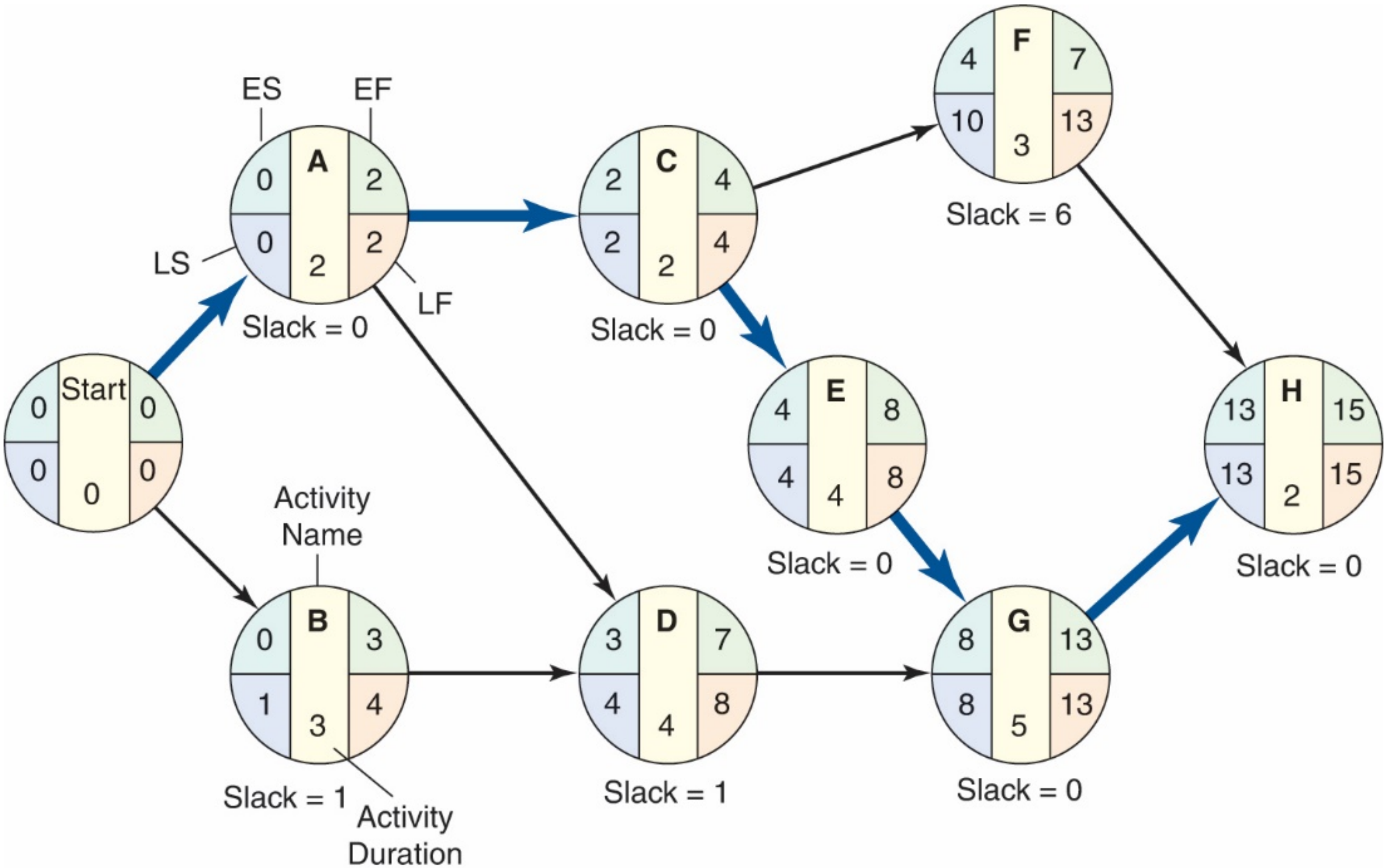
Critical Path and Slack Times for Milwaukee Paper

Figure 3.16



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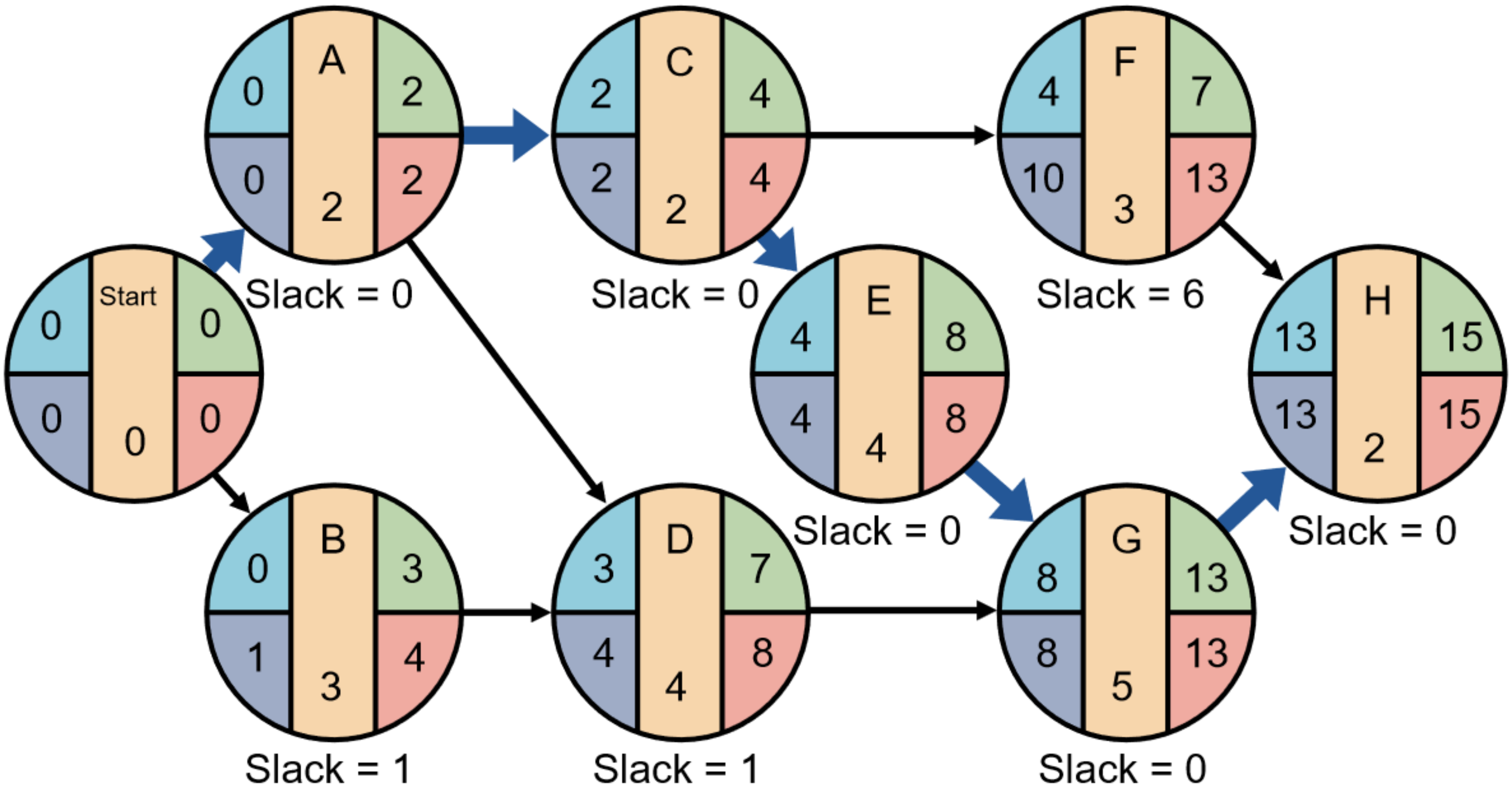
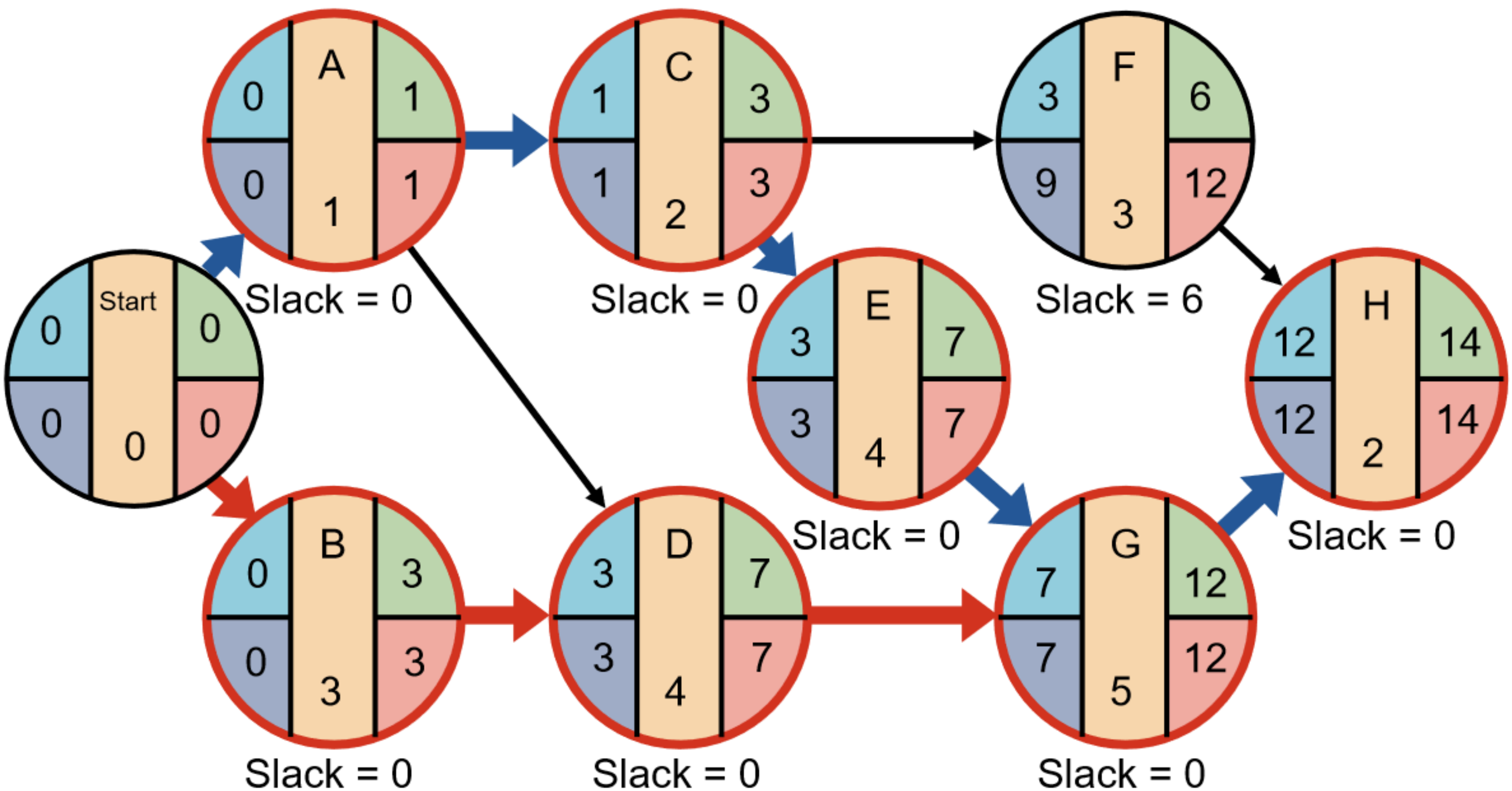
Crashing Activity A One Week (1 of 2)

Figure 3.16 (revised)



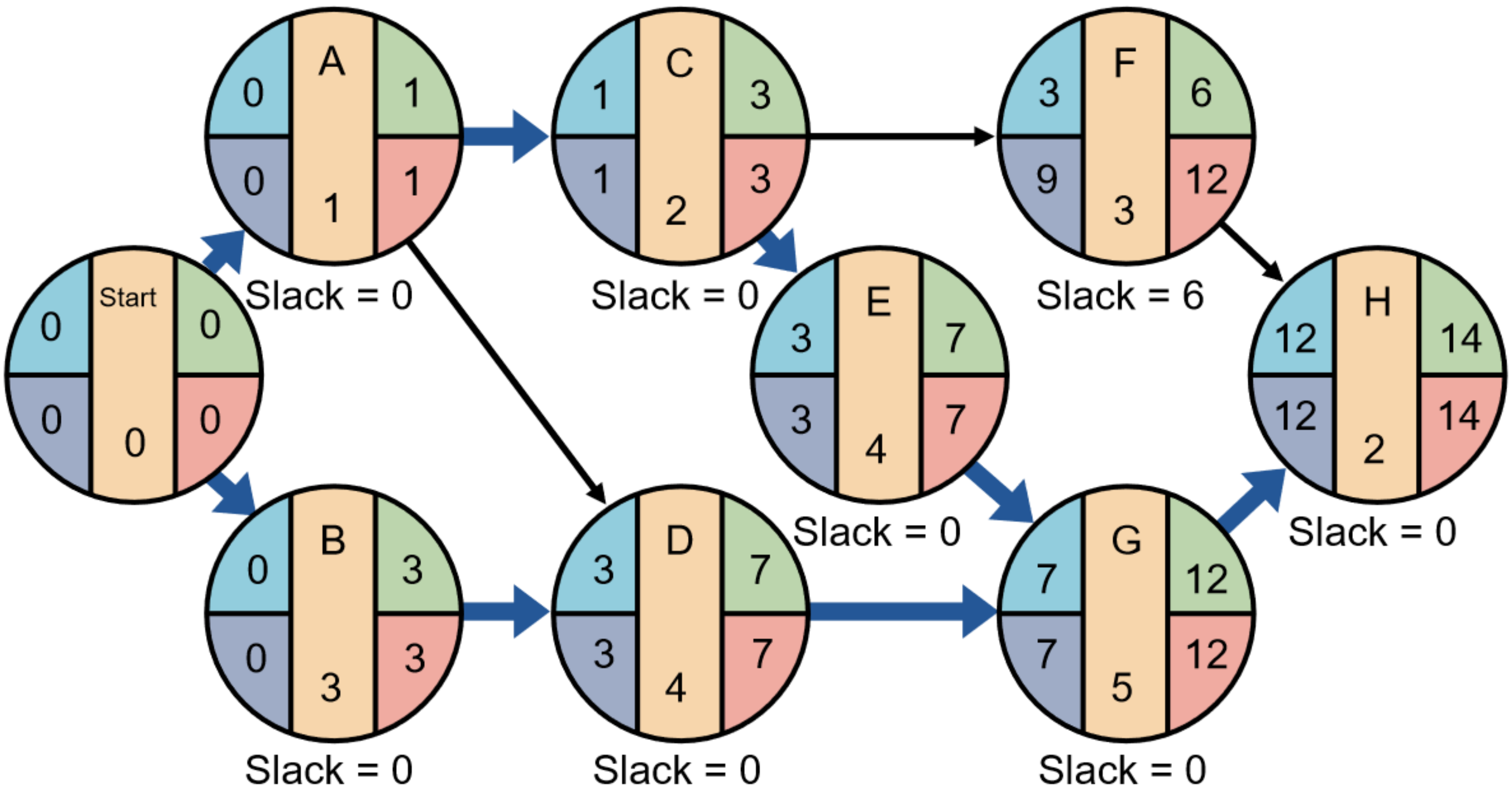
Crashing Activity A One Week (2 of 2)

Figure 3.16 (revised)



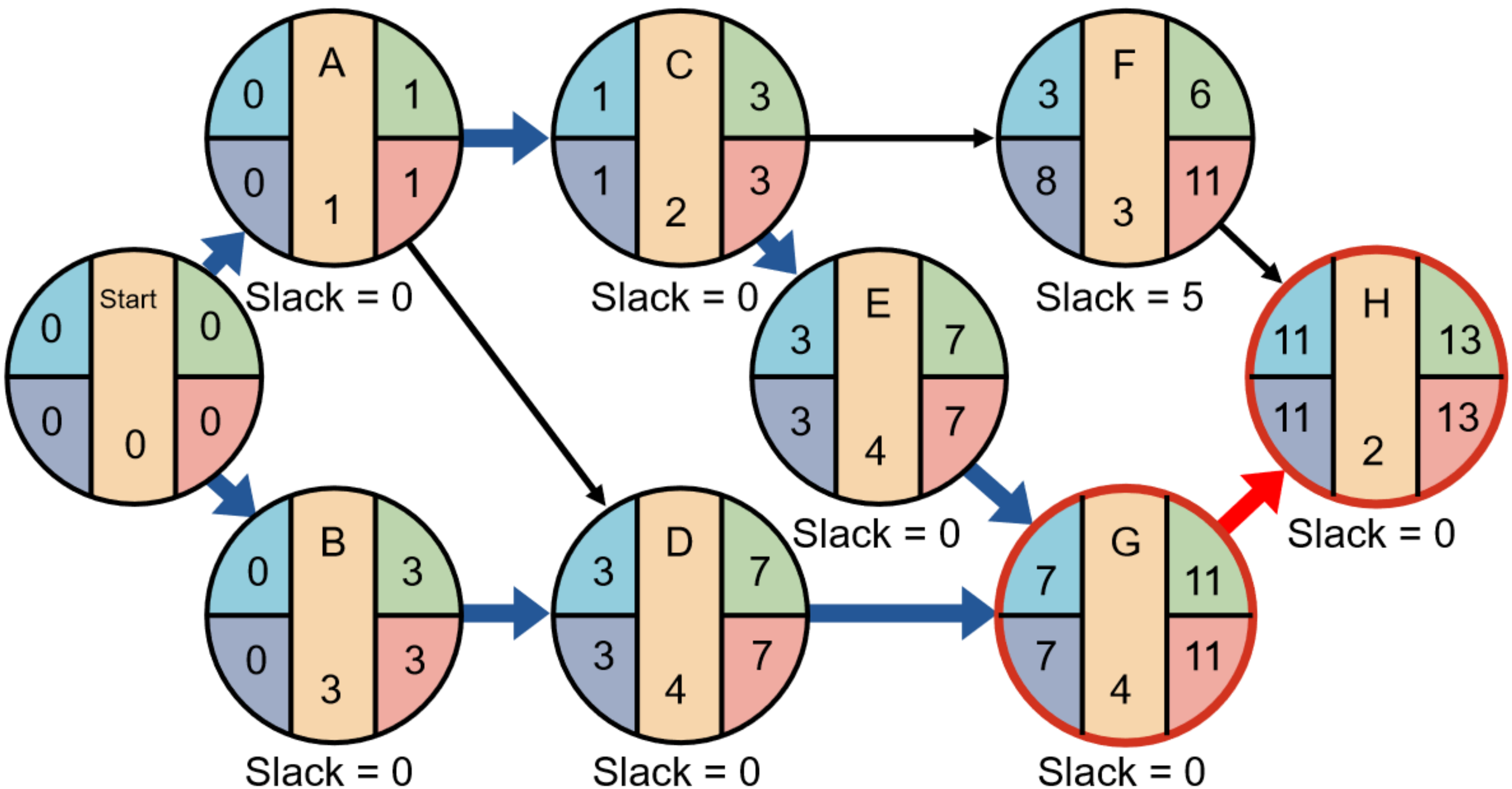
Crashing Activity G One Week (1 of 2)

Figure 3.16 (revised)



Crashing Activity G One Week (2 of 2)

Figure 3.16 (revised)



Advantages of PERT/CPM (1 of 2)

1. Especially useful when scheduling and controlling large projects
2. Straightforward concept and not mathematically complex
3. Graphical networks help highlight relationships among project activities
4. Critical path and slack time analyses help pinpoint activities that need to be closely watched

Advantages of PERT/CPM (2 of 2)

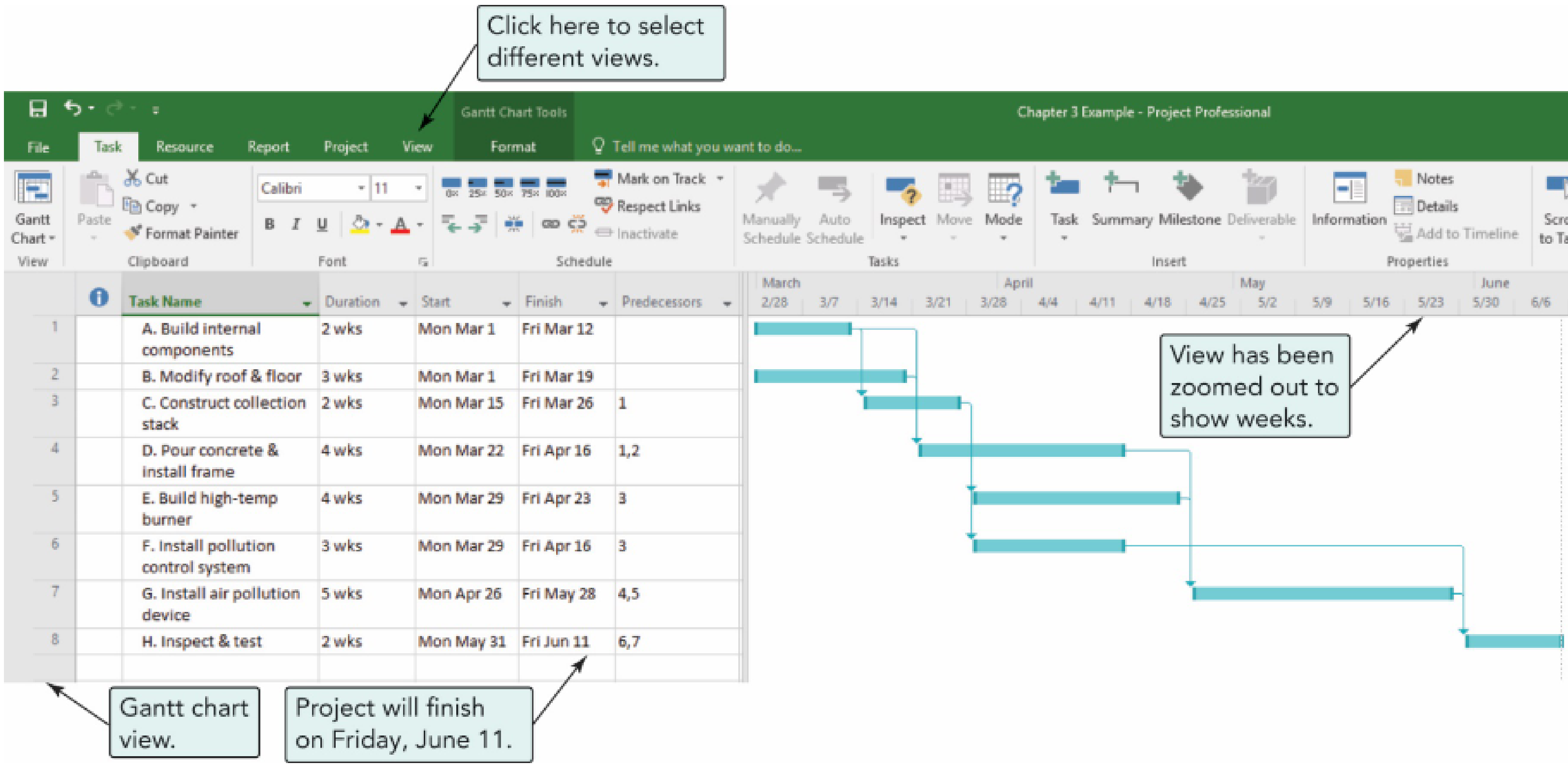
5. Project documentation and graphics point out who is responsible for various activities
6. Applicable to a wide variety of projects
7. Useful in monitoring not only schedules but costs as well

Limitations of PERT/CPM

1. Project activities have to be clearly defined, independent, and stable in their relationships
2. Precedence relationships must be specified and networked together
3. Time estimates tend to be subjective and are subject to fudging by managers
4. There is an inherent danger of too much emphasis being placed on the longest, or critical, path

Using Microsoft Project (1 of 3)

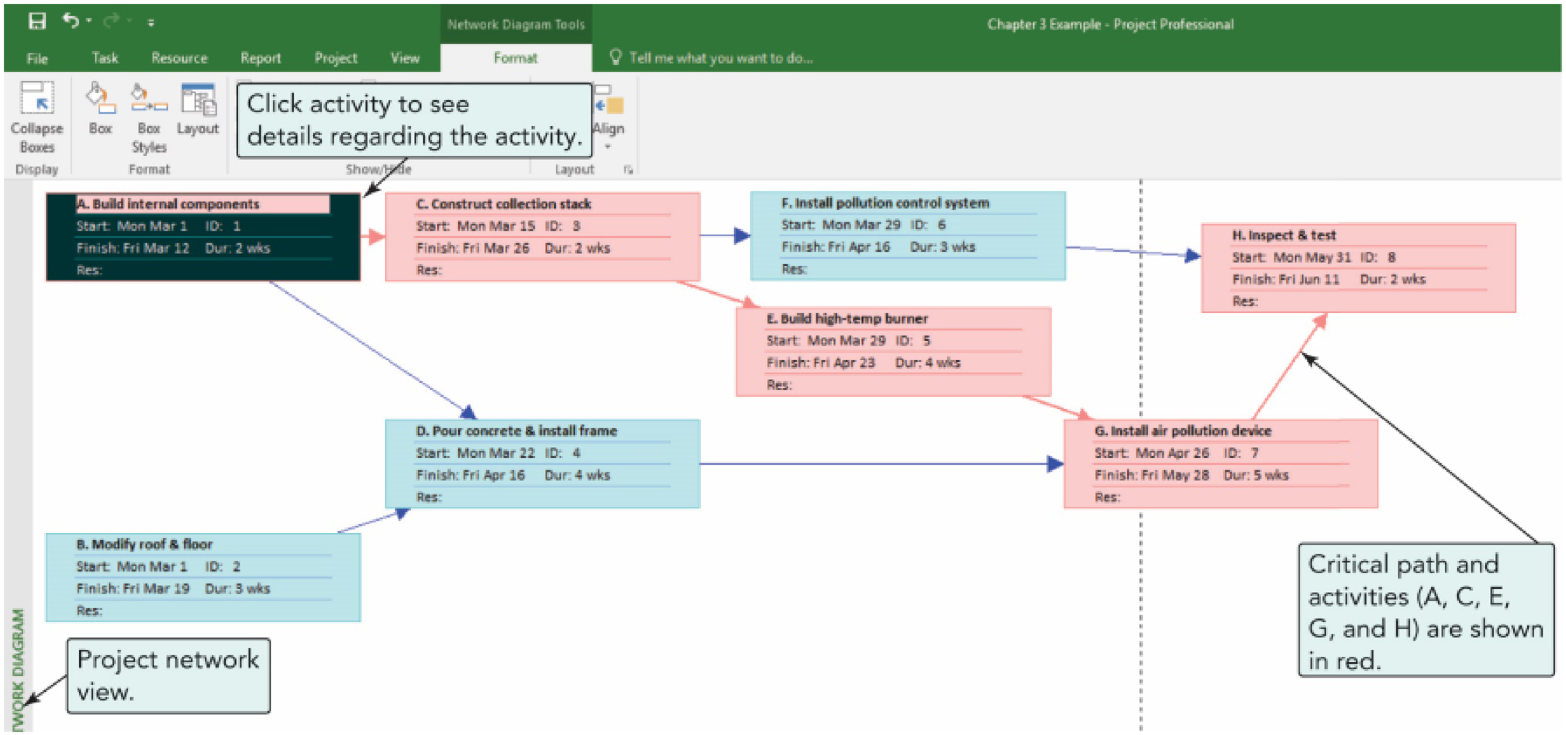
Program 3.1



Pearson

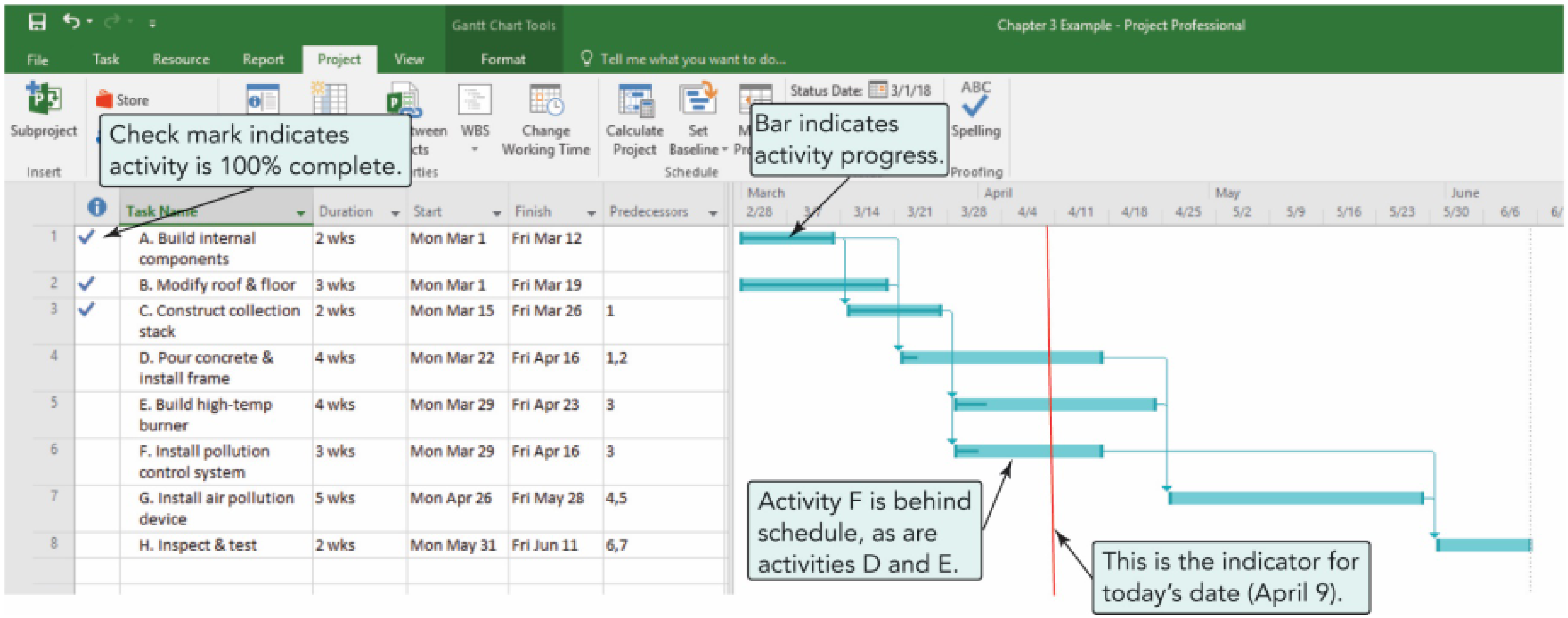
Using Microsoft Project (2 of 3)

Program 3.2



Using Microsoft Project (3 of 3)

Program 3.3



Pollution Project Percentage Completed on April 9

ACTIVITY	COMPLETED	ACTIVITY	COMPLETED
A	100	E	20
B	100	F	20
C	100	G	0
D	10	H	0

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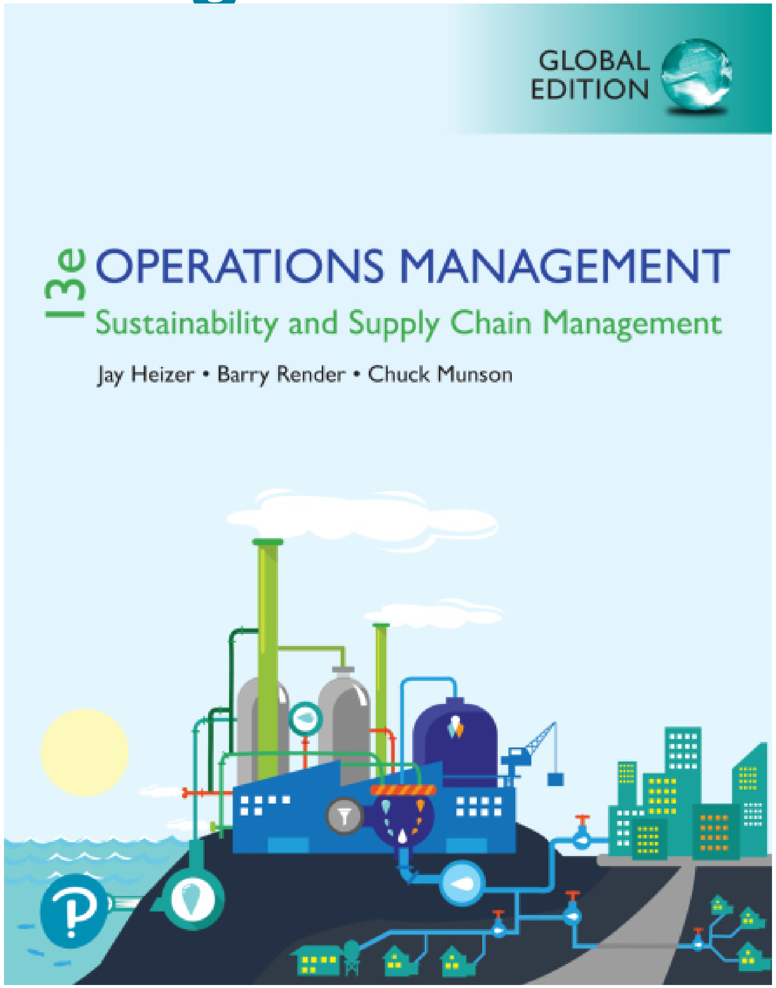
Operations Management: Sustainability and Supply Chain Management

Thirteenth Edition, Global Edition



Chapter 4

Forecasting

Outline (1 of 2)

- Global Company Profile: *Walt Disney Parks & Resorts*
- What Is Forecasting?
- The Strategic Importance of Forecasting
- Seven Steps in the Forecasting System
- Forecasting Approaches

Outline (2 of 2)

- Time-Series Forecasting
- Associative Forecasting Methods: Regression and Correlation Analysis
- Monitoring and Controlling Forecasts
- Forecasting in the Service Sector

Forecasting Provides a Competitive Advantage for Disney (1 of 4)

- Global portfolio includes parks in Shanghai, Hong Kong, Paris, Tokyo, Orlando, and Anaheim
- Revenues are derived from people - how many visitors and how they spend their money
- Daily management report contains only the forecast and actual attendance at each park

Forecasting Provides a Competitive Advantage for Disney (2 of 4)

- Disney generates daily, weekly, monthly, annual, and 5-year forecasts
- Forecast used by labor management, maintenance, operations, finance, and park scheduling
- Forecast used to adjust opening times, rides, shows, staffing levels, and guests admitted

Forecasting Provides a Competitive Advantage for Disney (3 of 4)

- 20% of customers come from outside the USA
- Economic model includes gross domestic product, cross-exchange rates, arrivals into the USA
- A staff of 35 analysts and 70 field people survey 1 million park guests, employees, and travel professionals each year

Forecasting Provides a Competitive Advantage for Disney (4 of 4)

- Inputs to the forecasting model include airline specials, Federal Reserve policies, Wall Street trends, vacation/ holiday schedules for 3,000 school districts around the world
- Average forecast error for the 5-year forecast is 5%
- Average forecast error for annual forecasts is between 0% and 3%

Learning Objectives (1 of 2)

When you complete this chapter you should be able to:

4.1 ***Understand*** the three time horizons and which models apply for each

4.2 ***Explain*** when to use each of the four qualitative models

4.3 ***Apply*** the naive, moving-average, exponential smoothing, and trend methods

Learning Objectives (2 of 2)

When you complete this chapter you should be able to:

4.4 ***Compute*** three measures of forecast accuracy

4.5 ***Develop*** seasonal indices

4.6 ***Conduct*** a regression and correlation analysis

4.7 ***Use*** a tracking signal

What is Forecasting?

- Process of predicting a future event
- Underlying basis of all business decisions
  - Production
  - Inventory
  - Personnel
  - Facilities

Forecasting Time Horizons

1. *Short-range forecast*
   - Up to 1 year, generally less than 3 months
   - Purchasing, job scheduling, workforce levels, job assignments, production levels
2. *Medium-range forecast*
   - 3 months to 3 years
   - Sales and production planning, budgeting
3. *Long-range forecast*
   - 3+ years
   - New product planning, facility location, capital expenditures, research and development

Distinguishing Differences

1. Medium/long range forecasts *deal with more comprehensive issues* and support management decisions regarding planning and products, plants and processes
2. Short-term forecasting usually *employs different methodologies* than longer-term forecasting
3. Short-term forecasts *tend to be more accurate* than longer-term forecasts

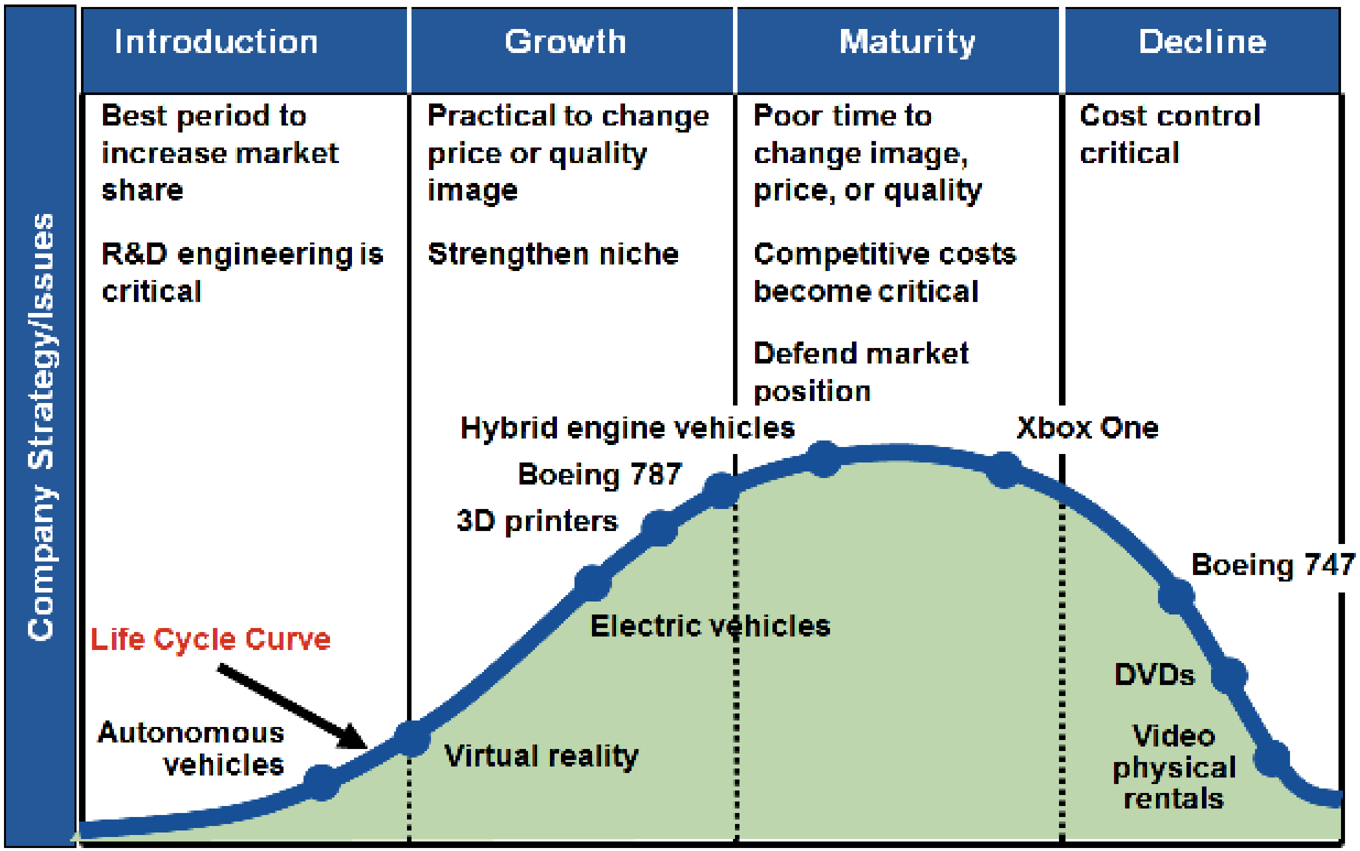
Influence of Product Life Cycle

Introduction – Growth – Maturity – Decline

- Introduction and growth require longer forecasts than maturity and decline
- As product passes through life cycle, forecasts are useful in projecting
  - Staffing levels
  - Inventory levels
  - Factory capacity

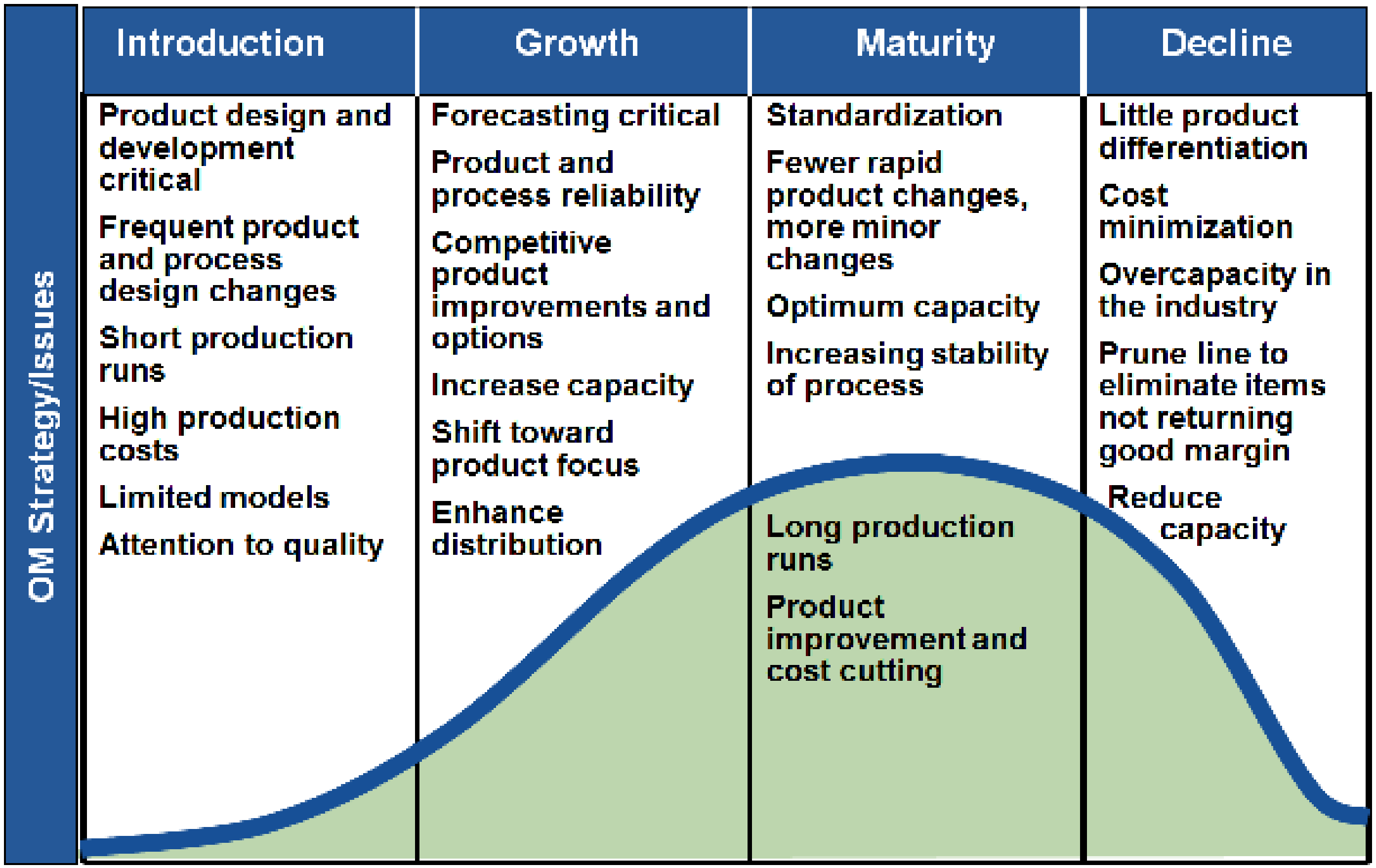
Product Life Cycle (1 of 2)

Figure 2.5



Product Life Cycle (2 of 2)

Figure 2.5



Types of Forecasts

1. **Economic forecasts**
   – Address business cycle – inflation rate, money supply, housing starts, etc.
2. **Technological forecasts**
   – Predict rate of technological progress
   – Impacts development of new products
3. **Demand forecasts**
   – Predict sales of existing products and services

Strategic Importance of Forecasting

- Supply Chain Management – Good supplier relations, advantages in product innovation, cost and speed to market
- Human Resources – Hiring, training, laying off workers
- Capacity – Capacity shortages can result in undependable delivery, loss of customers, loss of market share

Seven Steps in Forecasting

1. Determine the use of the forecast
2. Select the items to be forecasted
3. Determine the time horizon of the forecast
4. Select the forecasting model(s)
5. Gather the data needed to make the forecast
6. Make the forecast
7. Validate and implement the results

The Realities!

