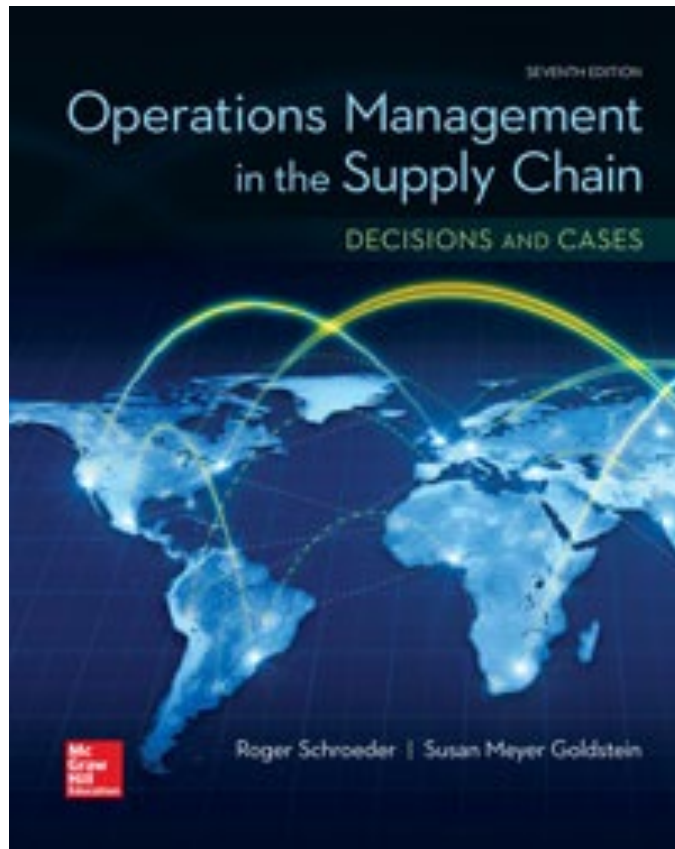


Operations Management in the Supply Chain

Decisions and Cases

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Chapter 1

The Operations Function

Learning Objectives

- 1.1 Define operations management.
- 1.2 Describe the five main decisions made by operations and supply chain managers.
- 1.3 Explain the nature of cross-functional decision making with operations.
- 1.4 Define typical inputs and outputs of an operations transformation system.
- 1.5 Identify contemporary challenges facing operations and supply chain managers.

Why Study Operations Management?

- Cross-functional nature of decisions
- Operations is a major function in every organization
- Principles of process thinking can be applied across the organization
- Operations Management is an interesting and challenging field of study

Definition of Operations Management

- Operations management focuses on decisions for the production and delivery of the firm's products and services.

Three Aspects of Operations Management

- **Decisions:**

- The operations manager must decide:

- Process, quality, capacity, inventory, and supply chain

قرارات ← continues or patching → fine

- **Function:**

- Major functional areas in organizations:

- Operations, marketing, finance

- **Process:**

- Planning and controlling the transformation process and its interfaces (internal/external)

input → transformation → output

Definition of Supply Chain

- Network of manufacturing and service operations that supply one another
- From raw materials through production to the end consumer
- Flows of materials, money, and information
- Links operations **across** organizations

Major Decisions at Pizza USA

- Process
 - How should we produce pizzas?
- Quality
 - How do we meet quality standards and ensure a good customer experience?
- Capacity
 - How much output do we need at various times?
- Inventory
 - Which ingredients, when & how much?
- Supply Chain
 - How to source inputs and manage logistics?

Contingencies (1 of 2)

- Decisions related to process, quality, capacity, inventory and supply chain must account for:
 - upstream suppliers
 - downstream customers
 - other functions (marketing, finance)
 - support functions (HR, Info systems, accounting)
 - situations (supply disruption, seasonal demand peaks)
 - conditions (economy, changing customer preferences)
 - *many other contingencies*

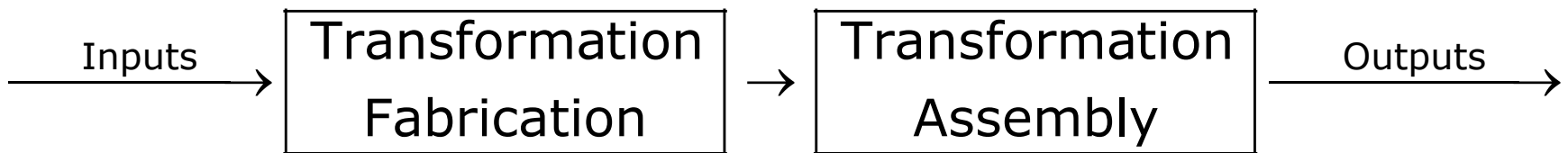
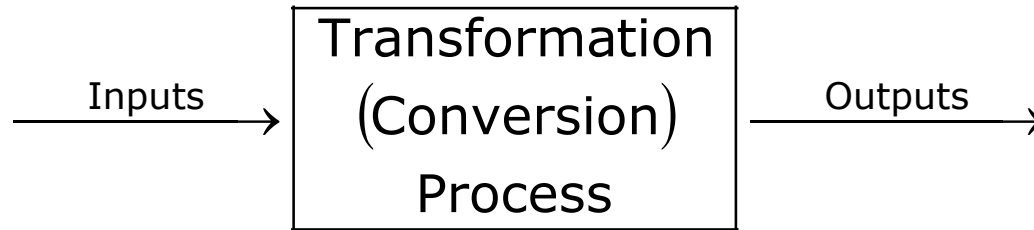
Contingencies (2 of 2)

In other words, there is no single set of “best” practices. The best decision-making will depend on the situation.

Cross-Functional Decision Making

- Operations as the primary production **function**.
- Other primary functions:
 - Marketing
 - Finance
- Supporting functions: all others
- Major cross-functional decision making relationships (See Table 1.2)

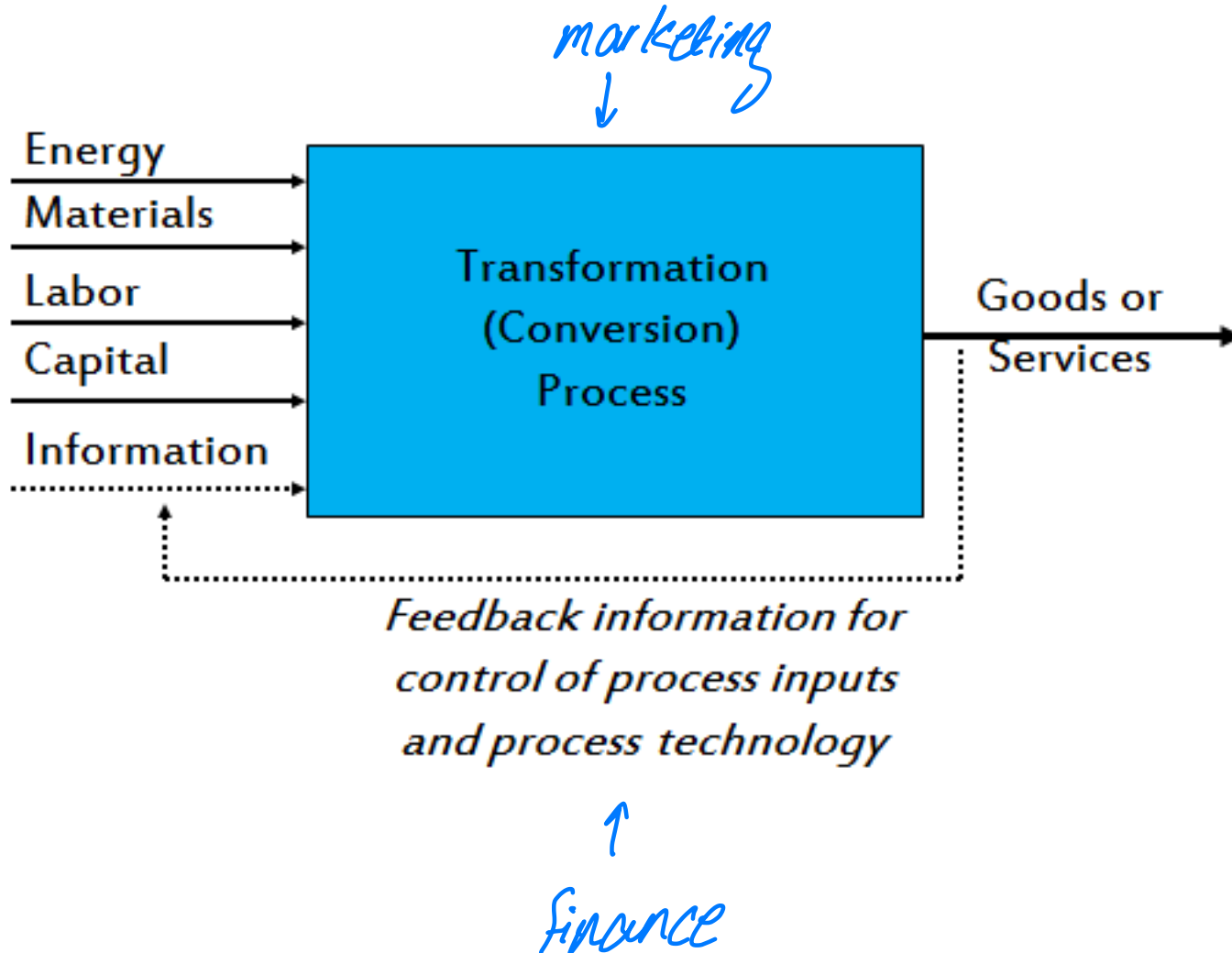
Operations as a Process



Fabrication: making the parts

Assembly: putting the parts together

Operations as a Process (Figure 1.2)



Contemporary Operations Challenges

- Service and Manufacturing (differences and implications)
- Customer-Directed Operations (“voice of the customer”)
- Integration of Decisions Internally and Externally
- Environmental Sustainability
- Globalization of Operations and the Supply Chain

Summary

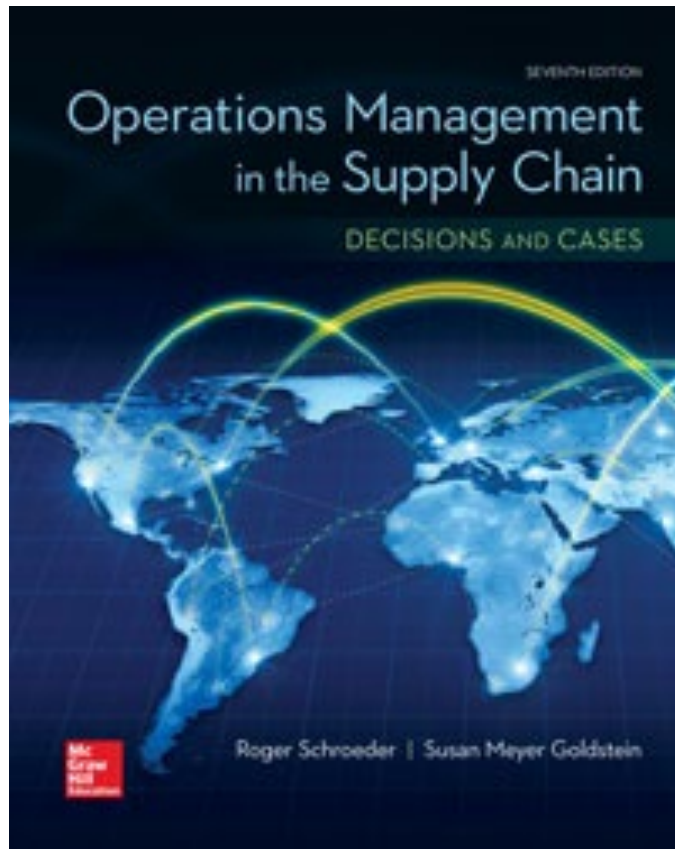
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End of Presentation

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Chapter 2

Operations and Supply Chain Strategy

Learning Objectives (1 of 2)

- 2.1 Define operations strategy.
- 2.2 Describe the elements of operations strategy and alignment with business and other functional strategies.
- 2.3 Differentiate the ways to compete with operations objectives.
- 2.4 Compare product imitator and innovator strategies.

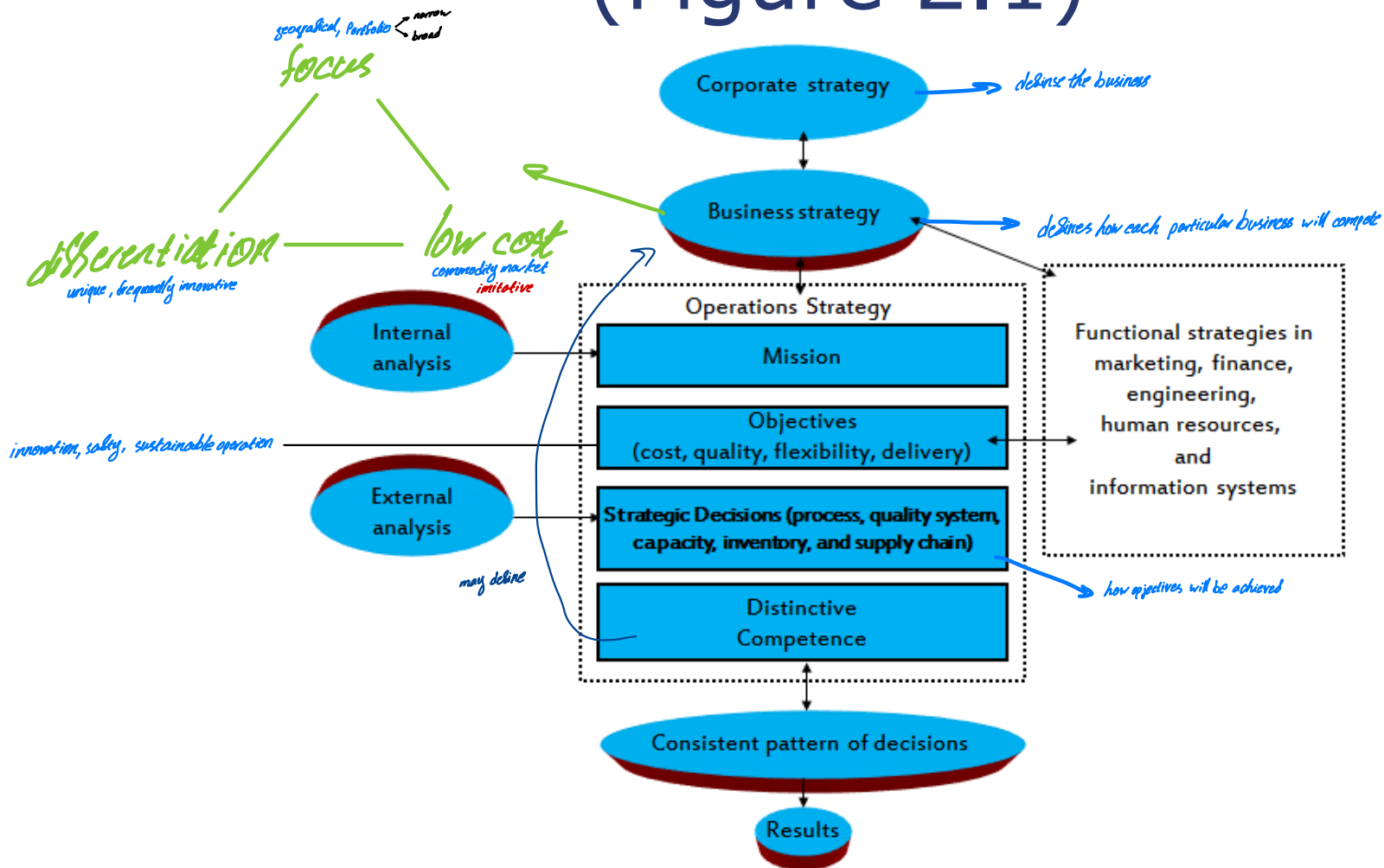
Learning Objectives (2 of 2)

- 2.5 Provide examples of a distinctive competence for operations
- 2.6 Explain the nature of global operations and supply chains.
- 2.7 Describe two types of supply chain strategies.
- 2.8 Illustrate how operations can become more environmentally sustainable.

Operations Strategy

*A **consistent pattern of business decisions** for operations and the associated supply chain...
... that are **linked to the business strategy** and other functional strategies, leading to a competitive advantage for the firm."*

Operations Strategy Process (Figure 2.1)



Operations Strategic Objectives

- Cost – resources used
- Quality – conformance to customer expectations
- Delivery – quickly and on time
- Flexibility – ability to rapidly change operations

How does a firm use these objectives to gain a competitive advantage?

What trade-offs exist among the objectives?

Examples of Important Strategic Decisions in Operations (Table 2.2)

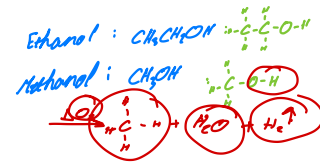
<i>Strategic Decision</i>	<i>Decision Type</i>	<i>Strategic Choice</i>
Process	Span of process Automation Process flow Job specialization	Make or buy Hand/machine-made Project, batch, line or continuous High or low specialization
Quality	Approach Training Suppliers	Prevention or inspection Technical or managerial training Selected on quality or cost
Capacity	Facility size Location Investment	One large or several small facilities Near markets, low cost or foreign Permanent or temporary
Inventory	Amount Distribution Control Systems	High or low levels of inventory Centralized or decentralized warehouse Control in greater or less detail
Supply Chain	Sourcing Logistics	Insource or outsource products National or global distribution

Distinctive Competence

- *This operations capability is something an organization does better than any competing organization that adds value for the customer.*
- *Examples: patents, proprietary technology, operations innovations*

Linking Operations to Business Strategies (1 of 2)

- Business strategy alternatives
 - Product Imitator
 - Operations must focus on keeping costs low.
 - Product Innovator
 - Operations must maintain flexibility in processes, labor and suppliers.
- Customer perspective
 - Order Qualifiers: objectives customers consider in the product/service
 - Order Winners: objectives that cause customer to choose a particular product/service



Linking Operations to Business Strategies (2 of 2)

- Business strategy alternatives
 - Product Imitator
 - Order Winner = price (low cost)
 - Order Qualifiers = flexibility, quality, delivery
 - Product Innovator
 - Order Winner = flexibility (rapid introduction of new products)
 - Order Qualifiers = cost, delivery, quality

Example: McDonald's Operations Strategy

- **Mission:** *fast product/service, consistent quality, low cost, clean/friendly environment*
- **Operations Objectives:** *cost, quality, service*
- **Strategic Decisions:** *process, quality, capacity, inventory, supply chain*
- **Distinctive Competence:** *today: continuous improvement of the transformation system, and brand (originally: unique service/supply chain)*

Global Operations and Supply Chains

معمولاً بین المللی (از آن جهت که در کشورهای مختلف فعالیت می کند)

- Traditional" (multi-country, multi-strategy) versus "Global" (single-strategy) firm.
- Characteristics of the "*Global Corporation*" differ from the traditional company.
- Rethink the supply chain (product design, process design, location, workforce policies).

تجارت جهانی و فعالیت در تمام جهان

Characteristics of “Global Corporations”

- Facilities located worldwide, not country by country.
- Products & services can be shifted among countries.
- Sourcing on a global basis.
- Supply chain is global in nature.
- Product design & process technology are global.
- Products/service fit global tastes.
- Demand is considered on worldwide basis.
- Logistics & inventory control is on worldwide basis.

Supply Chain Strategy

- To achieve competitive advantage for entire supply chain, rather than individual entities.
- Two supply chain strategies:
 - Imitative Products (e.g. commodities)
 - Predictable demand
 - Efficient, low-cost supply chain
 - Innovative Products (e.g. new technologies)
 - Unpredictable demand
 - Flexible, fast supply chain
- Firms design supply chain for each product/service or group of products/services
 - Avoid “one size fits all” strategy

Environment & Sustainable Operations (1 of 2)

- **Operations Sustainability:**
 - minimizing or eliminating environmental impact of operations
 - social and financial viability of the firm for future generations

Environment & Sustainable Operations (2 of 2)

- Operations '**greening**' may include:
 - Eliminating air, water, landfill pollution
 - Reducing energy consumption
 - Minimizing transportation and total carbon footprint
 - Working with suppliers to use recyclable and biodegradable packaging
 - Incorporating product reuse, end-of-life return, recycling

Summary (1 of 2)

- 2.1 Define operations strategy.
- 2.2 Describe the elements of operations strategy and alignment with business and other functional strategies.
- 2.3 Differentiate the ways to compete with operations objectives.
- 2.4 Compare product imitator and innovator strategies.
- 2.5 Provide examples of a distinctive competence for operations.

Summary (2 of 2)

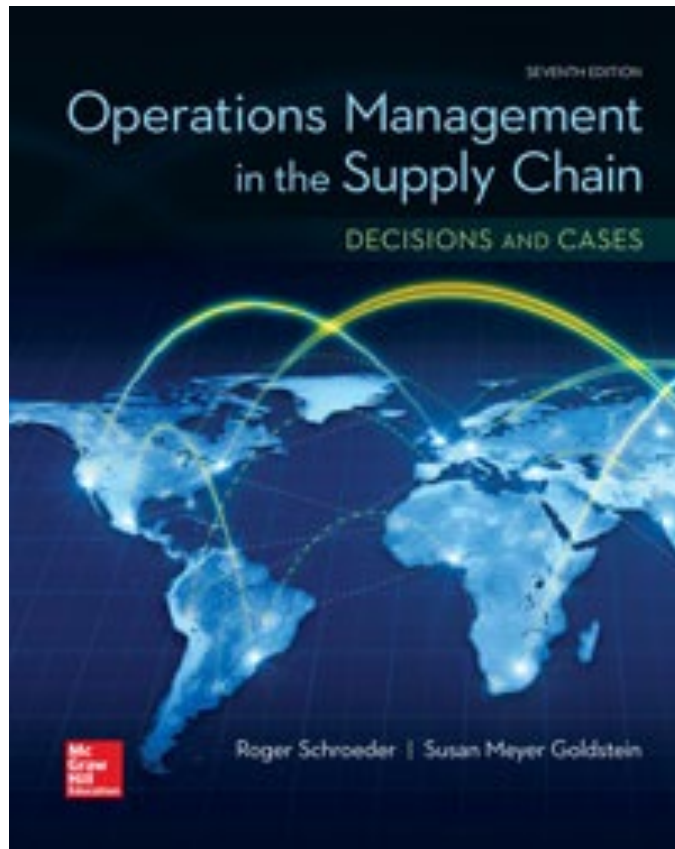
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- 2.8 Illustrate how operations can become more environmentally sustainable.