- Forecasts are seldom perfect; unpredictable outside factors may impact the forecast
- Most techniques assume an underlying stability in the system
- Product family and aggregated forecasts are more accurate than individual product forecasts

Forecasting Approaches (1 of 2)

Qualitative Methods

- Used when situation is vague and little data exist
  - New products
  - New technology
- Involves intuition, experience
  - e.g., forecasting sales on Internet

Forecasting Approaches (2 of 2)

Quantitative Methods

- Used when situation is ‘stable’ and historical data exist
  - Existing products
  - Current technology
- Involves mathematical techniques
  - e.g., forecasting sales of color televisions

Overview of Qualitative Methods (1 of 2)

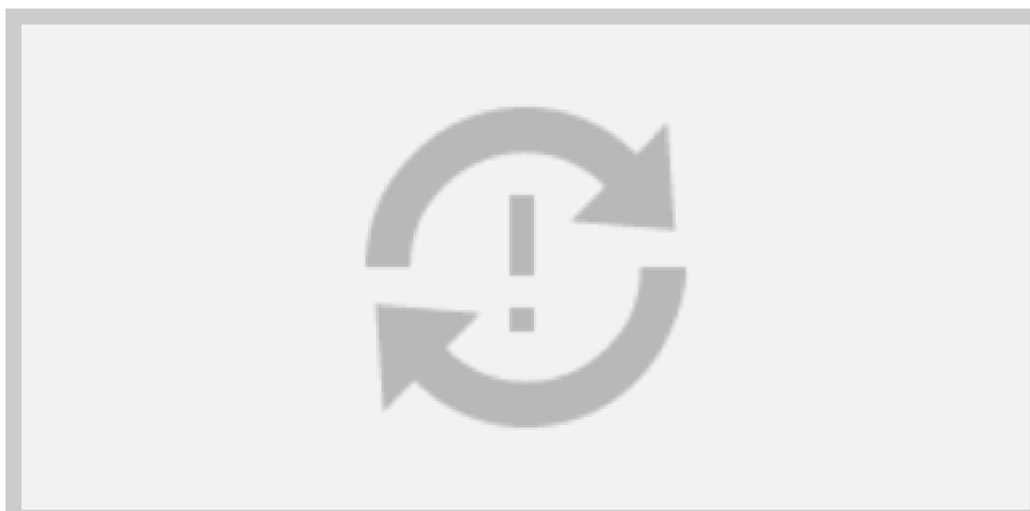
1. **Jury of executive opinion**
   – Pool opinions of high-level experts, sometimes augmented by statistical models
2. **Delphi method**
   – Panel of experts, queried iteratively

Overview of Qualitative Methods (2 of 2)

3. **Sales force composite**
   – Estimates from individual salespersons are reviewed for reasonableness, then aggregated
4. **Market Survey**
   – Ask the customer

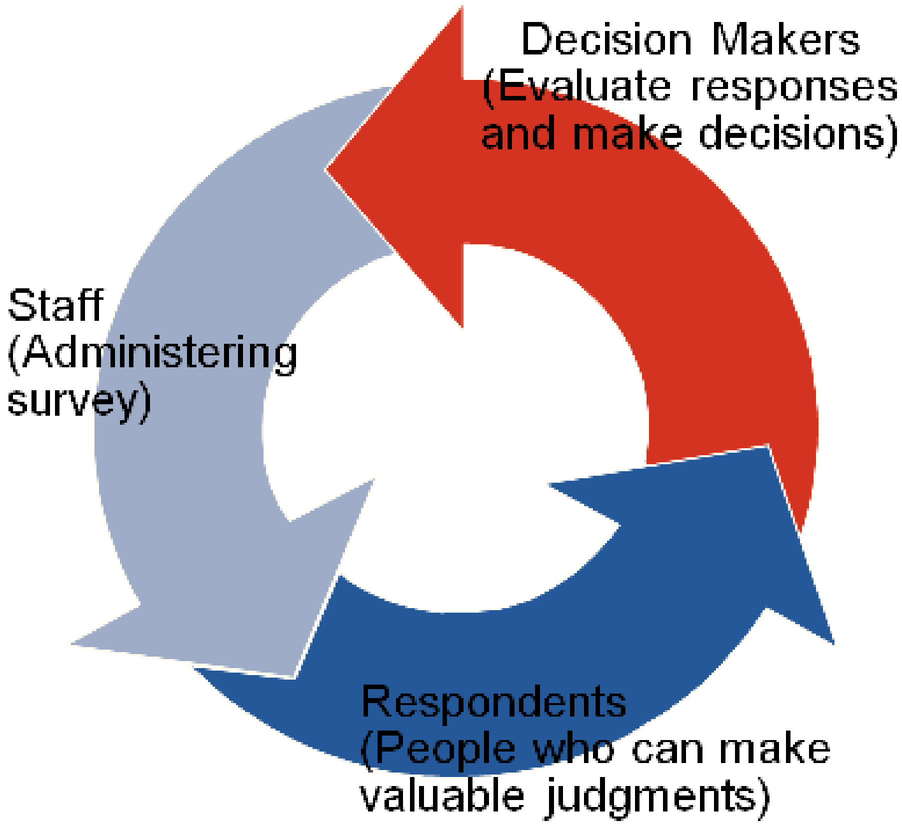
Jury of Executive Opinion

- Involves small group of high-level experts and managers
- Group estimates demand by working together
- Combines managerial experience with statistical models
- Relatively quick
- ‘Group-think’ disadvantage



Delphi Method

- Iterative group process, continues until consensus is reached
- Three types of participants
  - Decision makers
  - Staff
  - Respondents



Sales Force Composite

- Each salesperson projects his or her sales
- Combined at district and national levels
- Sales reps know customers’ wants
- May be overly optimistic

Market Survey

- Ask customers about purchasing plans
- Useful for demand and product design and planning
- What consumers say and what they actually do may be different
- May be overly optimistic

Overview of Quantitative Approaches

1. Naive approach
2. Moving averages
3. Exponential smoothing
4. Trend projection
5. Linear regression

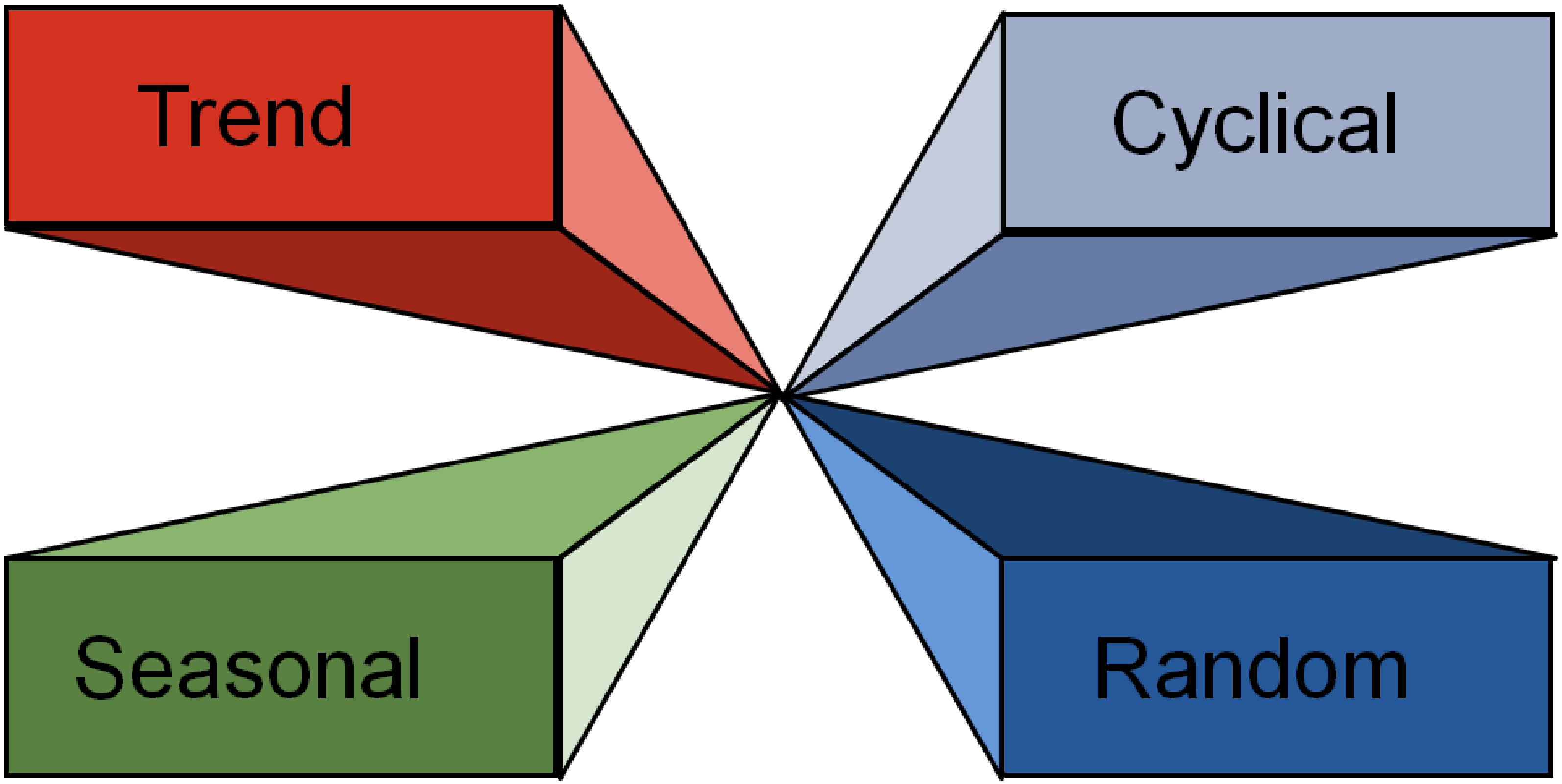
Items 1–4: Time-series models

Item 5: Associative model

Time-Series Forecasting

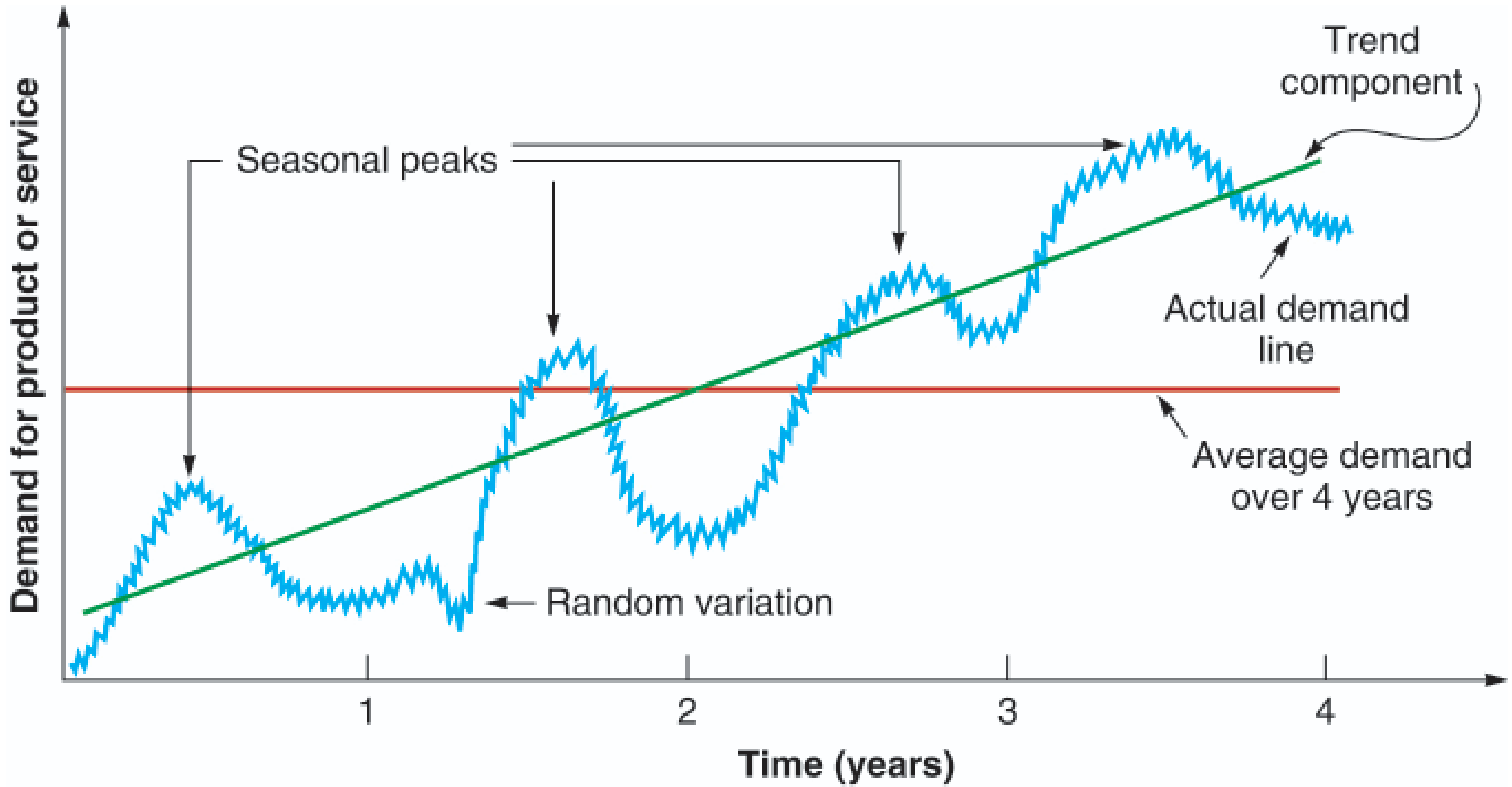
- Set of evenly spaced numerical data
  - Obtained by observing response variable at regular time periods
- Forecast based only on past values, no other variables important
  - Assumes that factors influencing past and present will continue influence in future

Time-Series Components



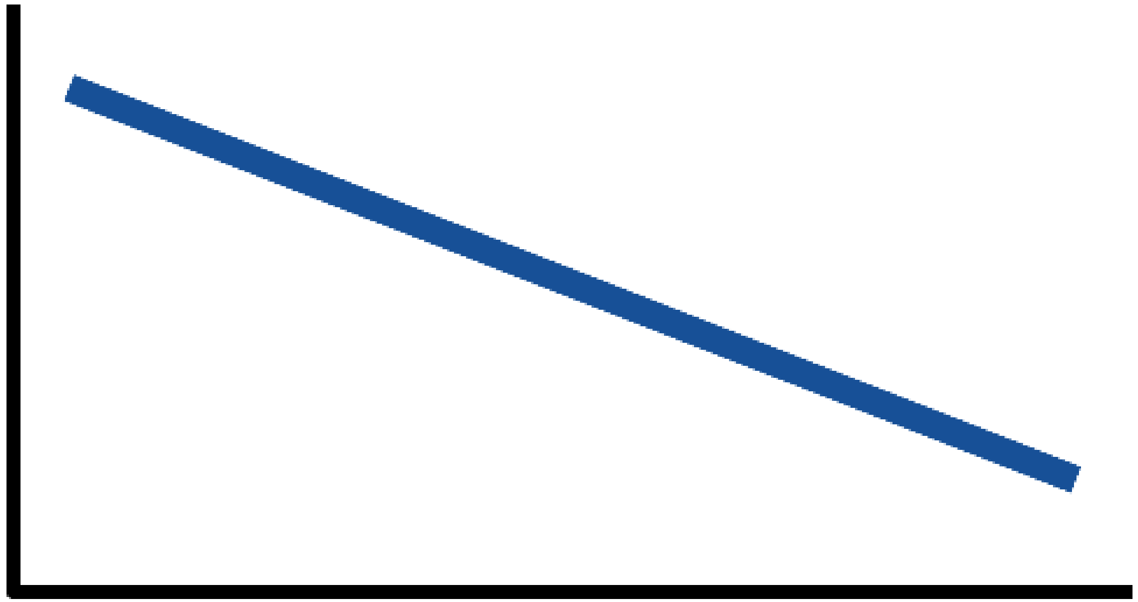
Components of Demand

Figure 4.1



Trend Component

- Persistent, overall upward or downward pattern
- Changes due to population, technology, age, culture, etc.
- Typically several years duration



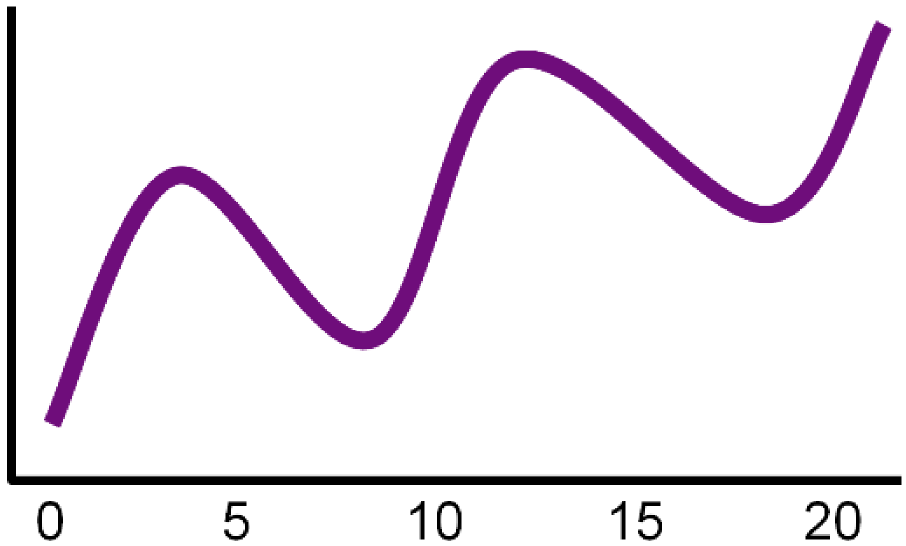
Seasonal Component

- Regular pattern of up and down fluctuations
- Due to weather, customs, etc.
- Occurs within a single year

PERIOD LENGTH	"SEASON" LENGTH	NUMBER OF "SEASON" IN PATTERN
Week	Day	7
Month	Week	4 – 4.5
Month	Day	28 – 31
Year	Quarter	4
Year	Month	12
Year	Week	52

Cyclical Component

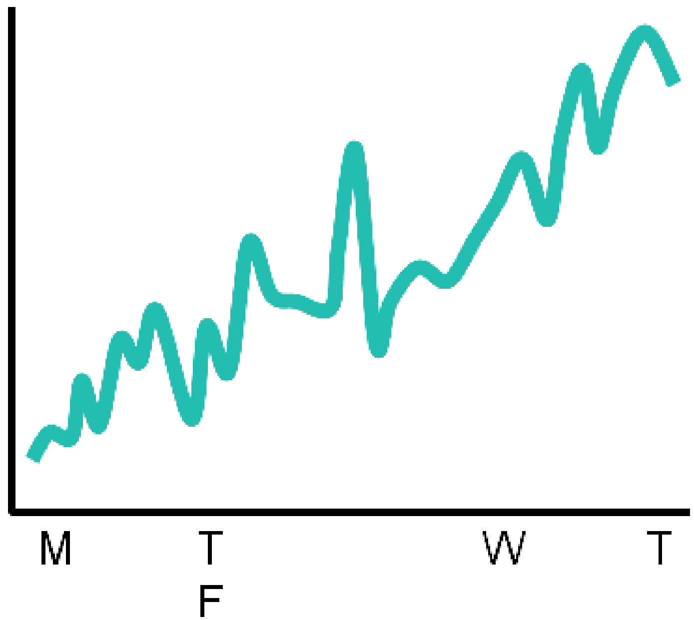
- Repeating up and down movements
- Affected by business cycle, political, and economic factors
- Multiple years duration
- Often causal or associative relationships



Pearson

Random Component

- Erratic, unsystematic, ‘residual’ fluctuations
- Due to random variation or unforeseen events
- Short duration and nonrepeating



Pearson

Naive Approach

- Assumes demand in next period is the same as demand in most recent period
  - e.g., If January sales were 68, then February sales will be 68
- Sometimes cost effective and efficient
- Can be good starting point

Pearson

Moving Averages

- MA is a series of arithmetic means
- Used if little or no trend
- Used often for smoothing
  - Provides overall impression of data over time

Moving Average Example

MONTH	ACTUAL SHED SALES	3-MONTH MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	$(10 + 12 + 13)/3 = 11\ ^2/_3$
May	19	$(12 + 13 + 16)/3 = 13\ ^2/_3$
June	23	$(13 + 16 + 19)/3 = 16$
July	26	$(16 + 19 + 23)/3 = 19\ ^1/_3$
August	30	$(19 + 23 + 26)/3 = 22\ ^2/_3$
September	28	$(23 + 26 + 30)/3 = 26\ ^1/_3$
October	18	$(26 + 30 + 28)/3 = 28$
November	16	$(30 + 28 + 18)/3 = 25\ ^1/_3$
December	14	$(28 + 18 + 16)/3 = 20\ ^2/_3$

Weighted Moving Average (1 of 3)

- Used when some trend might be present
  - Older data usually less important
- Weights based on experience and intuition

$$\textit{Weighted moving average} = \frac{\sum\left(\left(\text{Weight for period } n\right)\left(\text{Demand in period } n\right)\right)}{\sum \text{Weights}}$$

Weighted Moving Average (2 of 3)

MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (10)]/6 = 12\ {}^{1}/_{6}$
May	19	
June		
July		
August		
September		
October		
November		
December		

WEIGHTS APPLIED	PERIOD
3	Last month
2	Two months ago
1	Three months ago
6	Sum of the weights

Forecast for this month =

$$\frac{3 \times \text{Sales last mo.} + 2 \times \text{Sales 2 mos. ago} + 1 \times \text{Sales 3 mos. ago}}{\text{Sum of the weights}}$$

Pearson

Weighted Moving Average (3 of 3)

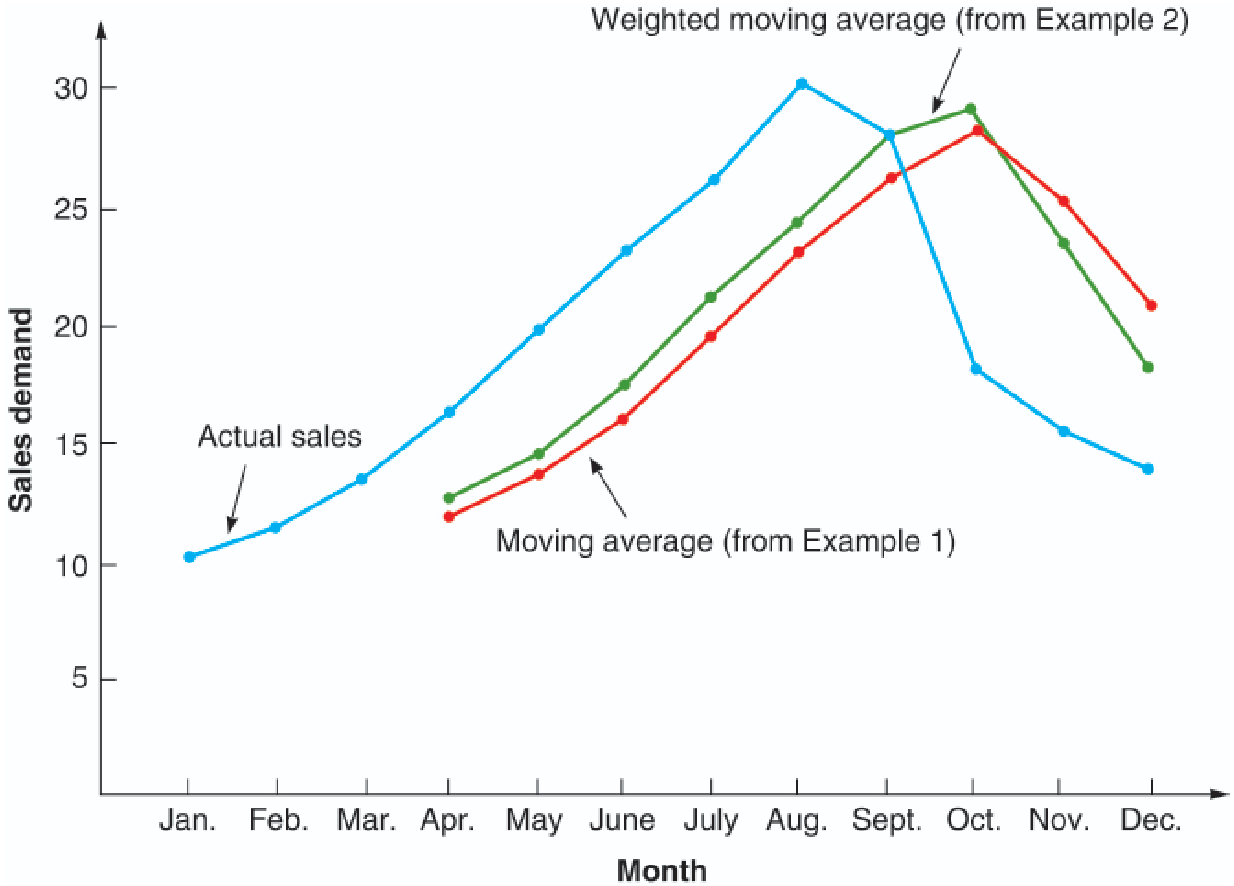
MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (10)]/6 = 12\ ^1/_6$
May	19	$[(3 \times 16) + (2 \times 13) + (12)]/6 = 14\ ^1/_3$
June	23	$[(3 \times 19) + (2 \times 16) + (13)]/6 = 17$
July	26	$[(3 \times 23) + (2 \times 19) + (16)]/6 = 20\ ^1/_2$
August	30	$[(3 \times 26) + (2 \times 23) + (19)]/6 = 23\ ^5/_6$
September	28	$[(3 \times 30) + (2 \times 26) + (23)]/6 = 27\ ^1/_2$
October	18	$[(3 \times 28) + (2 \times 30) + (26)]/6 = 28\ ^1/_3$
November	16	$[(3 \times 18) + (2 \times 28) + (30)]/6 = 23\ ^1/_3$
December	14	$[(3 \times 16) + (2 \times 18) + (28)]/6 = 18\ ^2/_3$

Potential Problems With Moving Average (1 of 2)

1. Increasing *n* smooths the forecast but makes it less sensitive to changes
2. Does not forecast trends well
3. Requires extensive historical data

Graph of Moving Averages

Figure 4.2



Pearson

Potential Problems With Moving Average (2 of 2)

- Form of weighted moving average
  - Weights decline exponentially
  - Most recent data weighted most
- Requires smoothing constant (α)
  - Ranges from 0 to 1
  - Subjectively chosen
- Involves little record keeping of past data

Exponential Smoothing

New forecast = Last period's forecast

+ α (Last period's actual demand

− Last period's forecast)

$$F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$$

where F_t = new forecast

F_{t-1} = previous period's forecast

α = smoothing (or weighting) constant $(0 \le \alpha \le 1)$

A_{t-1} = previous period's actual demand

Exponential Smoothing Example (1 of 3)

- Predicted demand = 142 Ford Mustangs
- Actual demand = 153
- Smoothing constant α = .20

Exponential Smoothing Example (2 of 3)

Predicted demand = 142 Ford Mustangs

Actual demand = 153

Smoothing constant α = .20

New forecast = 142 + .2(153 – 142)

Exponential Smoothing Example
(3 of 3)

Predicted demand = 142 Ford Mustangs

Actual demand = 153

Smoothing constant $\alpha = .20$

New forecast $= 142 + .2(153 - 142)$

$= 142 + 2.2$

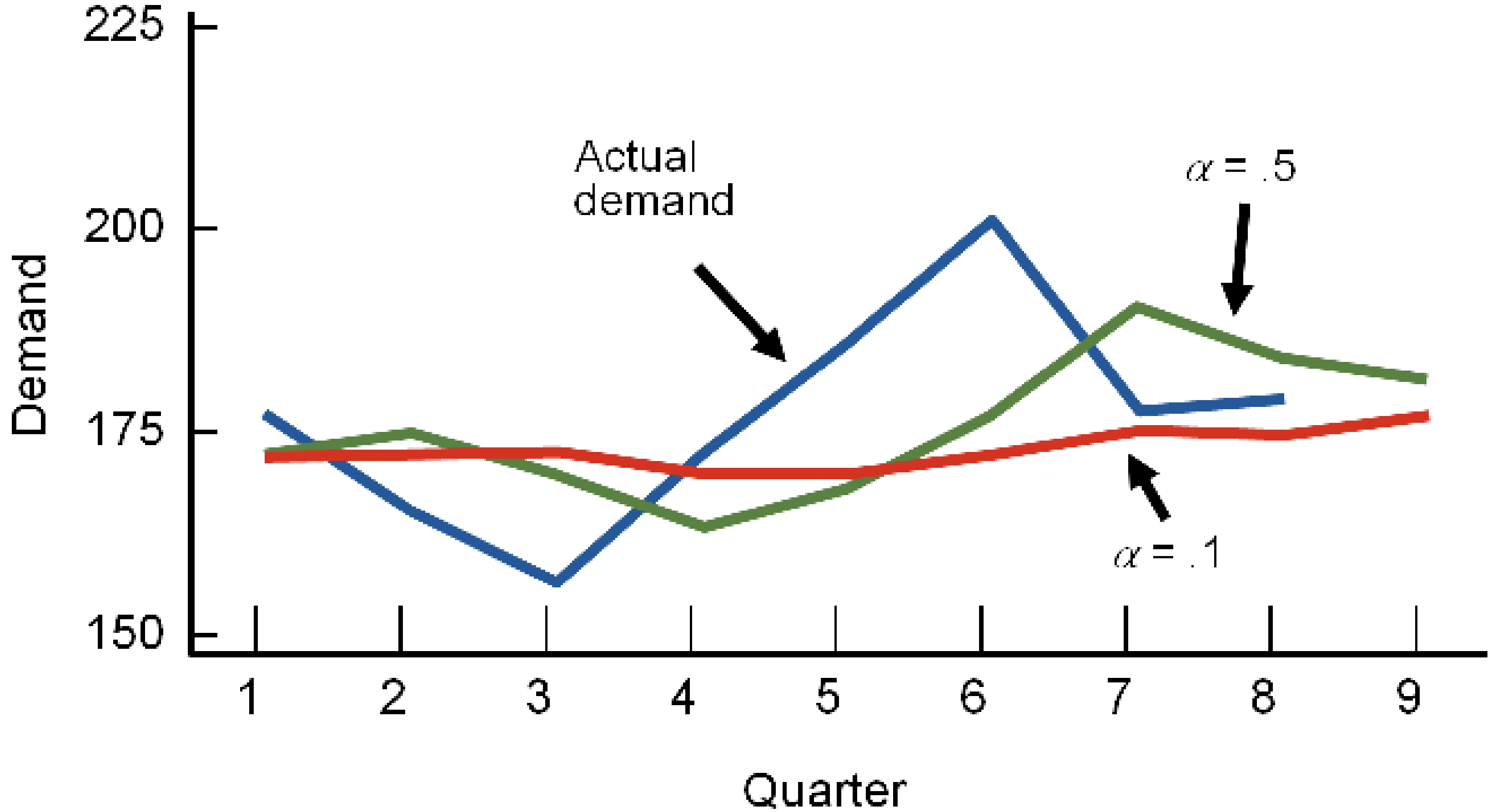
$= 144.2 \approx 144$ cars

Effect of Smoothing Constants

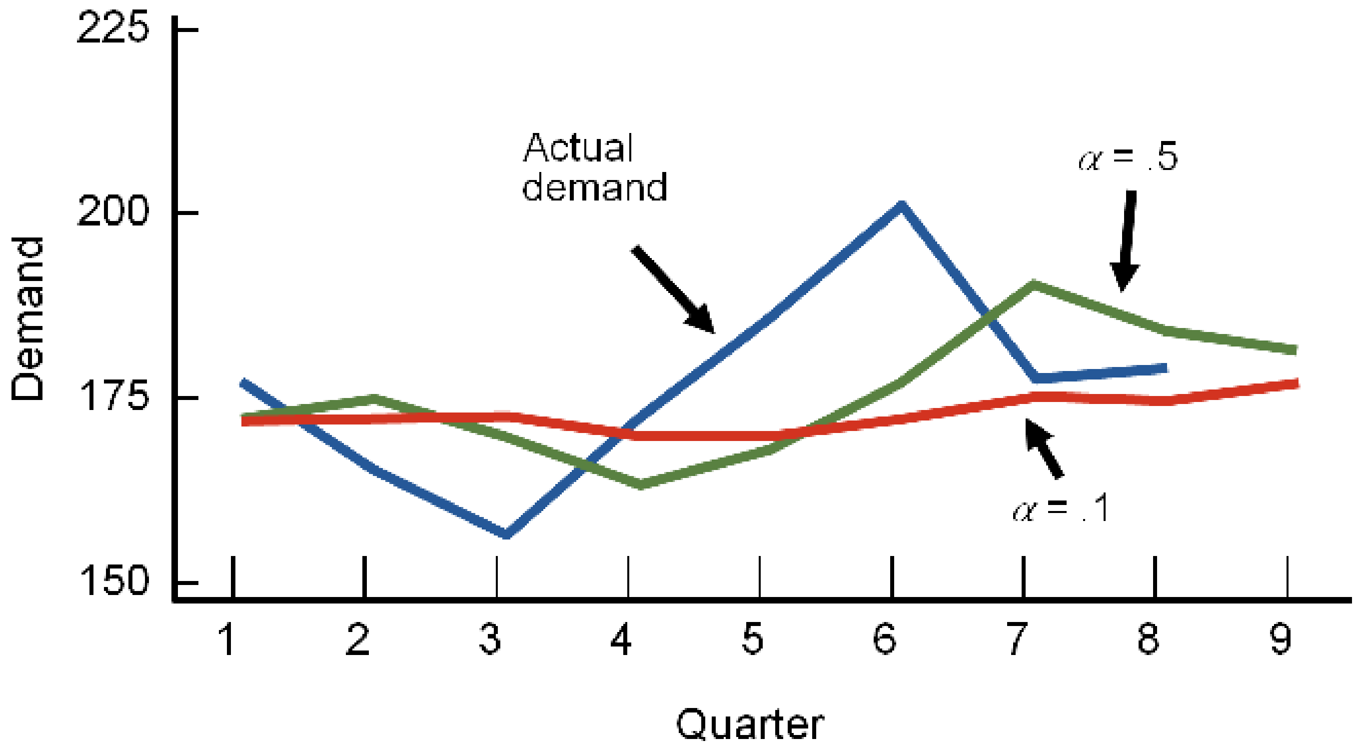
- Smoothing constant generally $.05 \le \alpha \le .50$
- As α increases, older values become less significant

	WEIGHT ASSIGNED TO				
SMOOTHING CONSTANT	MOST RECENT PERIOD (α)	2ND MOST RECENT PERIOD $\alpha(1-\alpha)$	3RD MOST RECENT PERIOD $\alpha(1-\alpha)^2$	4th MOST RECENT PERIOD $\alpha(1-\alpha)^3$	5th MOST RECENT PERIOD $\alpha(1-\alpha)^4$
$\alpha = .1$	.1	.09	.081	.073	.066
$\alpha = .5$	.5	.25	.125	.063	.031

Impact of Different α (1 of 2)



Impact of Different α (2 of 2)



- **Choose high values of α when underlying average is likely to change**
- **Choose low values of α when underlying average is stable**

Selecting the Smoothing Constant

The objective is to obtain the most accurate forecast no matter the technique

We generally do this by selecting the model that gives us the lowest forecast error according to one of three preferred measures:

- Mean Absolute Deviation (MAD)
- Mean Squared Error (MSE)
- Mean Absolute Percent Error (MAPE)

Common Measures of Error (1 of 3)

Mean Absolute Deviation (MAD)

Determining the MAD (1 of 2)

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH $\alpha = .10$	FORECAST WITH $\alpha = .50$
1	**180**	**175**	175
2	168	175.50 = **175.00** + .10(**180** − **175**)	177.50
3	159	174.75 = 175.50 + .10(168 − 175.50)	172.75
4	175	173.18 = 174.75 + .10(159 − 174.75)	165.88
5	190	173.36 = 173.18 + .10(175 − 173.18)	170.44
6	205	175.02 = 173.36 + .10(190 − 173.36)	180.22
7	180	178.02 = 175.02 + .10(205 − 175.02)	192.61
8	182	178.22 = 178.02 + .10(180 − 178.02)	186.30
9	?	178.59 = 178.22 + .10(182 − 178.22)	184.15

Determining the MAD (2 of 2)

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH $\alpha = .10$	ABSOLUTE DEVIATION FOR $\alpha = .10$	FORECAST WITH $\alpha = .50$	ABSOLUTE DEVIATION FOR $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.50	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
	Sum of absolute deviations:		82.45		98.62
	$\text{MAD} = \dfrac{\Sigma\lvert\text{Deviations}\rvert}{n}$		10.31		12.33

Common Measures of Error (2 of 3)

Mean Squared Error (MSE)

$$\text{MSE} = \frac{\sum (\text{Forecast errors})^2}{n}$$

Determining the MSE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR $\alpha = .10$	$(\text{ERROR})^2$
1	180	175	$5^2 = 25$
2	168	175.50	$(-7.5)^2 = 56.25$
3	159	174.75	$(-15.75)^2 = 248.06$
4	175	173.18	$(1.82)^2 = 3.31$
5	190	173.36	$(16.64)^2 = 276.89$
6	205	175.02	$(29.98)^2 = 898.80$
7	180	178.02	$(1.98)^2 = 3.92$
8	182	178.22	$(3.78)^2 = 14.29$
			Sum of errors squared = 1,526.52

$$\text{MSE} = \frac{\sum (\text{Forecast errors})^2}{n} = 1{,}526.52/8 = 190.8$$

Common Measures of Error (3 of 3)

Mean Absolute Percent Error (MAPE)

$$\text{MAPE} = \frac{\sum_{i=1}^{n} 100\left|\text{Actual}_i - \text{Forecast}_i\right| / \text{Actual}_i}{n}$$

Determining the MAPE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR $\alpha = .10$	ABSOLUTE PERCENT ERROR 100(|ERROR|/ACTUAL)
1	180	175.00	100(5/180) = 2.78%
2	168	175.50	100(7.5/168) = 4.46%
3	159	174.75	100(15.75/159) = 9.90%
4	175	173.18	100(1.82/175) = 1.05%
5	190	173.36	100(16.64/190) = 8.76%
6	205	175.02	100(29.98/205) = 14.62%
7	180	178.02	100(1.98/180) = 1.10%
8	182	178.22	100(3.78/182) = 2.08%
			Sum of % errors = 44.75%

$$\text{MAPE} = \frac{\sum \text{absolute percent error}}{n} = \frac{44.75\%}{8} = 5.59\%$$

Comparison of Measures

Table 4.1 Comparison of Measures of Forecast Error

MEASURE	MEANING	APPLICATION TO CHAPTER EXAMPLE
Mean absolute deviation (MAD)	How much the forecast missed the target	For α = .10 in Example 4, the forecast for grain unloaded was off by an average of 10.31 tons.
Mean squared error (MSE)	The square of how much the forecast missed the target	For α = .10 in Example 5, the square of the forecast error was 190.8. This number does not have a physical meaning, but is useful when compared to the MSE of another forecast.
Mean absolute percent error (MAPE)	The average percent error	For α = .10 in Example 6, the forecast is off by 5.59% on average. As in Examples 4 and 5, some forecasts were too high, and some were low.

Comparison of Forecast Error (1 of 5)

Quarter	Actual Tonnage Unloaded	Rounded Forecast with $\alpha = .10$	Absolute Deviation for $\alpha = .10$	Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.5	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
			82.45		98.62

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Comparison of Forecast Error (2 of 5)

$$\text{MAD} = \frac{\sum |\text{deviations}|}{n}$$

For $\alpha = .10$

$$= 82.45/8 = 10.31$$

For $\alpha = .50$

$$= 98.62/8 = 12.33$$

82.45

Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
175	5.00
177.50	9.50
172.75	13.75
165.88	9.12
170.44	19.56
180.22	24.78
192.61	12.61
186.30	4.30
	98.62

Comparison of Forecast Error (3 of 5)

$$\text{MSE} = \frac{\sum (\text{forecast errors})^2}{n}$$

For $\alpha = .10$

$= 1{,}526.52/8 = 190.8$

For $\alpha = .50$

$= 1{,}561.91/8 = 195.24$

		Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
		175	5.00
		177.50	9.50
		172.75	13.75
		165.88	9.12
		170.44	19.56
		180.22	24.78
		192.61	12.61
		186.30	4.30
	82.45		98.62
MAD	10.31		12.33

Comparison of Forecast Error (4 of 5)

$$\text{MAPE} = \frac{\sum_{i=1}^{n} 100|\text{deviation}_i|/\text{actual}_i}{n}$$

For $\alpha = .10$

$= 44.75\%/8 = 5.59\%$

For $\alpha = .50$

$= 54.00\%/8 = 6.75\%$

...ed ...st ...)	Absolute Deviation for $\alpha = .50$
	5.00
0	9.50
5	13.75
8	9.12
4	19.56
2	24.78
1	12.61
0	4.30

	82.45	98.62
MAD	10.31	12.33
MSE	190.82	195.24

Comparison of Forecast Error (5 of 5)

Quarter	Actual Tonnage Unloaded	Rounded Forecast with $\alpha = .10$	Absolute Deviation for $\alpha = .10$	Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.5	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
			82.45		98.62
		MAD	10.31		12.33
		MSE	190.82		195.24
		MAPE	5.59%		6.75%

Exponential Smoothing with Trend Adjustment (1 of 3)

When a trend is present, exponential smoothing must be modified

MONTH	ACTUAL DEMAND	FORECAST (F_t) FOR MONTHS 1 – 5
1	100	$F_1 = 100$ (given)
2	200	$F_2 = F_1 + \alpha(A_1 - F_1) = 100 + .4(100 - 100)$ $= 100$
3	300	$F_3 = F_2 + \alpha(A_2 - F_2) = 100 + .4(200 - 100)$ $= 140$
4	400	$F_4 = F_3 + \alpha(A_3 - F_3) = 140 + .4(300 - 140)$ $= 204$
5	500	$F_5 = F_4 + \alpha(A_4 - F_4) = 204 + .4(400 - 204)$ $= 282$

Exponential Smoothing with Trend Adjustment (2 of 3)

$$\begin{matrix}\text{Forecast} \\ \text{including} \\ \text{trend}\end{matrix} (FIT_t) = \begin{matrix}\text{Exponentially} \\ \text{smoothed} \\ \text{forecast}\end{matrix} (F_t) = \begin{matrix}\text{Exponentially} \\ \text{smoothed} \\ \text{forecast}\end{matrix} (T_t)$$

$$F_t = \alpha(A_{t-1}) + (1 - a)(F_{t-1} + T_{t-1})$$

$$T_t = \beta(F_t - F_{t-1}) + (1 - \beta)T_{t-1}$$

where F_t = exponentially smoothed forecast average

T_t = exponentially smoothed trend

A_t = actual demand

α = smoothing constant for average ($0 \leq \alpha \leq 1$)

β = smoothing constant for trend ($0 \leq \beta \leq 1$)

Exponential Smoothing with Trend Adjustment (3 of 3)

Step 1: Compute F_t

Step 2: Compute T_t

Step 3: Calculate the forecast $FIT_t = F_t + T_t$

Exponential Smoothing with Trend Adjustment Example

MONTH (t)	ACTUAL DEMAND (A_t)	MONTH (t)	ACTUAL DEMAND (A_t)
1	12	6	21
2	17	7	31
3	20	8	28
4	19	9	36
5	24	10	?