End of Presentation

Operations Management in the Supply Chain

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Chapter 3 Product Design

Learning Objectives

- 3.1 Compare the three strategies for new product introduction.
- 3.2 Describe the three phases of new-product development.
- 3.3 Evaluate how concurrent engineering deals with misalignment.
- 3.4 Describe the criteria that should be used for supplier selection.
- 3.5 Evaluate an example of Quality Function Deployment.
- 3.6 Explain the benefits of modular design.

Product Design: Why Does Operations Care?

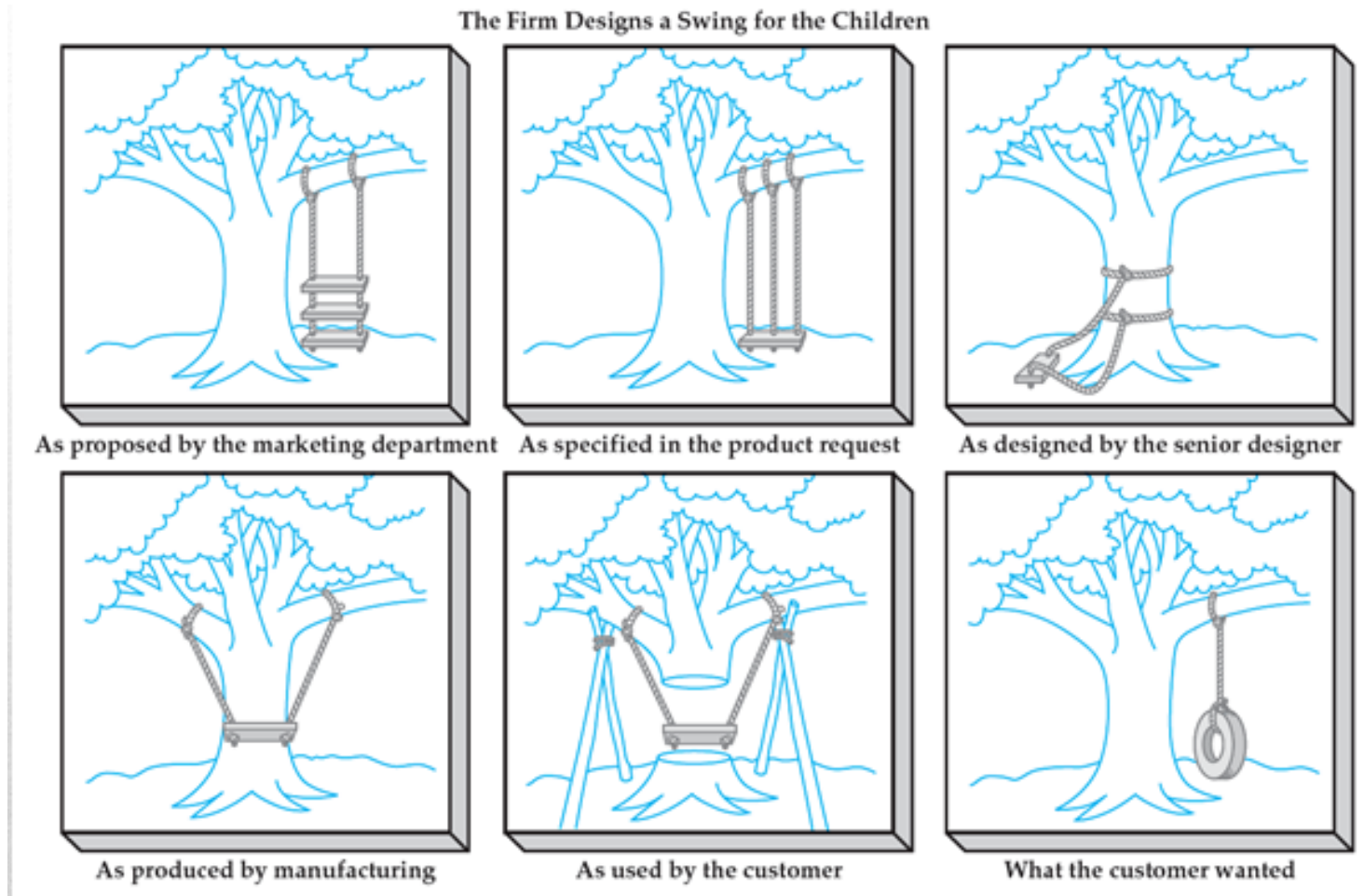
- Traditionally: throw design “over the wall”
- Today:
 - must be able to make the product (process)
 - technology
 - availability of resources
 - must have the right type and amount of capacity
 - must deliver a quality product or service
 - must have right inventory at right time

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Strategies for New-Product Introduction

- Market Pull: *"Make what we can sell"*
 - Organize resources to fulfill customer demand
 - Food industry
- Technology Push: *"Sell what we can make"*
 - Develop superior technologies and products
 - Electronics
- Interfunctional View: *most difficult*
 - Cross-functional design team – marketing, engineering, operations, finance
 - Challenge to gain cooperation of all functions
 - Consider existing and new markets

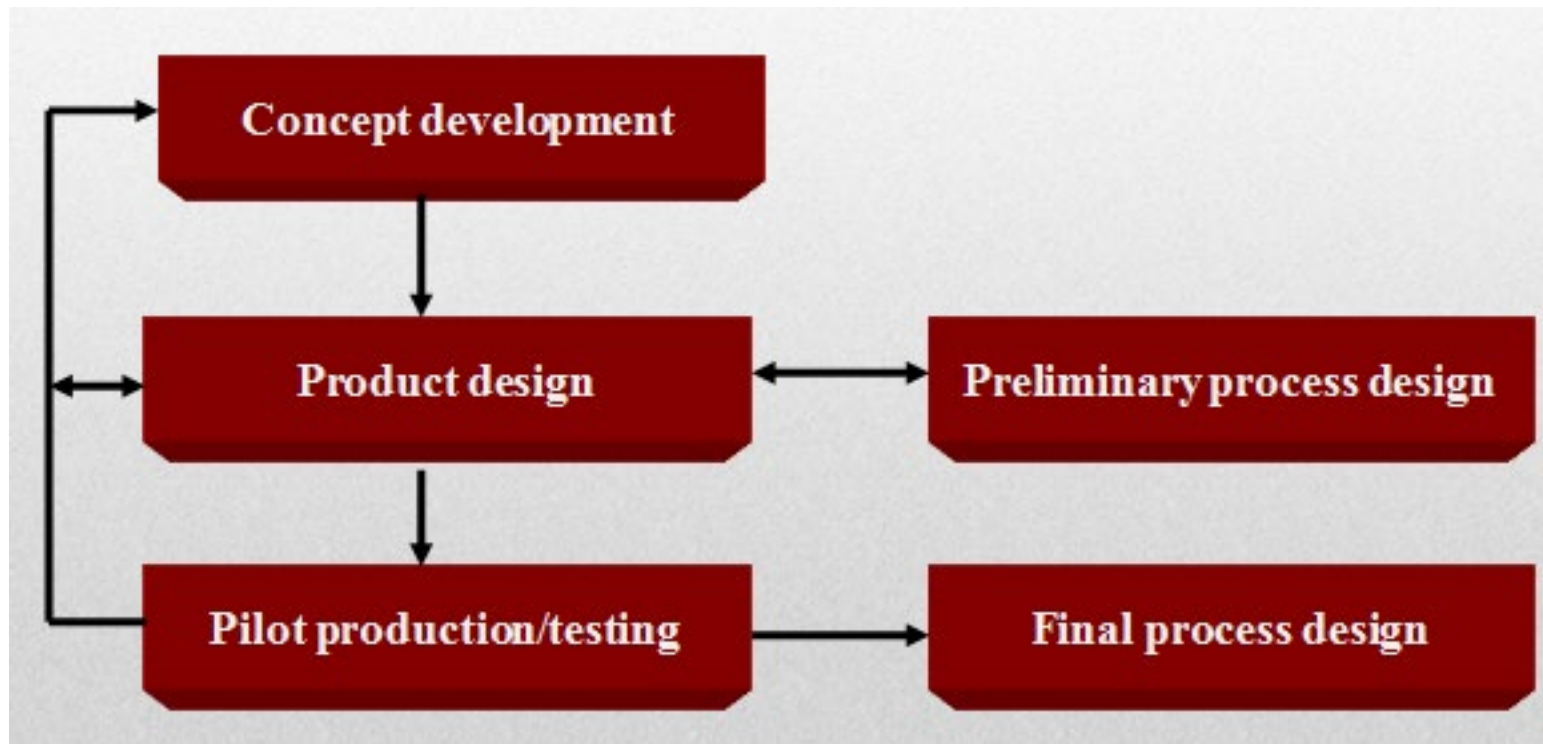
Figure 3.1 Lack of cooperation in designing a swing



New Product Development Process

- Concept Development
 - Idea generation and evaluation of alternative ideas
- Product Design
 - Design of the physical product
 - Design of the production process
- Pilot Production/Testing
 - Testing production prototypes (e.g., 3D printing)
 - Finalizing production process
 - Finalizing 'information package' specifying product and process design details

New Product Design Process (Figure 3.2)



Cross-Functional Product Design (1 of 2)

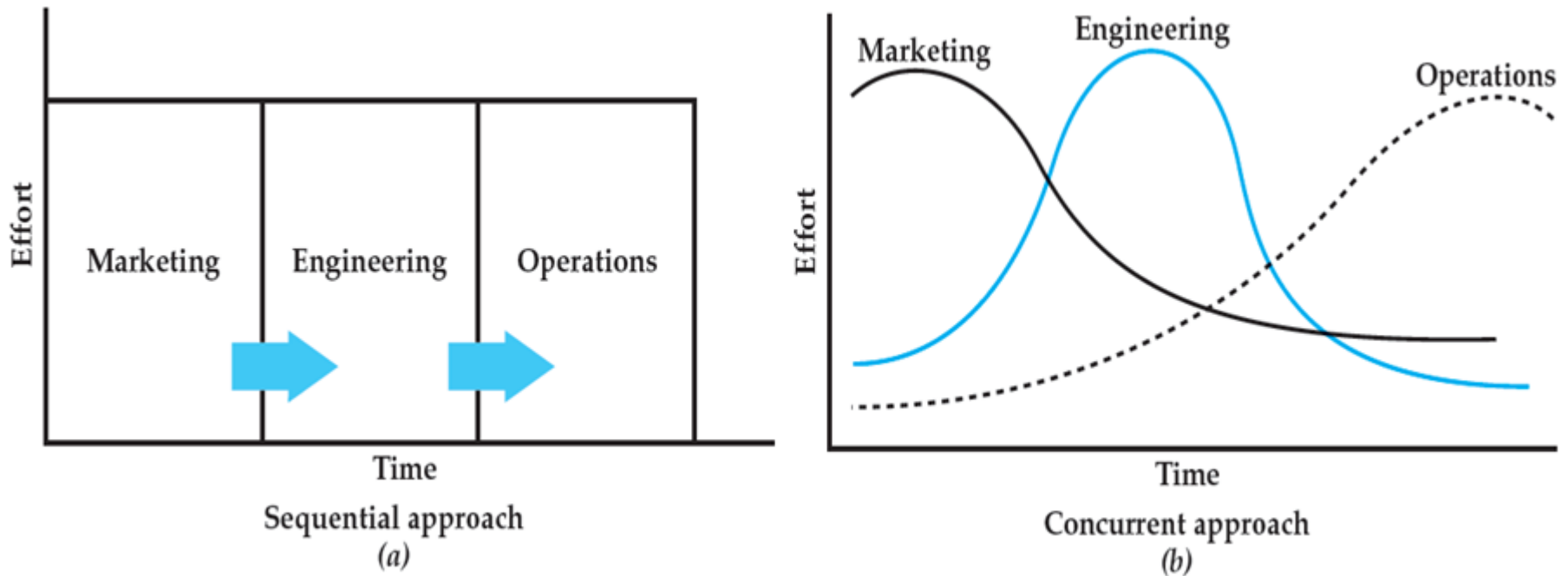
- Sequential approach
 - Functions (marketing, engineering, operations) work independently before passing work to next step. This is the 'over the wall' approach.
 - Often results in misalignment of market needs, design, and production process.

Cross-Functional Product Design (2 of 2)

- Concurrent approach
 - Also called concurrent engineering.
 - Functions cooperate, work together over the same time frame.
 - Cross-functional teams.
 - Not always “best” approach (e.g. high uncertainty of market or technology).

Cross-Functional Product Design

FIGURE 3.3 Sequential and concurrent approaches.



Supply Chain Collaboration

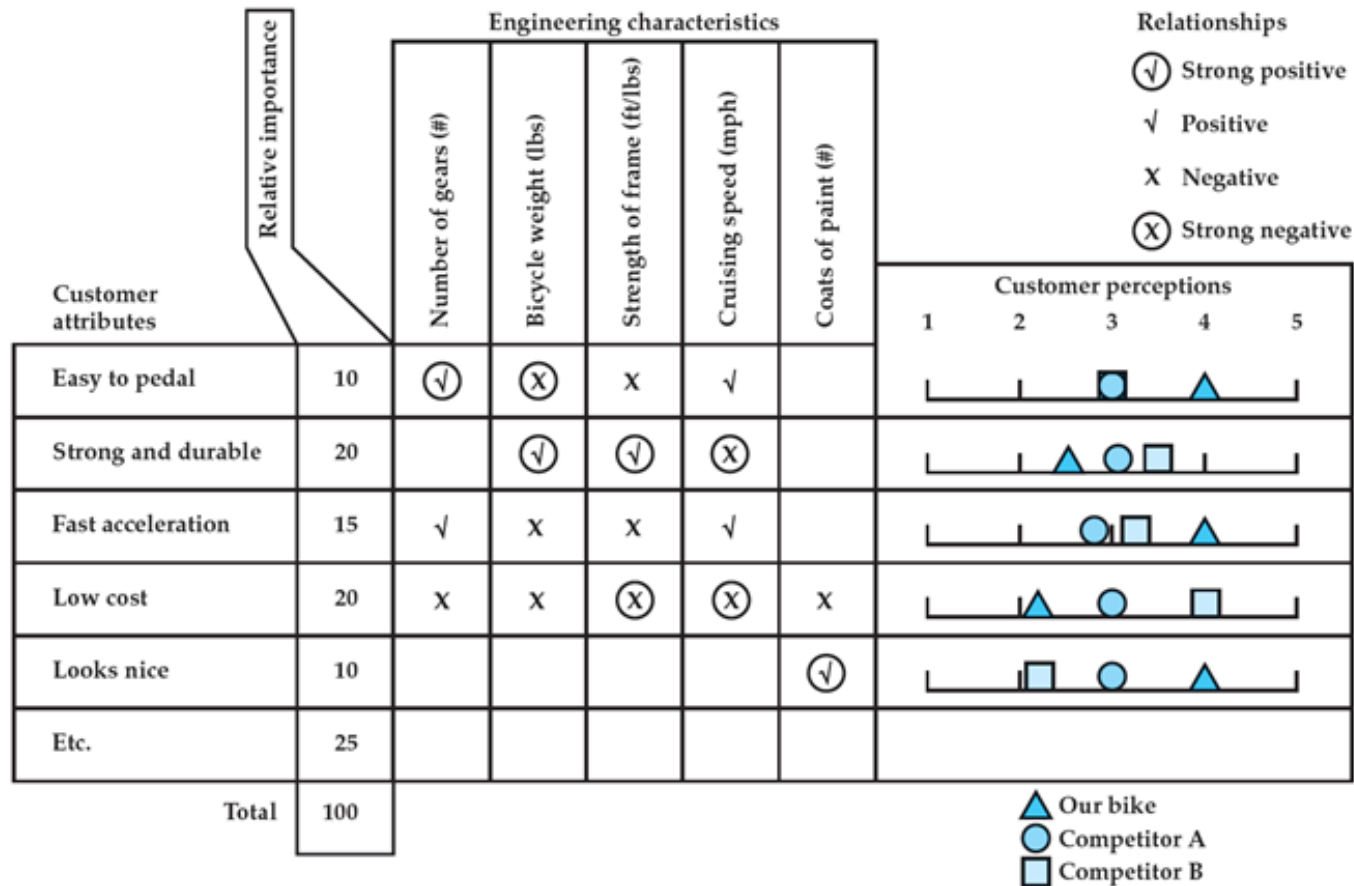
- Relationships with **Customers**
 - Ask right questions
 - Align incentives to share knowledge
 - Create collaborative technology platform
 - Include as advisors to design team
- Criteria for Relationships with **Suppliers** *only those who are critical to the design*
 - Technical expertise
 - Capabilities – cost, time, quality targets
 - Capacity availability
 - Low risk

Quality Function Deployment (QFD)

- “House of Quality”
- Tool for interfunctional cooperation
- Customer Attributes
 - “Voice of the Customer”
- Engineering Characteristics
 - “Voice of the Engineer”
- Helps identify tradeoffs
- Can include target values and competitive comparison

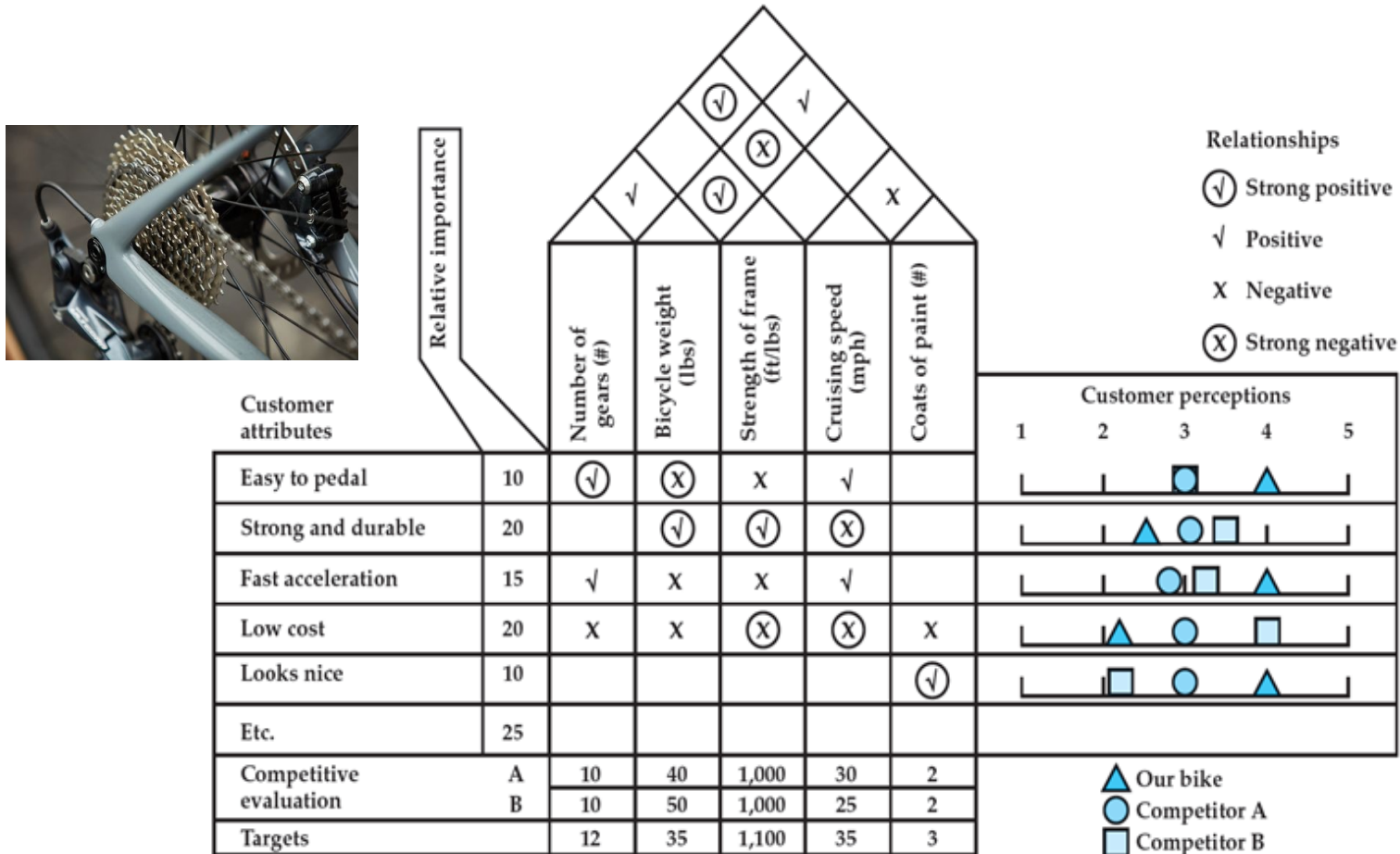
House of Quality (QFD) (1 of 2)

FIGURE 3.4 Relationship matrix.



House of Quality (QFD) (2 of 2)

FIGURE 3.5 House of quality.