$\alpha = .2$ $\beta = .4$

Pearson

Exponential Smoothing with Trend Adjustment Example (1 of 5)

Table 4.2 Forecast with α = .2 and β = .4

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80		
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 1: Average for Month 2

$$F_2 = \alpha A_1 + (1 - \alpha)(F_1 + T_1)$$
$$F_2 = (.2)(12) + (1 - .2)(11 + 2)$$
$$= 2.4 + (.8)(13) = 2.4 + 10.4$$
$$= 12.8 \text{ units}$$

Exponential Smoothing with Trend Adjustment Example (2 of 5)

Table 4.2 Forecast with α = .2 and β = .4

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 2: Trend for Month 2

$$T_2 = \beta(F_2 - F_1) + (1 - \beta)T_1$$

$$T_2 = (.4)(12.8 - 11) + (1 - .4)(2)$$

$$= .72 + 1.2 = 1.92 \text{ units}$$

Exponential Smoothing with Trend Adjustment Example (3 of 5)

Table 4.2 Forecast with α = .2 and β = .4

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	14.72
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 3: Calculate FIT for Month 2

$$FIT_2 = F_2 + T_2$$
$$FIT_2 = 12.8 + 1.92$$
$$= 14.72 \text{ units}$$

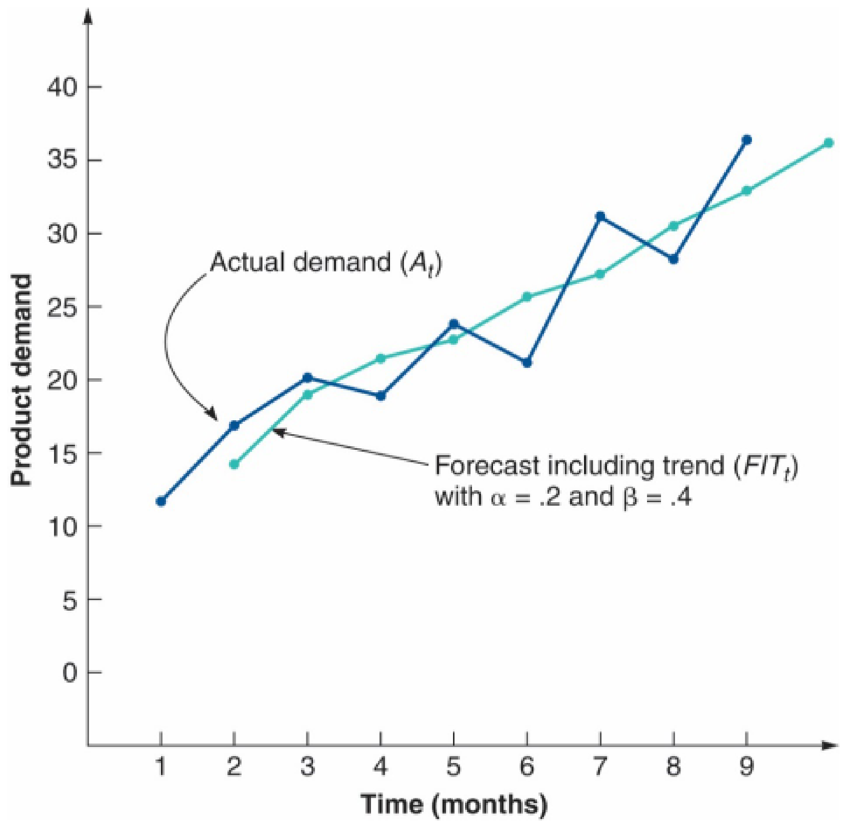
Exponential Smoothing with Trend Adjustment Example (4 of 5)

Table 4.2 Forecast with $\alpha = .2$ and $\beta = .4$

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	14.72
3	20	15.18	2.10	17.28
4	19	17.82	2.32	20.14
5	24	19.91	2.23	22.14
6	21	22.51	2.38	24.89
7	31	24.11	2.07	26.18
8	28	27.14	2.45	29.59
9	36	29.28	2.32	31.60
10		32.48	2.68	35.16

Exponential Smoothing with Trend Adjustment Example (5 of 5)

Figure 4.3



Trend Projections (1 of 2)

- Fitting a trend line to historical data points to project into the medium to long-range
- Linear trends can be found using the least-squares technique

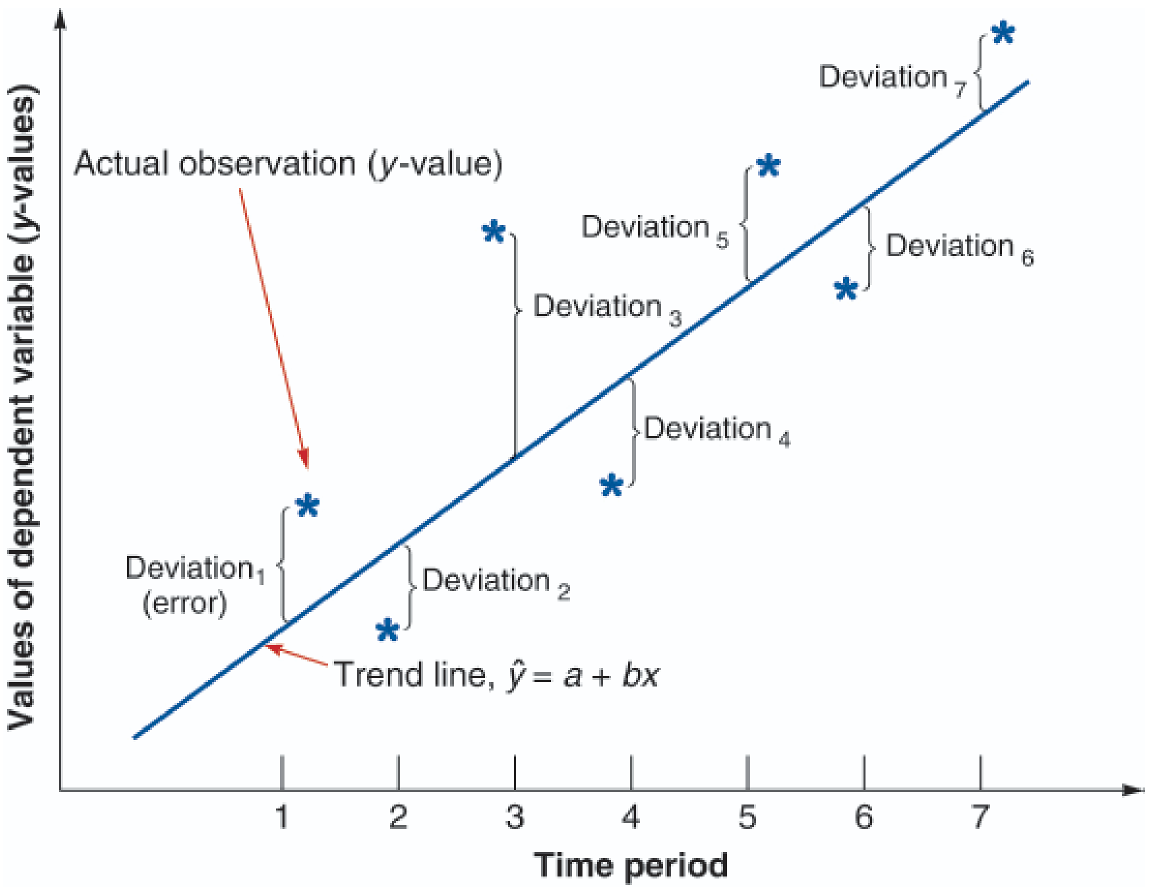
$$\hat{y} = a + bx$$

where $\hat{y}$ = computed value of the variable to be predicted (dependent variable)

a = y-axis intercept
b = slope of the regression line
x = the independent variable

Least Squares Method (1 of 2)

Figure 4.4



Least Squares Method (2 of 2)

Equations to calculate the regression variables

Least Squares Example (1 of 4)

YEAR	ELECTRICAL POWER DEMAND	YEAR	ELECTRICAL POWER DEMAND
1	74	5	105
2	79	6	142
3	80	7	122
4	90		

Least Squares Example (2 of 4)

YEAR (x)	ELECTRICAL POWER DEMAND (y)	x^2	xy
1	74	1	74
2	79	4	158
3	80	9	240
4	90	16	360
5	105	25	525
6	142	36	852
7	122	49	854
$\Sigma x = 28$	$\Sigma y = 692$	$\Sigma x^2 = 140$	$\Sigma xy = 3{,}063$

$$\bar{x} = \frac{\sum x}{n} = \frac{28}{7} = 4 \qquad \bar{y} = \frac{\sum y}{n} = \frac{692}{7} = 98.86$$

Least Squares Example (3 of 4)

$\Sigma x = 28$	$\Sigma y = 692$	$\Sigma x^2 = 140$	$\Sigma xy = 3{,}063$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{3{,}063 - (7)(4)(98.86)}{140 - (7)(4^2)} = \frac{295}{28} = 10.54$$

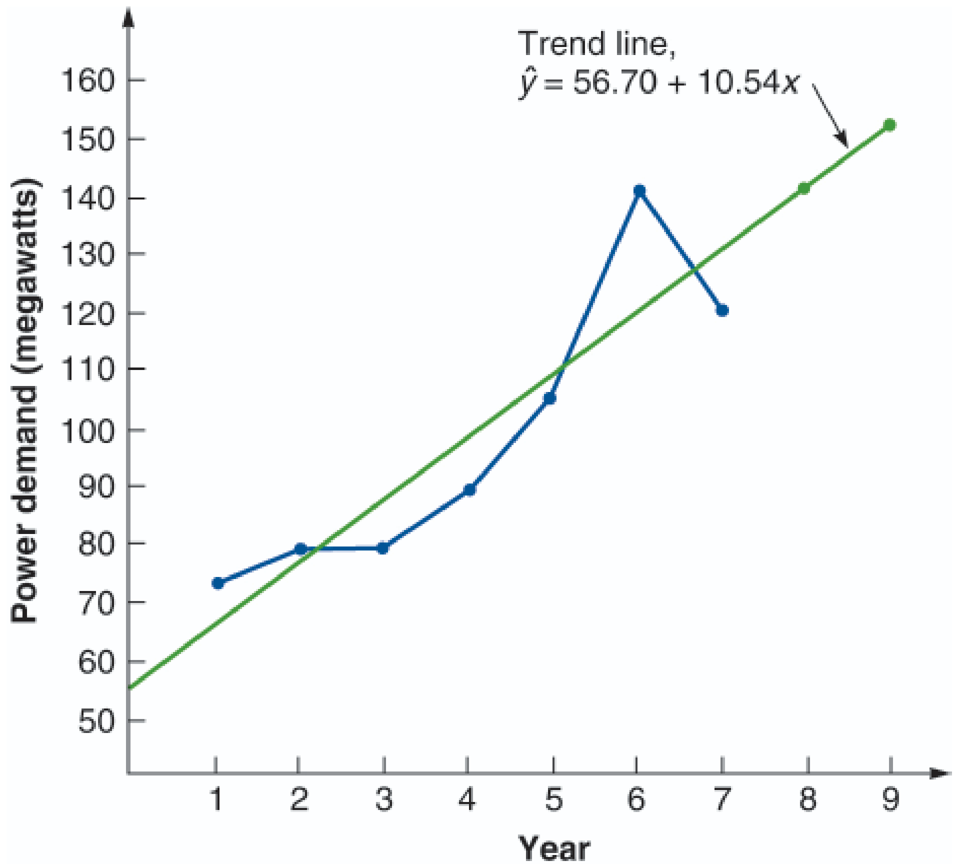
$$a = \bar{y} - b\bar{x} = 98.86 - 10.54(4) = 56.70$$

$$\text{Thus,} \quad \hat{y} = 56.70 + 10.54x$$

Demand in year 8 = 56.70 + 10.54(8)
= 141.02, or 141 megawatts

Least Squares Example (4 of 4)

Figure 4.5



Least Squares Requirements

1. We always plot the data to insure a linear relationship
2. We do not predict time periods far beyond the database
3. Deviations around the least squares line are assumed to be random

Seasonal Variations In Data (1 of 2)

The multiplicative seasonal model can adjust trend data for seasonal variations in demand

Seasonal Variations In Data (2 of 2)

Steps in the process for monthly seasons:

1. Find average historical demand for each month
2. Compute the average demand over all months
3. Compute a seasonal index for each month
4. Estimate next year's total demand
5. Divide this estimate of total demand by the number of months, then multiply it by the seasonal index for that month

Seasonal Index Example (1 of 6)

DEMAND						
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90		
Feb	70	85	85	80		
Mar	80	93	82	85		
Apr	90	95	115	100		
May	113	125	131	123		
June	110	115	120	115		
July	100	102	113	105		
Aug	88	102	110	100		
Sept	85	90	95	90		
Oct	77	78	85	80		
Nov	75	82	83	80		
Dec	82	78	80	80		
Total average annual demand =				1,128		

Seasonal Index Example (2 of 6)

DEMAND						
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	
Feb	70	85	85	80	94	
Mar	[illegible]	[illegible]	[illegible]	[illegible]5	94	
Apr	[illegible]	[illegible]	[illegible]	[illegible]0	94	
May	[illegible]	[illegible]	[illegible]	[illegible]3	94	
June	[illegible]	[illegible]	[illegible]	[illegible]5	94	
July	100	102	113	105	94	
Aug	88	102	110	100	94	
Sept	85	90	95	90	94	
Oct	77	78	85	80	94	
Nov	75	82	83	80	94	
Dec	82	78	80	80	94	
Total average annual demand =				1,128		

$$\text{Average monthly demand} = \frac{1{,}128}{12 \text{ months}} = 94$$

Seasonal Index Example (3 of 6)

	DEMAND					
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	.957 (= 90/94)
Feb	70	85	85	80	94	
Mar	80	93	82	85	94	
Apr	90	95	115	100	94	
Sept	85	90	95	90	94	
Oct	77	78	85	80	94	
Nov	75	82	83	80	94	
Dec	82	78	80	80	94	
		Total average annual demand =		1,128		

$$\text{Seasonal index} = \frac{\text{Average monthly demand for past 3 years}}{\text{Average monthly demand}}$$

Seasonal Index Example (4 of 6)

	DEMAND					
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	.957 (= 90/94)
Feb	70	85	85	80	94	.851 (= 80/94)
Mar	80	93	82	85	94	.904 (= 85/94)
Apr	90	95	115	100	94	1.064 (= 100/94)
May	113	125	131	123	94	1.309 (= 123/94)
June	110	115	120	115	94	1.223 (= 115/94)
July	100	102	113	105	94	1.117 (= 105/94)
Aug	88	102	110	100	94	1.064 (= 100/94)
Sept	85	90	95	90	94	.957 (= 90/94)
Oct	77	78	85	80	94	.851 (= 80/94)
Nov	75	82	83	80	94	.851 (= 80/94)
Dec	82	78	80	80	94	.851 (= 80/94)
		Total average annual demand =		1,128		

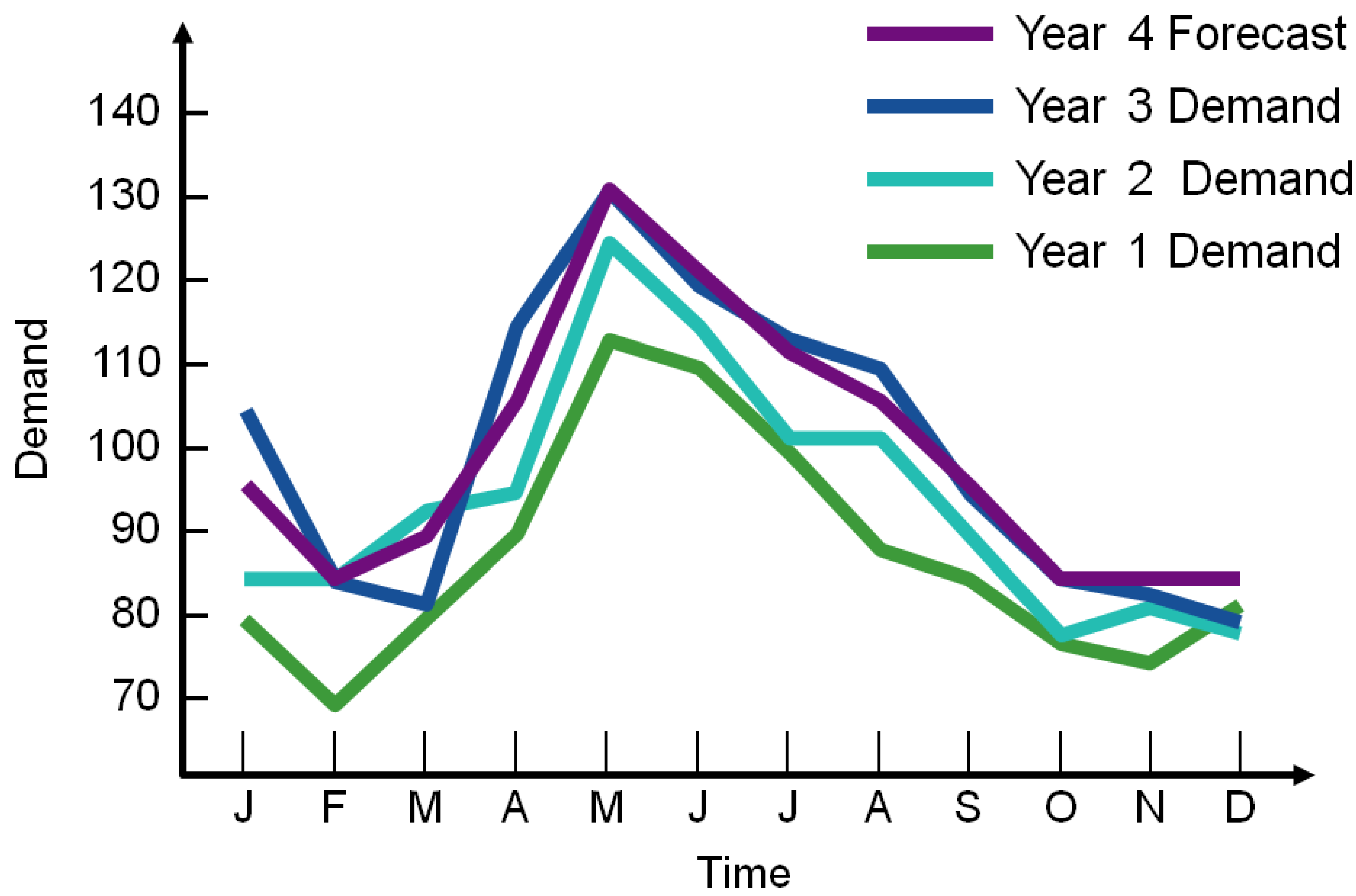
Pearson

Seasonal Index Example (5 of 6)

Seasonal forecast for Year 4

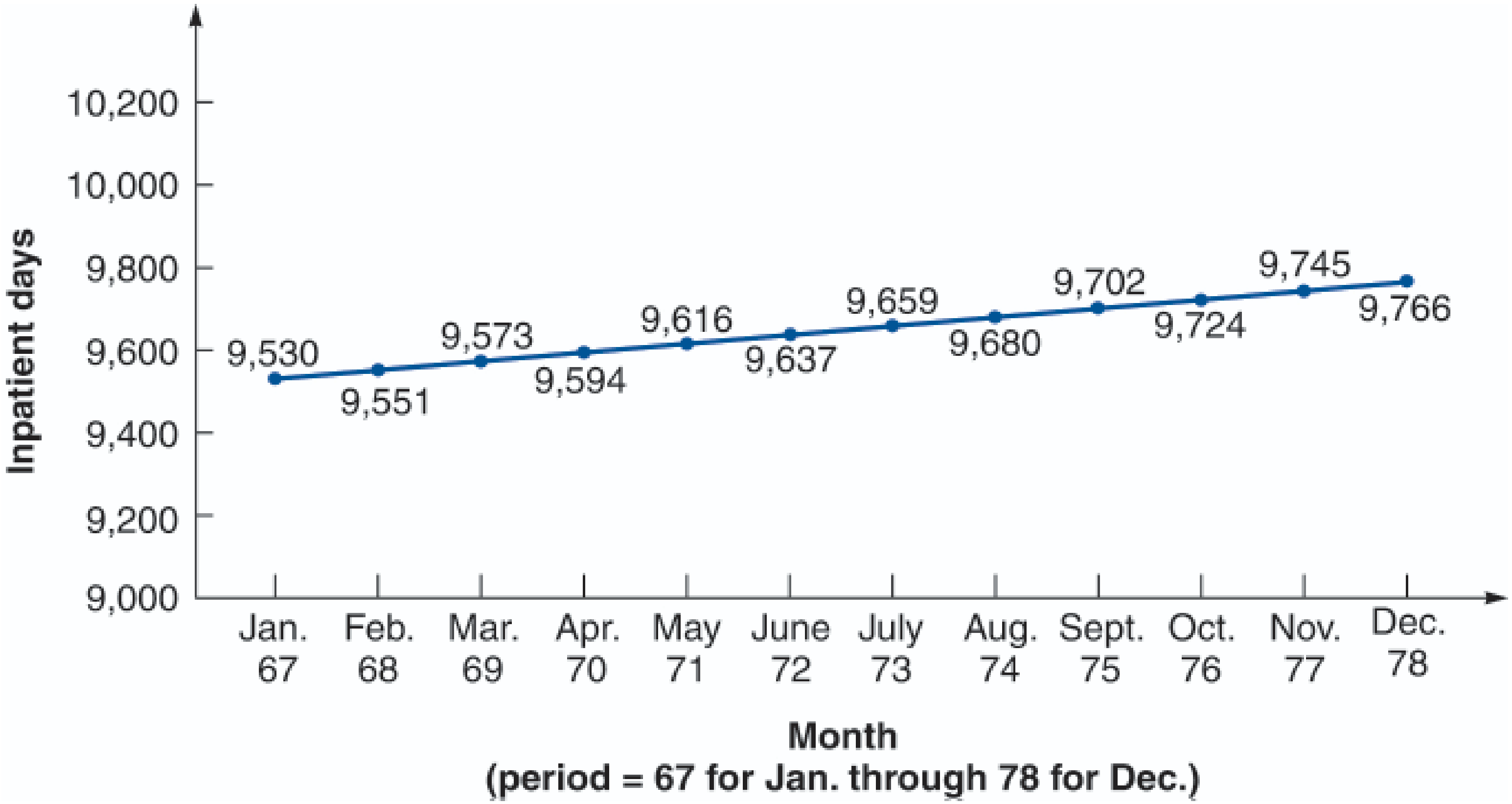
MONTH	DEMAND	MONTH	DEMAND
Jan	$\frac{1,200}{12} \times .957 = 96$	July	$\frac{1,200}{12} \times 1.117 = 112$
Feb	$\frac{1,200}{12} \times .851 = 85$	Aug	$\frac{1,200}{12} \times 1.064 = 106$
Mar	$\frac{1,200}{12} \times .904 = 90$	Sept	$\frac{1,200}{12} \times .957 = 96$
Apr	$\frac{1,200}{12} \times 1.064 = 106$	Oct	$\frac{1,200}{12} \times .851 = 85$
May	$\frac{1,200}{12} \times 1.309 = 131$	Nov	$\frac{1,200}{12} \times .851 = 85$
June	$\frac{1,200}{12} \times 1.223 = 122$	Dec	$\frac{1,200}{12} \times .851 = 85$

Seasonal Index Example (6 of 6)



San Diego Hospital (1 of 5)

Figure 4.6

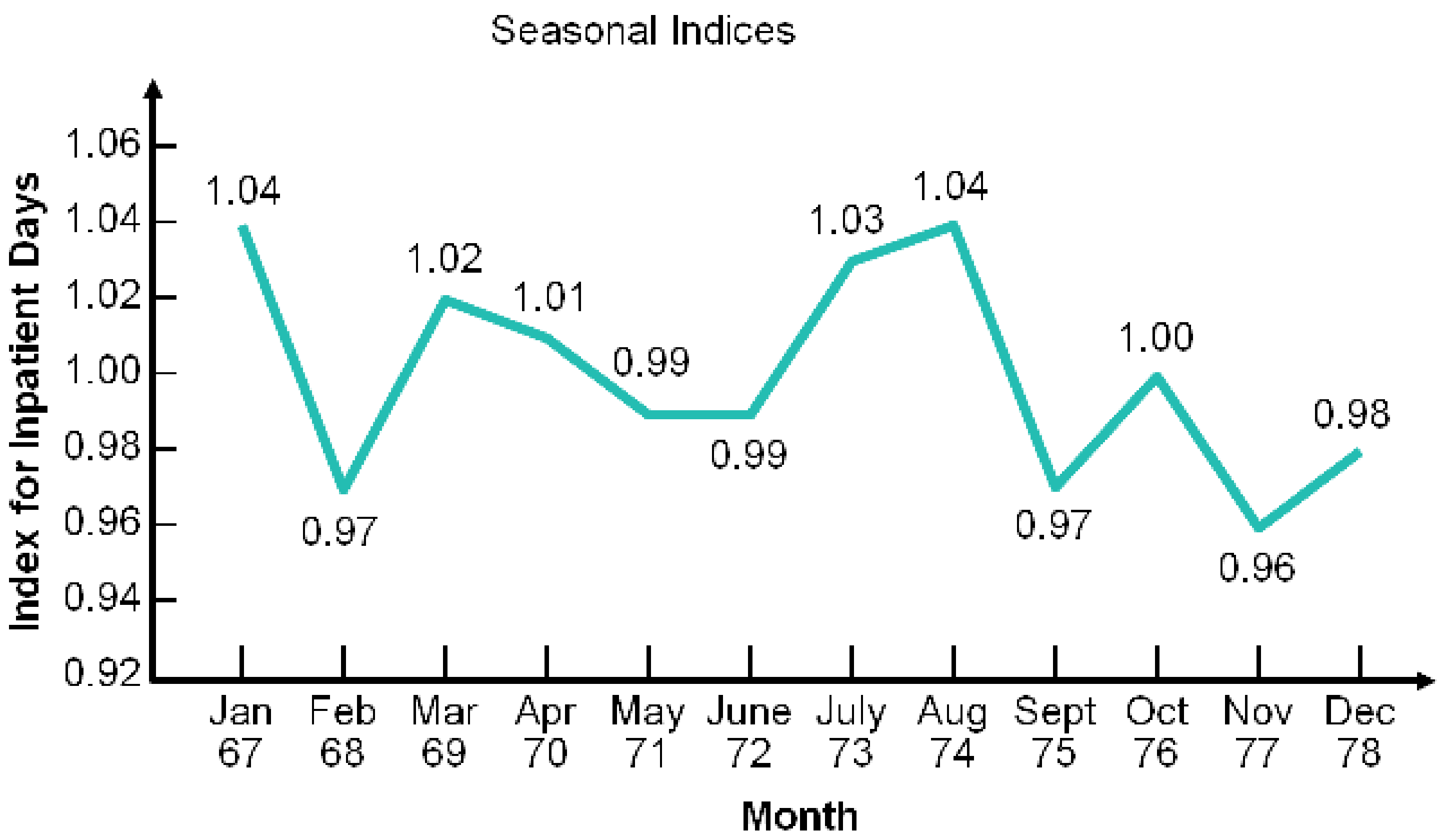


San Diego Hospital (2 of 5)

	Seasonality Indices for Adult Inpatient Days at San Diego Hospital		
MONTH	**SEASONALITY INDEX**	**MONTH**	**SEASONALITY INDEX**
January	1.04	July	1.03
February	0.97	August	1.04
March	1.02	September	0.97
April	1.01	October	1.00
May	0.99	November	0.96
June	0.99	December	0.98

San Diego Hospital (3 of 5)

Figure 4.7

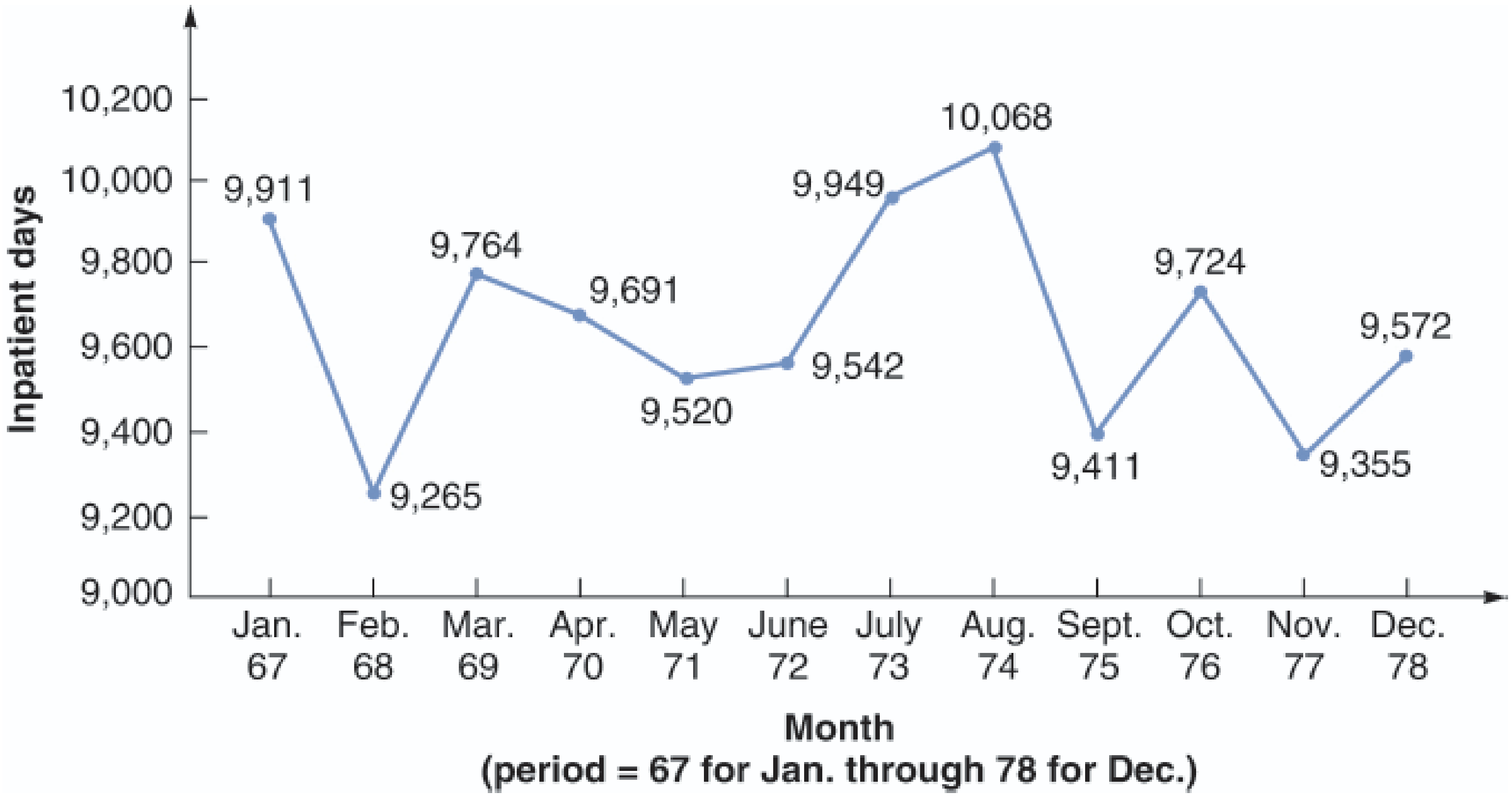


San Diego Hospital (4 of 5)

Period	67	68	69	70	71	72
Month	Jan	Feb	Mar	Apr	May	June
Forecast with Trend & Seasonality	9,911	9,265	9,764	9,691	9,520	9,542
Period	73	74	75	76	77	78
Month	July	Aug	Sept	Oct	Nov	Dec
Forecast with Trend & Seasonality	9,949	10,068	9,411	9,724	9,355	9,572

San Diego Hospital (5 of 5)

Figure 4.8



Adjusting Trend Data

$$\hat{y}_{seasonal} = \text{Index} \times \hat{y}_{trend\ forecast}$$

$$\text{Quarter I:} \quad \hat{y}_{I} = (1.30)(\$100,000) = \$130,000$$

$$\text{Quarter II:} \quad \hat{y}_{II} = (.90)(\$120,000) = \$108,000$$

$$\text{Quarter III:} \quad \hat{y}_{III} = (.70)(\$140,000) = \$98,000$$

$$\text{Quarter IV:} \quad \hat{y}_{IV} = (1.10)(\$160,000) = \$176,000$$

Cyclical Variations

- Cycles – patterns in the data that occur every several years
  - Forecasting is difficult
  - Wide variety of factors

Associative Forecasting

Used when changes in one or more independent variables can be used to predict the changes in the dependent variable

Most common technique is **linear-regression analysis**

We apply this technique just as we did in the time-series example

Trend Projections (2 of 2)

Forecasting an outcome based on predictor variables using the least squares technique

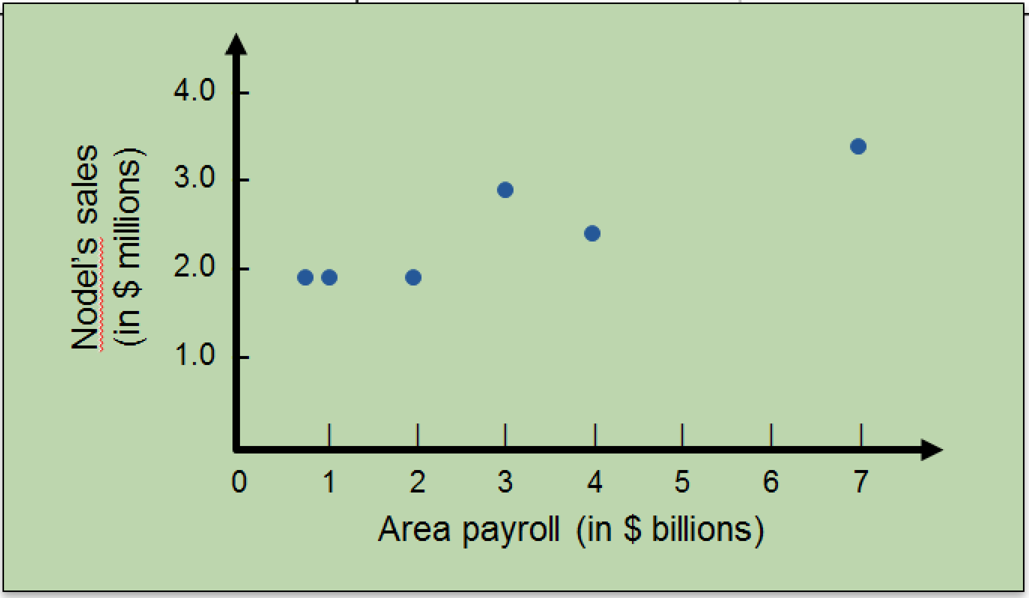
$$\hat{y} = a + bx$$

where $\hat{y}$ = value of the dependent variable (in our example, sales)

a = y-axis intercept
b = slope of the regression line
x = the independent variable

Associative Forecasting Example
(1 of 6)

NODEL'S SALES (IN $ MILLIONS), y	AREA PAYROLL (IN $ BILLIONS), x	NODEL'S SALES (IN $ MILLIONS), y	AREA PAYROLL (IN $ BILLIONS), x
2.0	1	2.0	2
3.0	3	2.0	1
2.5	4	3.5	7



Associative Forecasting Example

SALES, y	PAYROLL, x	x^2	xy
2.0	1	1	2.0
3.0	3	9	9.0
2.5	4	16	10.0
2.0	2	4	4.0
2.0	1	1	2.0
3.5	7	49	24.5
$\Sigma y =$ 15.0	$\Sigma x =$ 18	$\Sigma x^2 =$ 80	$\Sigma xy =$ 51.5

$$\bar{x} = \frac{\sum x}{6} = \frac{18}{6} = 3 \qquad \bar{y} = \frac{\sum y}{6} = \frac{15}{6} = 2.5$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

Associative Forecasting Example (3 of 6)

SALES, y	PAYROLL, x	x^2	xy
2.0			
3.0			
2.5			
2.0			
2.0			
3.5	7	49	24.5
$\Sigma y =$ 15.0	$\Sigma x =$ 18	$\Sigma x^2 =$ 80	$\Sigma xy =$ 51.5

$$\hat{y} = 1.75 + .25x$$

$$\text{Sales} = 1.75 + .25(\text{payroll})$$

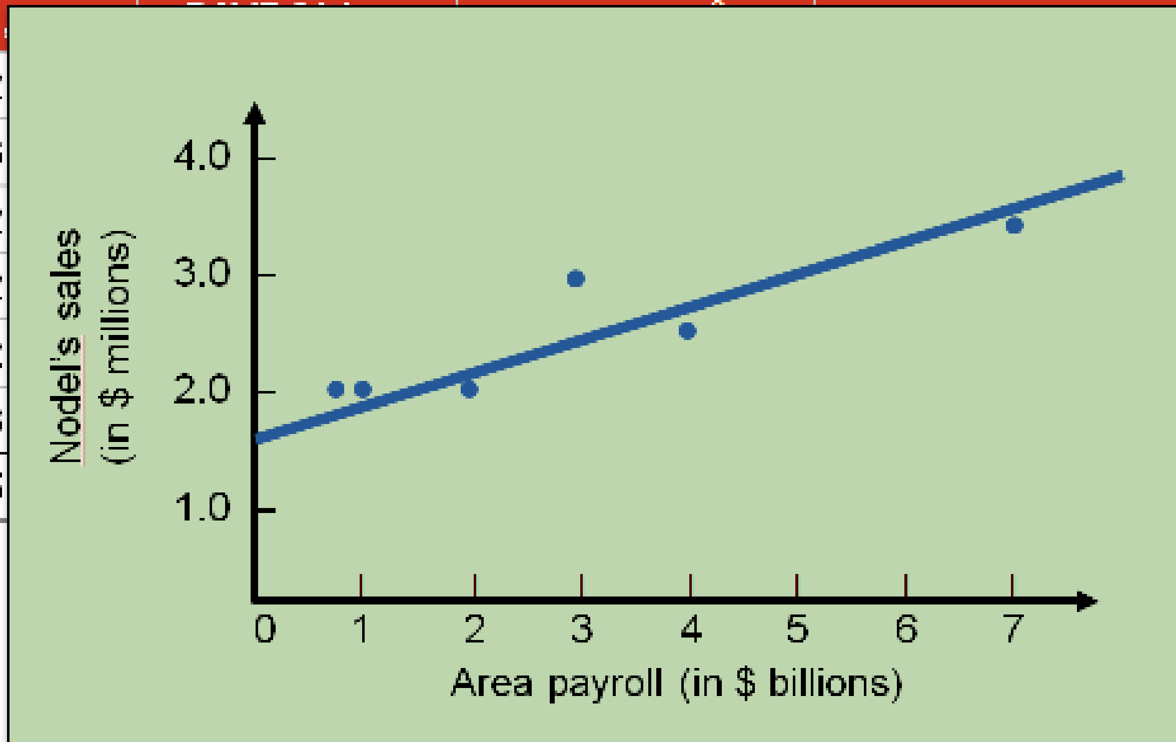
$$\bar{x} = \frac{\sum x}{6} = \frac{18}{6} = 3 \qquad \bar{y} = \frac{\sum y}{6} = \frac{15}{6} = 2.5$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

Pearson

Associative Forecasting Example (4 of 6)

SALES,
2
3
2
2
2
3
$\Sigma y =$ 15



$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

Associative Forecasting Example
(5 of 6)

If payroll next year is estimated to be \$6 billion, then:

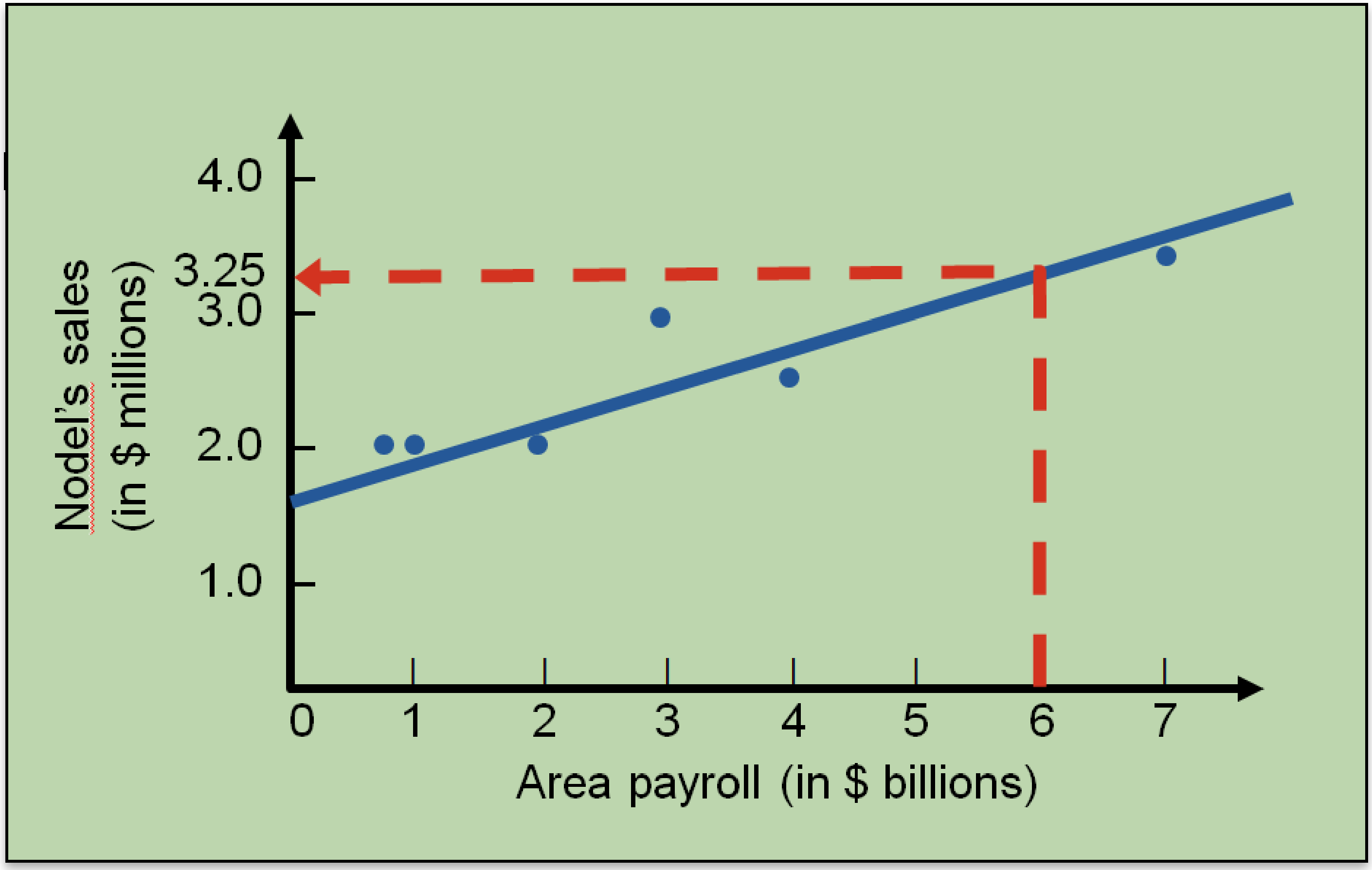
$$\text{Sales (in \$ millions)} = 1.75 + .25(6)$$

$$= 1.75 + 1.5 = 3.25$$

$$\text{Sales} = \$3{,}250{,}000$$

Associative Forecasting Example (6 of 6)

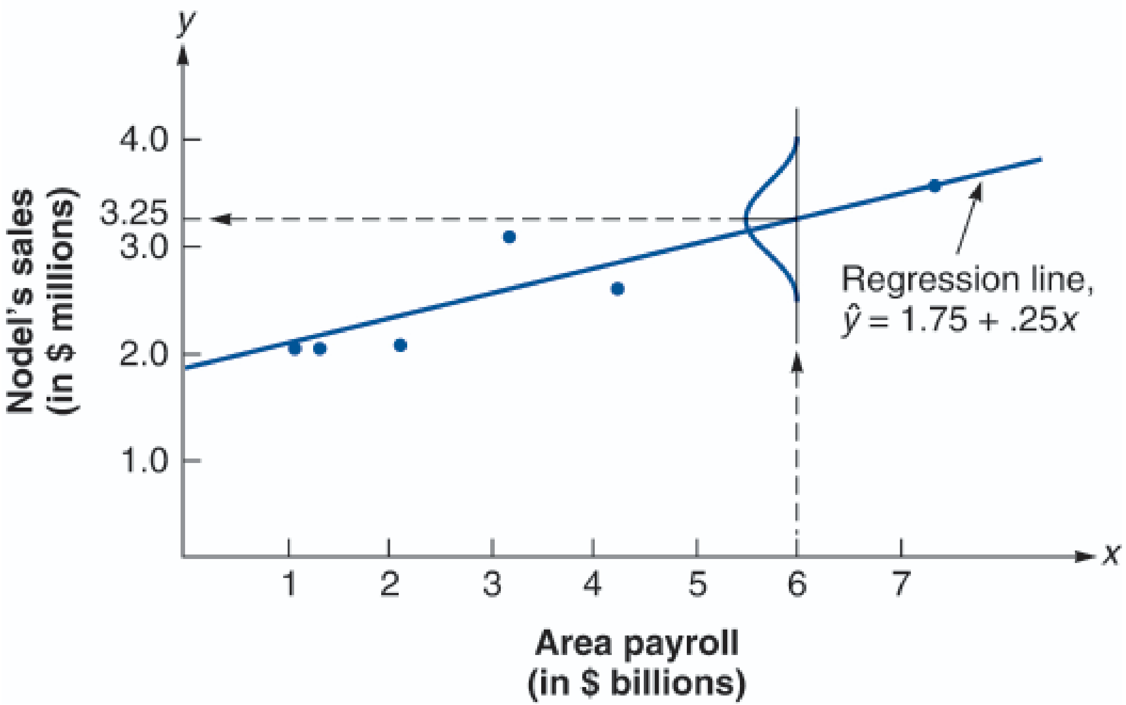
If pay
then:



Standard Error of the Estimate (1 of 4)

- A forecast is just a *point estimate* of a future value
- This point is actually the *mean* or *expected value* of a probability distribution

Figure 4.9



Standard Error of the Estimate (2 of 4)

$$S_{y,x} = \sqrt{\frac{\sum (y - y_c)^2}{n - 2}}$$

where y = y-value of each data point

y_c = computed value of the dependent variable, from the regression equation

n = number of data points

Standard Error of the Estimate (3 of 4)

Computationally, this equation is considerably easier to use

$$S_{y,x} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n-2}}$$

We use the standard error to set up prediction intervals around the point estimate

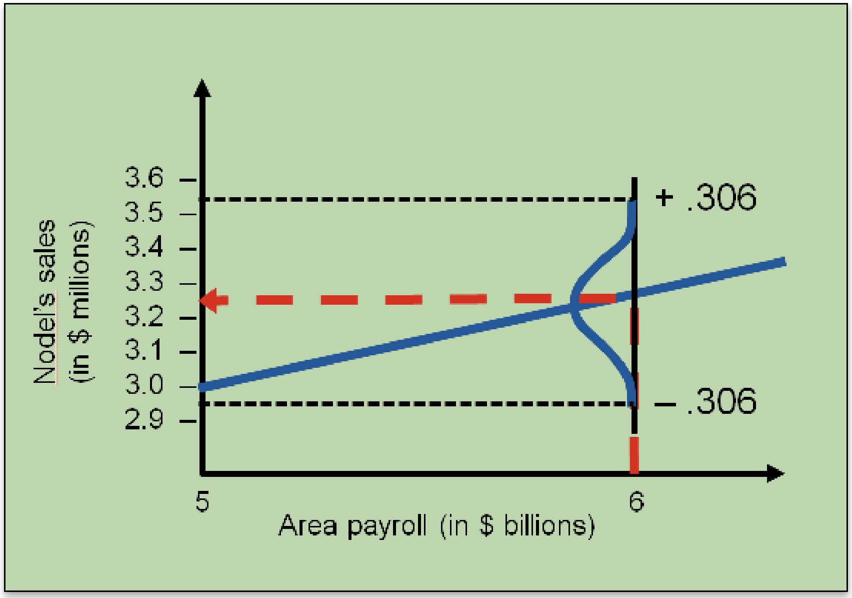
Standard Error of the Estimate (4 of 4)

$$S_{y,x} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n-2}} = \sqrt{\frac{39.5 - 1.75(15.0) - .25(51.5)}{6-2}}$$

$$= \sqrt{.09375}$$

$$= .306 (in\ \$\ millions)$$

The standard error of the estimate is $306,000 in sales

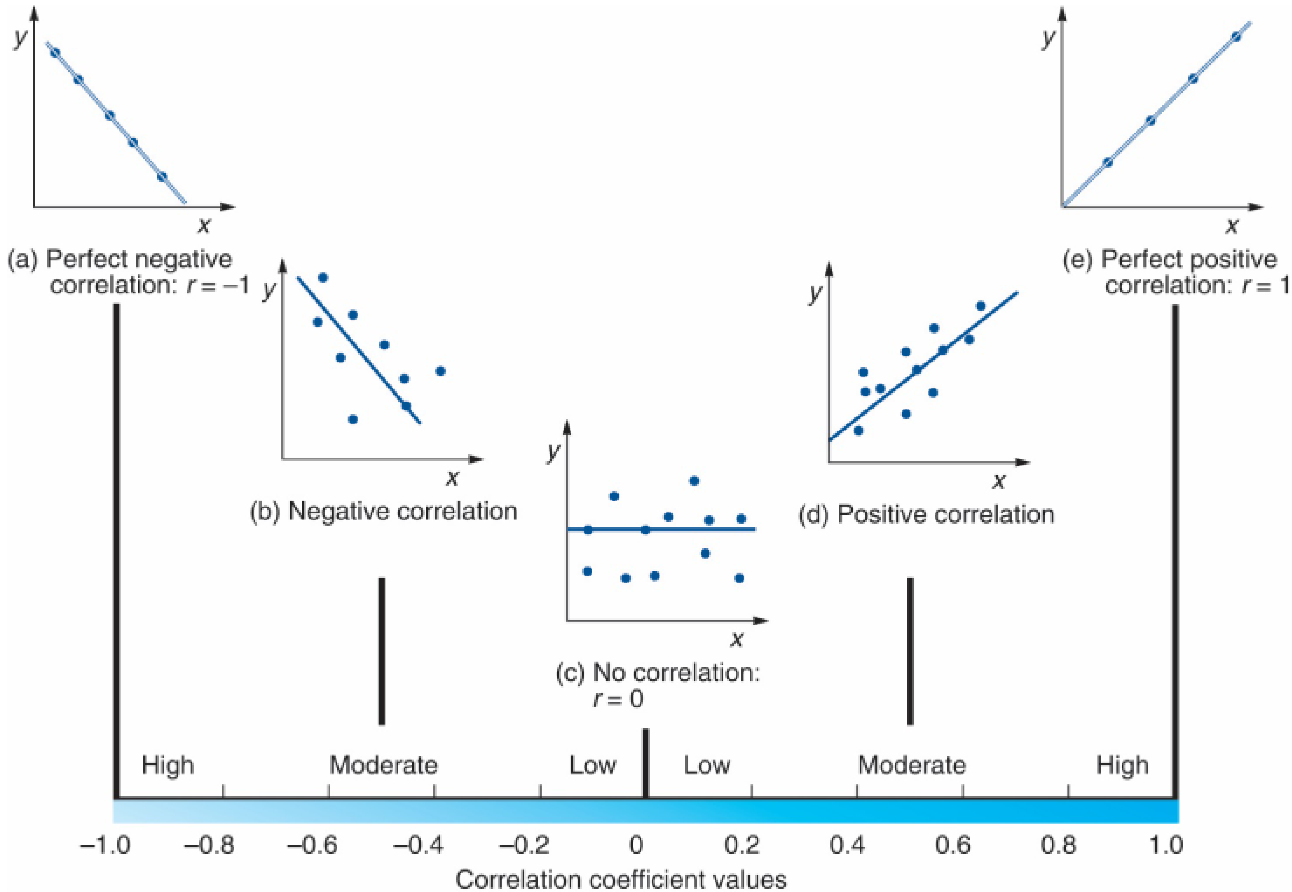


Correlation (1 of 2)

- How strong is the linear relationship between the variables?
- Correlation does not necessarily imply causality!
- **Coefficient of correlation**, r, measures degree of association
  - Values range from -1 to $+1$

Correlation Coefficient (1 of 4)

Figure 4.10



Correlation Coefficient (2 of 4)

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 \left(\sum x\right)^2\right]\left[n\sum y^2 \left(\sum y\right)^2\right]}}$$

Correlation Coefficient (3 of 4)

y	x	x^2	xy	y^2
2.0	1	1	2.0	4.0
3.0	3	9	9.0	9.0
2.5	4	16	10.0	6.25
2.0	2	4	4.0	4.0
2.0	1	1	2.0	4.0
3.5	7	49	24.5	12.25
$\Sigma y =$ 15.0	$\Sigma x =$ 18	$\Sigma x^2 =$ 80	$\Sigma xy =$ 51.5	$\Sigma y^2 =$ 39.5

$$r = \frac{(6)(51.5) - (18)(15.0)^2}{\sqrt{\left[(6)(80) - (18)^2\right]\left[(16)(39.5) - (15.0)^2\right]}}$$

$$= \frac{309 - 270}{\sqrt{(156)(12)}} = \frac{39}{\sqrt{1,872}} = \frac{39}{43.3} = .901$$

Correlation (2 of 2)

- **Coefficient of Determination**, r^2, measures the percent of change in y predicted by the change in x
  - Values range from 0 to 1
  - Easy to interpret

For the Nodel Construction example:

$$r = .901$$

$$r^2 = .81$$

Multiple-Regression Analysis (1 of 2)

If more than one independent variable is to be used in the model, linear regression can be extended to multiple regression to accommodate several independent variables

$$\hat{y} = a + b_1 x_1 + b_2 x_2$$

Computationally, this is quite complex and generally done on the computer

Multiple-Regression Analysis (2 of 2)

In the Nodel example, including interest rates in the model gives the new equation:

$$\hat{y} = 1.80 + .30x_1 - 5.0x_2$$

An improved correlation coefficient of r = .96 suggests this model does a better job of predicting the change in construction sales

$$\text{Sales} = 1.80 + .30(6) - 5.0(.12) = 3.00$$
$$\text{Sales} = \$3,000,000$$

Monitoring and Controlling Forecasts (1 of 2)

Tracking Signal

- Measures how well the forecast is predicting actual values
- Ratio of cumulative forecast errors to mean absolute deviation (MAD)
  - Good tracking signal has low values
  - If forecasts are continually high or low, the forecast has a bias error

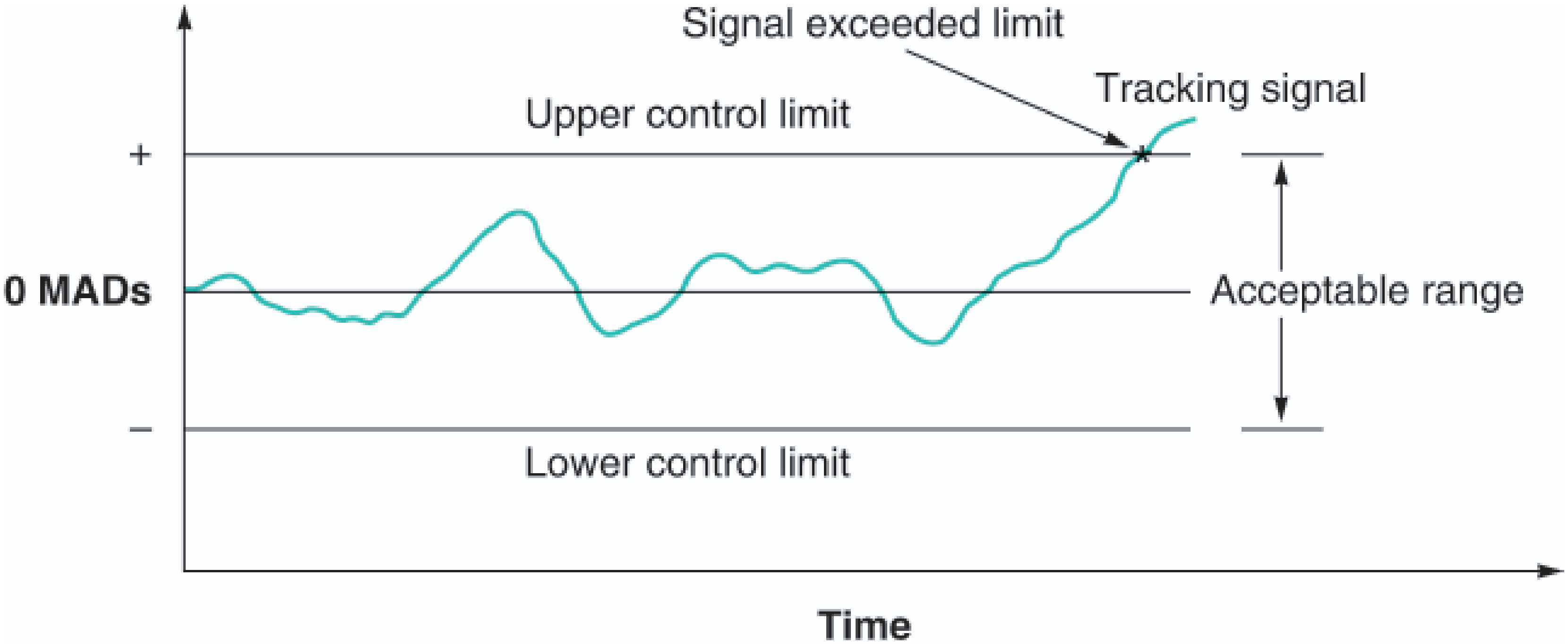
Monitoring and Controlling Forecasts (2 of 2)

$$\text{Tracking signal} = \frac{\text{Cumulative error}}{\text{MAD}}$$

$$= \frac{\sum (\text{Actual demand in period i - Forecast demad in period i})}{\dfrac{\sum |\text{Actual} - \text{Forecast}|}{n}}$$

Correlation Coefficient (4 of 4)

Figure 4.11



Tracking Signal Example

QTR	ACTUAL DEMAND	FORECAST DEMAND	ERROR	CUM ERROR	ABSOLUTE FORECAST ERROR	CUM ABS FORECAST ERROR	MAD	TRACKING SIGNAL (CUM ERROR/MAD)
1	90	100	–10	–10	10	10	10.0	–10/10 = –1
2	95	100	–5	–15	5	15	7.5	–15/7.5 = –2
3	115	100	+15	0	15	30	10.0	0/10 = 0
4	100	110	–10	–10	10	40	10.0	10/10 = –1
5	125	110	+15	+5	15	55	11.0	+5/11 = +0.5
6	140	110	+30	+35	30	85	14.2	+35/14.2 = +2.5

$$\text{At the end of quarter 6, MAD} = \frac{\sum |\text{Forecast errors}|}{n} = \frac{85}{6} = 14.2$$

$$\text{Tracking signal} = \frac{\text{Cumulative error}}{\text{MAD}} = \frac{35}{14.2} = 2.5\text{ MADs}$$

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Adaptive Smoothing

- It's possible to use the computer to continually monitor forecast error and adjust the values of the α and β coefficients used in exponential smoothing to continually minimize forecast error
- This technique is called **adaptive smoothing**

Focus Forecasting

- Developed at American Hardware Supply, based on two principles:
  1. Sophisticated forecasting models are not always better than simple ones
  2. There is no single technique that should be used for all products or services
- Uses historical data to test multiple forecasting models for individual items
- Forecasting model with the lowest error used to forecast the next demand

Forecasting in the Service Sector

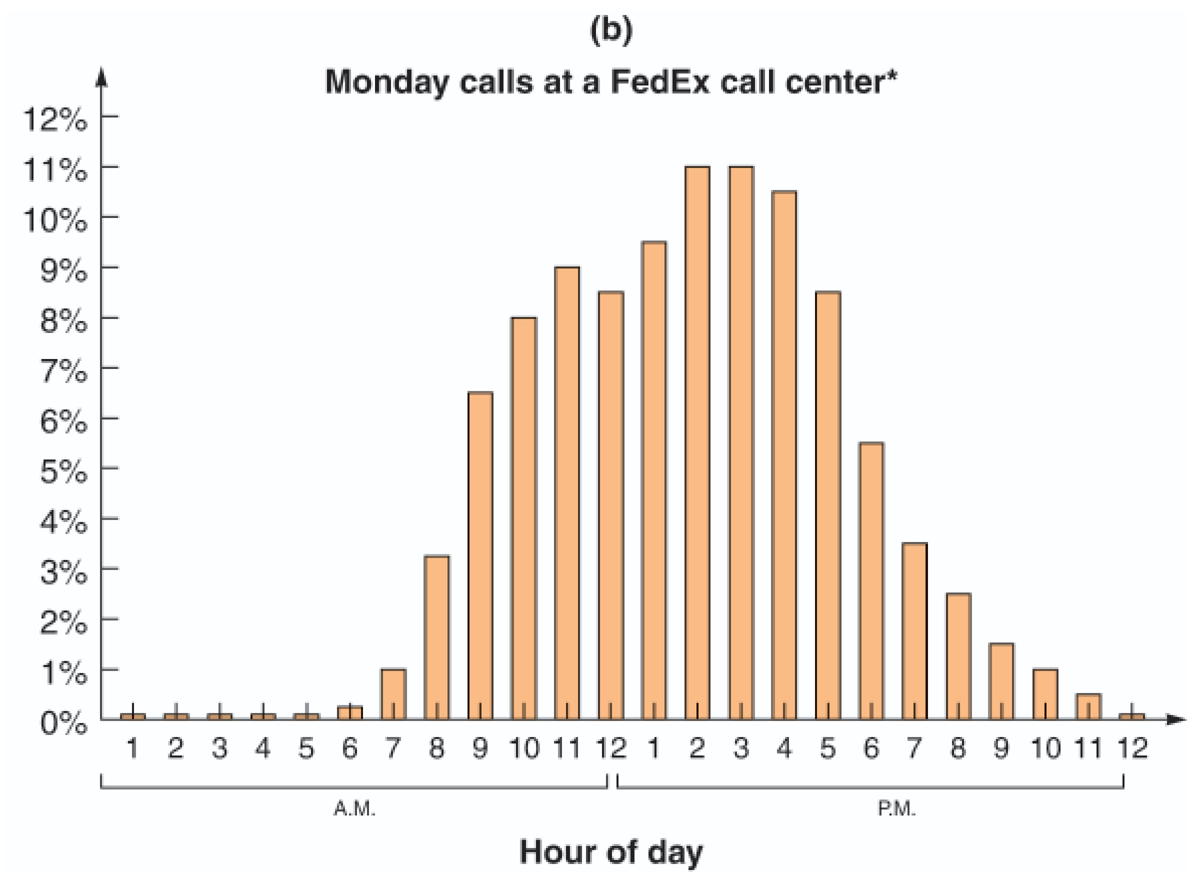
- Presents unusual challenges
  - Special need for short-term records
  - Needs differ greatly as function of industry and product
  - Holidays and other calendar events
  - Unusual events

Fast Food Restaurant Forecast

Figure 4.12a

FedEx Call Center Forecast

Figure 4.12b



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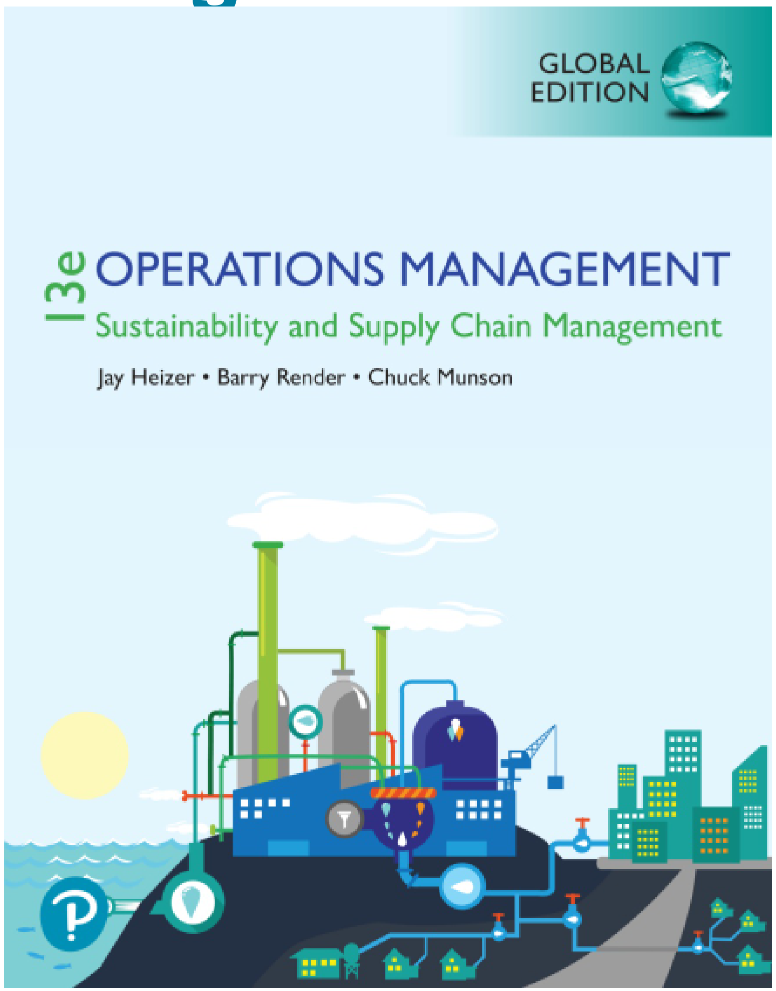


Chapter 6

Managing Quality

Pearson

Outline

- **Global Company Profile:** *Arnold Palmer Hospital*
- Quality and Strategy
- Defining Quality
- Total Quality Management
- Tools of TQM
- The Role of Inspection
- TQM in Services

Managing Quality Provides a Competitive Advantage

Arnold Palmer Hospital

- Delivers over 14,000 babies annually
- Virtually every type of quality tool is employed
  - Continuous improvement
  - Employee empowerment
  - Benchmarking
  - Just-in-time (JIT)
  - Quality tools

Pearson

Learning Objectives

When you complete this chapter you should be able to:

6.1 ***Define*** quality and T QM

6.2 ***Describe*** the ISO international quality standards

6.3 ***Explain*** Six Sigma

6.4 ***Explain*** how benchmarking is used in TQM

6.5 ***Explain*** quality robust products and Taguchi concepts

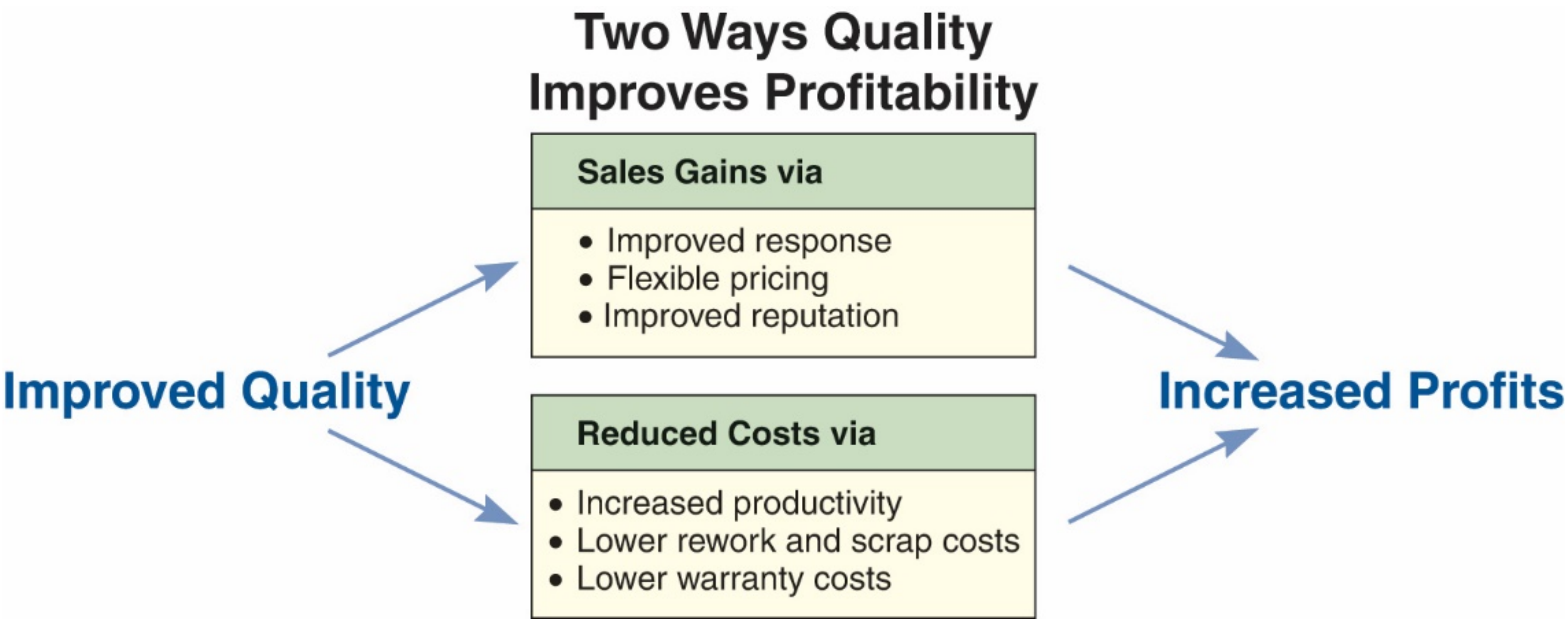
6.6 ***Use*** the seven tools of TQM

Quality and Strategy

- Managing quality supports *differentiation*, *low cost*, and *response* strategies
- Quality helps firms increase sales and reduce costs
- *Building* a quality organization is a demanding task

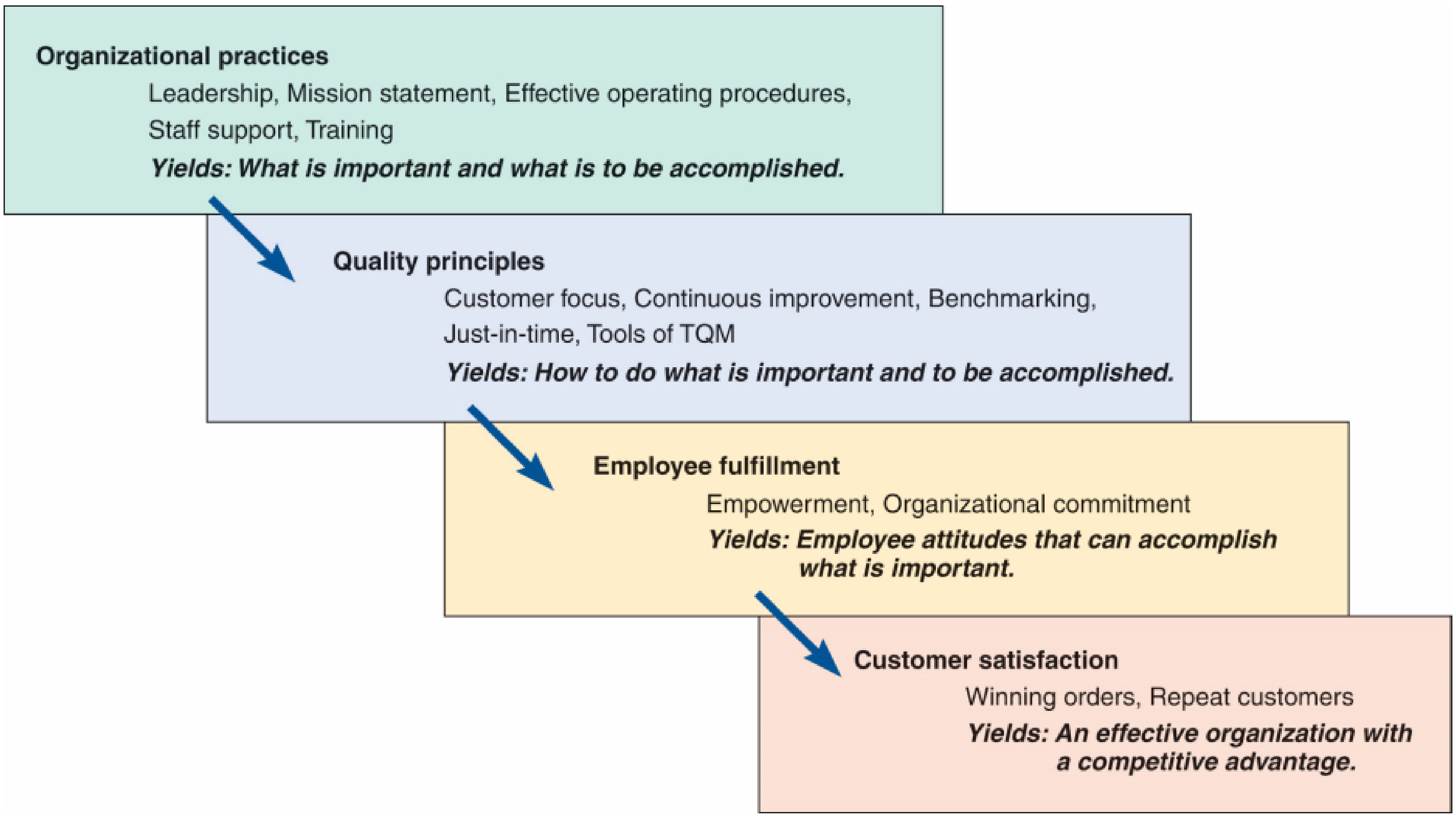
Two Ways Quality Improves Profitability

Figure 6.1



The Flow of Activities

Figure 6.2



Defining Quality (1 of 2)

An operations manager's objective is to build a total quality management system that identifies and satisfies customer needs

Defining Quality (2 of 2)

The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs

American Society for Quality

Different Views

- ***User based:*** better performance, more features
- ***Manufacturing based:*** conformance to standards, making it right the first time
- ***Product based:*** specific and measurable attributes of the product

Implications of Quality

1. Company reputation
   – Perception of new products
   – Employment practices
   – Supplier relations
2. Product liability
   – Reduce risk
4. Global implications
   – Improved ability to compete

Malcolm Baldrige National Quality Award

- Established in 1988 by the U.S. government
- Designed to promote TQM practices
- Recent winners include

  Bristol Tennessee Essential Services, Stellar Solutions, Adventist Health Castle, MidwayUSA, Charter School of San Diego, Mid-America Transplant Services, Hill Country Memorial, Elevations Credit Union, MESA Products Inc.

Baldrige Criteria

Applicants are evaluated on:

CATEGORIES	POINTS
Leadership	120
Strategic Planning	85
Customer Focus	85
Measurement, Analysis, and Knowledge Management	90
Workforce Focus	85
Operations Focus	85
Results	450

ISO 9000 International Quality Standards (1 of 2)

- International recognition
- Encourages quality management procedures, detailed documentation, work instructions, and recordkeeping
- 2015 revision gives greater emphasis to *risk-based thinking*
- Over 1.6 million certifications in 201 countries
- Critical for global business

ISO 9000 International Quality Standards (2 of 2)

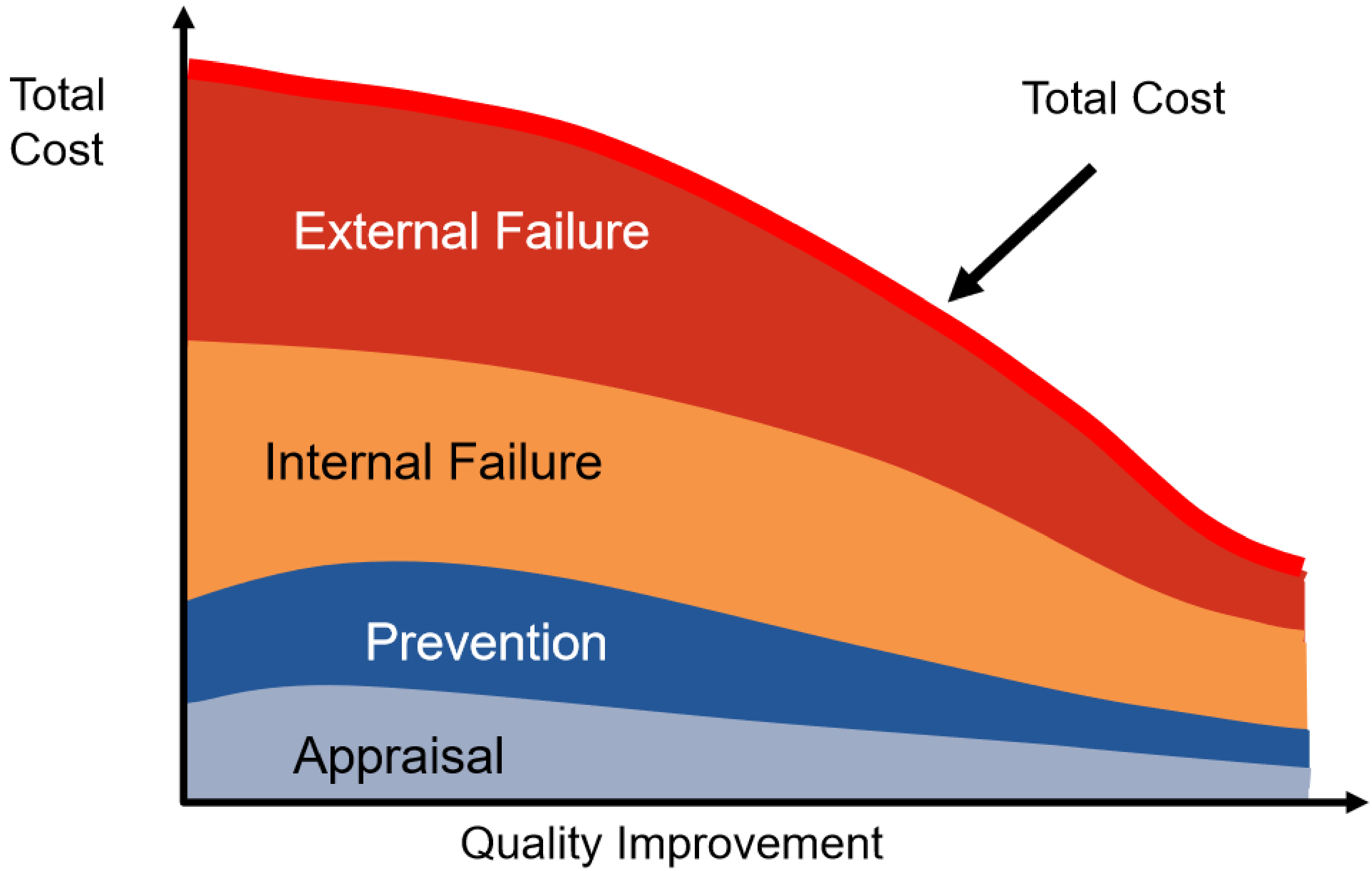
- Management principles

1. Top management leadership
2. Customer satisfaction
3. Continual improvement
4. Involvement of people
5. Process analysis
6. Use of data-driven decision making
7. A systems approach to management
8. Mutually beneficial supplier relationships

Costs of Quality (1 of 2)

- *Prevention costs* - reducing the potential for defects
- *Appraisal costs* - evaluating products, parts, and services
- *Internal failure costs* - producing defective parts or service before delivery
- *External failure costs* - defects discovered after delivery

Costs of Quality (2 of 2)



Takumi

A Japanese character that symbolizes a broader dimension than quality, a deeper process than education, and a more perfect method than persistence

Leaders in Quality (1 of 2)

Table 6.1 Leaders in the Field of Quality Management

LEADER	PHILOSOPHY/CONTRIBUTION
W. Edwards Deming	Deming insisted management accept responsibility for building good systems. The employee cannot produce products that on average exceed the quality of what the process is capable of producing. His 14 points for implementing quality improvement are presented in this chapter.
Joseph M. Juran	A pioneer in teaching the Japanese how to improve quality, Juran believed strongly in top-management commitment, support, and involvement in the quality effort. He was also a believer in teams that continually seek to raise quality standards. Juran varies from Deming somewhat in focusing on the customer and defining quality as fitness for use, not necessarily the written specifications.

Leaders in Quality (2 of 2)

Table 6.1 Leaders in the Field of Quality Management

LEADER	PHILOSOPHY/CONTRIBUTION
Armand Feigenbaum	His 1961 book Total Quality Control laid out 40 steps to quality improvement processes. He viewed quality not as a set of tools but as a total field that integrated the processes of a company. His work in how people learn from each other's successes led to the field of cross-functional teamwork.
Philip B. Crosby	Quality Is Free was Crosby's attention-getting book published in 1979. Crosby believed that in the traditional trade-off between the cost of improving quality and the cost of poor quality, the cost of poor quality is understated. The cost of poor quality should include all of the things that are involved in not doing the job right the first time. Crosby coined the term zero defects and stated, "There is absolutely no reason for having errors or defects in any product or service."

Ethics and Quality Management

- Operations managers must deliver healthy, safe, quality products and services
- Poor quality risks injuries, lawsuits, recalls, and regulation
- Ethical conduct must dictate response to problems
- All stakeholders must be considered

Total Quality Management

- Encompasses entire organization from supplier to customer
- Stresses a commitment by management to have a continuing companywide drive toward excellence in all aspects of products and services that are important to the customer

Deming's Fourteen Points (1 of 2)

Table 6.2 Deming's 14 Points for Implementing Quality Improvement

1.	Create consistency of purpose
2.	Lead to promote change
3.	Build quality into the product; stop depending on inspections to catch problems
4.	Build long-term relationships based on performance instead of awarding business on price
5.	Continuously improve product, quality, and service
6.	Start training
7.	Emphasize leadership

Deming's Fourteen Points (2 of 2)

Table 6.2 Deming's 14 Points for Implementing Quality Improvement

8.	Drive out fear
9.	Break down barriers between departments
10.	Stop haranguing workers
11.	Support, help, and improve
12.	Remove barriers to pride in work
13.	Institute a vigorous program of education and self-improvement
14.	Put everyone in the company to work on the transformation

Seven Concepts of TQM

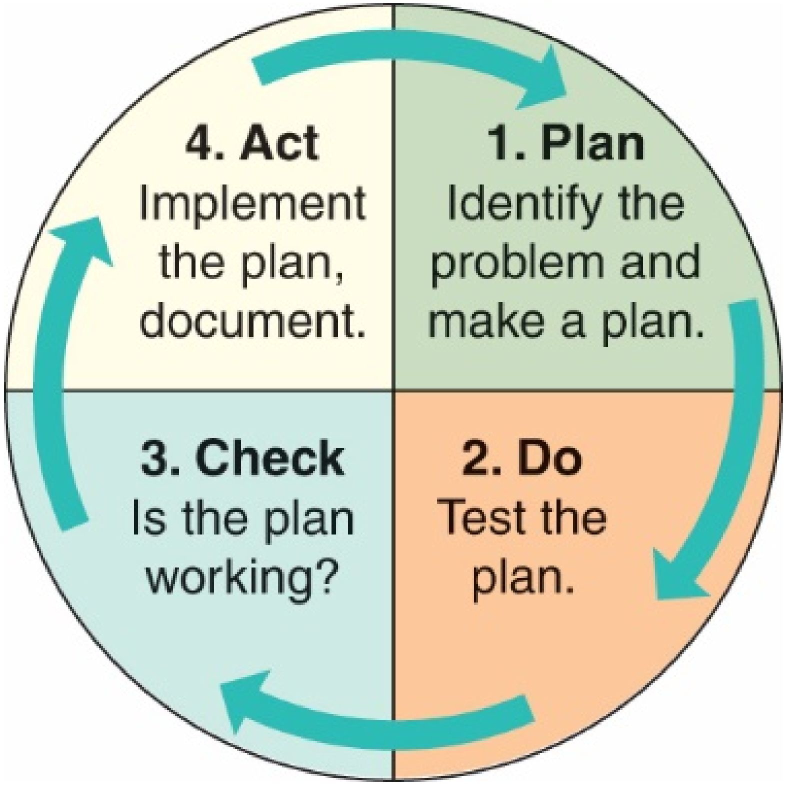
1) Continuous improvement
2) Six Sigma
3) Employee empowerment
4) Benchmarking
5) Just-in-time (JIT)
6) Taguchi concepts
7) Knowledge of TQM tools

Continuous Improvement (1 of 2)

- Never-ending process of continuous improvement
- Covers people, equipment, suppliers, materials, procedures
- Every operation can be improved

Shewhart's PDCA Model

Figure 6.3



Continuous Improvement (2 of 2)

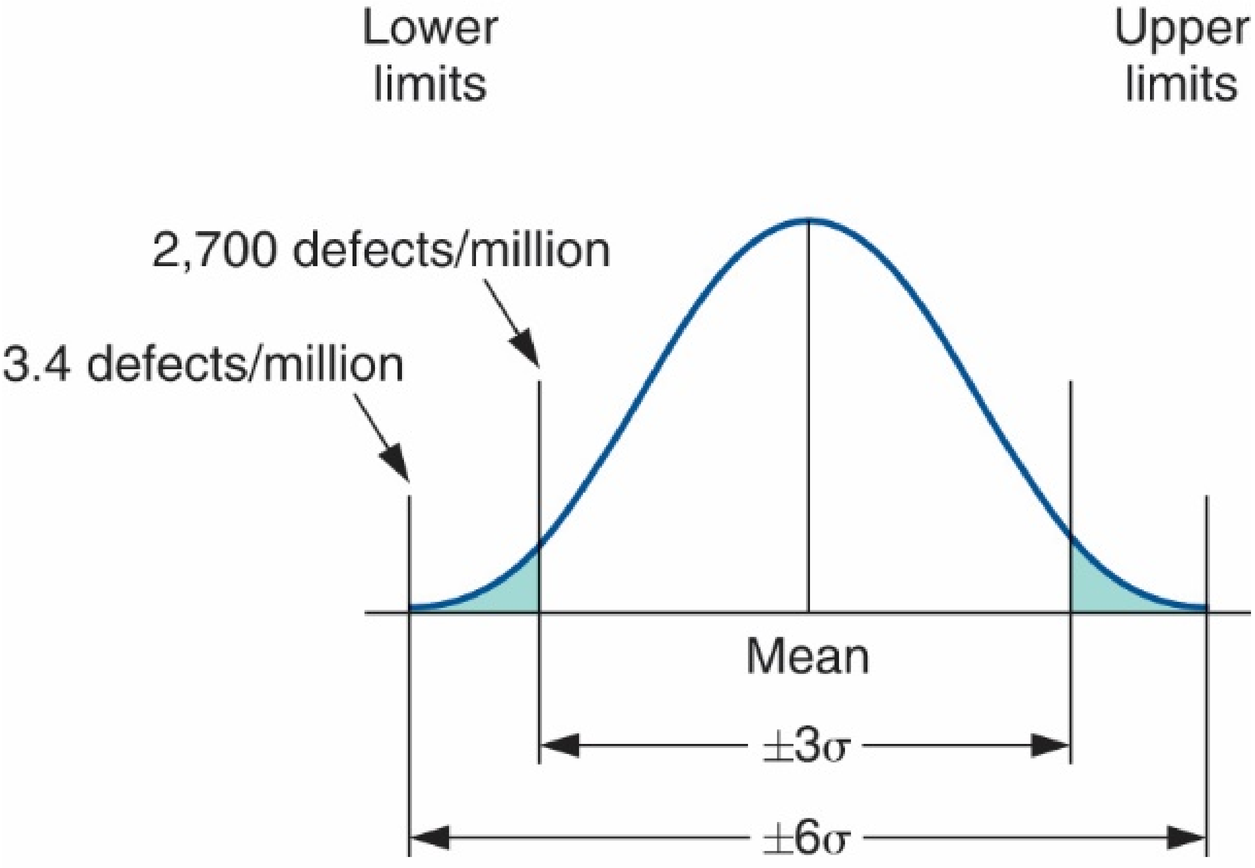
- *Kaizen* describes the ongoing process of unending improvement
- *TQM and zero defects* also used to describe continuous improvement

Six Sigma (1 of 3)

- Two meanings
  - *Statistical* definition of a process that is 99.9997% capable, 3.4 defects per million opportunities (DPMO)
  - A *program* designed to reduce defects, lower costs, save time, and improve customer satisfaction
- A comprehensive system for achieving and sustaining business success

Six Sigma (2 of 3)

Figure 6.4



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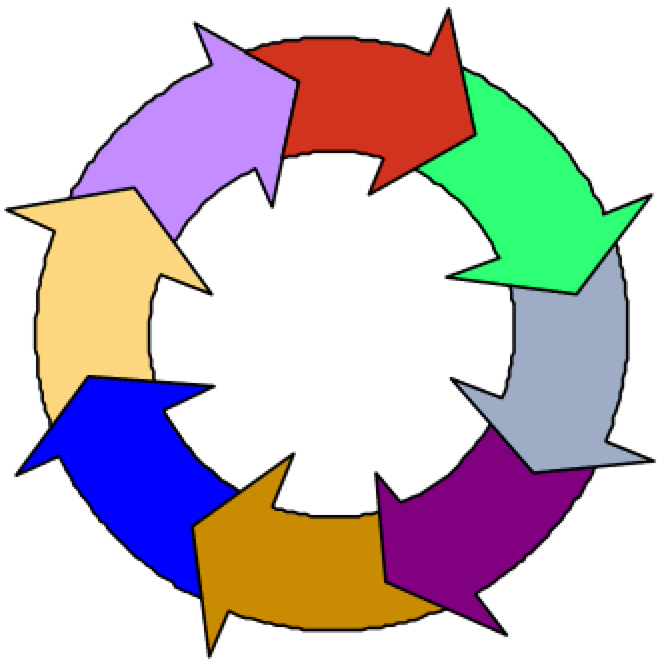
Six Sigma Program

- Originally developed by Motorola, adopted and enhanced by Honeywell and GE
- Highly structured approach to process improvement
- A strategy
- A discipline – DMAIC
- A set of 7 tools

Six Sigma (3 of 3)

- ***Defines*** the project's purpose, scope, and outputs, then identifies the required process information keeping in mind the customer's definition of quality
- ***Measures*** the process and collects data
- ***Analyzes*** the data, ensuring repeatability and reproducibility
- ***Improves*** by modifying or redesigning existing processes and procedures
- ***Controls*** the new process to make sure performance levels are maintained