- 



Modular Design (2 of 2)

- Volkswagen A5/A5+ Platform

- Audi A1
- Skoda Rapid
- VW Santana
- VW Jetta
- VW Vento
- VW Polo

- Chrysler LX Platform

- Chrysler 300
- Dodge Charger
- Dodge Magnum wagon
- Lancia Thema (Italian)

Summary

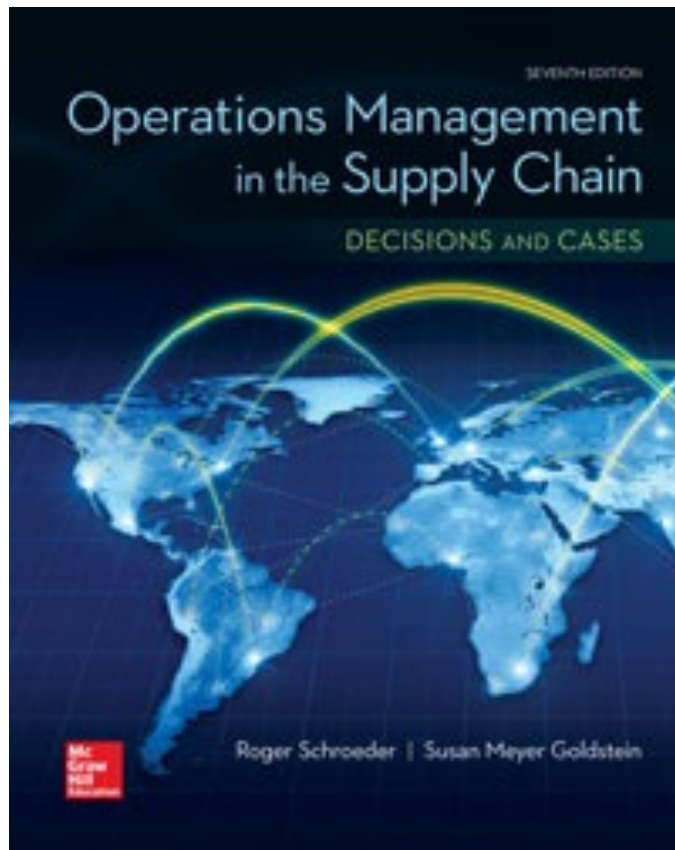
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End of Presentation

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Chapter 5

Service Process Design

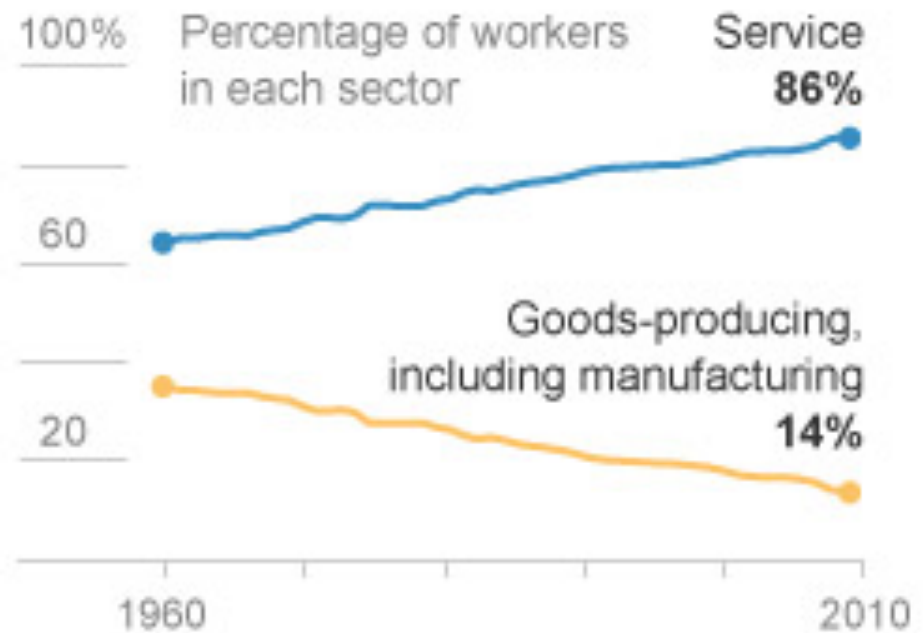
Learning Objectives

- 5.1 Differentiate the characteristics of a service organization from a manufacturing organization.
- 5.2 Explain the elements of a service-product bundle.
- 5.3 Organize a variety of service offerings into the service delivery system matrix.
- 5.5 Explain service recovery and service guarantees.
- 5.6 Evaluate the role of technology and globalization in service management.
- 5.7 Define the attributes of the service profit chain

The Service Economy

Largest 15 U.S. employers

- *1960*
 - 12 manufacturers
 - 3 services
- *2010*
 - 3 manufacturers
 - 12 services



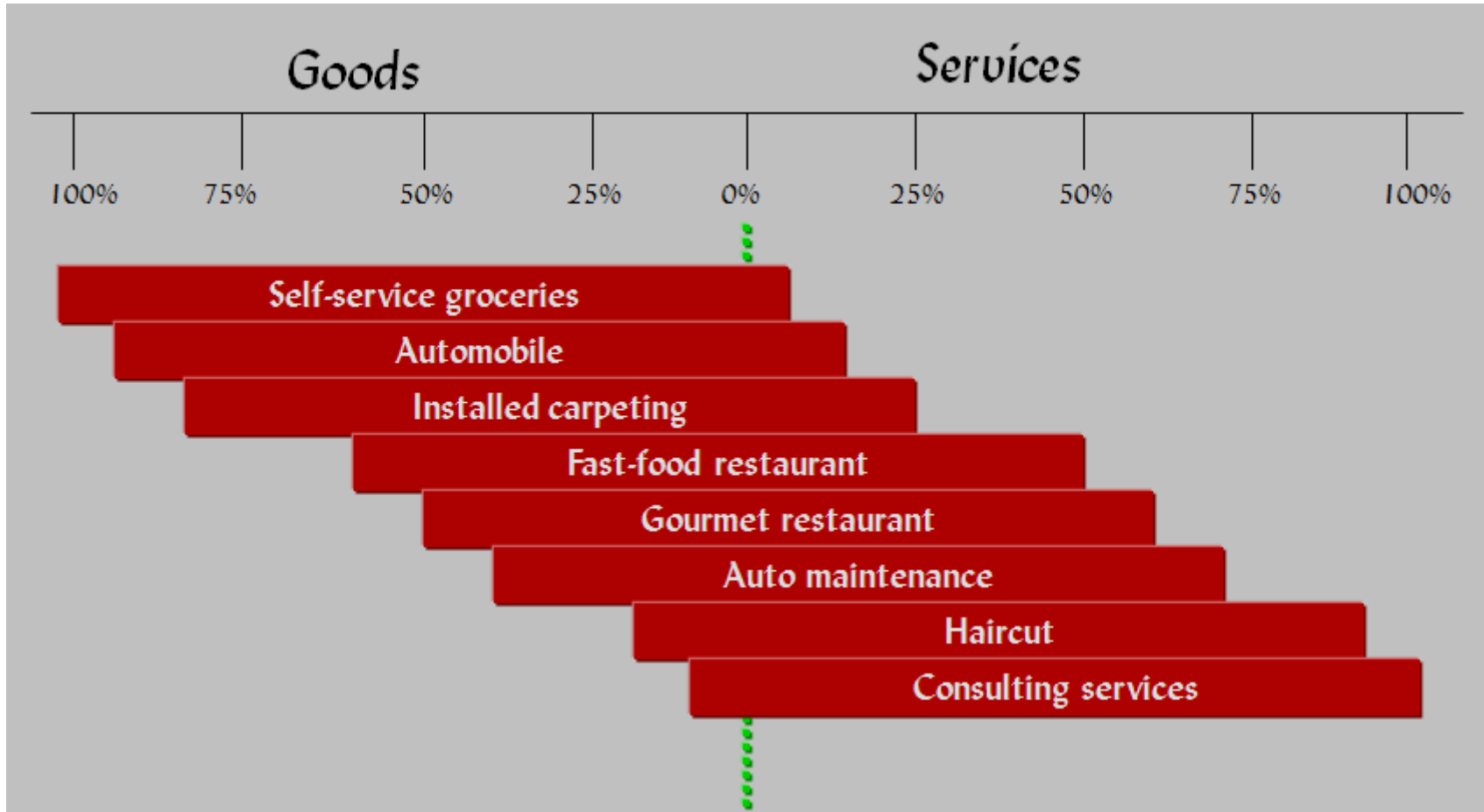
Defining Service

- Intangibility of the offering
- Simultaneous production and consumption
- No finished goods inventory
- Front office vs. back office
- Cannot be stored/resold

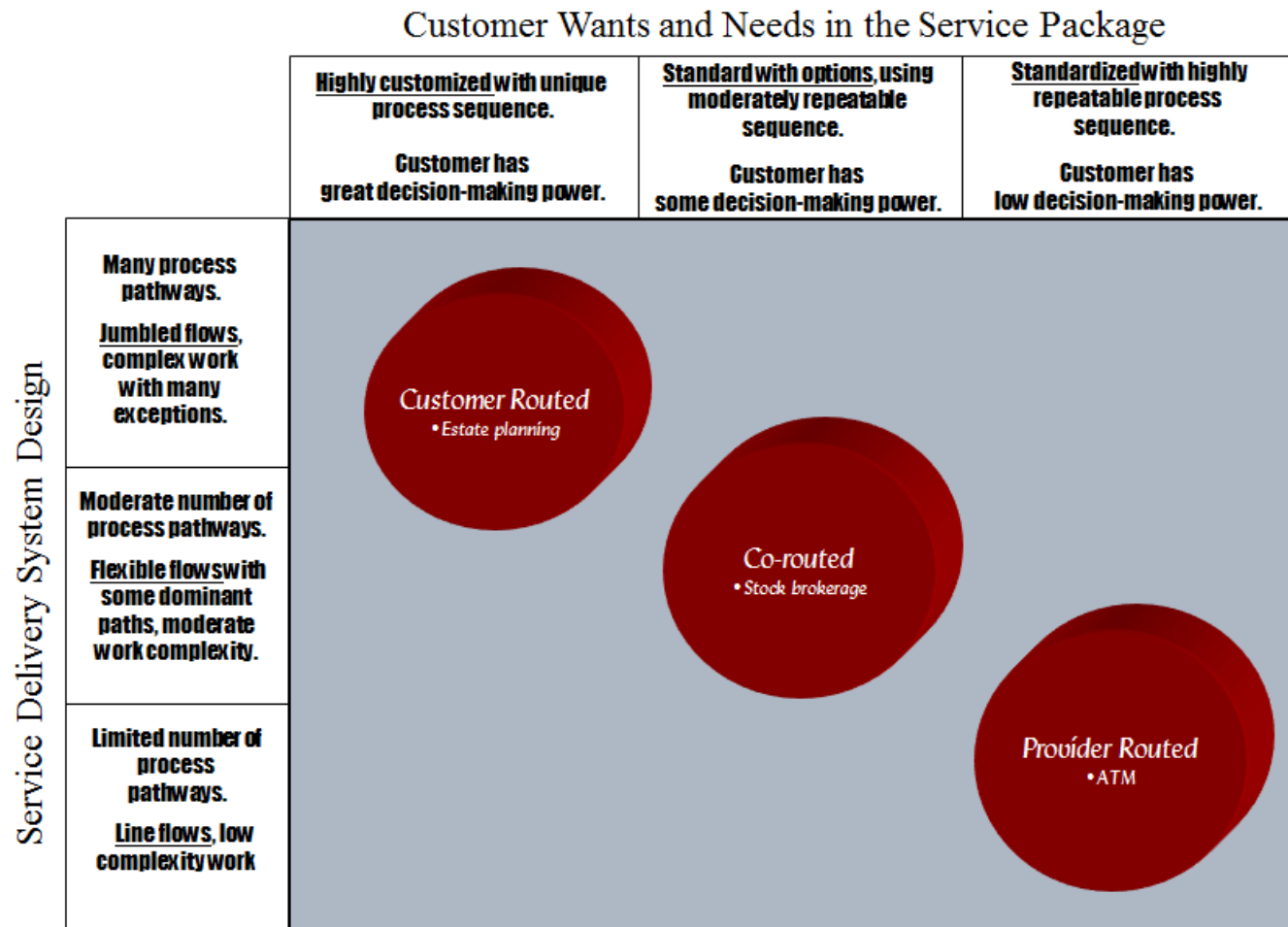
Service-Product Bundle

- **Service** - explicit service
 - what the provider does for customer
- **Psychological benefits** - implicit service
 - how customer feels after service
- **Physical goods** - facilitating goods
 - used during service or received by customer
- Pizza delivery
 - Enjoyment
 - Pizza
 - Delivery vehicle
 - Speed/ convenience

Goods and Services Packages (Figure 5.1)



Service Delivery System Matrix (Figure 5.2)