DMAIC Approach



Implementing Six Sigma (1 of 2)

- Emphasize defects per million opportunities as a standard metric
- Provide extensive training
- Focus on top management leadership (Champion)
- Create qualified process improvement experts (Black Belts, Green Belts, etc.)
- Set stretch objectives

Implementing Six Sigma (2 of 2)

- Emphasize defects per million opportunities as a standard metric
- Provide extensive training
- Focus on top management leadership (Champion)
- Create qualified process improvement experts (Black Belts, Green Belts, etc.)
- Set stretch objectives

This cannot be accomplished without a major commitment from top level management

Employee Empowerment

- Getting employees involved in product and process improvements
  - 85% of quality problems are due to materials and process
- Techniques
  1. Build communication networks that include employees
  2. Develop open, supportive supervisors
  3. Move responsibility to employees
  4. Build a high-morale organization
  5. Create formal team structures

Quality Circles

- Group of employees who meet regularly to solve problems
- Trained in planning, problem solving, and statistical methods
- Often led by a *facilitator*
- Very effective when done properly

Benchmarking

Selecting best practices to use as a standard for performance

1. Determine what to benchmark
2. Form a benchmark team
3. Identify benchmarking partners
4. Collect and analyze benchmarking information
5. Take action to match or exceed the benchmark

Best Practices for Resolving Customer Complaints

Table 6.3

BEST PRACTICE	JUSTIFICATION
Make it easy for clients to complain	It is free market research
Respond quickly to complaints	It adds customers and loyalty
Resolve complaints on first contact	It reduces cost
Use computers to manage complaints	Discover trends, share them, and align your services
Recruit the best for customer service jobs	It should be part of formal training and career advancement

Internal Benchmarking

- When the organization is large enough
- Data more accessible
- Can and should be established in a variety of areas

Just-in-Time (JIT) (1 of 2)

- 'Pull' system of production scheduling including supply management
  - Production only when signaled
- Allows reduced inventory levels
  - Inventory costs money and hides process and material problems
- Encourages improved process and product quality

Just-in-Time (JIT) (2 of 2)

Relationship to quality:

- JIT cuts the cost of quality
- JIT improves quality
- Better quality means less inventory and better, easier-to-employ JIT system

Pearson

Taguchi Concepts

- Engineering and experimental design methods to improve product and process design
  - Identify key component and process variables affecting product variation
- Taguchi Concepts
  - *Quality robustness*
  - *Target-oriented quality*
  - *Quality loss function*

Quality Robustness

- Ability to produce products uniformly in adverse manufacturing and environmental conditions
  - Remove the *effects* of adverse conditions
  - Small variations in materials and process do not destroy product quality

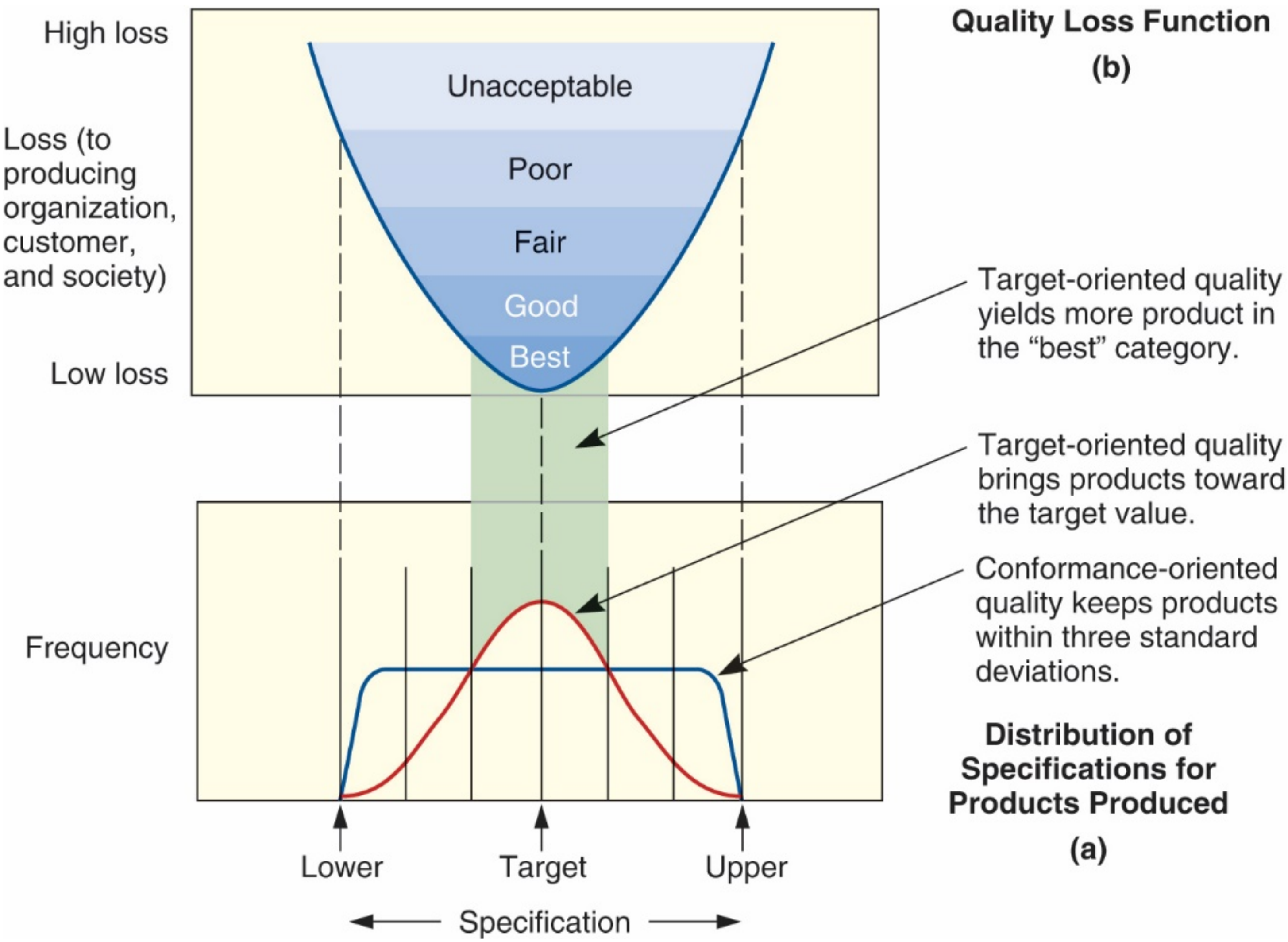
Quality Loss Function (1 of 2)

- Shows that costs increase as the product moves away from what the customer wants
- Costs include customer dissatisfaction, warranty and service, internal scrap and repair, and costs to society
- Traditional conformance specifications are too simplistic

Target-oriented quality

Quality Loss Function (2 of 2)

Figure 6.5



TQM Tools (1 of 2)

- Tools for Generating Ideas
  - Check Sheet
  - Scatter Diagram
  - Cause-and-Effect Diagram
- Tools to Organize the Data
  - Pareto Chart
  - Flowchart (Process Diagram)

TQM Tools (2 of 2)

- Tools for Identifying Problems
  - Histogram
  - Statistical Process Control Chart

Seven Tools of TQM (1 of 7)

Figure 6.6

(a) *Check Sheet:* An organized method of recording data

Tools for Generating Ideas

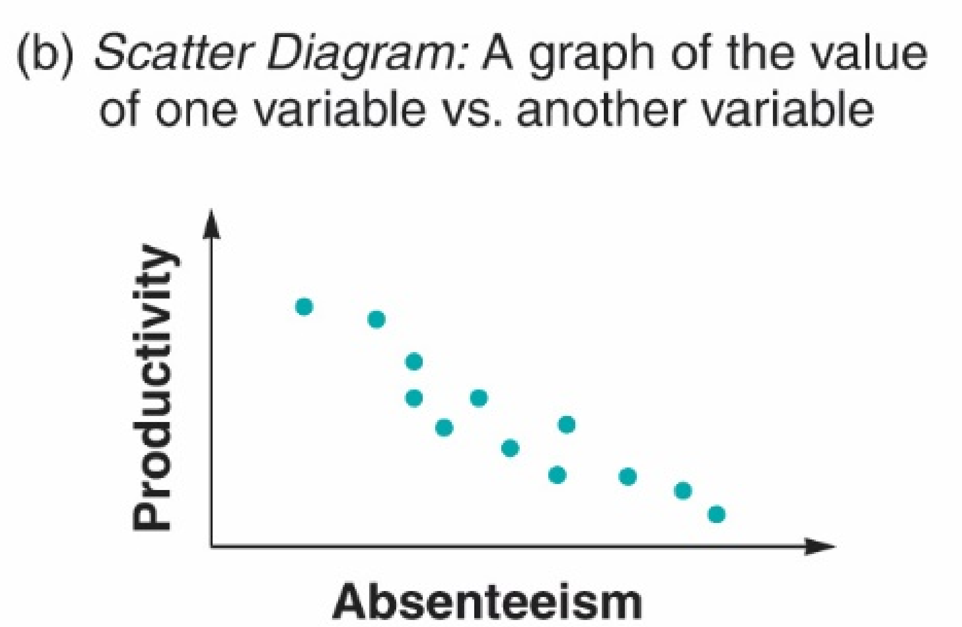
(a) *Check Sheet:* An organized method of recording data

	Hour							
Defect	1	2	3	4	5	6	7	8
A	///	/		/	/	/	///	/
B	//	/	/	/			//	///
C	/	//					//	////

Seven Tools of TQM (2 of 7)

Figure 6.6

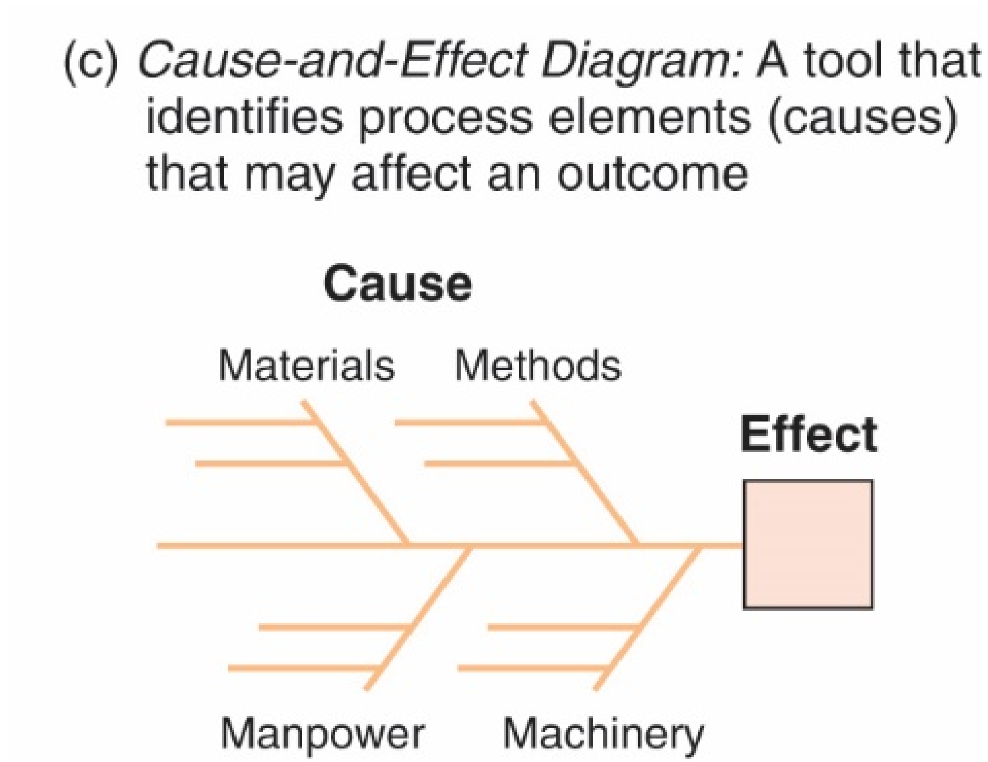
(b) *Scatter Diagram:* A graph of the value of one variable vs. another variable



Seven Tools of TQM (3 of 7)

Figure 6.6

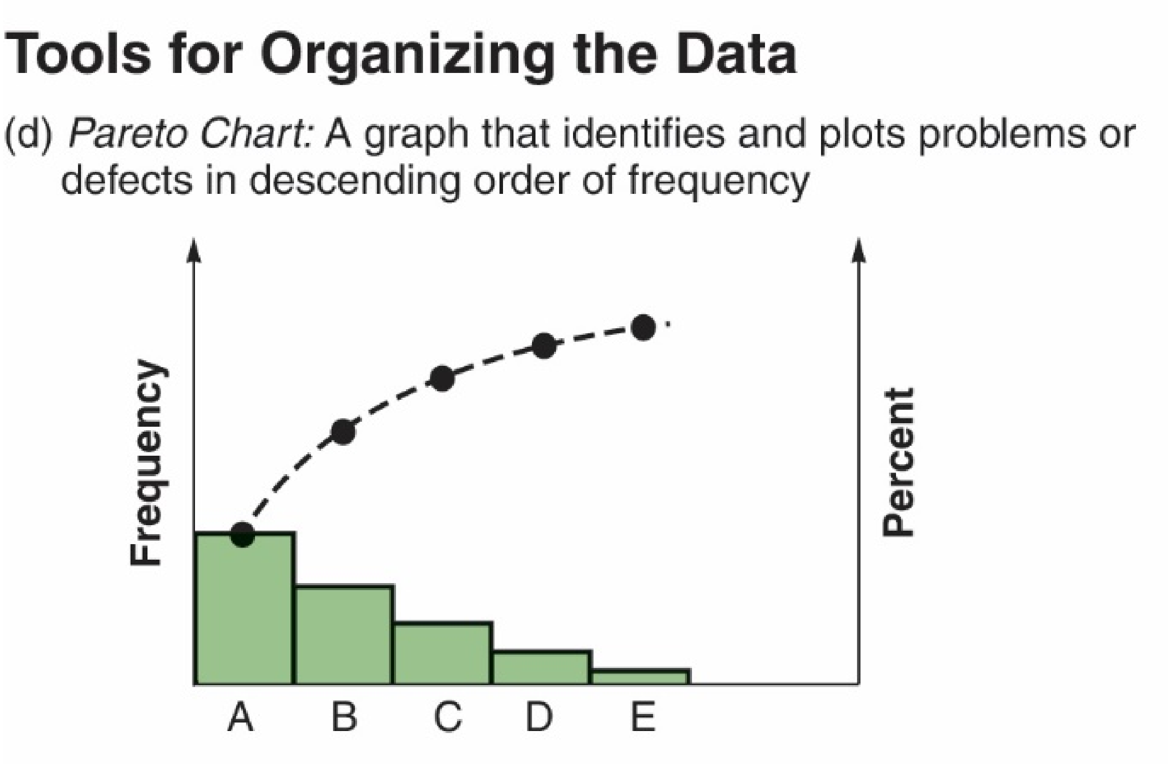
(c) *Cause-and-Effect Diagram:* A tool that identifies process elements (causes) that may effect an outcome



Seven Tools of TQM (4 of 7)

Figure 6.6

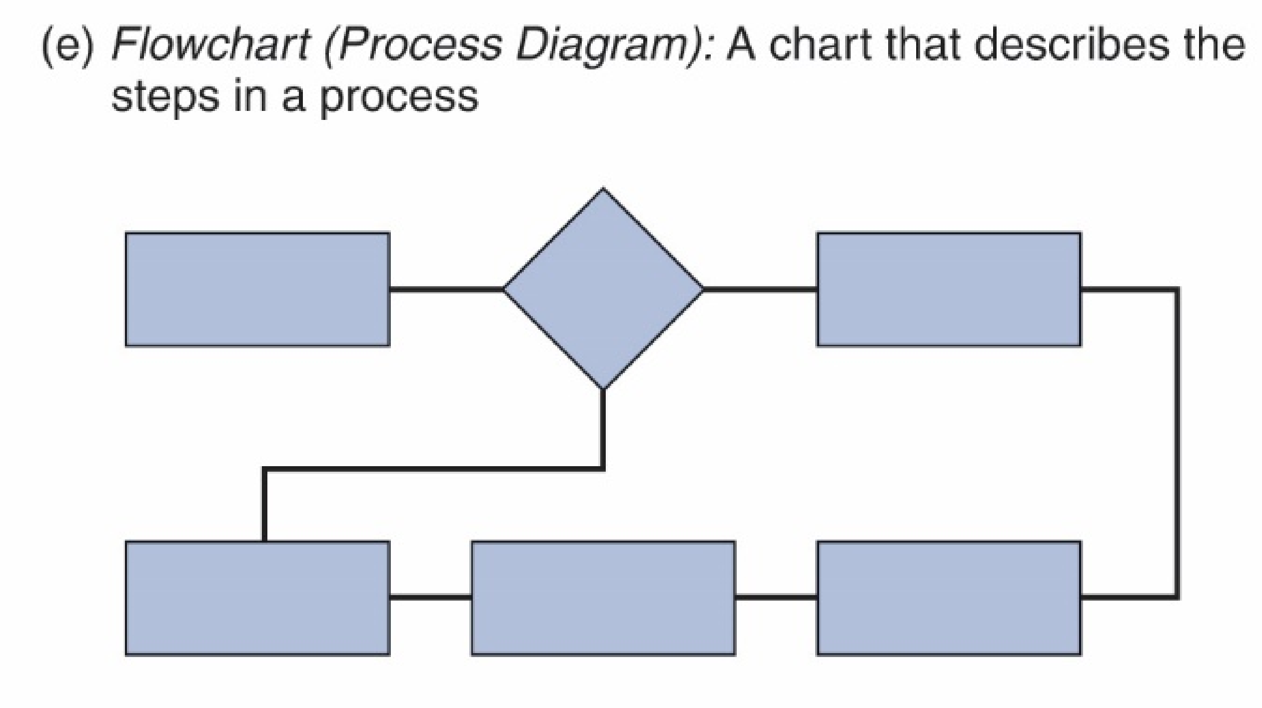
(d) *Pareto Chart:* A graph to identify and plot problems or defects in descending order of frequency



Seven Tools of TQM (5 of 7)

Figure 6.6

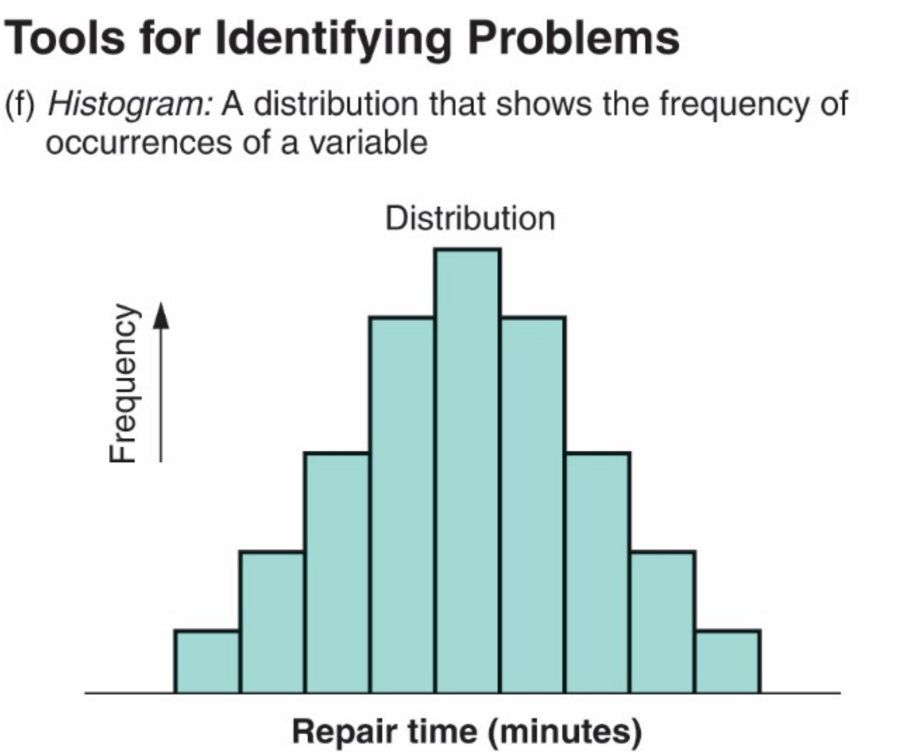
(e) *Flowchart (Process Diagram):* A chart that describes the steps in a process



Seven Tools of TQM (6 of 7)

Figure 6.6

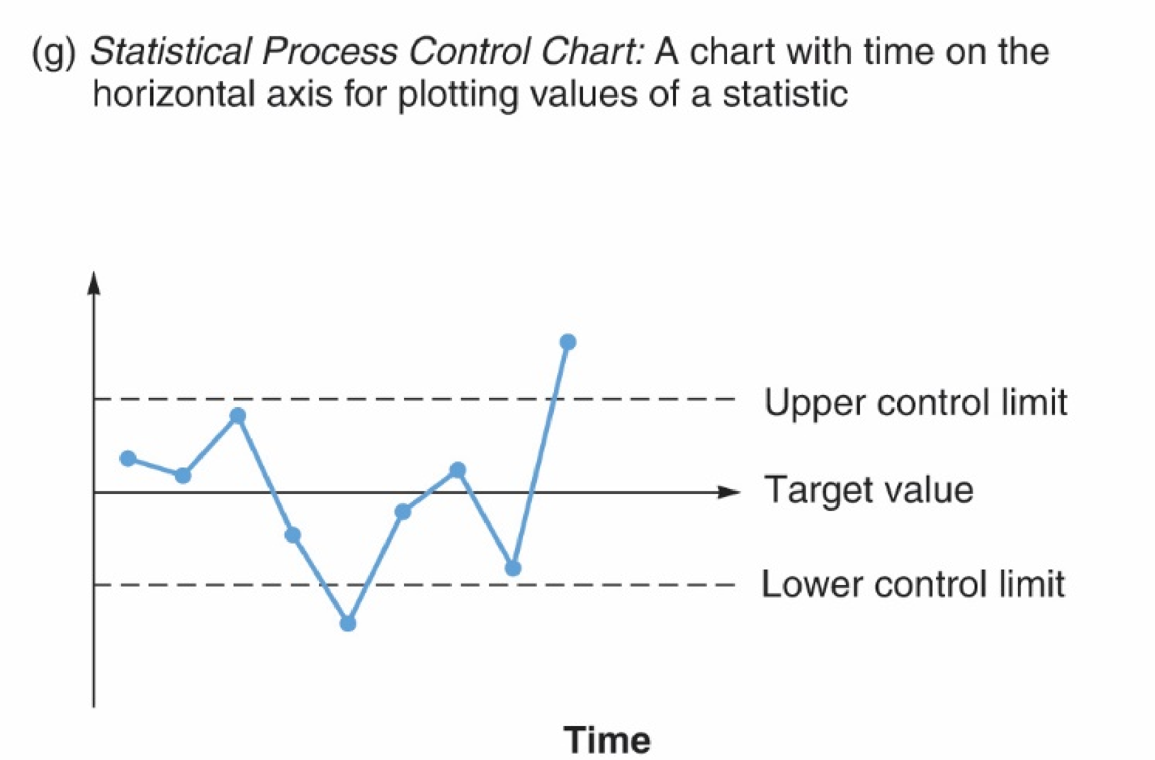
(f) *Histogram:* A distribution showing the frequency of occurrences of a variable



Seven Tools of TQM (7 of 7)

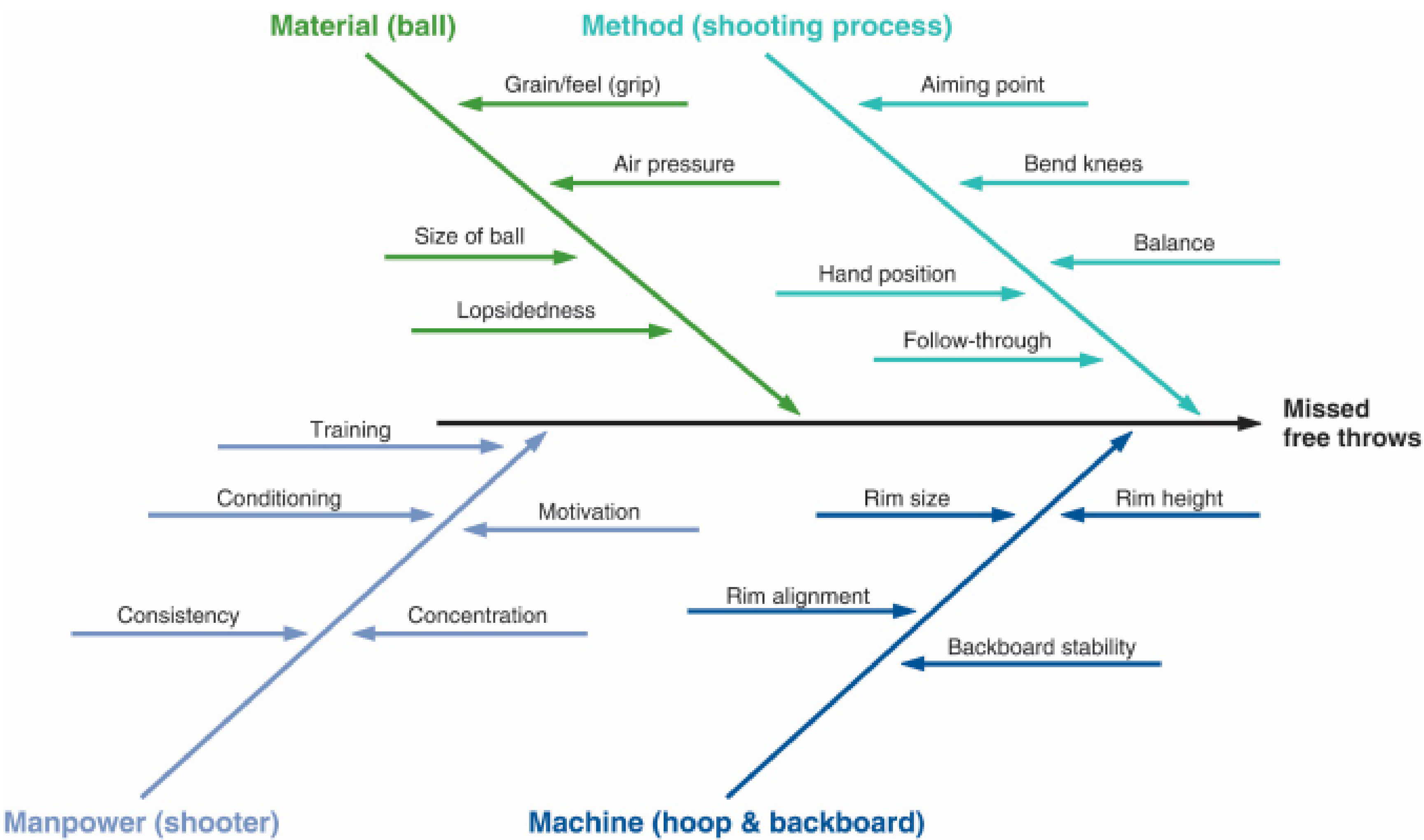
Figure 6.6

(g) *Statistical Process Control Chart:* A chart with time on the horizontal axis to plot values of a statistic

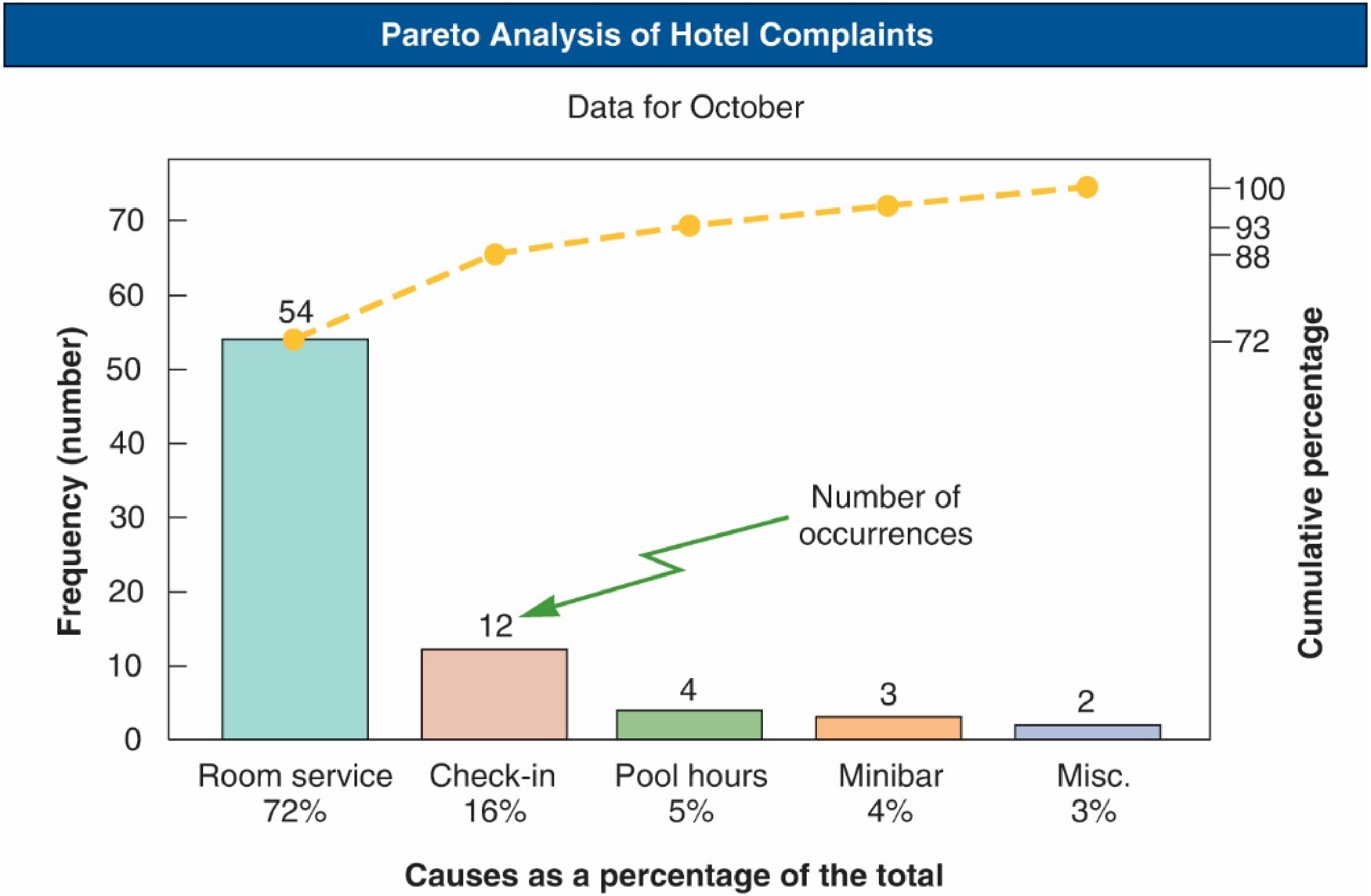


Cause-and-Effect Diagrams

Figure 6.7



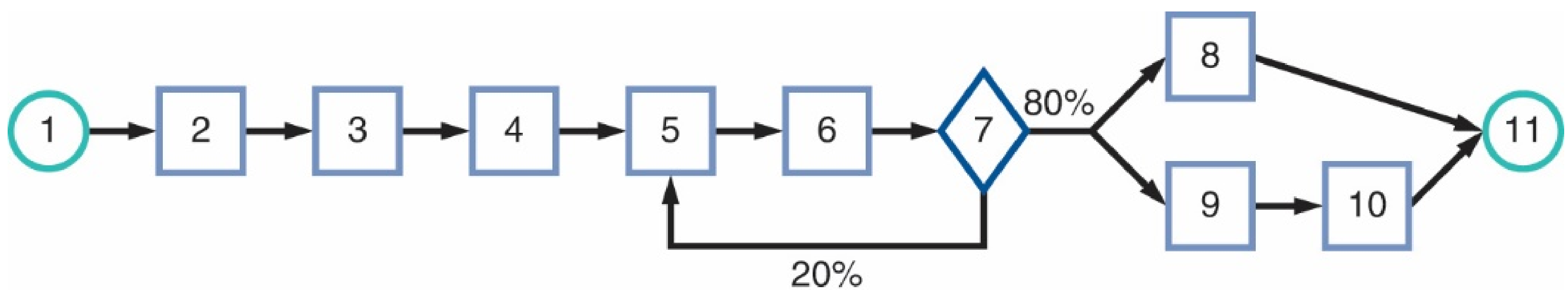
Pareto Charts



Flow Charts

MRI Flowchart

1. Physician schedules MRI
2. Patient taken to MRI
3. Patient signs in
4. Patient is prepped
5. Technician carries out MRI
6. Technician inspects film
7. If unsatisfactory, repeat
8. Patient taken back to room
9. MRI read by radiologist
10. MRI report transferred to physician
11. Patient and physician discuss

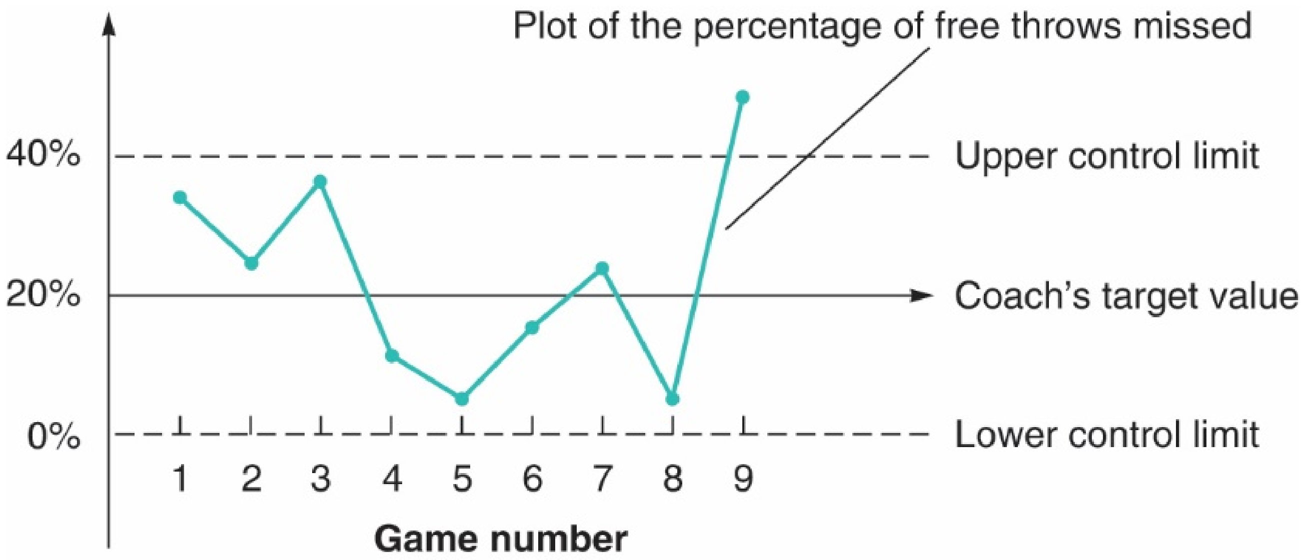


Statistical Process Control (SPC)

- Uses statistics and control charts to tell when to take corrective action
- Drives process improvement
- Four key steps
  - Measure the process
  - When a change is indicated, find the assignable cause
  - Eliminate or incorporate the cause
  - Restart the revised process

Control Charts

Figure 6.8



Inspection (1 of 2)

- Involves examining items to see if an item is good or defective
- Detect a defective product
  - Does not correct deficiencies in process or product
  - It is expensive
- Issues
  - When to inspect
  - Where in process to inspect

When and Where to Inspect (1 of 2)

1. At the supplier's plant while the supplier is producing
2. At your facility upon receipt of goods from your supplier
3. Before costly or irreversible processes
4. During the step-by-step production process
5. When production or service is complete
6. Before delivery to your customer
7. At the point of customer contact

When and Where to Inspect (2 of 2)

Table 6.4 How Samsung Tests Its Smartphones

Durability	Stress testing with nail punctures, extreme temperatures and overcharging
Visual inspection	Comparing the battery with standardized models
X-ray	Looking for internal abnormalities
Charge and discharge	Power up and down the completed phone
Organic pollution (TVOC)	Looking for battery leakage
Disassembling	Opening the battery cell to inspect tab welding and insulation tape conditions
Accelerated usage	Simulated 2 weeks of real-life use in 5 days
Volatility (OVC)	Checking for change in voltage throughout the manufacturing process

Inspection (2 of 2)

- Many problems
  - Worker fatigue
  - Measurement error
  - Process variability
- Cannot inspect quality into a product
- Robust design, empowered employees, and sound processes are better solutions

Source Inspection (1 of 2)

- Also known as source control
- The next step in the process is your customer
- Ensure perfect product to your customer

Source Inspection (2 of 2)

- **Poka-yoke** is the concept of foolproof devices or techniques designed to pass only acceptable products
- **Checklists** ensure consistency and completeness

Service Industry Inspection (1 of 3)

Table 6.5 Examples of Inspection in Services

ORGANIZATION	WHAT IS INSPECTED	STANDARD
Alaska Airlines	Last bag on carousel Airplane door opened	Less than 20 minutes after arrival at the gate Less than 2 minutes after arrival at the gate
Jones Law Office	Receptionist performance Billing Attorney	Phone answered by the second ring Accurate, timely, and correct format Promptness in returning calls
Hard Rock Hotel	Reception desk Doorman Room Minibar	Use customer's name Greet guest in less than 30 seconds All lights working, spotless bathroom Restocked and charges accurately posted to bill

Service Industry Inspection (2 of 3)

Table 6.5 Examples of Inspection in Services

ORGANIZATION	WHAT IS INSPECTED	STANDARD
Arnold Palmer Hospital	Billing Pharmacy Lab Nurses Admissions	Accurate, timely, and correct format Prescription accuracy, inventory accuracy Audit for lab-test accuracy Charts immediately updated Data entered correctly and completely
Olive Garden Restaurant	Busboy Busboy Waiter	Serves water and bread within 1 minute Clears all entrée items and crumbs prior to dessert Knows and suggests specials, desserts

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Service Industry Inspection (3 of 3)

Table 6.5 Examples of Inspection in Services

ORGANIZATION	WHAT IS INSPECTED	STANDARD
Nordstrom Department Store	Display areas Stockrooms Salesclerks	Attractive, well-organized, stocked, good lighting Rotation of goods, organized, clean Neat, courteous, very knowledgeable

Attributes Versus Variables

- *Attributes*
  - Items are either good or bad, acceptable or unacceptable
  - Does not address degree of failure
- *Variables*
  - Measures dimensions such as weight, speed, height, or strength
  - Falls within an acceptable range
- Use different statistical techniques

TQM In Services

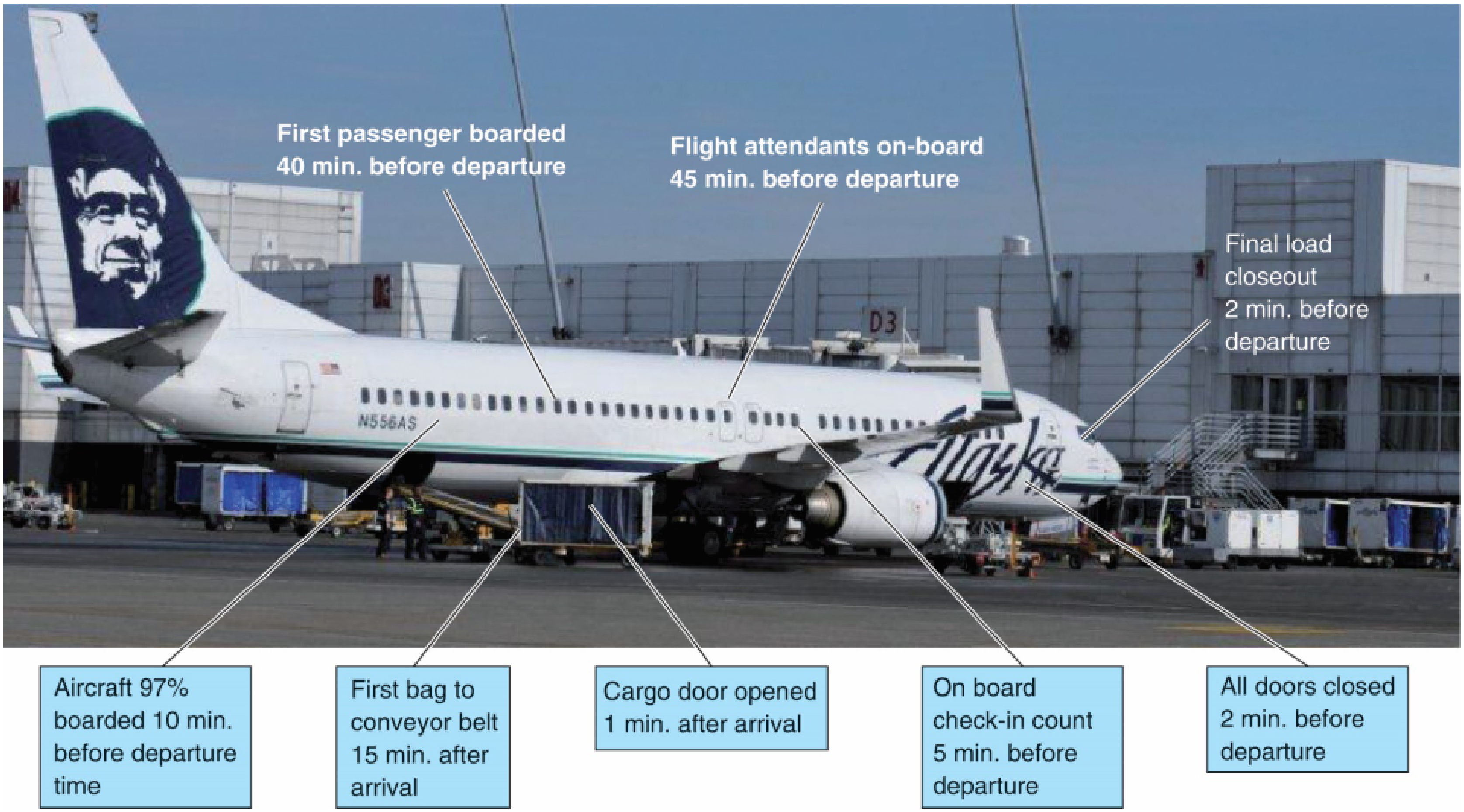
- Service quality is more difficult to measure than the quality of goods
- Service quality perceptions depend on
  1) *Intangible differences between products*
  2) *Intangible expectations customers have of those products*

Service Quality

The operations manager must recognize:

- Selecting best practices to use as a standard for performance
- The tangible component of services is important
- The service process is important
- The service is judged against the customer’s expectations
- Exceptions will occur

Service Specifications



Determinants of Service Quality

Table 6.6

Reliability involves consistency of performance and dependability
Responsiveness concerns the willingness or readiness of employees to provide service
Competence means possession of the required skills and knowledge to perform the service
Access involves approachability and ease of contact
Courtesy involves politeness, respect, consideration, and friendliness
Communication means keeping customers informed and listening to them
Credibility involves trustworthiness, believability, and honesty
Security is the freedom from danger, risk, or doubt
Understanding/knowing the customer involves making the effort to understand the customer's needs
Tangibles include the physical evidence of the service

Service Recovery Strategy

- Managers should have a plan for when services fail
- Marriott's **LEARN** routine
  - Listen
  - Empathize
  - Apologize
  - React
  - Notify

Evaluating Performance (1 of 2)

- The SERVQUAL technique
- Direct comparisons between customer service expectations and actual service provided
- Focuses on gaps in the 10 service quality determinants

Evaluating Performance (2 of 2)

- Most common version collapses the determinants to
  - Reliability
  - Assurances
  - Tangibles
  - Empathy
  - Responsiveness

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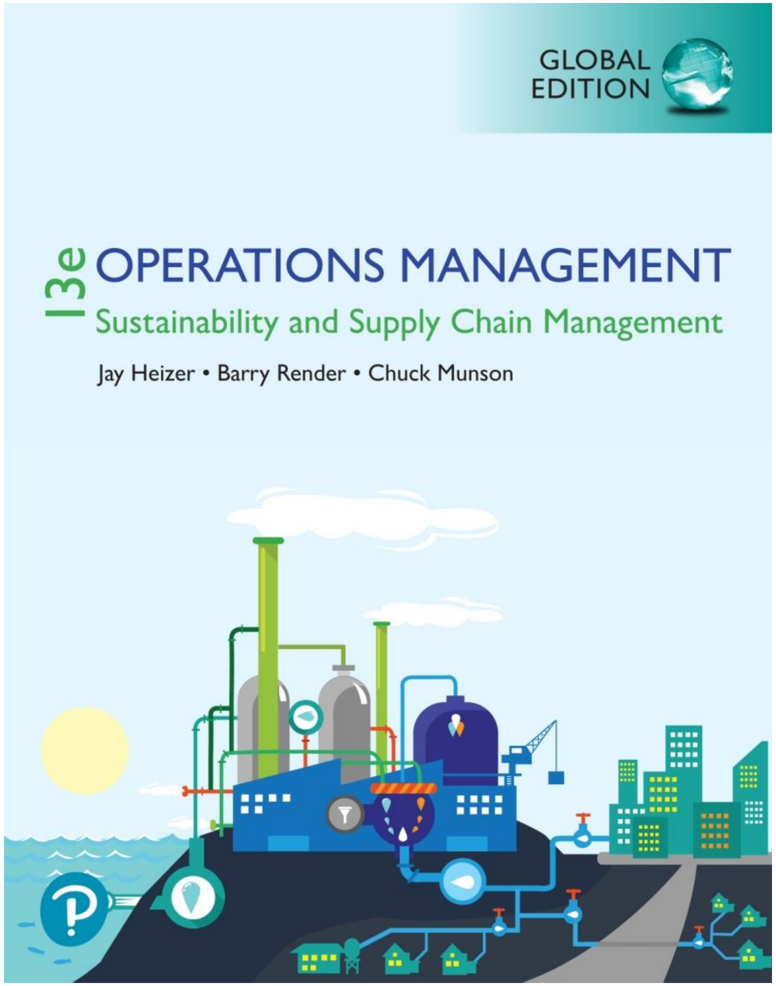


Chapter 6s

Statistical Process Control

Pearson

Outline

- Statistical Process Control (SPC)
- Process Capability
- Acceptance Sampling

Learning Objectives (1 of 2)

When you complete this supplement you should be able to:

S6.1 ***Explain*** the purpose of a control chart

S6.2 ***Explain*** the role of the central limit theorem in SPC

S6.3 ***Build*** $\bar{x}$ -charts and *R*-charts

S6.4 ***List*** the five steps involved in building control charts

Learning Objectives (2 of 2)

When you complete this supplement you should be able to:

S6.5 ***Build*** *p*-charts and *c*-charts

S6.6 ***Explain*** process capability and compute C_p and C_{pk}

S6.7 ***Explain*** acceptance sampling

Statistical Process Control

The objective of a process control system is to provide a statistical signal when assignable causes of variation are present

Statistical Process Control (SPC)

- Variability is inherent in every process
  - Natural or common causes
  - Special or assignable causes
- Provides a statistical signal when assignable causes are present
- Quickens appropriate actions to eliminate assignable causes

Natural Variations

- Also called common causes
- Affect virtually all production processes
- Expected amount of variation
- Output measures follow a probability distribution
- For any distribution there is a measure of central tendency and dispersion
- If the distribution of outputs falls within acceptable limits, the process is said to be "in control"

Assignable Variations

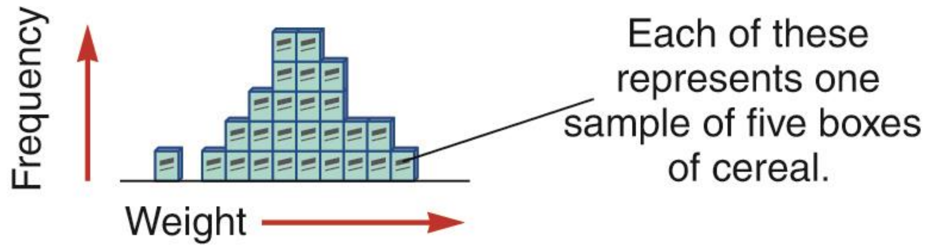
- Also called special causes of variation
  - Generally this is some change in the process
- Variations that can be traced to a specific reason
- The objective is to discover when assignable causes are present
  - Eliminate the bad causes
  - Incorporate the good causes

Samples (1 of 5)

To measure the process, we take samples and analyze the sample statistics following these steps

Figure S6.1

(a) Samples of the product, say five boxes of cereal taken off the filling machine line, vary from one another in weight.