Customer Contact

- Definition: Extent of interaction between service provider and customer
- Lower contact = provider routed (standardized)
- Higher contact = customer routed (customized)
- Potential inefficiency = f (degree of customer contact)

Customer Contact (see Fig. 5.3)

(1 of 2)

- Low customer contact
 - Higher production efficiency
 - Lower sales opportunity
 - Workers with technical skills
 - Focus on paper handling
 - Office automation

Customer Contact (see Fig. 5.3)

(2 of 2)

- High customer contact
 - Lower production efficiency
 - Higher sales opportunity
 - Workers with diagnostic skills, more flexible and personable
 - Focus on client mix
 - Client/worker teams

Customer-Introduced Variability (1 of 2)

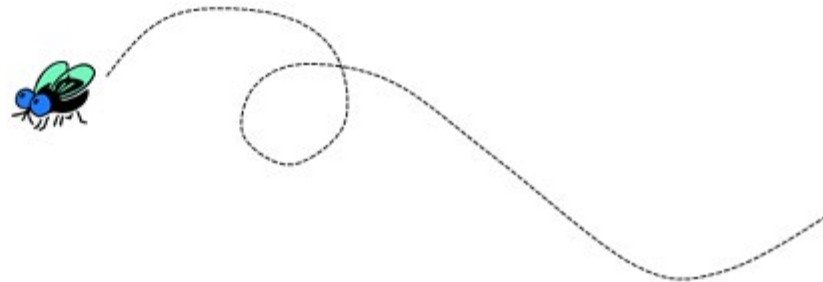
- Arrival
 - Uncertainty in when customers will arrive to consume a service
- Request
 - Uncertainty in what customers ask for in the service-product bundle
- Capability
 - Uncertainty in the ability of customers to participate in a service

Customer-Introduced Variability (2 of 2)

- Effort
 - Uncertainty in the willingness of customers to perform appropriate actions
- Subjective preference
 - Uncertainty in the intangible preferences of customers in how service is carried out

Service Failure / Service Recovery

- Failing right before the customer's eyes!
 - Taking swift and appropriate action to compensate customer for a failed service.
 - Fly in customer's soup → New bowl of soup plus free dessert!



Manager's Tool: Service Guarantee

- Benefits to the customer
 - Promise of service to be delivered
 - Payout to customer if promise not delivered
 - FedEx package delivery → On time, or it is free!
- Benefits to the organization
 - Focuses on customer (service promise)
 - Clearly defines payout
 - Improves customer loyalty

Technology and Globalization (1 of 2)

- **Production-line approach** (Levitt, 1972)
 - Standardize to minimize errors or deviations from standards
 - Automate to keep costs low
 - **Example: McDonald's**

Technology and Globalization (2 of 2)

- **Employees are the center** of service delivery (Schlesinger & Heskett, 1991)
 - Use technology to support front-line employees
 - Value investments in both employees & technology
 - Focus on recruiting and training front-line employees
 - **Example: Ritz-Carlton Hotel**

Outsourcing & Offshoring Services



- Outsourcing:
 - An outside firm performs service activities such as workforce recruiting, payroll management, accounting services, and call center functions.
- Offshoring:
 - Export of these service activities to other countries.

Study of Offshoring (Duke and Booz & Co. 2008)

- Transaction-intensive services (simple, standard, limited differentiation) are becoming commoditized (call centers, etc.) – competing on cost.
- Professional services (engineering, data analysis, legal work) are more commonly offshored.
- Firms are moving fast to scoop up global talent.
- Collaboration and maintaining quality are challenging with globally dispersed providers.

Service Profit Chain (Figure 5.4)

- Internal service quality, leads to...
- Employee satisfaction, leads to...
- Employee retention & productivity, lead to...
- External service value (to customer), leads to...
- Customer satisfaction, leads to...
- Customer loyalty, leads to...
- Revenue growth & profitability (the goal)
 - feed investment back into internal service quality

The process is repeated from the beginning
(Internal service quality, leads to...)

Summary

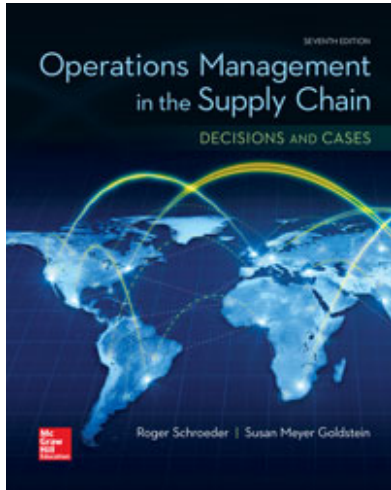
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End of Presentation

Operations Management in the Supply Chain

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Chapter 6

Process-Flow Analysis

Learning Objectives

- 6.1 Describe process thinking and system boundaries.
- 6.2 Explain how the process view of business includes various functions.
- 6.3 Construct a process flowchart for a given process.
- 6.4 Analyze a process by asking a wide variety of questions informed by the process flowchart.
- 6.5 Determine process capabilities from analysis.
- 6.6 Explain the principles of process redesign.

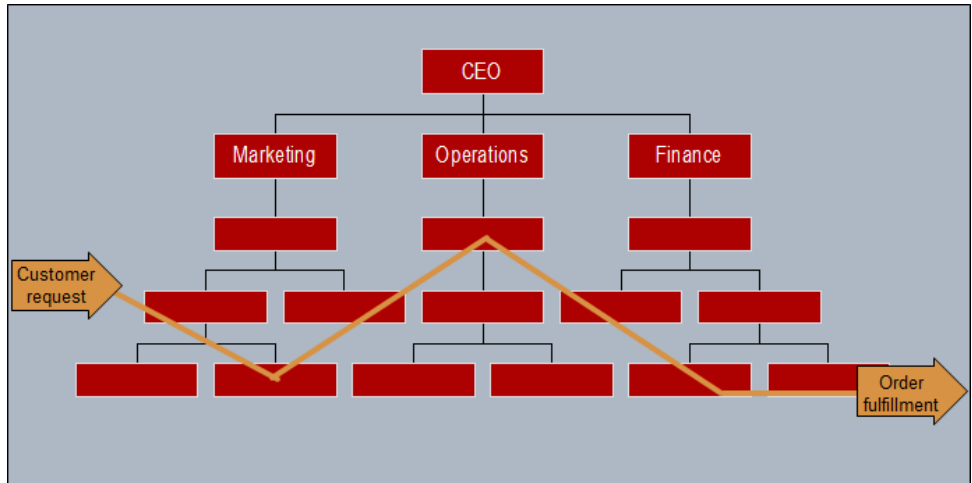
Process Thinking

- Process thinking: All work is a process.
- System: Collection of interrelated elements where...

Whole > Sum of parts

- Apply systems thinking to businesses
 - Defining system boundaries
- Use cross-functional teams for systems analysis
 - Include all affected functions

Process View of Business



Process Flowcharting (1 of 3)

- Process flowcharting: Creating a visual diagram to describe (represent) a transformation process
- Also called (or similar to):
 - Process mapping
 - Flow-process charting
 - Service blueprinting
 - Systems flowchart



Process Flowcharting (2 of 3)

- Purpose: To visually describe and then find ways of improving the current process.
- Find repetitive operations
- Identify bottlenecks
- Describe directions and distances of flows
(people, material and information)
- Reduce waste
- Required for certifications such as ISO9000.



Process Flowcharting (3 of 3)

- Select a transformation process to study.
- Form a team to develop flowchart & for analysis (to improve the system).
- Specify the boundaries of transformation process.
- Identify and sequence the operational steps.
- Identify the performance metrics for the steps.
 - e.g., time to complete each step
- Draw the flowchart, using consistent symbols.



Common Flowcharting Symbols



Terminator: "START" and "END"



Process: operation, activity, or task

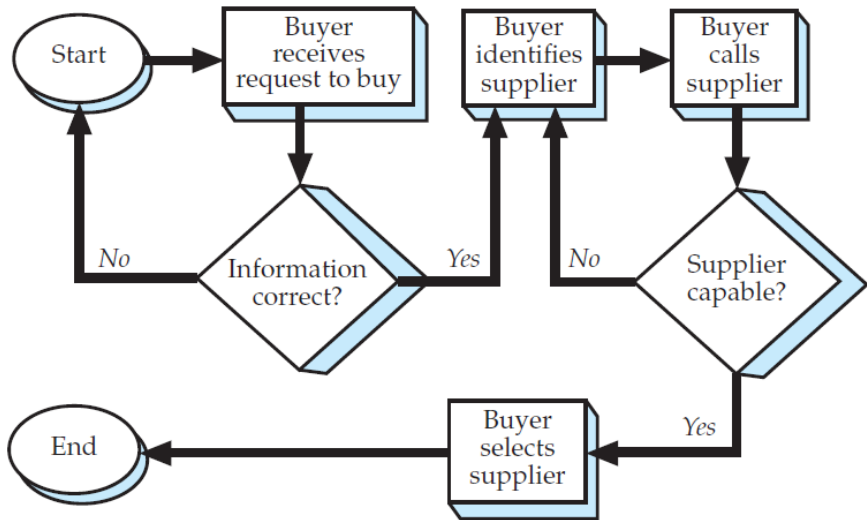


Decision: evaluation or "IF-THEN"



Flow: materials, information, customer

Flowchart Example: Selecting a Supplier (Figure 6.2)



Symbols for Flow-Process Chart



Operation: task or work activity



Inspection: checking product quantity or quality



Transportation: movement of material from point to point



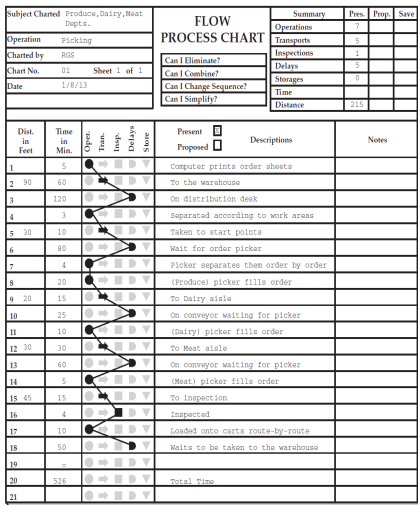
Storage: inventory of materials awaiting next operation



Delay: delay in sequence of operations

Flow-Process Chart Example:

Picking Operations at Grocery Store Distribution Center (Figure 6.5)



Questions to Ask in Process-Flow Analysis

- **Flow:** Is it balanced? Where is the bottleneck? Are all steps necessary? How jumbled is the flow?
 - **Time:** How long to produce one unit? Can it be reduced? Is set-up time excessive? Is waiting time excessive?
 - **Quantity:** Theoretical production amount? How easy to change? How many units actually produced?
 - **Quality:** Historical defect rate? Which steps contribute to defects? Where do errors occur?
 - **Cost:** How much to produce one unit? What are cost buckets for one unit? Can some cost buckets be reduced or eliminated?
-

Measuring Process Flows (1 of 2)

- **Capacity** of a system = capacity of the most constraining resource
 - The single resource with the least capacity is called the **bottleneck**
- **Flow rate** = minimum (Supply, Demand, Capacity)
- **Throughput time** = from when processing begins until product or service is completed

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Measuring Process Flows (2 of 2)

- **Little's Law**

- Calculation: $I = T \times R$
 - I = average number of things in the system
 - T = average throughput time
 - R = average flow rate into the process
 - Relates number of items in the system (I) to arrival rate (R) and throughput time (T).
- Assumes system is in a 'steady state.'