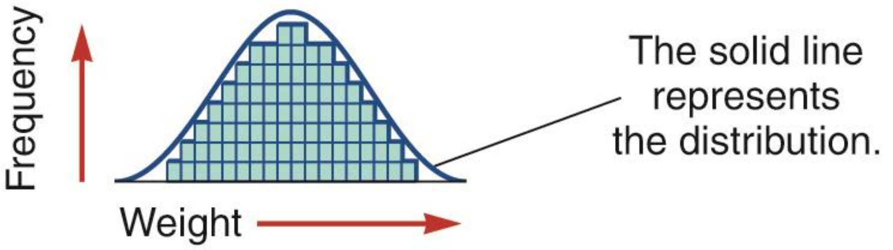


Samples (2 of 5)

To measure the process, we take samples and analyze the sample statistics following these steps

Figure S6.1

(b) After enough sample means are taken from a stable process, they form a pattern called a *distribution*.

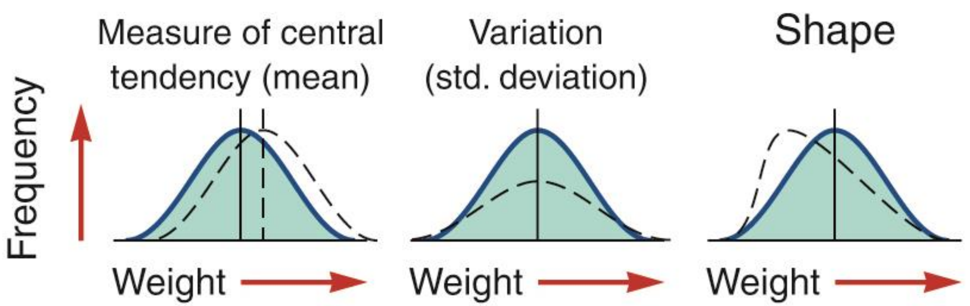


Samples (3 of 5)

To measure the process, we take samples and analyze the sample statistics following these steps

Figure S6.1

(c) There are many types of distributions, including the normal (bell-shaped) distribution, but distributions do differ in terms of central tendency (mean), standard deviation or variance, and shape.

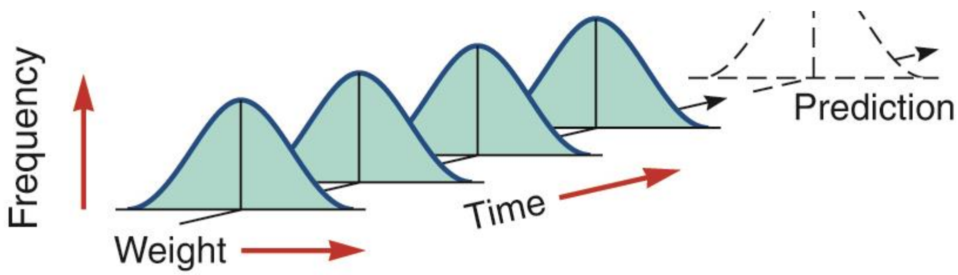


Samples (4 of 5)

To measure the process, we take samples and analyze the sample statistics following these steps

Figure S6.1

(d) If only natural causes of variation are present, the output of a process forms a distribution that is stable over time and is predictable.

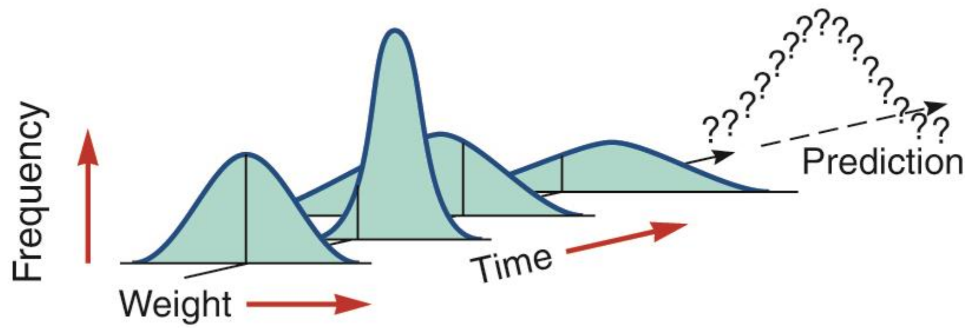


Samples (5 of 5)

To measure the process, we take samples and analyze the sample statistics following these steps

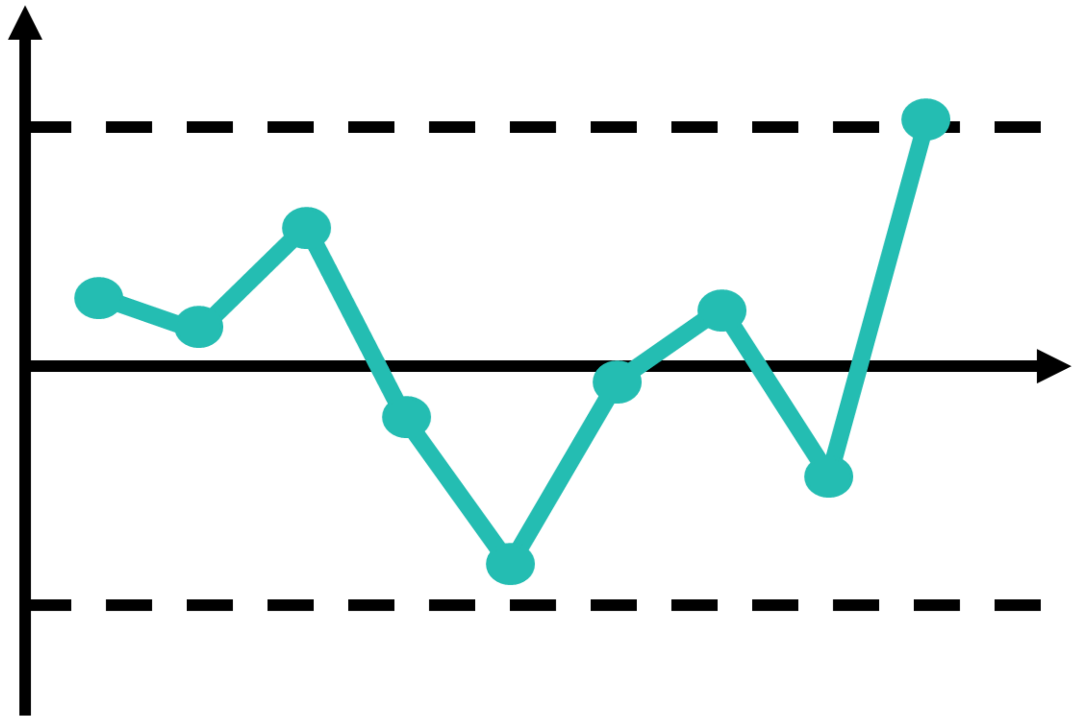
Figure S6.1

(e) If assignable causes of variation are present, the process output is not stable over time and is not predictable. That is, when causes that are not an expected part of the process occur, the samples will yield unexpected distributions that vary by central tendency, standard deviation, and shape.



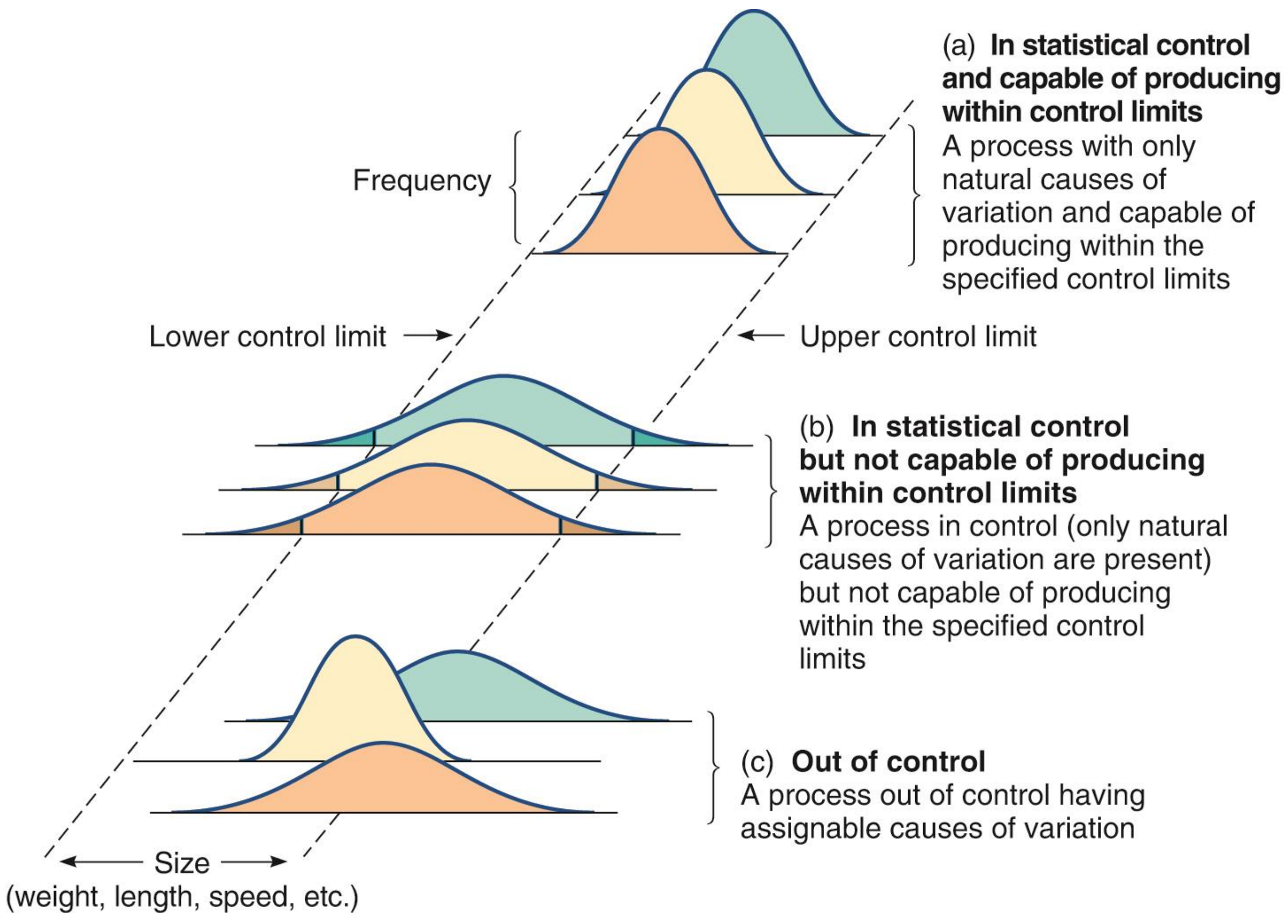
Control Charts

Constructed from historical data, the purpose of control charts is to help distinguish between natural variations and variations due to assignable causes



Process Control

Figure S6.2



Control Charts for Variables (1 of 2)

- Characteristics that can take any real value
- May be in whole or in fractional numbers
- Continuous random variables

$\overline{X}$ **- chart** tracks changes in the central tendency

R **- chart** indicates a gain or loss of dispersion

Control Charts for Variables (2 of 2)

- Characteristics that can take any real value
- May be in whole or in fractional numbers
- Continuous random variables

$\bar{X}$ **- chart** tracks changes in the central tendency

R **- chart** indicates a gain or loss of dispersion

These two charts must be used together

Central Limit Theorem

Regardless of the distribution of the population, the distribution of sample means drawn from the population will tend to follow a normal curve

1. The mean of the sampling distribution will be the same as the population mean μ

$$\bar{\bar{x}} = \mu$$

2. The standard deviation of the sampling distribution

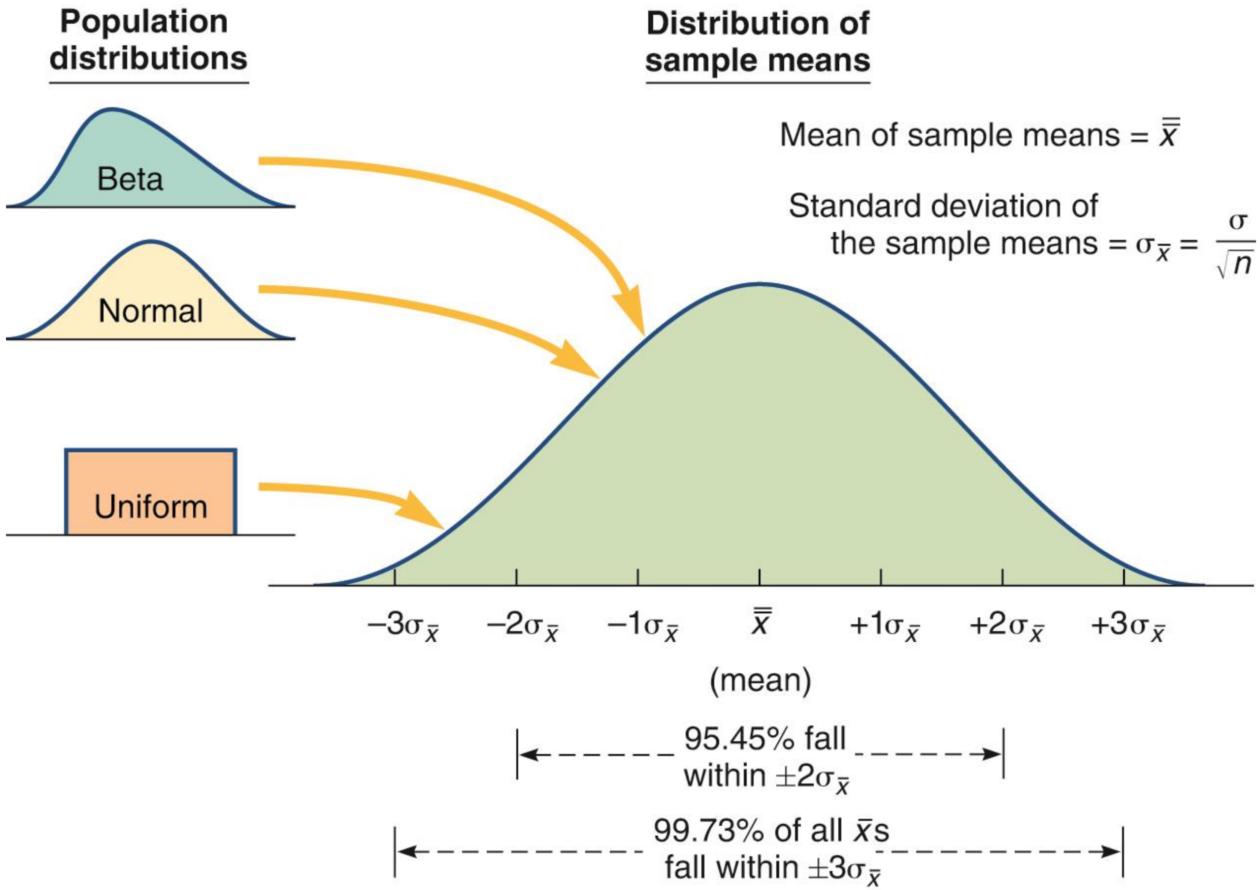
$(\sigma_{\bar{x}})$

will equal the population standard deviation (σ) divided by the square root of the sample size, n

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

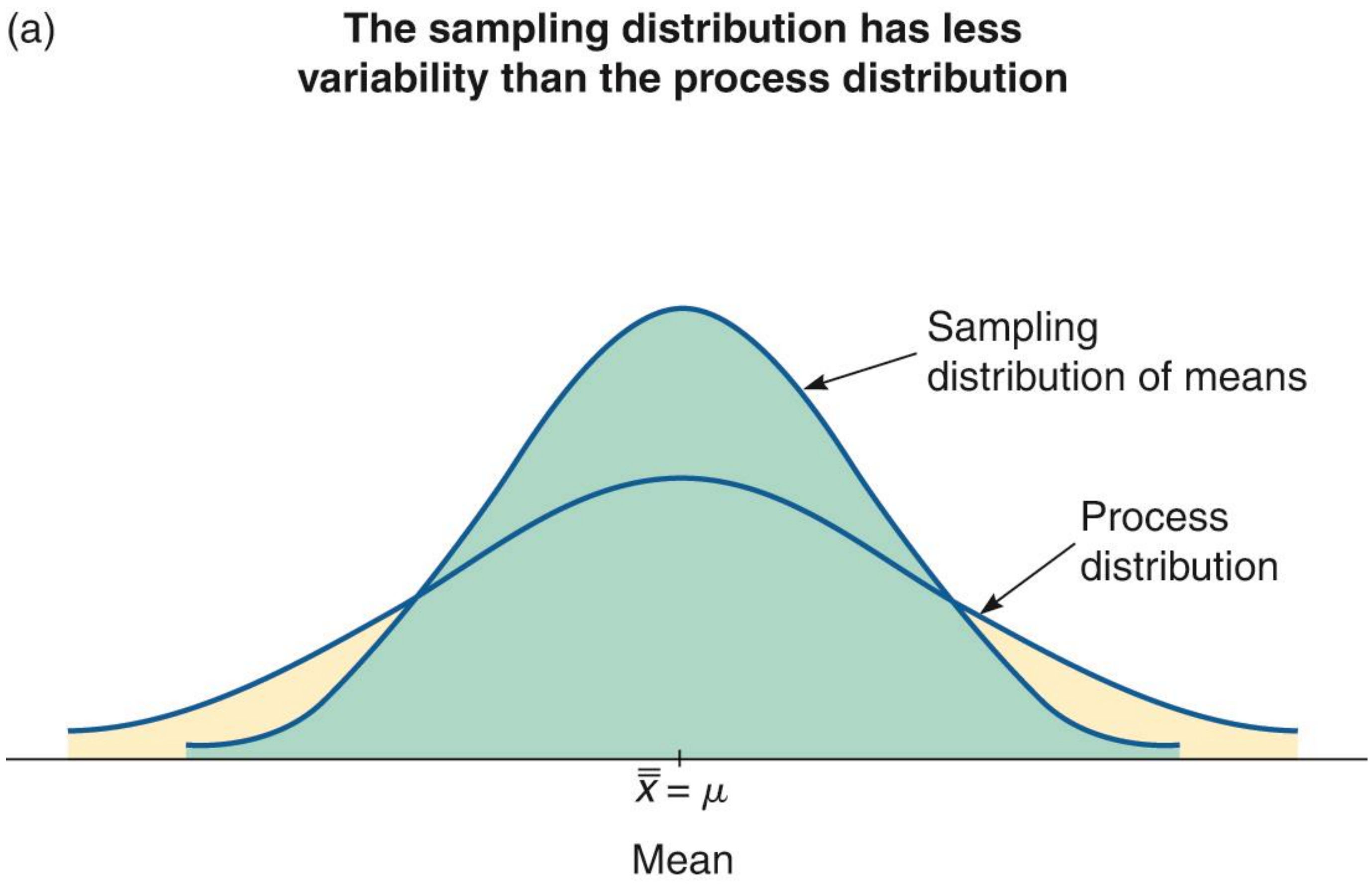
Population and Sampling Distributions

Figure S6.3



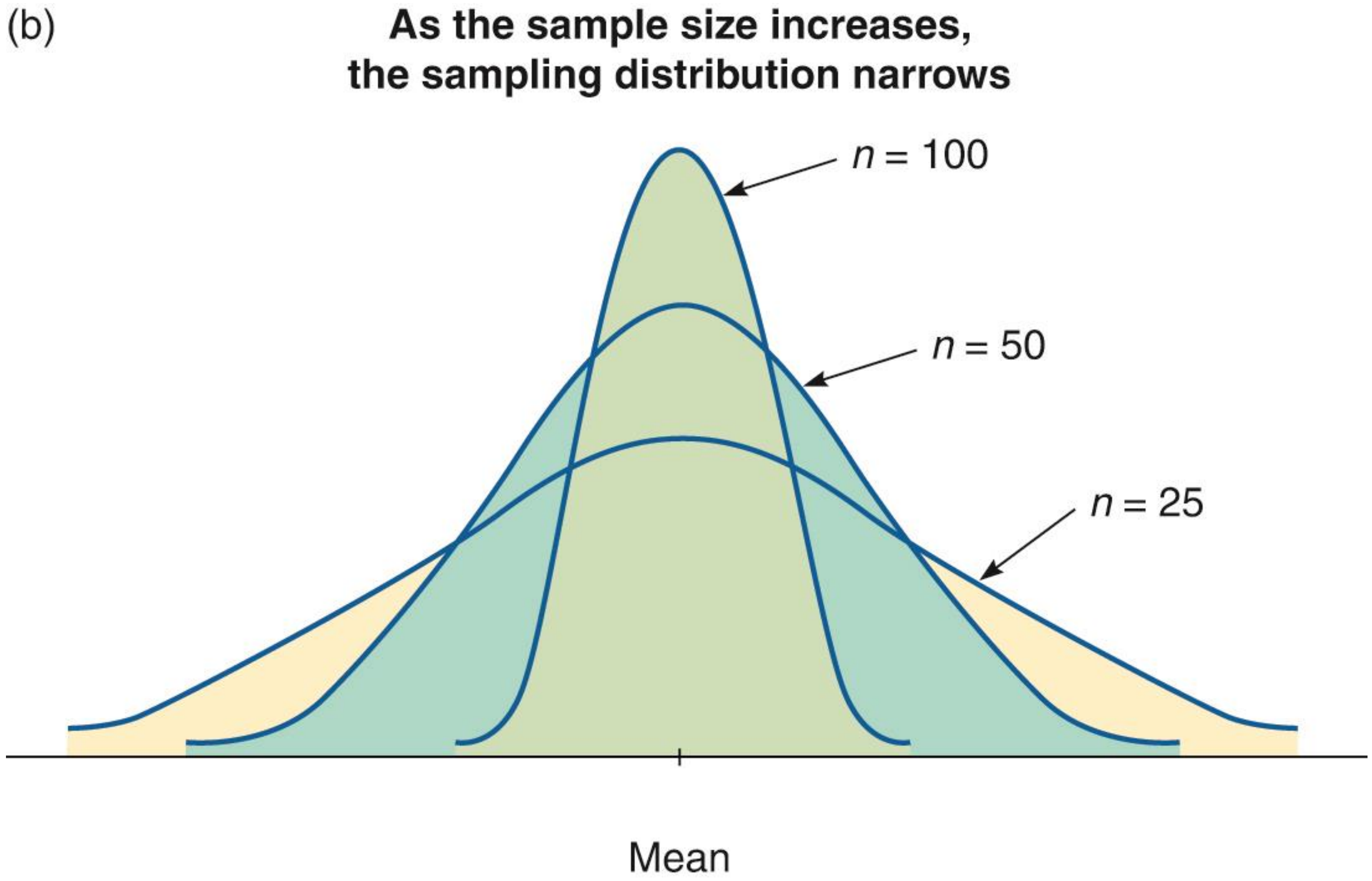
Sampling Distribution (1 of 2)

Figure S6.4



Sampling Distribution (2 of 2)

Figure S6.4



Setting Chart Limits

For $\bar{x}$ -Charts when we know σ

$$\text{Upper control limit (UCL)} = \bar{\bar{x}} + z\sigma_{\bar{x}}$$

$$\text{Lower control limit (LCL)} = \bar{\bar{x}} - z\sigma_{\bar{x}}$$

Where
$\bar{\bar{x}}$ = mean of the sample means or a target value set for the process
z = number of normal standard deviations
$\sigma_{\bar{x}}$ = standard deviation of the sample means $= \sigma / \sqrt{n}$
σ = population (process) standard deviation
n = sample size

Setting Control Limits (1 of 6)

- Randomly select and weigh nine (n = 9) boxes each hour

$$\text{Average weight in the first sample} = \frac{17+13+16+18+17+16+15+17+16}{9} = 16.1 \text{ ounces}$$

WEIGHT OF SAMPLE		WEIGHT OF SAMPLE		WEIGHT OF SAMPLE	
HOUR	(AVG. OF 9 BOXES)	HOUR	(AVG. OF 9 BOXES)	HOUR	(AVG. OF 9 BOXES)
1	16.1	5	16.5	9	16.3
2	16.8	6	16.4	10	14.8
3	15.5	7	15.2	11	14.2
4	16.5	8	16.4	12	17.3

Setting Control Limits (2 of 6)

$$\text{Average mean of 12 samples} = \left[\bar{\bar{x}} = \frac{\sum_{i=1}^{12} (\text{Avg of 9 boxes})}{12} \right]$$

$\bar{\bar{x}} = 16$ ounces

$n = 9$

$z = 3$

$\sigma = 1$ ounce

Number of samples $= 12$

Setting Control Limits (3 of 6)

Average mean of 12 samples $= \left[\bar{\bar{x}} = \dfrac{\sum_{i=1}^{12} (\text{Avg of 9 boxes})}{12} \right]$

$\bar{\bar{x}} = 16$ ounces

$n = 9$

$z = 3$

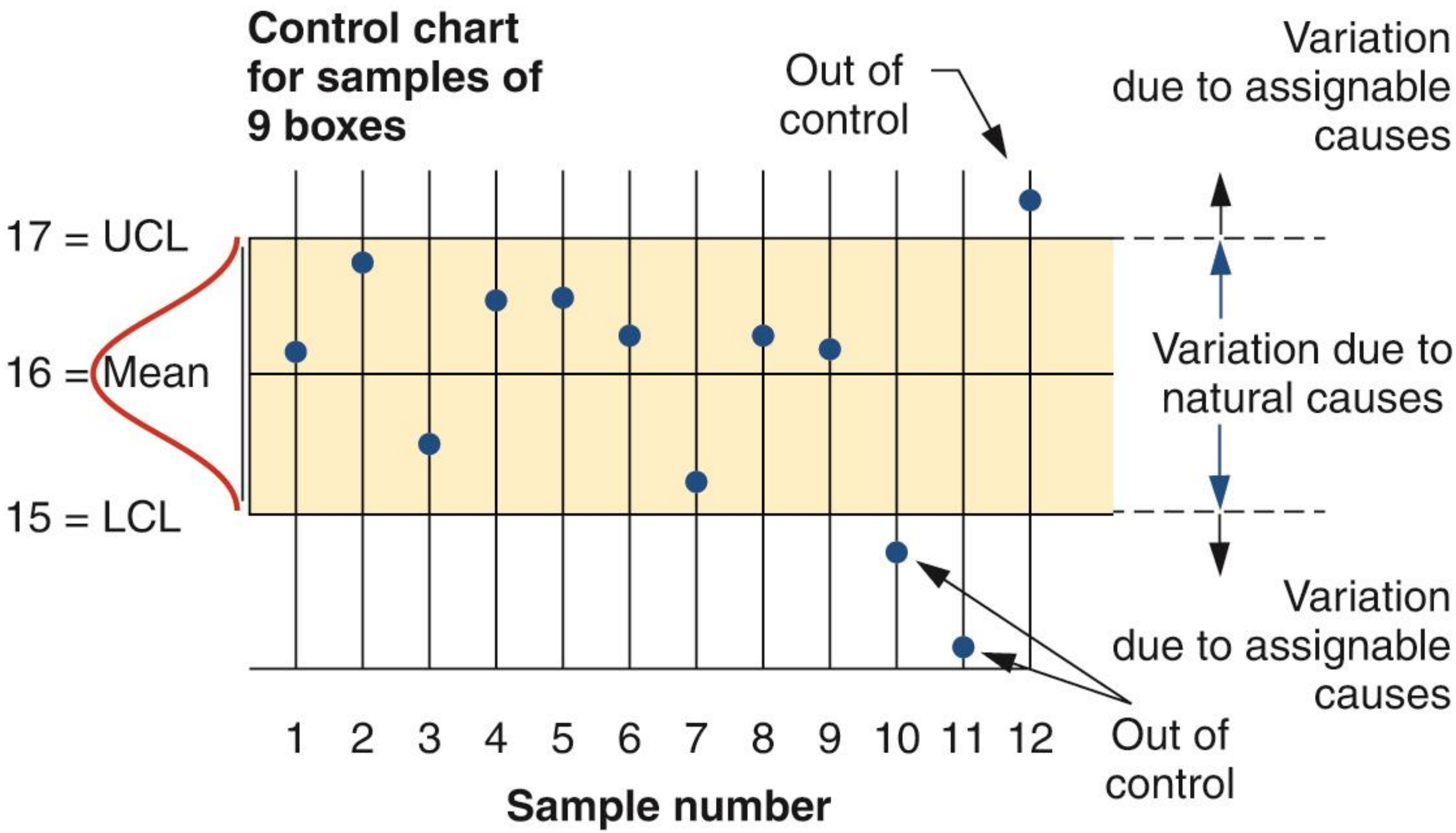
$\sigma = 1$ ounce

Number of samples = 12

$$\text{UCL}_{\bar{x}} = \bar{\bar{x}} + z\sigma_{\bar{x}} = 16 + 3\left(\frac{1}{\sqrt{9}}\right) = 16 + 3\left(\frac{1}{3}\right) = 17 \text{ ounces}$$

$$\text{LCL}_{\bar{x}} = \bar{\bar{x}} - z\sigma_{\bar{x}} = 16 - 3\left(\frac{1}{\sqrt{9}}\right) = 16 - 3\left(\frac{1}{3}\right) = 15 \text{ ounces}$$

Setting Control Limits (4 of 6)



Setting Limits Using Table Values (1 of 3)

- When process standard deviations are not available, we can calculate the average range value
- The *range* (R_i) is the difference between the largest and smallest items in one sample

Where

$$\bar{R} = \frac{\sum_{i=1}^{k} R_i}{k} \text{ average range of the samples}$$

$$R_i = \text{range for sample } i$$

$$k = \text{total number of samples}$$

Setting Limits Using Table Values (2 of 3)

- From Example S2

SAMPLE	WEIGHT OF LIGHTEST BOTTLE IN SAMPLE OF $n = 5$	WEIGHT OF HEAVIEST BOTTLE IN SAMPLE OF $n = 5$	RANGE (R_i) = DIFFERENCE BETWEEN THESE TWO
1	11.50	11.72	.22
2	11.97	12.00	.03
3	11.55	12.05	.50
4	12.00	12.20	.20
5	11.95	12.00	.05
6	10.55	10.75	.20
7	12.50	12.75	.25
8	11.00	11.25	.25
9	10.60	11.00	.40
10	11.70	12.10	.40
			$\Sigma R_i = 2.50$ ounces

Setting Limits Using Table Values
(3 of 3)

- From Example S2

SAMPLE	WEIGHT OF LIGHTEST BOTTLE IN SAMPLE OF n = 5	WEIGHT OF HEAVIEST BOTTLE IN SAMPLE OF n = 5	RANGE (R_i) = DIFFERENCE BETWEEN THESE TWO
1	11.50	11.72	.22
2			
3			
4			
5			
6			
7			
8	11.00	11.25	.25
9	10.60	11.00	.40
10	11.70	12.10	.40
			ΣR_i = 2.50 ounces

$$\text{Average range} = \frac{2.50}{10 \text{ samples}} = .25 \text{ ounces}$$

Control Chart Factors

Table S6.1 Factors for Computing Control Chart Limits (3 sigma)

SAMPLE SIZE, n	MEAN FACTOR, A_2	UPPER RANGE, D_4	LOWER RANGE, D_3
2	1.880	3.268	0
3	1.023	2.574	0
4	.729	2.282	0
5	.577	2.115	0
6	.483	2.004	0
7	.419	1.924	0.076
8	.373	1.864	0.136
9	.337	1.816	0.184
10	.308	1.777	0.223
12	.266	1.716	0.284

Setting Chart Limits (1 of 2)

- **For $\bar{x}$ -Charts when we don't know σ**

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

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

where

$$\bar{R} = \frac{\sum_{i=1}^{k} R_i}{k} \text{ average range of the samples}$$

$$A_2 = \text{control chart factor found in Table S6.1}$$

$$\bar{\bar{x}} = \text{mean of the sample means}$$

$$R_i = \text{range for sample } i$$

$$k = \text{total number of samples}$$

Setting Control Limits (5 of 6)

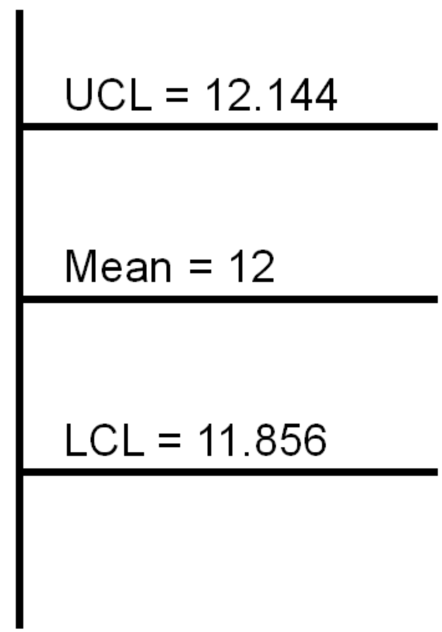
Super Cola example labeled as "net weight 12 ounces"

Process average = 12 ounces
Average range = .25 ounces
Sample size = 5

$$\begin{aligned} UCL_{\bar{x}} &= \bar{\bar{x}} + A_2\bar{R} \\ &= 12 + (.577)(.25) \\ &= 12 + .144 \\ &= 12.144 \text{ ounces} \end{aligned}$$

From Table S6.1

$$\begin{aligned} LCL_{\bar{x}} &= \bar{\bar{x}} - A_2\bar{R} \\ &= 12 - .144 \\ &= 11.856 \text{ ounces} \end{aligned}$$



R – Chart

- Type of variables control chart
- Shows sample ranges over time
  - Difference between smallest and largest values in sample
- Monitors process variability
- Independent from process mean

Setting Chart Limits (2 of 2)

For *R*-Charts

$$\text{Upper control limit } (\text{UCL}_R) = D_4\bar{R}$$

$$\text{Lower control limit } (\text{LCL}_R) = D_3\bar{R}$$

where

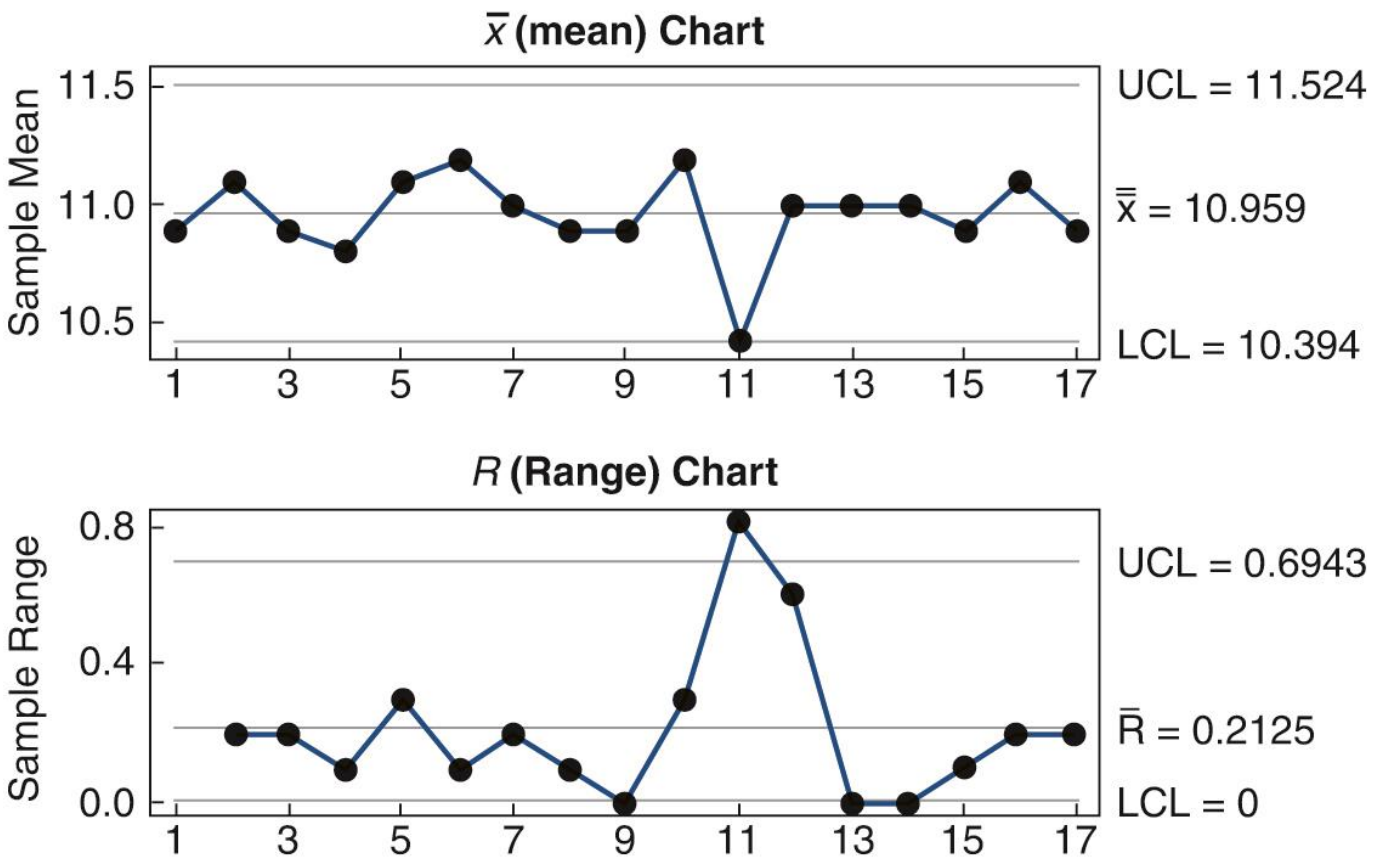
$$\text{UCL}_\text{R} = \text{upper control chart limit for the range}$$

$$\text{LCL}_\text{R} = \text{lower control chart limit for the range}$$

$$\text{D}_4 \text{ and } \text{D}_3 = \text{values from Table S6.1}$$

Restaurant Control Limits

For salmon fillets at Darden Restaurants

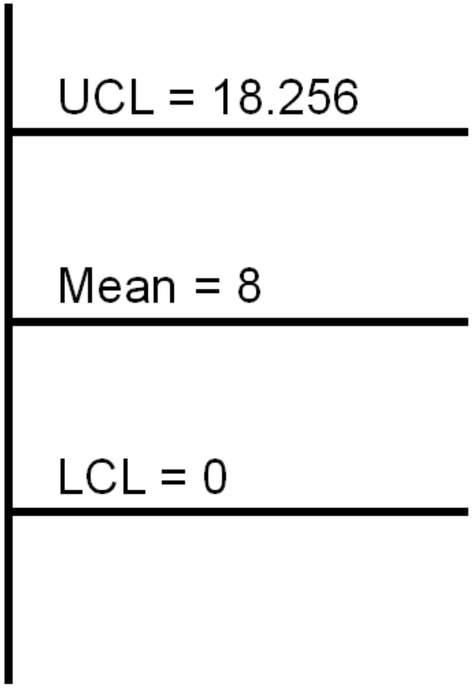


Setting Control Limits (6 of 6)

Average range = 8 minutes
Sample size = 4
From Table S6.1 $D_4 = 2.282$, $D_3 = 0$

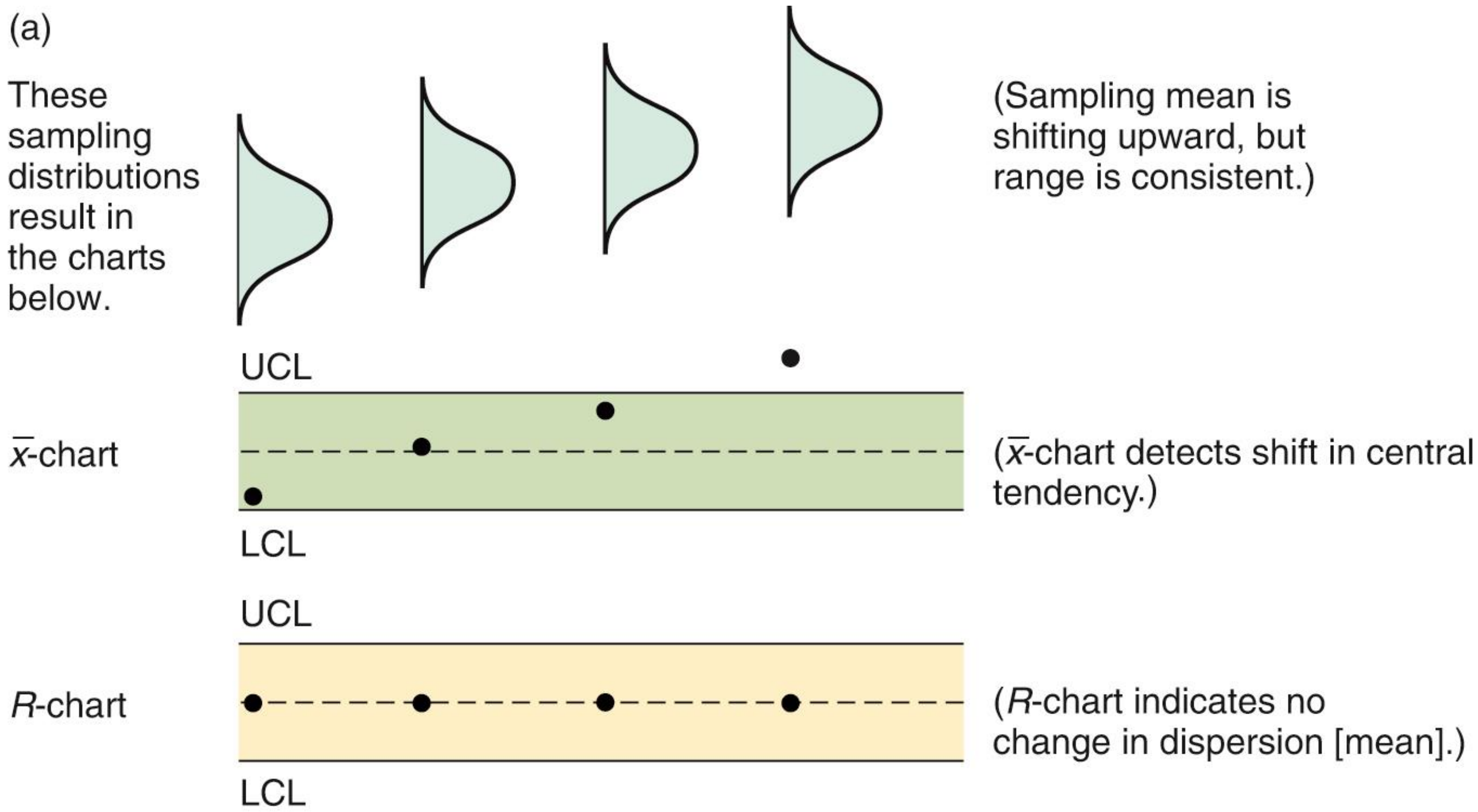
$$\begin{aligned} \text{UCL}_R &= D_4\bar{R} \\ &= (2.282)(8) \\ &= 18.256 \text{ minutes} \end{aligned}$$

$$\begin{aligned} \text{LCL}_R &= D_3\bar{R} \\ &= (0)(8) \\ &= 0 \text{ minutes} \end{aligned}$$



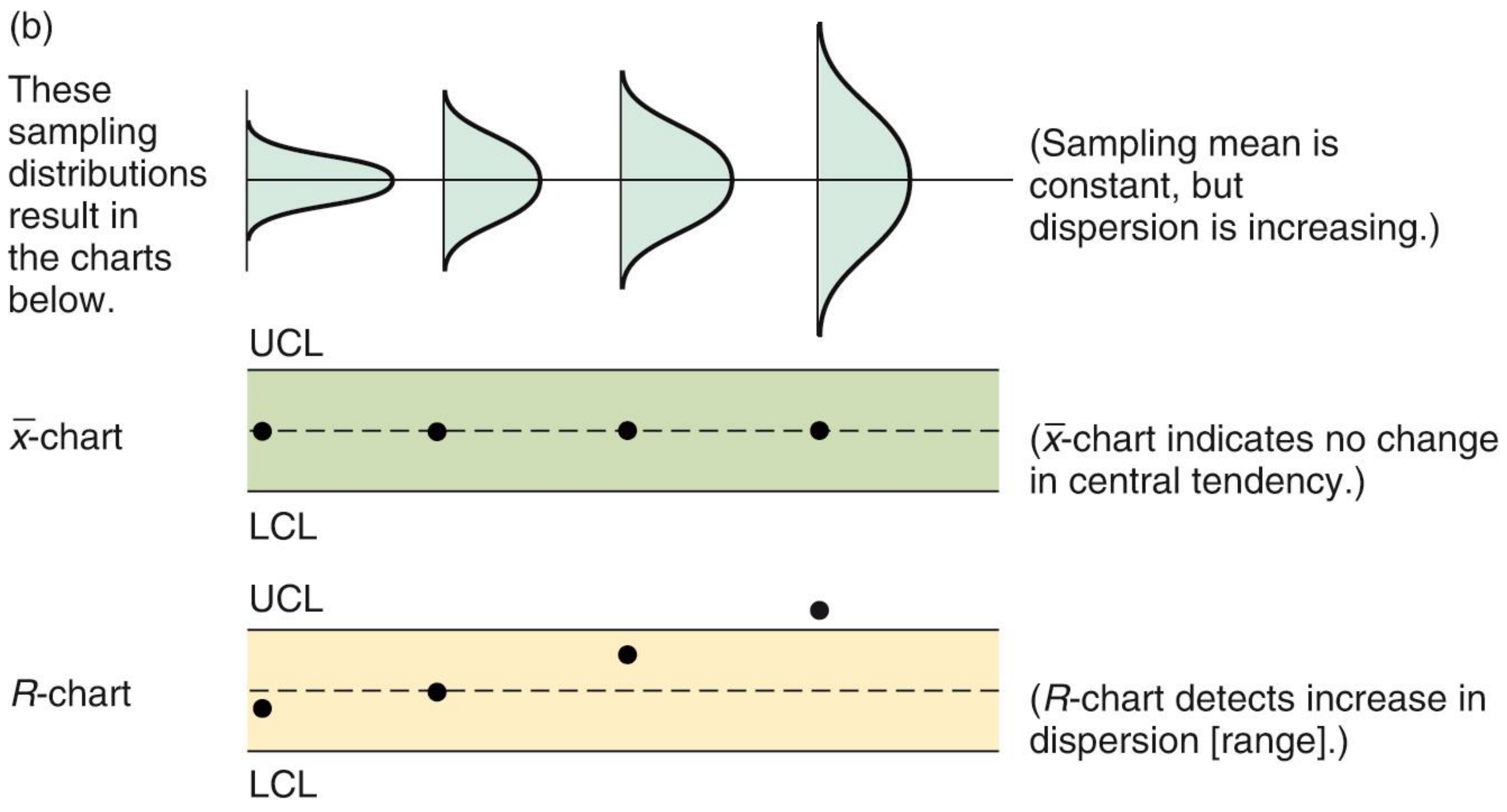
Mean and Range Charts (1 of 2)

Figure S6.5



Mean and Range Charts (2 of 2)

Figure S6.5



Steps In Building Control Charts

1. Collect 20 to 25 samples, often of $n = 4$ or $n = 5$ observations each, from a stable process, and compute the mean and range of each
2. Compute the overall means ($\bar{\bar{x}}$ and $\bar{R}$), set appropriate control limits, usually at the 99.73% level, and calculate the preliminary upper and lower control limits
   – If the process is not currently stable and in control, use the desired mean, μ, instead of $\bar{\bar{x}}$ to calculate limits.

Steps In Creating Control Charts

3. Graph the sample means and ranges on their respective control charts and determine whether they fall outside the acceptable limits
4. Investigate points or patterns that indicate the process is out of control – try to assign causes for the variation, address the causes, and then resume the process
5. Collect additional samples and, if necessary, revalidate the control limits using the new data

Setting Other Control Limits

Table S6.2 Common *z* Values

DESIRED CONTROL LIMIT (%)	*Z*-VALUE (STANDARD DEVIATION REQUIRED FOR DESIRED LEVEL OF CONFIDENCE)
90.0	1.65
95.0	1.96
95.45	2.00
99.0	2.58
99.73	3.00

Control Charts for Attributes

- For variables that are categorical
  - *Defective/nondefective, good/bad, yes/no, acceptable/unacceptable*
- Measurement is typically counting defectives
- Charts may measure
  1. *Percent* defective (*p*-chart)
  2. *Number* of defects (*c*-chart)

Control Limits for *p*-Charts

Population will be a binomial distribution, but applying the central limit theorem allows us to assume a normal distribution for the sample statistics

$$\text{UCL}_p = \bar{p} + z\sigma_p$$

$$\text{LCL}_p = \bar{p} - z\sigma_p$$

s_p is estimated by

$$\hat{\sigma}_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

where

$\bar{p}$ = mean fraction (percent) defective in the samples

z = number of standard deviations

s_p = standard deviation of the sampling distribution

n = number of observations in *each* sample

p-Chart for Data Entry (1 of 4)

SAMPLE NUMBER	NUMBER OF ERRORS	FRACTION DEFECTIVE $n = 100$	SAMPLE NUMBER	NUMBER OF ERRORS	FRACTION DEFECTIVE $n = 100$
1	6	.06	11	6	.06
2	5	.05	12	1	.01
3	0	.00	13	8	.08
4	1	.01	14	7	.07
5	4	.04	15	5	.05
6	2	.02	16	4	.04
7	5	.05	17	11	.11
8	3	.03	18	3	.03
9	3	.03	19	0	.00
10	2	.02	20	4	.04
				80	

Pearson

p-Chart for Data Entry (2 of 4)

$$\bar{p} = \frac{\text{Total number of errors}}{\text{Total number of records examined}} = \frac{80}{(100)(20)} = .04$$

$$\hat{\sigma}_p = \sqrt{\frac{(.04)(1-.04)}{100}} = .02 \text{ (rounded up from .0196)}$$

$$\text{UCL}_p = \bar{p} + z\hat{\sigma}_p = .04 + 3(.02) = .10$$

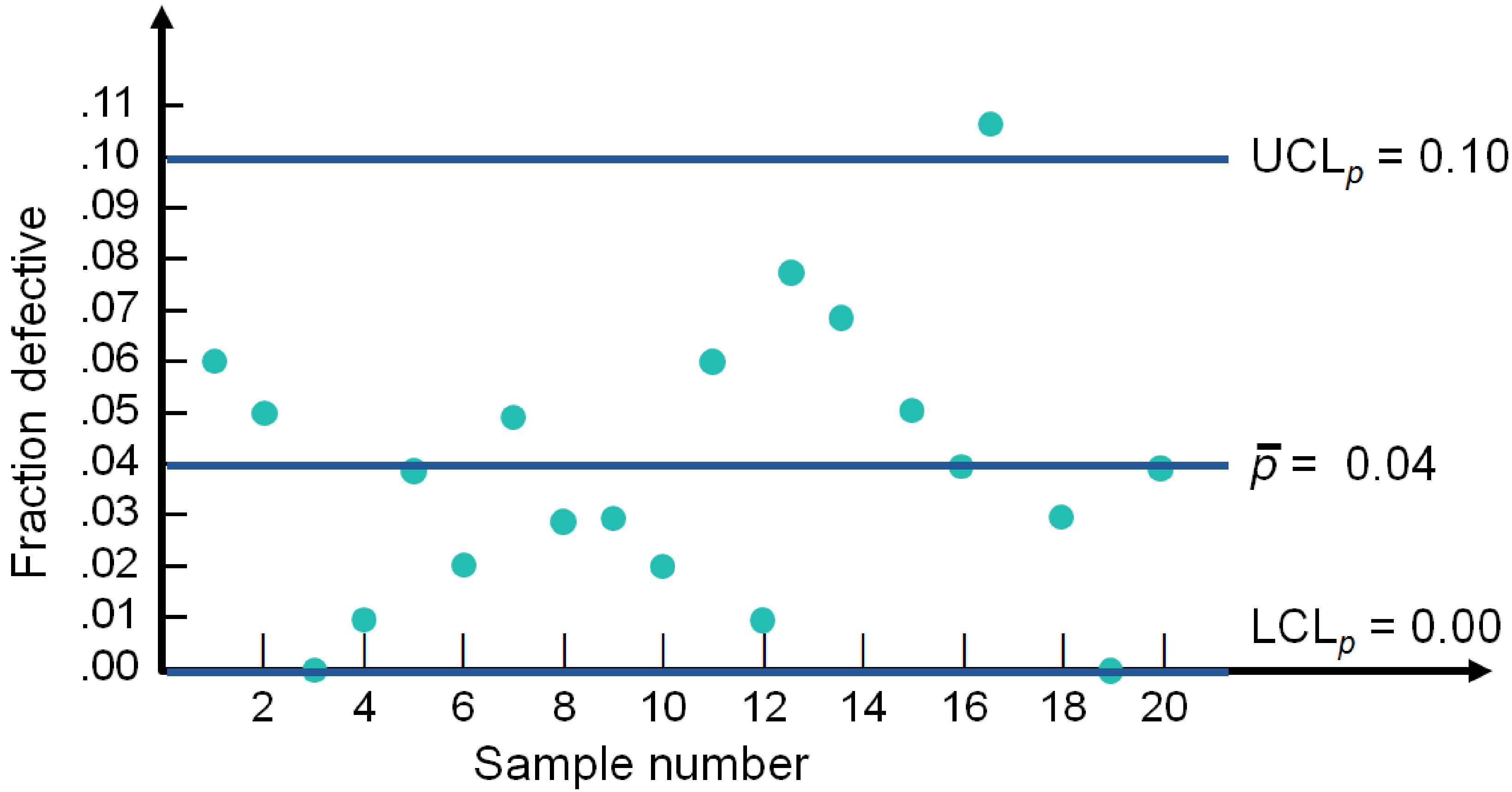
$$\text{LCL}_p = \bar{p} - z\hat{\sigma}_p = .04 - 3(.02) = 0$$

(because we cannot have a negative percent defective)

10	2	.02	20	

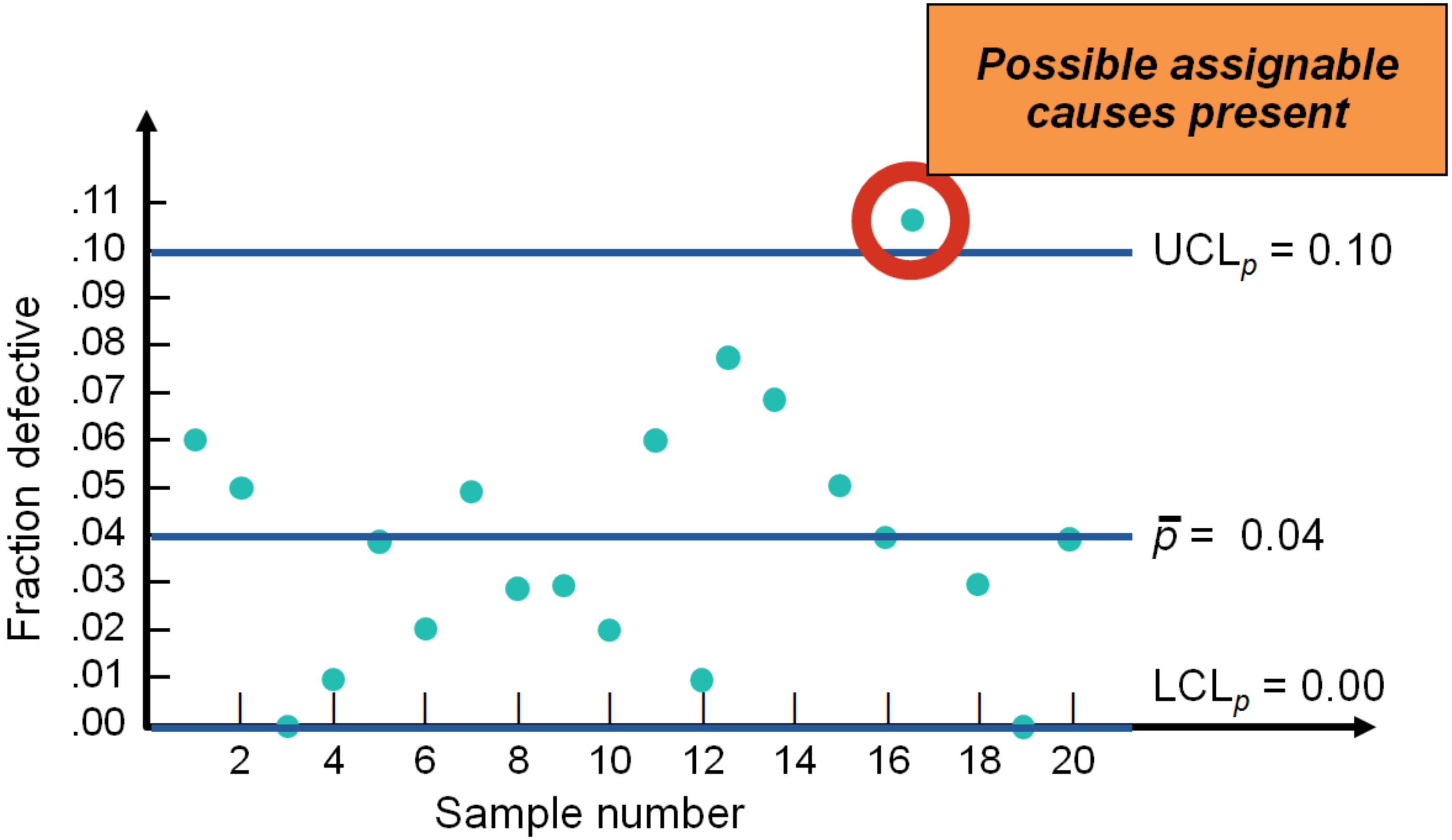
Pearson

p-Chart for Data Entry (3 of 4)



Pearson

p-Chart for Data Entry (4 of 4)



Pearson

Control Limits for *c*-Charts

Population will be a Poisson distribution, but applying the central limit theorem allows us to assume a normal distribution for the sample statistics

$$\bar{c} = \text{mean number of defects per unit}$$

$$\sqrt{\bar{c}} = \text{standard deviation of defects per unit}$$

$$\text{Control limits } (99.73\%) = \bar{c} \pm 3\sqrt{\bar{c}}$$

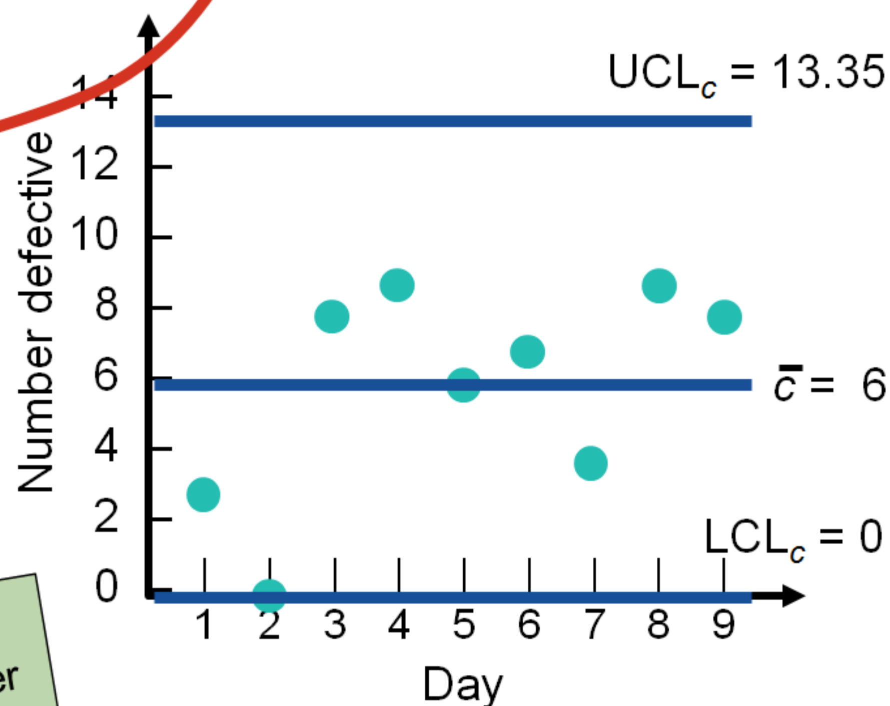
c-Chart for Cab Company

$$\bar{c} = \text{54 complaints/9 days} = \text{6 complaints/day}$$

$$\begin{aligned} UCL_c &= \bar{c} + 3\sqrt{\bar{c}} \\ &= 6 + 3\sqrt{6} \\ &= 13.35 \end{aligned}$$

$$\begin{aligned} LCL_c &= \bar{c} - 3\sqrt{\bar{c}} \\ &= 6 - 3\sqrt{6} \\ &= 0 \end{aligned}$$

Cannot be a negative number



Managerial Issues and Control Charts

Three major management decisions:

- Select points in the processes that need SPC
- Determine the appropriate charting technique
- Set clear and specific SPC policies and procedures

Which Control Chart to Use (1 of 2)

Table S6.3 Helping You Decide Which Control Chart to Use

VARIABLE DATA USING AN $\bar{x}$-CHART AND *R*-CHART
1. Observations are *variables*
2. Collect 20 to 25 samples of n = 4, or n = 5, or more, each from a stable process and compute the mean for the $\bar{x}$-chart and range for the *R*-chart
3. Track samples of n observations

Which Control Chart to Use (2 of 2)

Table S6.3 Helping You Decide Which Control Chart to Use

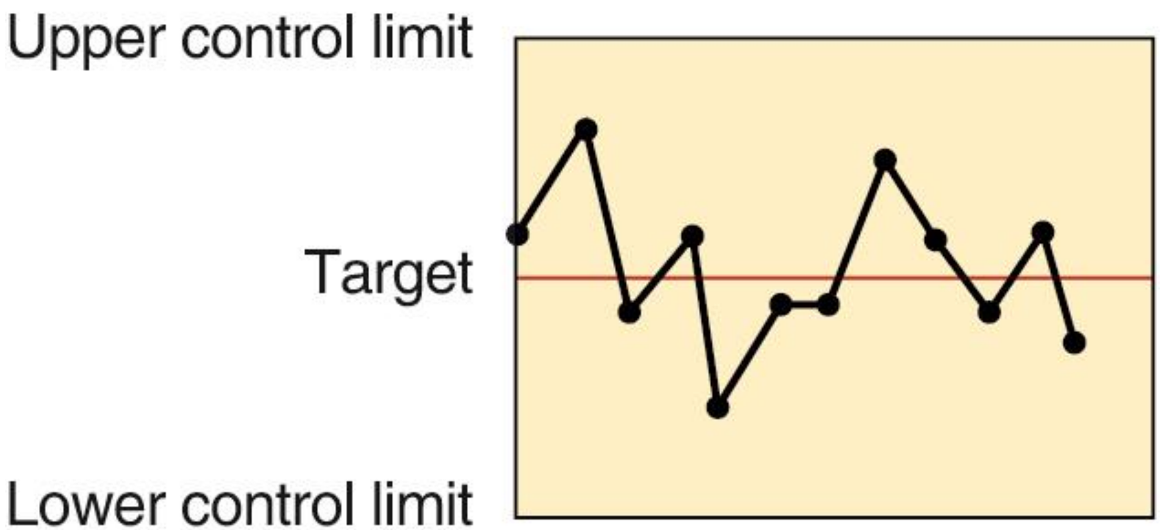
ATTRIBUTE DATA USING A *P*-CHART
1. Observations are *attributes* that can be categorized as good or bad (or pass–fail, or functional–broken), that is, in two states 2. We deal with fraction, proportion, or percent defectives 3. There are several samples, with many observations in each
ATTRIBUTE DATA USING A *C*-CHART
1. Observations are *attributes* whose defects per unit of output can be counted 2. We deal with the number counted, which is a small part of the possible occurrences 3. Defects may be: number of blemishes on a desk; flaws in a bolt of cloth; crimes in a year; broken seats in a stadium; typos in a chapter of this text; or complaints in a day

Patterns in Control Charts

- **Run test**
  - Identify abnormalities in a process
  - Runs of 5 or 6 points above or below the target or centerline suggest assignable causes may be present
  - Process may not be in statistical control
  - There are a variety of run tests

Patterns in Control Charts (1 of 6)

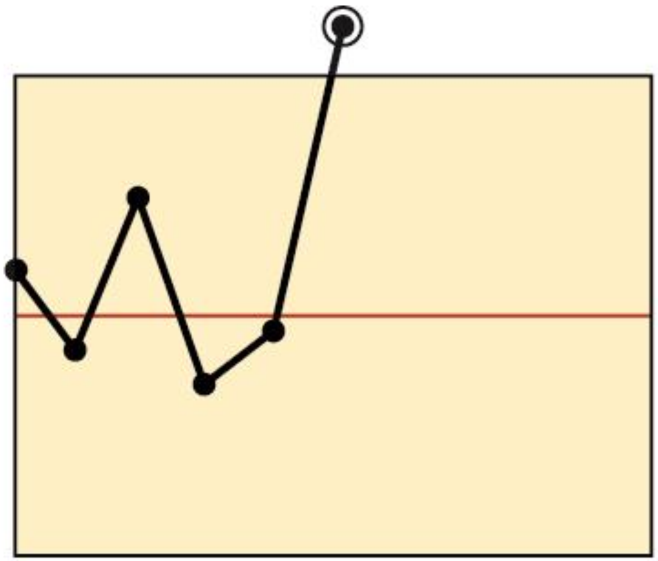
Figure S6.7



Normal behavior.
Process is "in control."

Patterns in Control Charts (2 of 6)

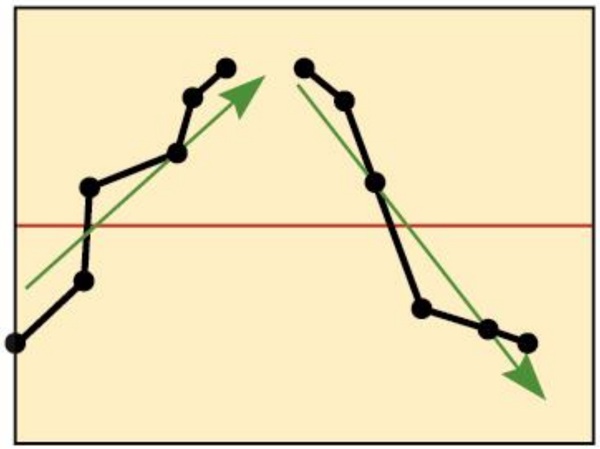
Figure S6.7



One point out above (or below). Investigate for cause. Process is "out of control."

Patterns in Control Charts (3 of 6)

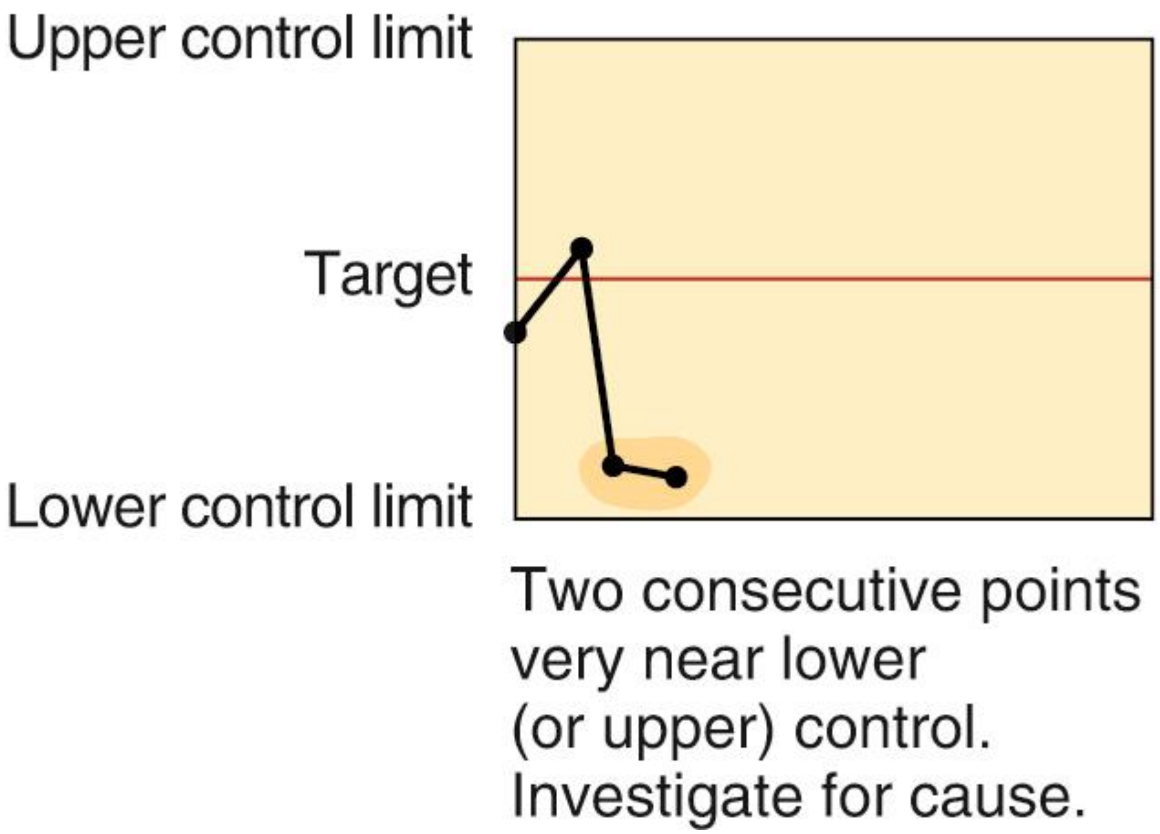
Figure S6.7



Trends in either direction, 5 points. Investigate for cause of progressive change. This could be the result of gradual tool wear.

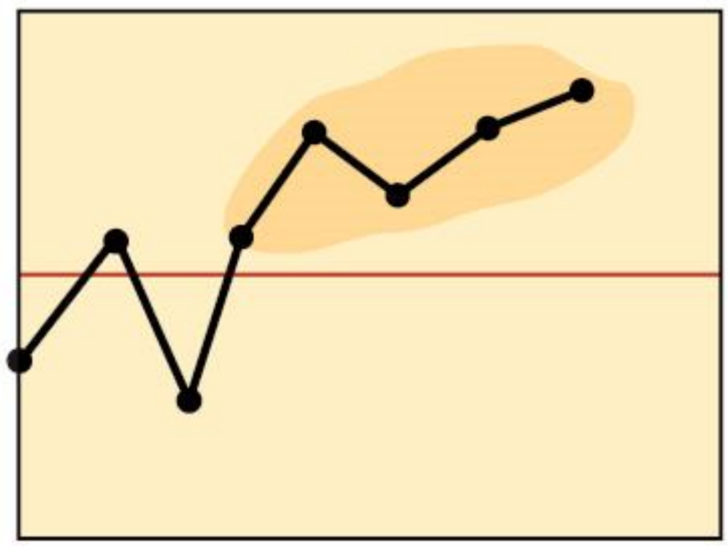
Patterns in Control Charts (4 of 6)

Figure S6.7



Patterns in Control Charts (5 of 6)

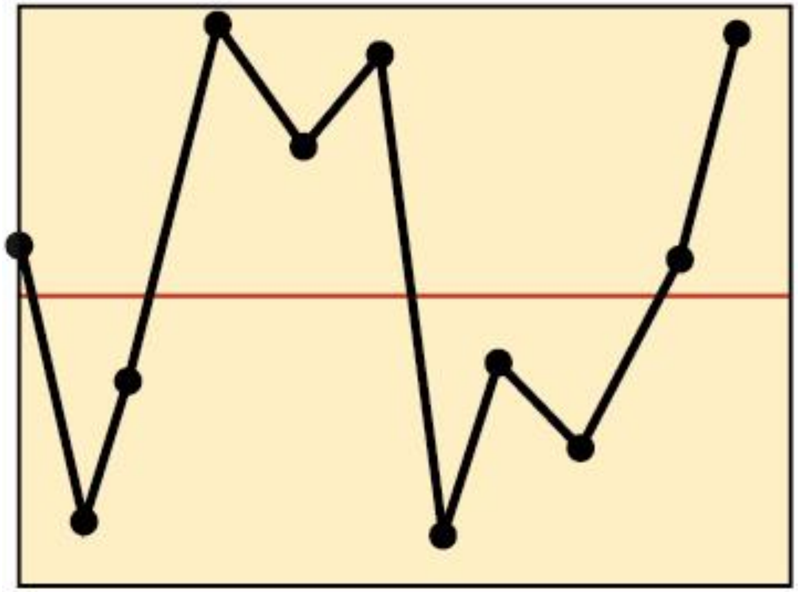
Figure S6.7



Run of 5 points above
(or below) central line.
Investigate for cause.

Patterns in Control Charts (6 of 6)

Figure S6.7



Erratic behavior.
Investigate.

Process Capability

- The natural variation of a process should be small enough to produce products that meet the standards required
- A process in statistical control does not necessarily meet the design specifications
- **Process capability** is a measure of the relationship between the natural variation of the process and the design specifications

Process Capability Ratio (1 of 4)

$$\text{Cp} = \frac{\text{Upper Specification} - \text{Lower Specification}}{6\sigma}$$

- A capable process must have a C_p of at least 1.0
- Does not look at how well the process is centered in the specification range
- Often a target value of $C_p = 1.33$ is used to allow for off-center processes
- Six Sigma quality requires a $C_p = 2.0$

Process Capability Ratio (2 of 4)

- Insurance claims process

$$\text{Process mean } \bar{x} = 210.0 \text{ minutes}$$

$$\text{Process standard deviations } \sigma = .516 \text{ minutes}$$

$$\text{Design specification } = 210 \pm 3 \text{ minutes}$$

$$\text{Cp} = \frac{\text{Upper Specification} - \text{Lower Specification}}{6\sigma}$$

Process Capability Ratio (3 of 4)

Insurance claims process

Process mean $\bar{x}$ = 210.0 minutes
Process standard deviation σ = .516 minutes
Design specification = 210 ± 3 minutes

$$C_p = \frac{\text{Upper Specification - Lower Specification}}{6\sigma}$$

$$= \frac{213 - 207}{6(.516)} = 1.938$$

Process Capability Ratio (4 of 4)

Insurance claims process

$$\text{Process mean } \bar{x} = 210.0 \text{ minutes}$$

$$\text{Process standard deviations } \sigma = .516 \text{ minutes}$$

$$\text{Design specification } = 210 \pm 3 \text{ minutes}$$

$$\text{Cp} = \frac{\text{Upper Specification} - \text{Lower Specification}}{6\sigma}$$

$$= \frac{213 - 207}{6(.516)} = 1.938$$

Process is capable

Process Capability Index (1 of 5)

$$C_{pk} = \text{minimum of} \left(\frac{\begin{matrix}\text{Upper} \\ \text{Specification} - \bar{x} \\ \text{Limit}\end{matrix}}{3\sigma} \right), \left(\frac{\begin{matrix}\text{Lower} \\ \bar{x} - \text{Specification} \\ \text{Limit}\end{matrix}}{3\sigma} \right)$$

- A capable process must have a C_{pk} of at least 1.0
- A capable process is not necessarily in the center of the specification, but it falls within the specification limit at both extremes

Process Capability Index (2 of 5)

New Cutting Machine

$$\text{New Process mean } \bar{x} = .250 \text{ inches}$$

$$\text{Process standard deviations } \sigma = .0005 \text{ inches}$$

$$\text{Upper Specification Limit } = .251 \text{ inches}$$

$$\text{Lower Specification Limit } = .249 \text{ inches}$$

Process Capability Index (3 of 5)

New Cutting Machine

New process mean $\bar{x}$ = .250 inches
Process standard deviation σ = .0005 inches
Upper Specification Limit = .251 inches
Lower Specification Limit = .249 inches

$$C_{pk} = \text{minimum of} \left[\frac{.251 - .250}{(3).0005} \right]$$

Process Capability Index (4 of 5)

New Cutting Machine

New process mean $\bar{x}$ = .250 inches
Process standard deviation σ = .0005 inches
Upper Specification Limit = .251 inches
Lower Specification Limit = .249 inches

$$C_{pk} = \text{minimum of} \left[\frac{.251 - .250}{(3).0005}\right], \left[\frac{.250 - .249}{(3).0005}\right]$$

Process Capability Index (5 of 5)

New Cutting Machine

New process mean $\bar{x}$ = .250 inches
Process standard deviation σ = .0005 inches
Upper Specification Limit = .251 inches
Lower Specification Limit = .249 inches

$$C_{pk} = \text{minimum of}\left[\frac{.251 - .250}{(3).0005}\right], \left[\frac{.250 - .249}{(3).0005}\right]$$

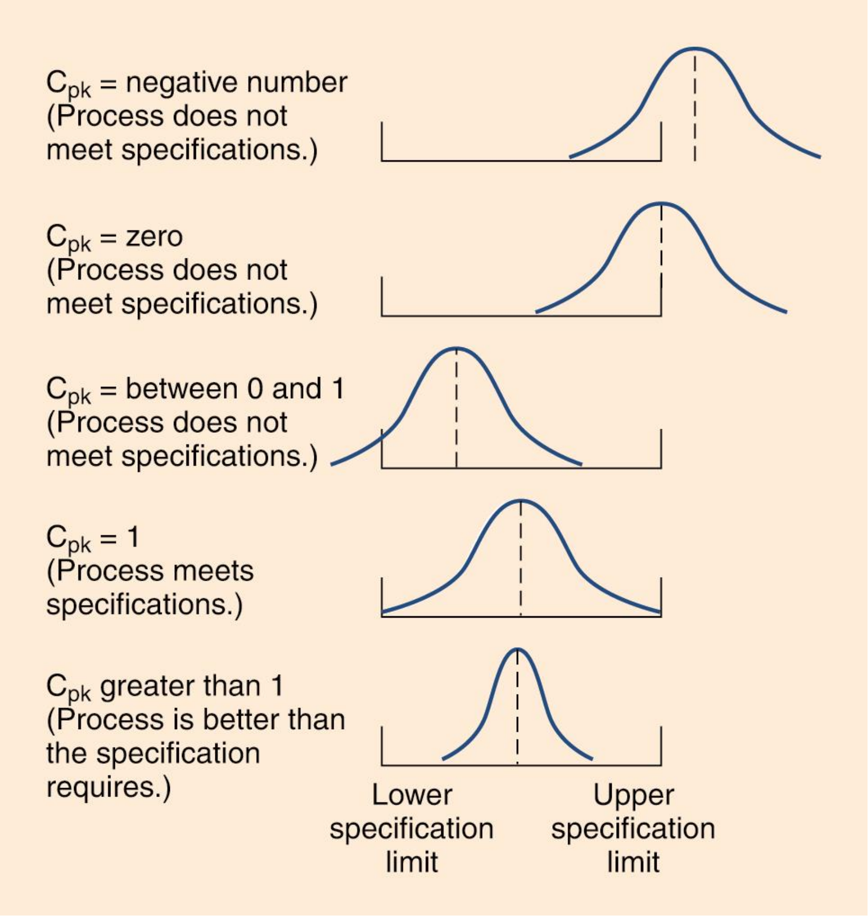
Both calculations result in

$$C_{pk} = \frac{.001}{.0015} = 0.67$$

New machine is NOT capable

Interpreting C_{pk}

Figure S6.8



Acceptance Sampling (1 of 2)

- Form of quality testing used for incoming materials or finished goods
  - Take samples at random from a lot (shipment) of items
  - Inspect each of the items in the sample
  - Decide whether to reject the whole lot based on the inspection results
- Only screens lots; does not drive quality improvement efforts

Acceptance Sampling (2 of 2)

- Form of quality testing used for incoming materials or finished goods
  - Take samples at random from a lot (shipment) of items
  - Inspect each of the items in the sample
  - Decide whether to reject the whole lot based on the inspection results
- Only screens lots; does not drive quality improvement efforts

Rejected lots can be:

1. Returned to the supplier
2. Culled for defectives (100% inspection)
3. May be re-graded to a lower specification

AQL and LTPD

- **Acceptable Quality Level (AQL)**
  - Poorest level of quality we are willing to accept
- **Lot Tolerance Percent Defective (LTPD)**
  - Quality level we consider bad
  - Consumer (buyer) does not want to accept lots with more defects than LTPD

Producer's and Consumer's Risks

- *Producer's risk* (α)
  - Probability of rejecting a good lot
  - Probability of rejecting a lot when the fraction defective is at or above the AQL
- *Consumer's risk* (β)
  - Probability of accepting a bad lot
  - Probability of accepting a lot when fraction defective is below the LTPD

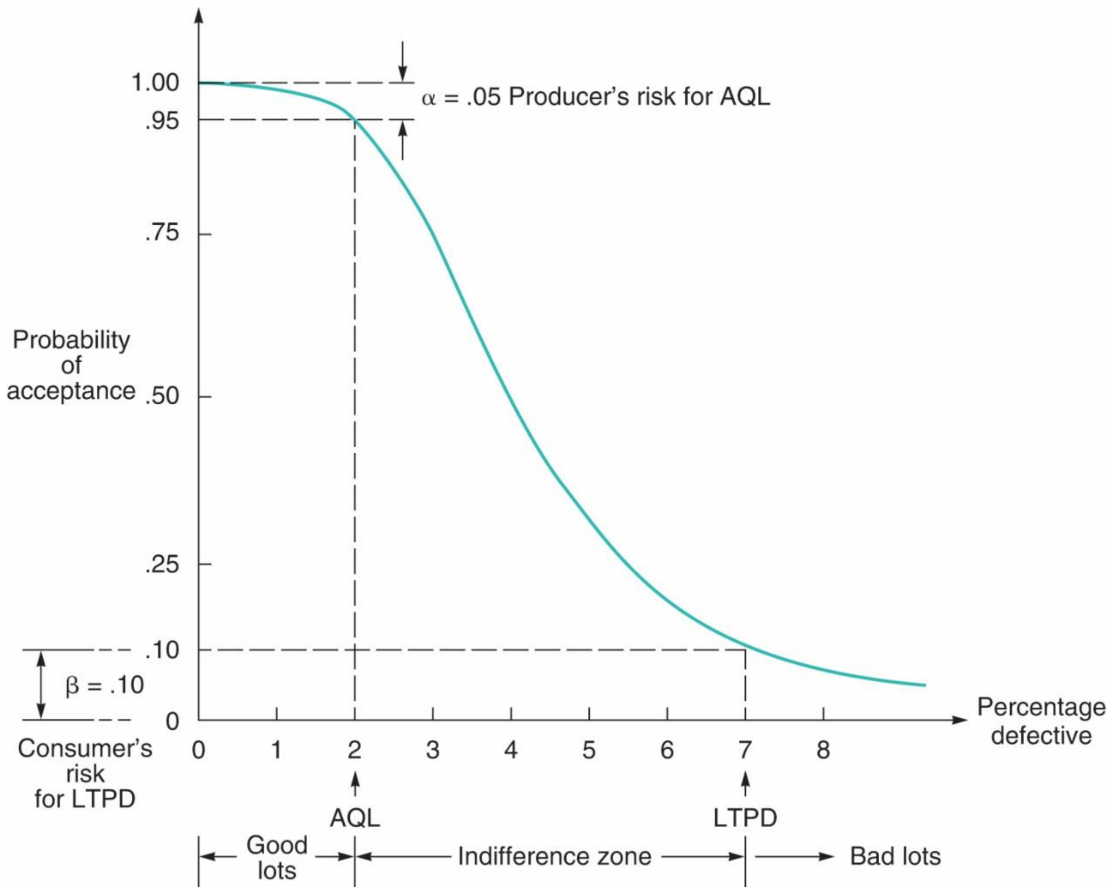
Operating Characteristic Curve

- Shows how well a sampling plan discriminates between good and bad lots (shipments)
- Shows the relationship between the probability of accepting a lot and its quality level

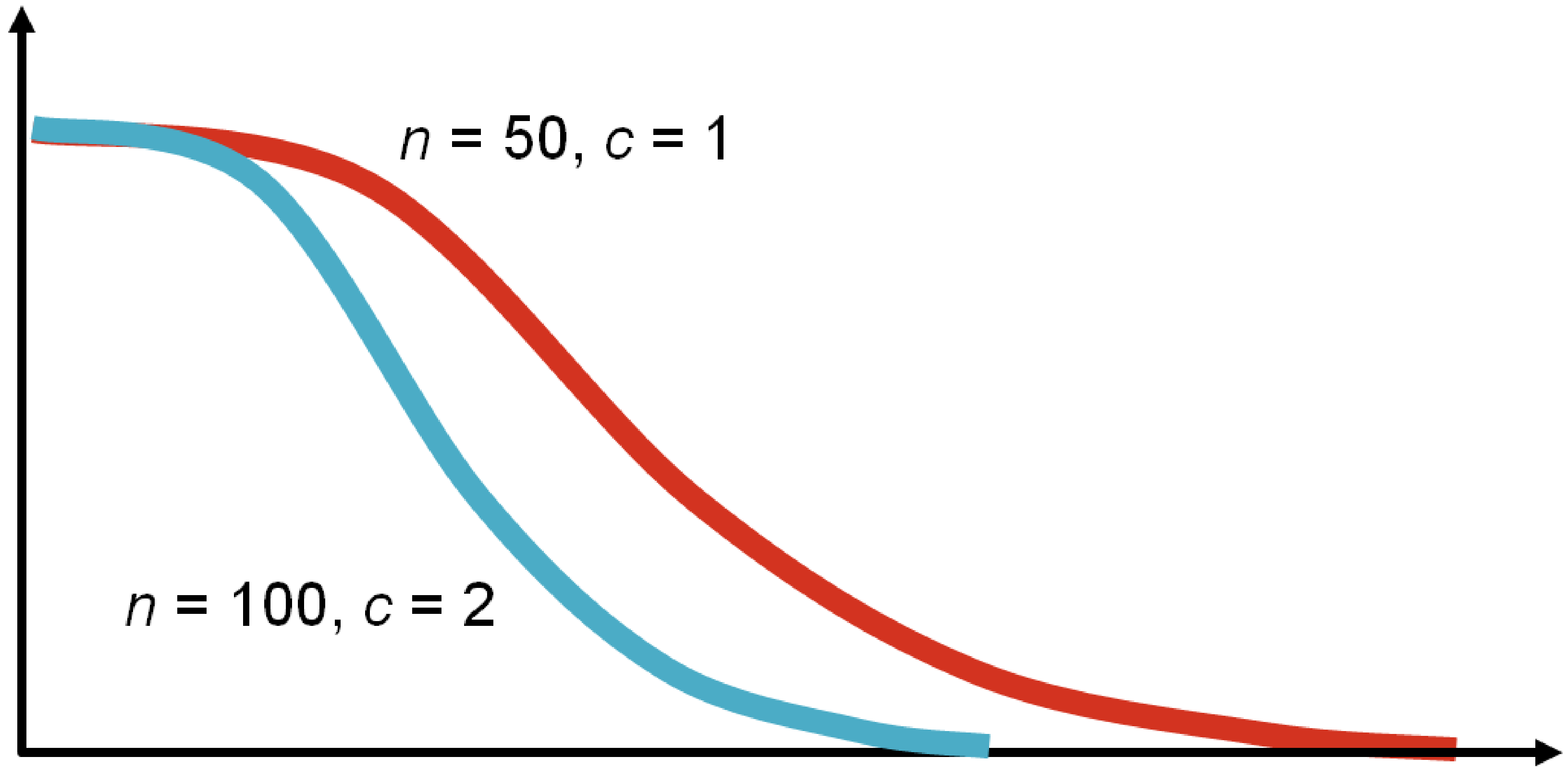
The "Perfect" OC Curve

An OC Curve

Figure S6.9



OC Curves for Different Sampling Plans



Average Outgoing Quality (1 of 2)

$$\text{AOQ} = \frac{(P_d)(P_a)(N - n)}{N}$$

where

P_d	=	true percent defective of the lot
P_a	=	probability of accepting the lot
N	=	number of items in the lot
n	=	number of items in the sample

Average Outgoing Quality (2 of 2)

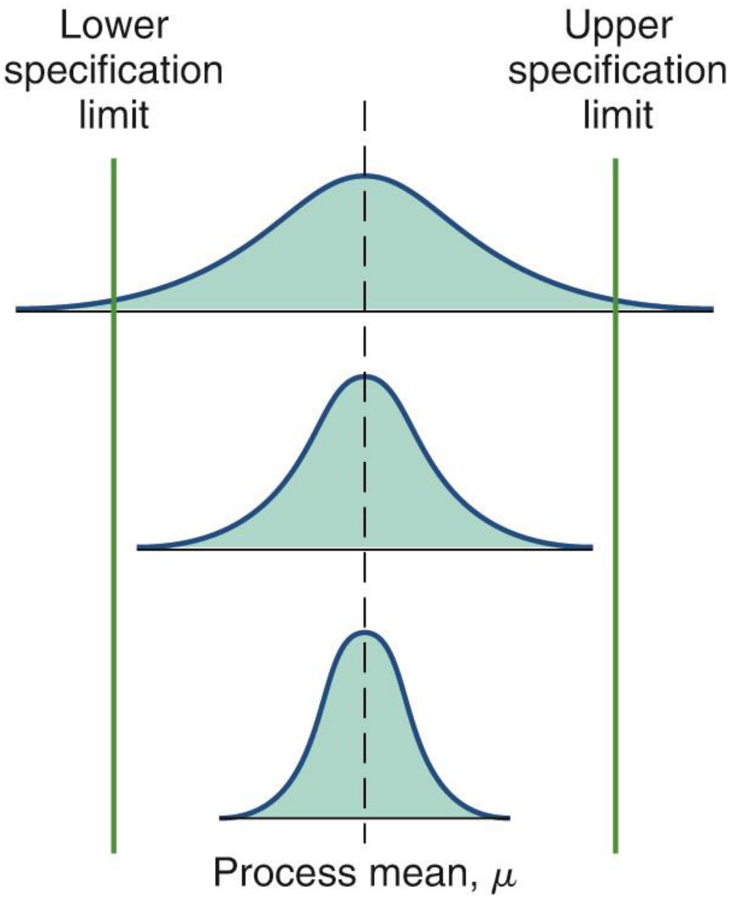
- If a sampling plan replaces all defectives
- If we know the true incoming percent defective for the lot

We can compute the **average outgoing quality** (**AOQ**) in percent defective

The maximum AOQ is the highest percent defective or the lowest average quality and is called the *average outgoing quality limit* (AOQL)

SPC and Process Variability

Figure S6.10



(a) Acceptance sampling (Some bad units accepted; the “lot” is good or bad.)