Little's Law Example (1 of 2)

- People are in a line to get through security checks at a music festival. An average of 10 people per minute are processed. People spend 24 minutes in line, on average.
- What is the average number of people in line?
- $I = T \times R$
- $I = 24 \times 10 \rightarrow I = 240$ people in line, on average

Little's Law Example (2 of 2)

- Same problem, but an average of 4 people per minute are processed, and the average number of people in line is 240.
- What is the average time spent in line?
- $T = I / R$
- $T = 240 / 4 \rightarrow T = 60$ minutes in line, on average

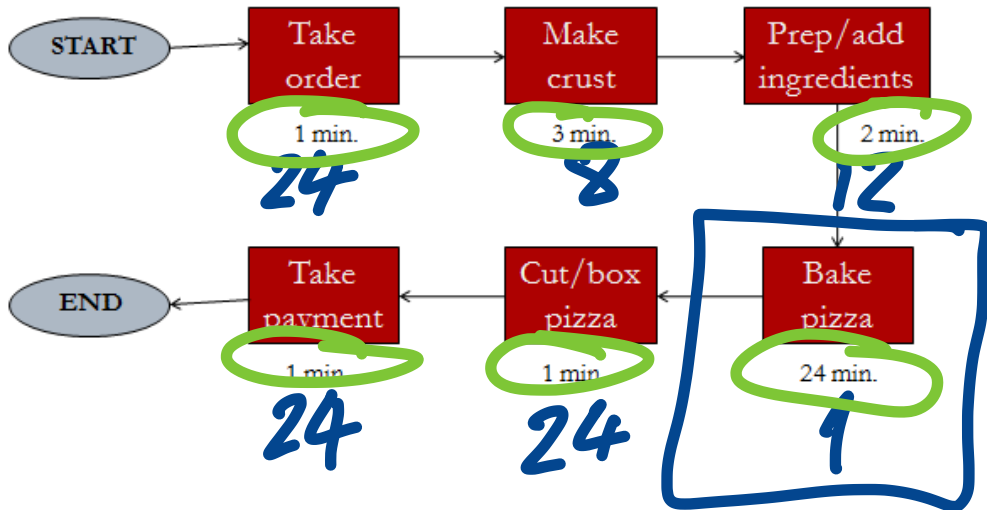
$$I = T \cdot R \quad T = \frac{I}{R}$$

Pizza U.S.A. Book Example

Activity	Minutes	Who/What
Take the order	1	Assistant
Make the crust	3	Chef
Prepare and add ingredients	2	Chef
Bake the pizza	24	Oven
Cut pizza and box the order	1	Assistant
Take payment	1	Assistant

Details: $1 \rightarrow 4 = 20$ 24
Assume all toppings added to every pizza
Two employees working at a time
Oven can bake up to 4 pizzas at a time 3

Map the Process



What is the Throughput Time?

Throughput time = time to **complete one** product or service

Pizza throughput time?


$$1 + 3 + 2 + 24 + 1 + 1 = 32 \text{ min.}$$


What is Process Capacity?

3 resources:

Assistant: $1+1+1=3$ min. per pizza, 20 pizzas per hr.

Chef: $3+2=5$ min. per pizza, 12 pizzas per hr.

Oven: $24/4=6$ min. per pizza, 10 pizzas per hr.

Therefore, process capacity (flow rate) = 10 pizzas/hour

What is the Process Bottleneck?

At an average process time of 6 min. per pizza...
the OVEN is the slowest activity.....
which determines process capacity....
and is, therefore, the bottleneck.
The process cannot produce more than the
slowest activity (flow rate = 10 pizzas/hr).

Process Redesign

- Identify, analyze, improve critical processes (may cross organizational boundaries).
- Extreme cases: Complete process reconfiguration (eliminating many steps).
- Business Process Reengineering (BPR)

Principles of Process Redesign

- Organize around outcomes, not tasks.
- Have the people who do the work process their own information.
 - Avoid handoffs, whenever possible.
- Put the decision point where work is performed, and build control into the process.
 - Make decisions at lowest possible level.
- Eliminate unnecessary steps in the process.
 - Simplify, eliminate non-value-added activities.

Summary

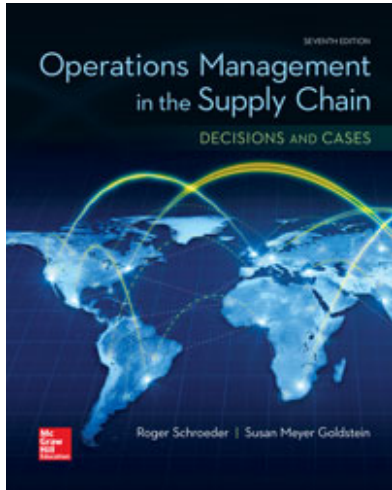
- 6.1 Describe process thinking and system boundaries.
- 6.2 Explain how the process view of business includes various functions.
- 6.3 Construct a process flowchart for a given process.
- 6.4 Analyze a process by asking a wide variety of questions informed by the process flowchart.
- 6.5 Determine process capabilities from analysis.
- 6.6 Explain the principles of process redesign.

End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 7

Lean Thinking and Lean Systems

Learning Objectives

- 7.1 Describe the origins and evolution of lean thinking.
- 7.2 Describe the five tenets of lean thinking and the seven forms of waste in a lean system.
- 7.3 Explain how a stabilized master schedule is achieved for repetitive manufacturing.
- 7.4 Design a kanban system for a lean system.
- 7.5 Explain how setup time, lot size, layout and maintenance are related to lean thinking.
- 7.6 Differentiate how employees, quality, and suppliers are unique in lean systems.
- ~~7.7 Explain how to implement a lean system.~~

Evolution of Lean

- Toyota Production System (TPS)
 - Developed in Japan following WWII (limited resources)
 - Also known as Just-in-Time (JIT) manufacturing
- Came to U.S.- 1981 at Kawasaki motorcycle plant in Lincoln, Nebraska
- Lean Production
 - Term coined in late 1980s
 - Popularized in 1990s by Womack, Jones & Roos' "The Machine That Changed the World"

Lean Tenets

- Create product/service value from customer perspective
 - Reduce waste - **muda**
- Identify, study, improve the value stream
 - Observe the process - **gemba** تجويز المشاكي
- Ensure simple, smooth, error-free flow
 - Determine **takt time** zero defects
- Produce only what is pulled by customer
 - Use **kanbans**
- Strive for perfection
 - Hold **kaizen** events, **5S**, **5 Whys**

The Seven Forms of Waste (1 of 2)

- **Overproduction:** Producing more than the demand for customers, resulting in unnecessary inventory, handling, paperwork, and warehouse space.
- **Waiting time:** Operators and machines waiting for parts or work to arrive from suppliers or other operations. Customers waiting in line.
- **Unnecessary transportation:** Double or triple movement of materials due to poor layouts, lack of coordination, and poor workplace organization.

The Seven Forms of Waste (2 of 2)

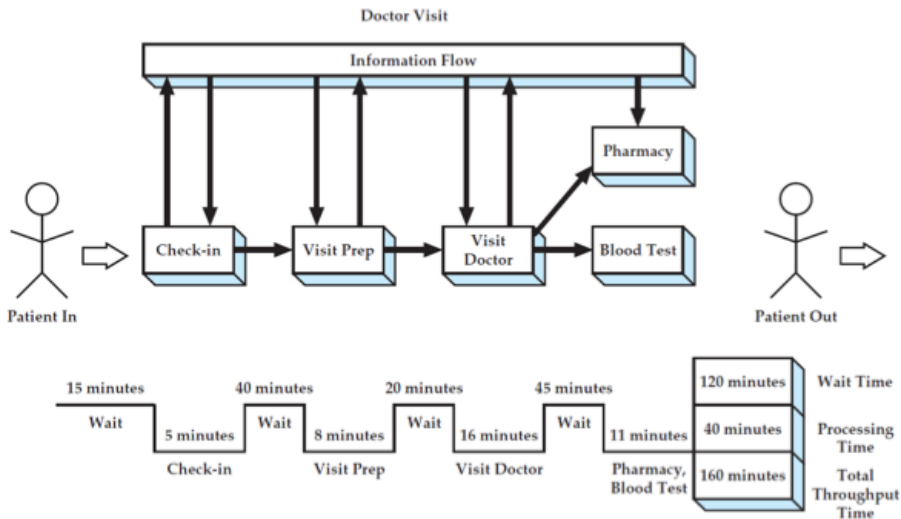
الزيادة

- **Excess processing:** Poor design or inadequate maintenance or processes, requiring additional labor or machine time.
- **Too much inventory:** Excess inventory due to large lot sizes, obsolete items, poor forecasts, or improper production planning.
- **Unnecessary motion:** Wasted movements of people or extra walking to get materials.
- **Defects:** Use of material, labor, and capacity for production of defects, sorting out bad parts, or warranty costs with customers.

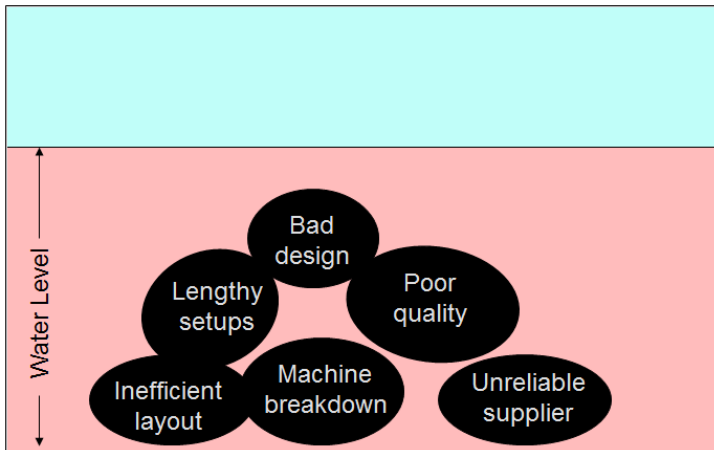
Value Stream Mapping (1 of 2)

- Value stream is all processing steps to complete product/service
- Extension of process flowcharting
- Includes value-adding/non-value-adding activities
- Requires direct observation of process – ***gemba***
- “Is this step or task necessary in creating value to the customer?”
- Change and improve process

Value Stream Mapping (2 of 2)

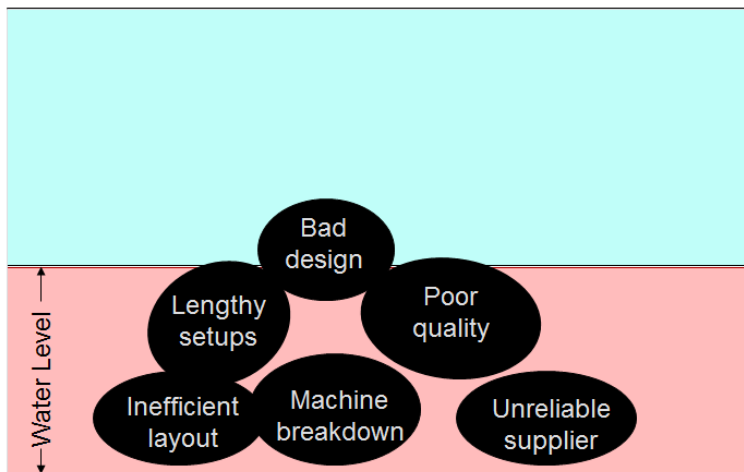


Inventory Covers Problems (Figure 7.2)