(b) Statistical process control (Keep the process “in control.”)

(c) $C_{pk} > 1$ (Design a process that is within specification.)

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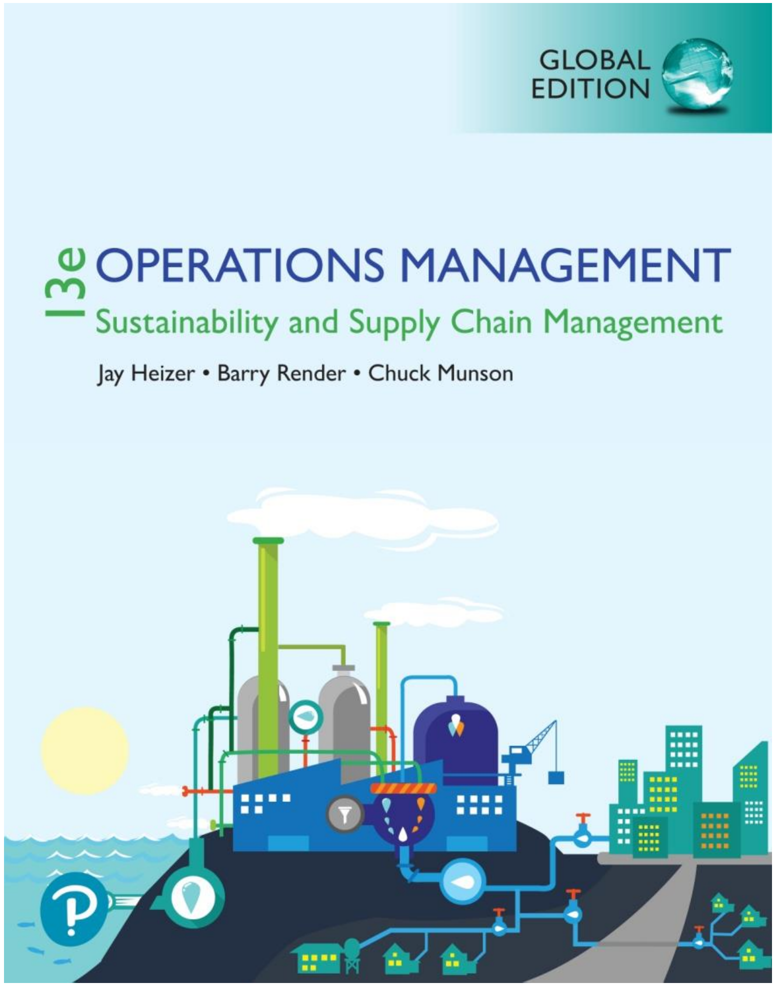
Operations Management: Sustainability and Supply Chain Management

Thirteenth Edition, Global Edition



Chapter 8

Location Strategies

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Outline

- **Global Company Profile:** *FedEx*
- The Strategic Importance of Location
- Factors That Affect Location Decisions
- Methods of Evaluating Location Alternatives
- Service Location Strategy
- Geographic Information Systems

Location Provides Competitive Advantage for FedEx

- Central hub concept (*superhub*)
  – Enables service to more locations with fewer aircraft
  – Enables matching of aircraft flights with package loads
  – Reduces mishandling and delay in transit because there is total control of packages from pickup to delivery

Learning Objectives (1 of 2)

When you complete this chapter you should be able to:

8.1 ***Identify*** and explain seven major factors that affect location decisions

8.2 ***Compute*** labor productivity

8.3 ***Apply*** the factor-rating method

8.4 ***Complete*** a locational cost-volume analysis graphically and mathematically

Learning Objectives (2 of 2)

When you complete this chapter you should be able to:

8.5 ***Use*** the center-of-gravity method

8.6 ***Understand*** the differences between service- and industrial-sector location analysis

The Strategic Importance of Location (1 of 3)

- One of the most important decisions a firm makes
- Increasingly global in nature
- Significant impact on fixed and variable costs
- Decisions made relatively infrequently

The Strategic Importance of Location (2 of 3)

- Long-term decisions
- Once committed to a location, many resource and cost issues are difficult to change

The Strategic Importance of Location (3 of 3)

The objective of location strategy is to maximize the benefit of location to the firm

Options include

1. Expand existing facilities
2. Maintain existing and add sites
3. Close existing and relocating

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Location and Costs

- Location decisions require careful consideration
- Once in place, location-related costs are fixed in place and difficult to reduce
- Effort spent determining optimal facility location is a good investment

Factors That Affect Location Decisions (1 of 7)

- Globalization adds to complexity
- Drivers of globalization
  - Market economics
  - Communication
  - Rapid, reliable transportation
  - Ease of capital flow
  - Differing labor costs
- Identify key success factors (KSFs)

Location Decisions (1 of 3)

Figure 8.1a

Key Success Factors

1. Political risks, government rules, attitudes, incentives
2. Cultural and economic issues
3. Location of markets
4. Labor talent, attitudes, productivity, costs
5. Availability of supplies, communications, energy
6. Exchange rates and currency risks

Location Decisions (2 of 3)

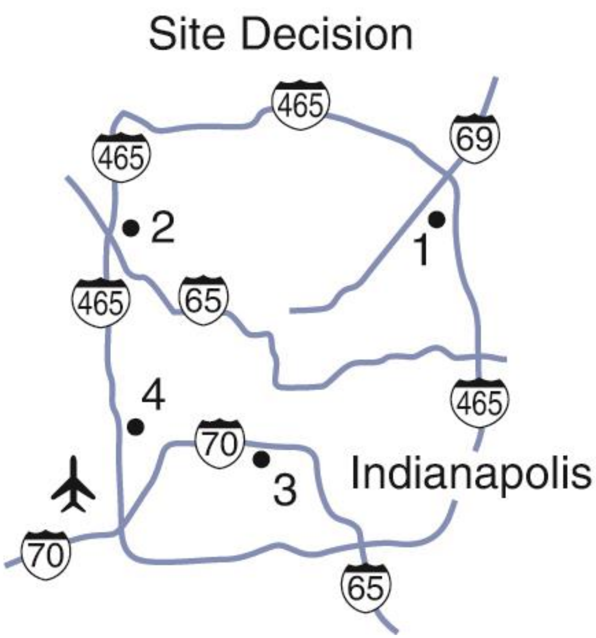
Figure 8.1b

Key Success Factors

1. Corporate desires
2. Attractiveness of region
3. Labor availability and costs
4. Costs and availability of utilities
5. Environmental regulations
6. Government incentives and fiscal policies
7. Proximity to raw materials and customers
8. Land/construction costs

Location Decisions (3 of 3)

Figure 8.1c



Key Success Factors

1. Site size and cost
2. Air, rail, highway, and waterway systems
3. Zoning restrictions
4. Proximity of services/supplies needed
5. Environmental impact issues
6. Customer density and demographics

Global Competitiveness Index of Countries

Table 8.1

Competitiveness of 137 Selected Countries

COUNTRY	2018 RANKING
Switzerland	1
U.S.	2
Singapore	3
Netherlands	4
Germany	5
Hong Kong	6
Canada	14
Israel	16
China	27
Russia	38
Mexico	51
Vietnam	55
Haiti	128
Mozambique	136
Yemen	137

Factors That Affect Location Decisions (2 of 7)

- Labor productivity
  - Wage rates are not the only cost
  - Lower productivity may increase total cost

$$\frac{\text{Labor cost per day}}{\text{Productivity (units per day)}} = \text{Labor cost per unit}$$

South Carolina

$$\frac{\$70}{60 \text{ units}} = \$1.17 \text{ per unit}$$

Mexico

$$\frac{\$25}{20 \text{ units}} = \$1.25 \text{ per unit}$$

Factors That Affect Location Decisions (3 of 7)

- Exchange rates and currency risks
  - Can have a significant impact on costs
  - Rates change over time
  - *Operational hedging* – shift production as exchange rates change
- Costs
  - **Tangible** – easily measured costs such as utilities, labor, materials, taxes
  - **Intangible** – not as easy to quantify and include education, public transportation, community, quality-of-life

Factors That Affect Location Decisions (4 of 7)

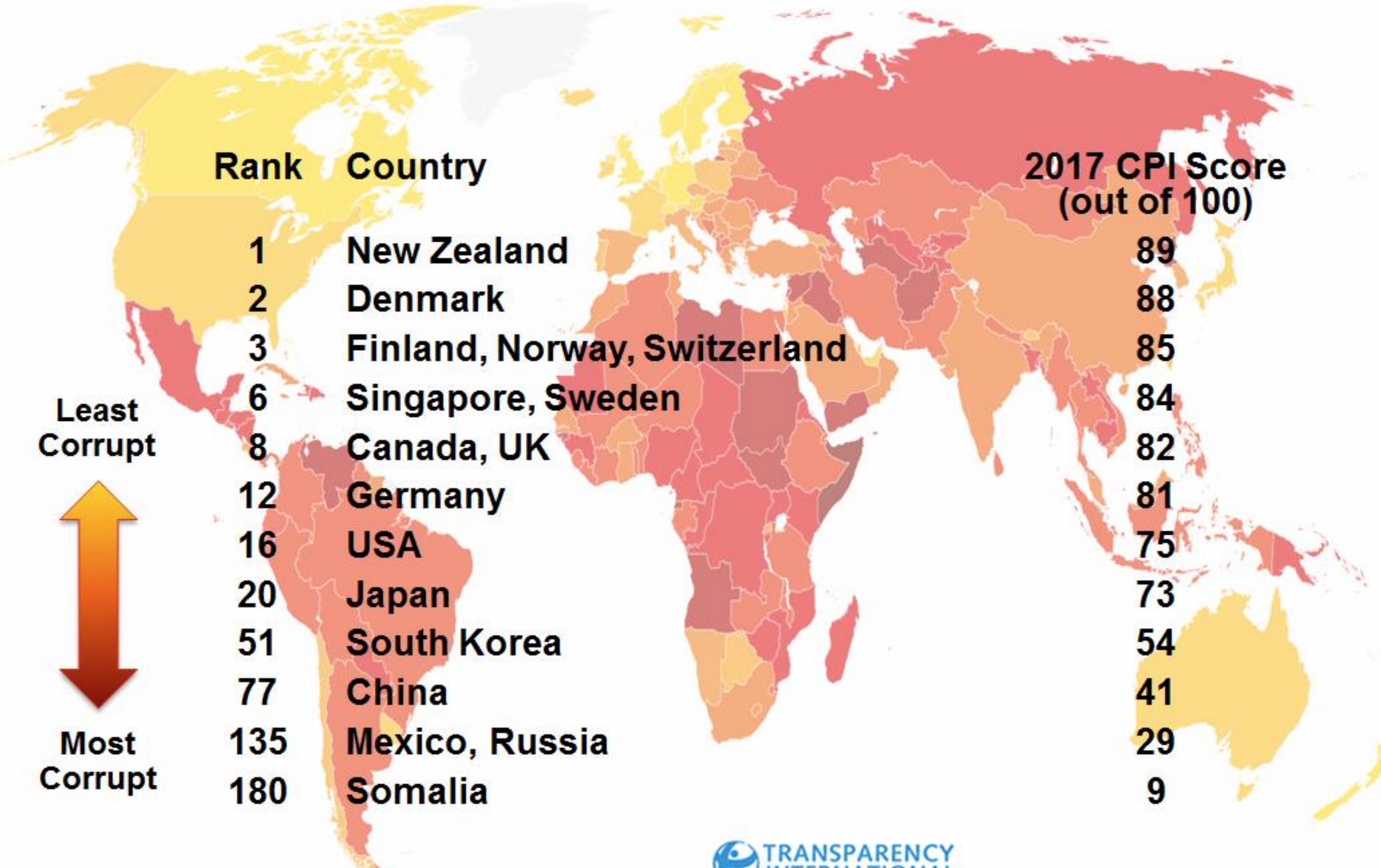
- Exchange rates and currency risks
  - Can have a significant impact on costs
  - Rates change over time
  - *Operational hedging* – shift production as exchange rates change
- Costs
  - **Tangible** – easily measured costs such as utilities, labor, materials, taxes
  - **Intangible** – not as easy to quantify and include education, public transportation, community, quality-of-life

Location decisions based on costs alone can create difficult ethical situations

Factors That Affect Location Decisions (5 of 7)

- Political risk, values, and culture
  - National, state, local governments' attitudes toward private and intellectual property, zoning, pollution, employment stability may be in flux
  - Worker attitudes toward turnover, unions, absenteeism
  - Globally cultures have different attitudes toward punctuality, legal, and ethical issues

Ranking Corruption



Rank	Country	2017 CPI Score (out of 100)
1	New Zealand	89
2	Denmark	88
3	Finland, Norway, Switzerland	85
6	Singapore, Sweden	84
8	Canada, UK	82
12	Germany	81
16	USA	75
20	Japan	73
51	South Korea	54
77	China	41
135	Mexico, Russia	29
180	Somalia	9

Least Corrupt

Most Corrupt

TRANSPARENCY INTERNATIONAL
the global coalition against corruption

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Factors That Affect Location Decisions (6 of 7)

- Proximity to markets
  - Very important to services
  - JIT systems or high transportation costs may make it important to manufacturers
- Proximity to suppliers
  - Perishable goods, high transportation costs, bulky products

Factors That Affect Location Decisions (7 of 7)

- Proximity to competitors (clustering)
  - Often driven by resources such as natural, information, capital, talent
  - Found in both manufacturing and service industries

Clustering of Companies (1 of 3)

Table 8.3 Clustering of Companies

INDUSTRY	LOCATIONS	REASON FOR CLUSTERING
Wine making	Napa Valley (U.S.) Bordeaux region (France)	Natural resources of land and climate
Software firms	Silicon Valley, Boston, Bangalore, Israel	Talent resources of bright graduates in scientific/technical areas, venture capitalists nearby
Clean energy	Colorado	Critical mass of talent and information, with 1,000 companies

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Clustering of Companies (2 of 3)

Table 8.3 Clustering of Companies

INDUSTRY	LOCATIONS	REASON FOR CLUSTERING
Theme parks (Disney World, Universal Studios, and Sea World)	Orlando, Florida	A hot spot for entertainment, warm weather, tourists, and inexpensive labor
Electronics firms (Sony, IBM, HP, Motorola, and Panasonic)	Northern Mexico	NAFTA, duty free export to U.S. (24% of all TVs are built here)
Computer hardware manufacturers	Singapore, Taiwan	High technological penetration rate and per capita GDP, skilled/educated workforce with large pool of engineers

Clustering of Companies (3 of 3)

Table 8.3 Clustering of Companies

INDUSTRY	LOCATIONS	REASON FOR CLUSTERING
Fast food chains (Wendy's, McDonald's, Burger King, Pizza Hut)	Sites within 1 mile of each other	Stimulate food sales, high traffic flows
General aviation aircraft (Cessna, Learjet, Boeing, Raytheon)	Wichita, Kansas	Mass of aviation skills (60-70% of world's small planes/jets are built here)
Athletic footwear, outdoor wear	Portland, Oregon	300 companies, many owned by Nike, deep talent pool and outdoor culture

Factor-Rating Method

- Popular because a wide variety of factors can be included in the analysis
- Six steps in the method
  1. Develop a list of relevant factors called *key success factors*
  2. Assign a weight to each factor
  3. Develop a scale for each factor
  4. Score each location for each factor
  5. Multiply score by weights for each factor and total the score for each location
  6. Make a recommendation based on the highest point score

Factor-Rating Example

Table 8.4 Weights, Scores, and Solution

KEY SUCCESS FACTOR	WEIGHT	SCORES (OUT OF 100)		WEIGHTED SCORES	
		FRANCE	DENMARK	FRANCE	DENMARK
Labor availability and attitude	.25	70	60	(.25)(70) = 17.50	(.25)(60) = 15.00
People-to-car ratio	.05	50	60	(.05)(50) = 2.50	(.05)(60) = 3.00
Per capita income	.10	85	80	(.10)(85) = 8.50	(.10)(80) = 8.00
Tax structure	.39	75	70	(.39)(75) = 29.25	(.39)(70) = 27.30
Education and health	.21	60	70	(.21)(60) = 12.60	(.21)(70) = 14.70
Totals	1.00			70.35	68.00

Locational Cost-Volume Analysis

- An economic comparison of location alternatives
- Three steps in the method
  1. Determine fixed and variable costs for each location
  2. Plot the costs for each location
  3. Select location with lowest total cost for expected production volume

Locational Cost-Volume Analysis Example (1 of 3)

Three locations:

Selling price = $120

Expected volume = 2,000 units

City	Fixed Cost	Variable Cost	Total Cost
Athens	$30,000	$75	$180,000
Brussels	$60,000	$45	$150,000
Lisbon	$110,000	$25	$160,000

$$\text{Total Cost} = \text{Fixed Cost} + \left(\text{Variable Cost} \times \text{Volume}\right)$$

Locational Cost-Volume Analysis Example (2 of 3)

Crossover point – Athens and Brussels

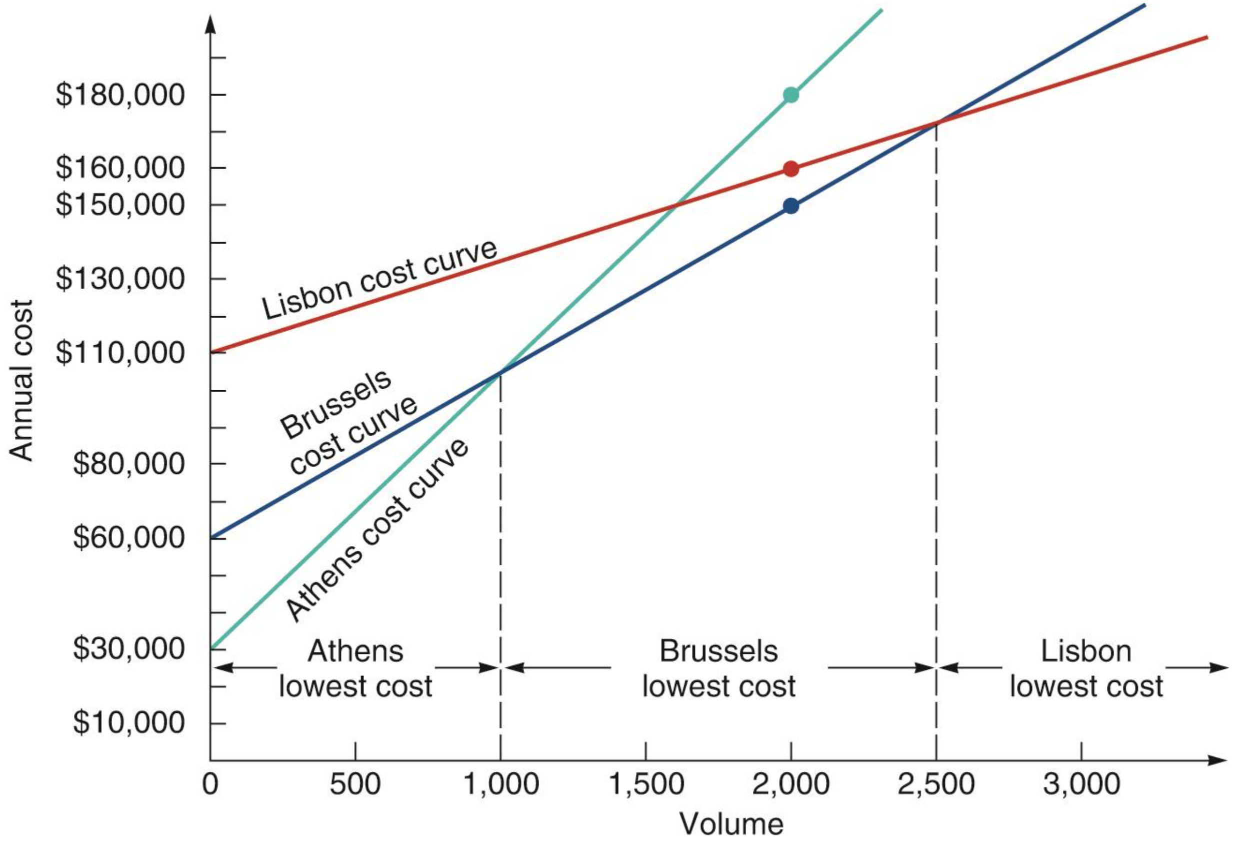
$$30,000 + 75(x) = 60,000 + 45(x)$$
$$30(x) = 30,000$$
$$x = 1,000$$

Crossover point – Brussels and Lisbon

$$60,000 + 45(x) = 110,000 + 25(x)$$
$$20(x) = 50,000$$
$$x = 2,500$$

Locational Cost-Volume Analysis Example (3 of 3)

Figure 8.2



Center-of-Gravity Method (1 of 7)

- Finds location of distribution center that minimizes distribution costs
- Considers
  - Location of markets
  - Volume of goods shipped to those markets
  - Shipping cost (or distance)

Center-of-Gravity Method (2 of 7)

- Place existing locations on a coordinate grid
  - Grid origin and scale are arbitrary
  - Maintain relative distances
- Calculate *x* and *y* coordinates for 'center of gravity'
  - Assumes cost is directly proportional to distance and volume shipped

Center-of-Gravity Method (3 of 7)

$$x\text{-coordinate of the center of gravity} = \frac{\sum_i x_i Q_i}{\sum_i Q_i}$$

$$y\text{-coordinate of the center of gravity} = \frac{\sum_i y_i Q_i}{\sum_i Q_i}$$

where

$x_i = x$-coordinate of location i

$y_i = y$-coordinate of location i

Q_i = Quantity of goods moved to or from location i

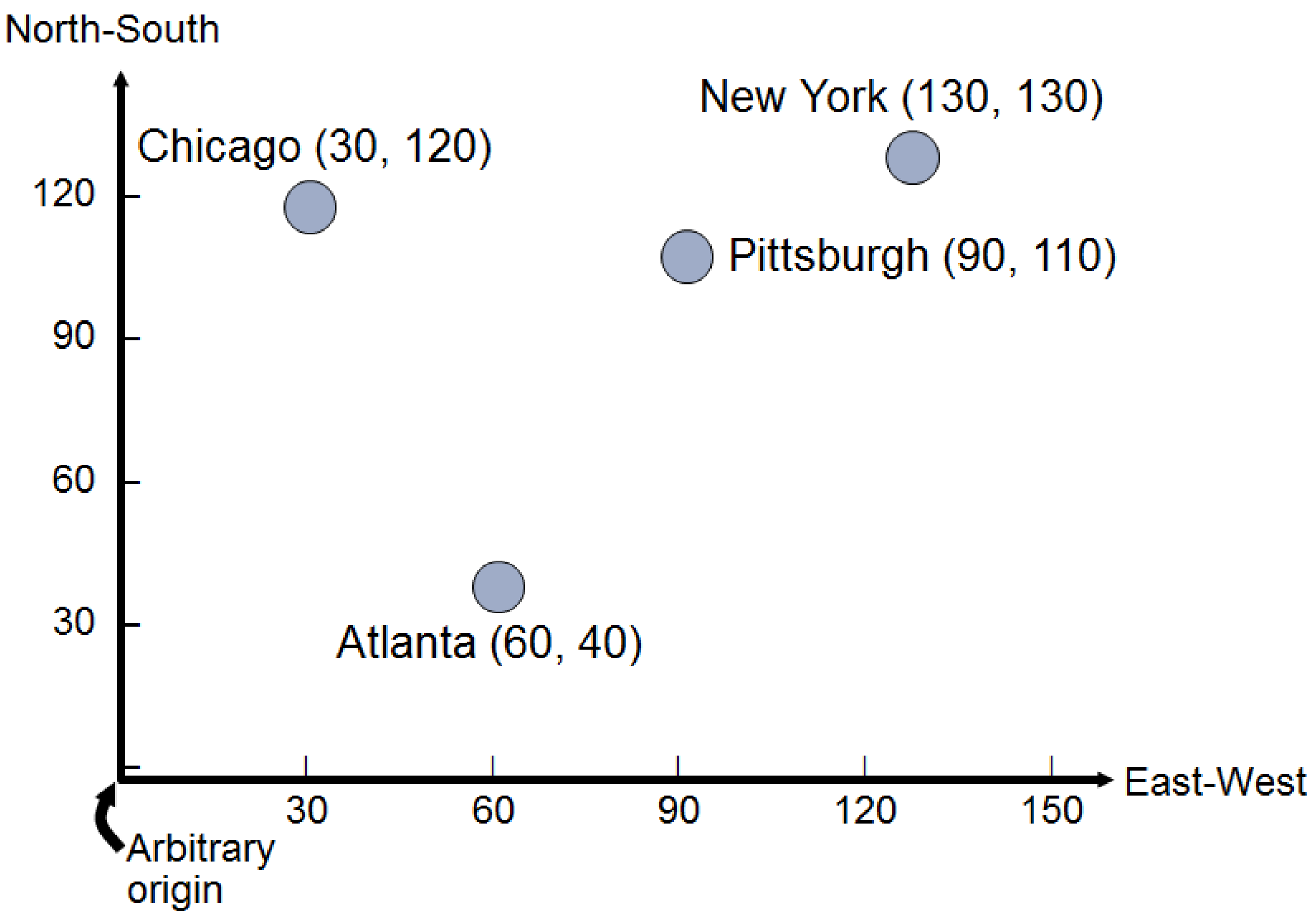
Center-of-Gravity Method (4 of 7)

Table 8.5 Demand for Quain's Discount Department Stores

STORE LOCATION	NUMBER OF CONTAINERS SHIPPED PER MONTH
Chicago	2,000
Pittsburgh	1,000
New York	1,000
Atlanta	2,000

Center-of-Gravity Method (5 of 7)

Figure 8.3



$x_1 = 30$

$y_1 = 120$

$Q_1 = 2{,}000$

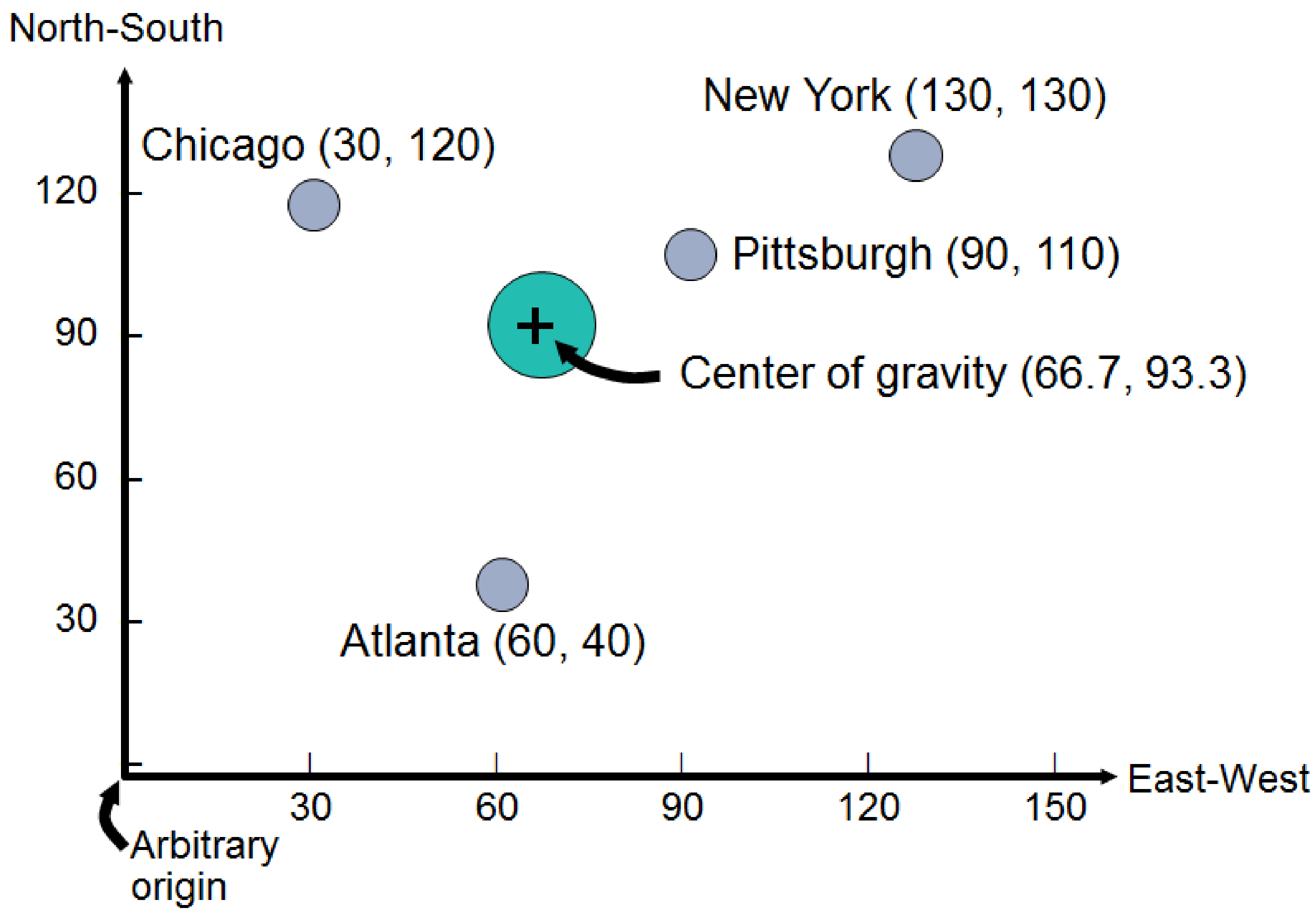
Center-of-Gravity Method (6 of 7)

$$x\text{-coordinate} = \frac{(30)(2000) + (90)(1000) + (130)(1000) + (60)(2000)}{2000 + 1000 + 1000 + 2000}$$
$$= 66.7$$

$$y\text{-coordinate} = \frac{(120)(2000) + (110)(1000) + (130)(1000) + (40)(2000)}{2000 + 1000 + 1000 + 2000}$$
$$= 93.3$$

Center-of-Gravity Method (7 of 7)

Figure 8.3

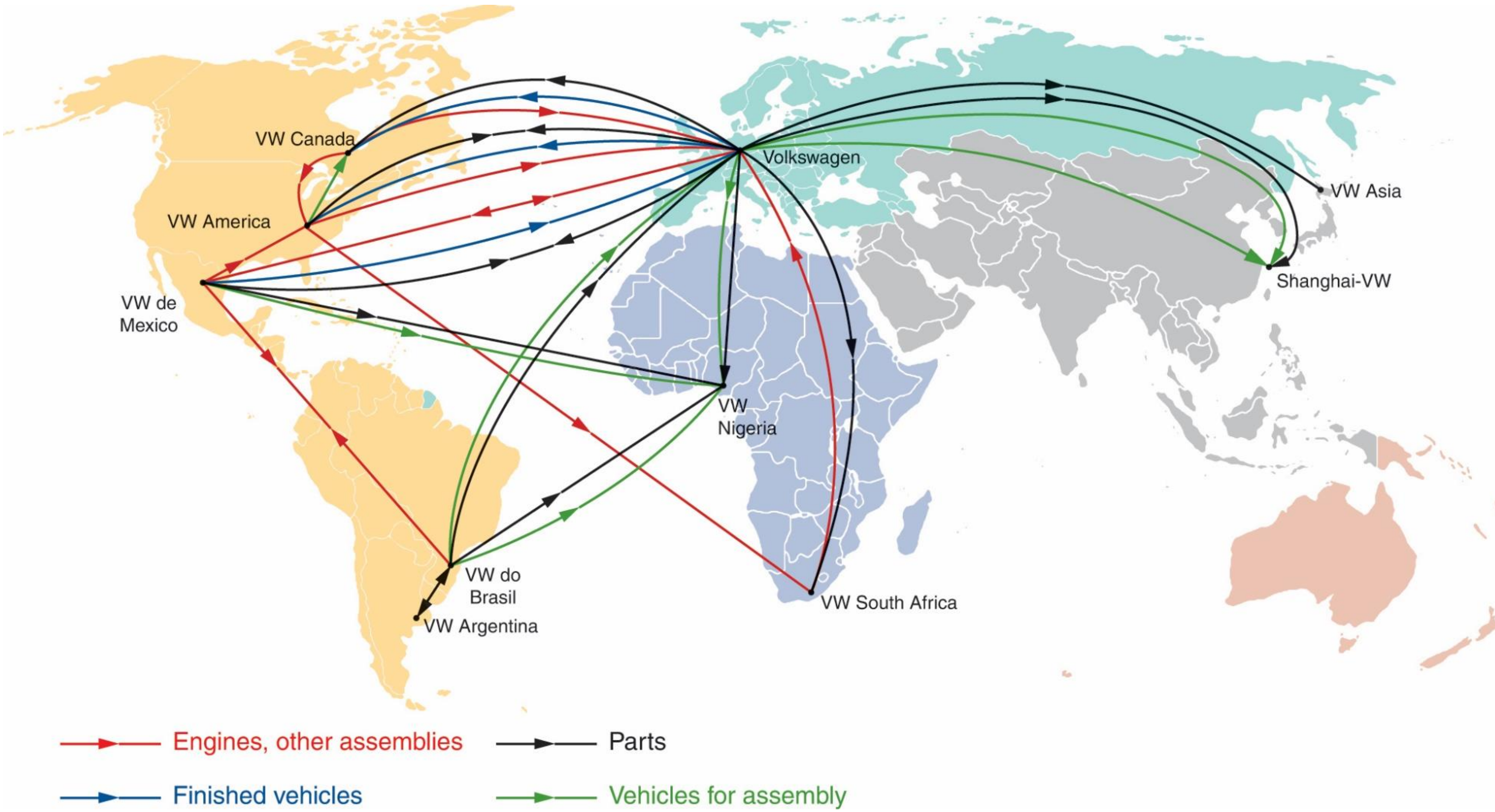


Transportation Model

- Finds amount to be shipped from several points of supply to several points of demand
- Solution will minimize total production and shipping costs
- A special class of linear programming problems

Worldwide Distribution of Volkswagens and Parts

Figure 8.4



Service Location Strategy

Major Determinants of Volume and Revenue

1. Purchasing power of customer-drawing area
2. Service and image compatibility with demographics of the customer-drawing area
3. Competition in the area
4. Quality of the competition
5. Uniqueness of the firm’s and competitors’ locations
6. Physical qualities of facilities and neighboring businesses
7. Operating policies of the firm
8. Quality of management

Location Strategies (1 of 2)

Table 8.6 Location Strategies – Service vs. Goods-Producing Organizations

SERVICE/RETAIL/PROFESSIONAL	*GOODS-PRODUCING*
REVENUE FOCUS	**COST FOCUS**
Volume/revenue Drawing area; purchasing power Competition; advertising/pricing **Physical quality** Parking/access; security/lighting Appearance/image **Cost determinants** Rent Management caliber Operation policies (hours, wage rates)	**Tangible costs** Transportation cost of raw material Shipment cost of finished goods Energy and utility cost; labor; raw material; taxes, and so on **Intangible and future costs** Attitude toward union Quality of life Education expenditures by state Quality of state and local government

Location Strategies (2 of 2)

Table 8.6 Location Strategies – Service vs. Goods-Producing Organizations

SERVICE/RETAIL/PROFESSIONAL	*GOODS-PRODUCING*
TECHNIQUES	**TECHNIQUES**
Regression models to determine importance of various factors Factor-rating method Traffic counts Demographic analysis of drawing area Purchasing power analysis of area Center-of-gravity method Geographic information systems	Transportation method Factor-rating method Locational cost–volume analysis Crossover charts
ASSUMPTIONS	**ASSUMPTIONS**
Location is a major determinant of revenue High customer-contact issues are critical Costs are relatively constant for a given area; therefore, the revenue function is critical	Location is a major determinant of cost Most major costs can be identified explicitly for each site Low customer contact allows focus on the identifiable costs Intangible costs can be evaluated

How Hotel Chains Select Sites (1 of 2)

- Location is a strategically important decision in the hospitality industry
- La Quinta started with 35 independent variables and worked to refine a regression model to predict profitability
- The final model had only four variables
  - Price of the inn
  - Median income levels
  - State population per inn
  - Location of nearby colleges

How Hotel Chains Select Sites (2 of 2)

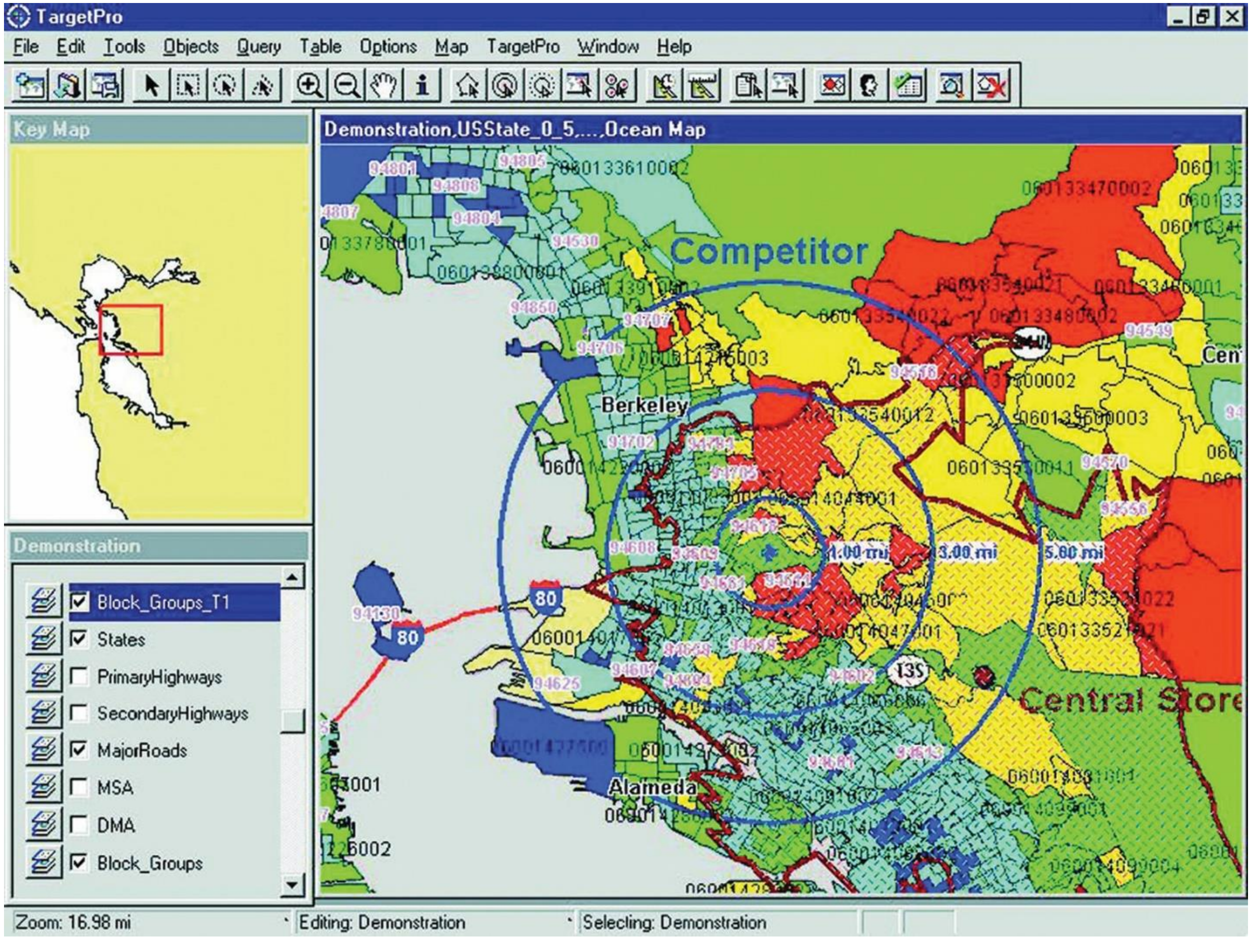
$R^2 = .51$

51% of the profitability is predicted by just these four variables!

Geographic Information Systems (GIS) (1 of 2)

- Important tool to help in location analysis
- Enables more complex demographic analysis
- Available databases include
  - Detailed census data
  - Detailed maps
  - Utilities
  - Geographic features
  - Locations of major services

Geographic Information Systems (GIS) (2 of 2)



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