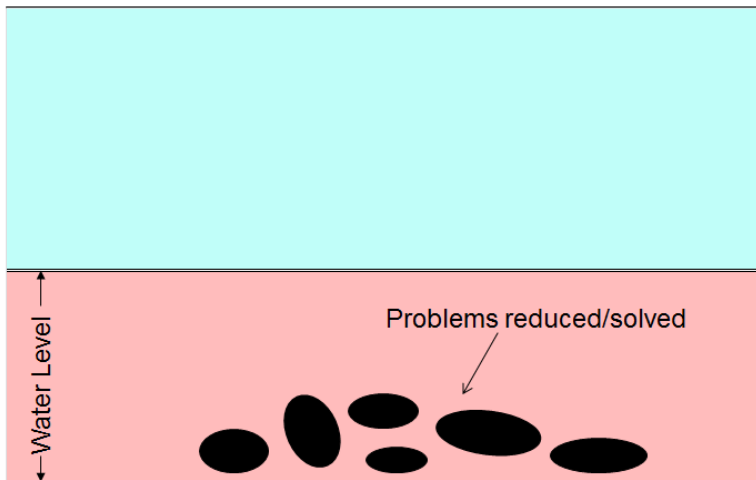
Water level indicates level of inventory in the system

Water Level Lowered To Expose Problems



Water level indicates level of inventory in the system

Water Flows Smoothly, Once Problems are Resolved



Water level indicates level of inventory in the system

5 Whys Technique

- Explores cause-and-effect relationships that underlie problems (**root causes**)
- Enables root causes to be identified/resolved
- Example: Truck won't start.
 - Why? *Battery is dead.*
 - Why? *Alternator not functioning.*
 - Why? *Alternator belt is broken.*
 - Why? *Truck was not maintained as recommended.*
 - Why? *Truck is old; no replacement parts available.*
 - Solution? *Find source for parts, or purchase new truck.*

5S Technique

- Organize workspace to improve employee morale, safety, process efficiency.
- Reduces time looking for “things.”
- Seiri to **Sort** (keep, toss)
- Seiton to **Straighten** or set in order
- Seiso to **Shine**, sweep, or clean
- Seiketsu to **Standardize**
- Shitsuke to **Sustain** (maintain)

5S Technique Example

Storage of chemicals in production area



Before



After

Elements of Lean System

- Stabilizing the master schedule
- Controlling flow with kanban system
- Reducing setup time (quick changeover)
- Small lot sizes (goal lot size of single unit)
- Efficient layout (linear flow, low inventories)
- Preventive maintenance
- Cross-training, rewarding workers
- Quality and continuous improvement
- Close relationships with suppliers (frequent deliveries)

Stabilizing the Master Schedule

- Production horizon set according to demand
- Production schedule repeated each day
- **Uniform load:** level work load across workers/machines
- **Takt time:** match supply (production rate) to demand rate
- Produce planned quantity each day, and no more
- Desirable, but not essential, to a lean system

The Kanban System (1 of 2)

- **Kanban:** “marker” (card, sign)
- “**Pull**” production system
- **Visual control** system of cards and containers, or other type of signal
- Number of **containers**:

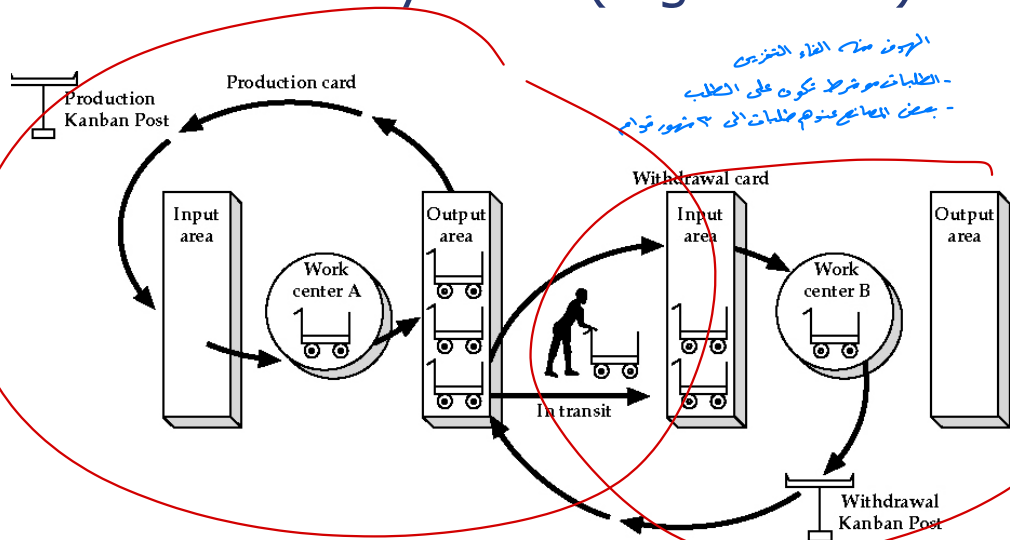
$$n = \frac{DT}{C}$$

- D = Demand rate (at work center)
- T = Time for container to complete circuit
- C = Container size (# units)

The Kanban System (2 of 2)

- Signals the need for more parts
- Uses simple cards or signals to control production/inventory
- Each work center receives production order (card) from succeeding work center
- Prevents the buildup of inventory
- Reduces lead time
- Extends to receiving orders from suppliers

Kanban System (Figure 7.3)

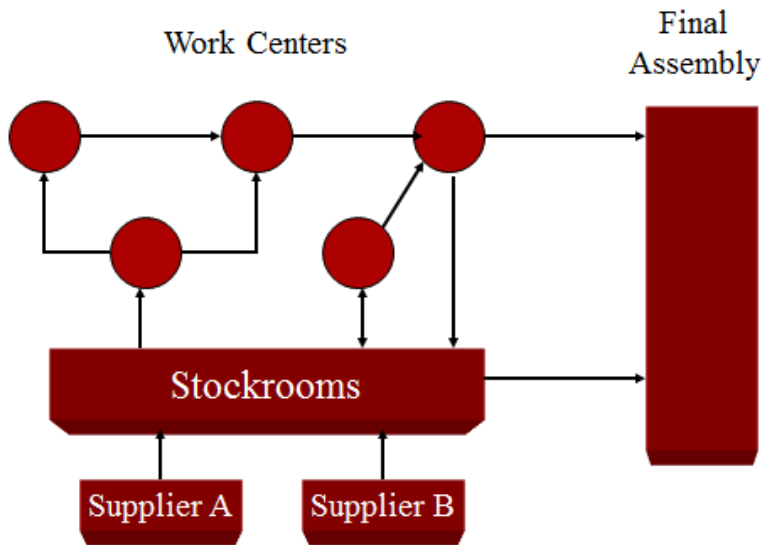


Reducing Setup Time and Lot Sizes

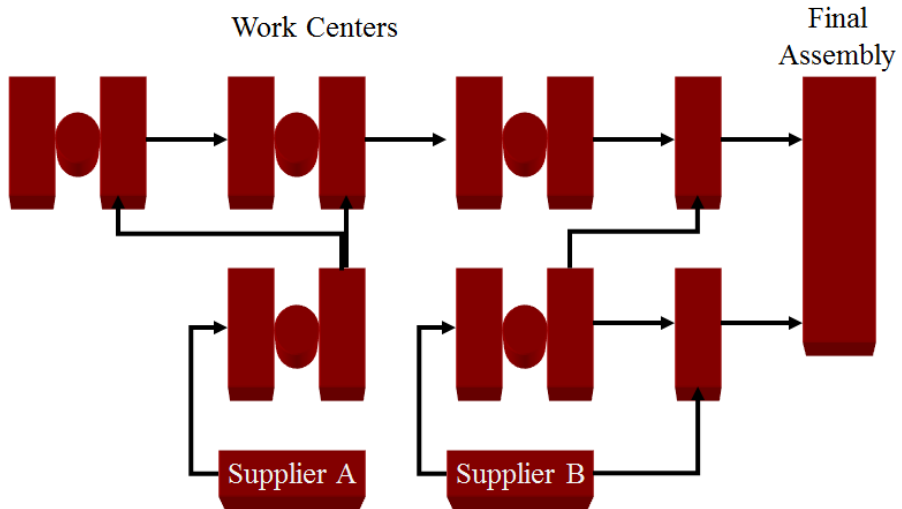
- Reducing setup time:
 - increases available capacity
 - increases flexibility to meet schedule changes
 - reduces inventory
- Setup types
 - Single (single digit minutes)
 - One-touch (less than 1 min; 2-step process)
- Internal (while machine stopped)
- External (while machine operating)
- Lot size reduction
 - Goal: single unit production

Lot size refers to the quantity of an item ordered for delivery on a specific date or manufactured in a single production run.

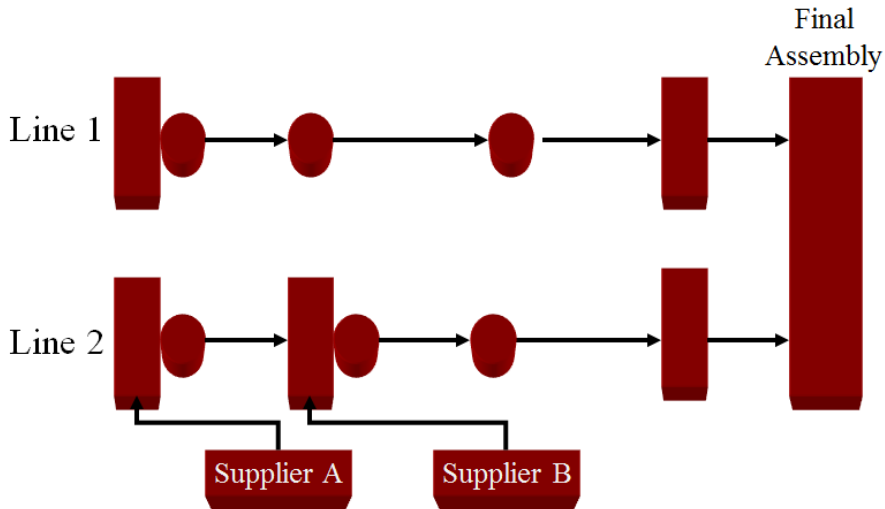
Non-Lean Layout (Figure 7.4)



Lean Layout



Lean Layout with Group Technology (Cellular Manufacturing)



Engaging Workers

- Multifunction, cross-trained workers
 - Flexibility to move to busy work centers
- New pay system to reflect skills variety
- Workers contribute individually and collaboratively
 - Perform own maintenance and inspection
 - Teamwork, problem solving
 - Suggestion systems

Quality in a Lean System

- Quality is essential input into lean system
- Defects are waste
- No inventory to cover up mistakes
- System designed to expose errors; correct them at their source (so not repeated in the future)
- Continuous improvement of the process

Supplier Relationships

- Viewed as the 'external factory'
- Co-location, frequent deliveries
- Fewer suppliers
- No inspection—high quality is assumed
(required)
- Integrated supplier programs
 - Early supplier selection
 - Family-of-parts sourcing
 - Long-term strategic relationship
 - Reduce paperwork and inspection

Implementation of Lean Systems

- Establish a cross-functional team
- Determine what customers value
- Construct value stream map
- Eliminate waste (non-value-adding activities)
- Use customer demand to pull work thru process
- Implement team ideas
- Repeat the cycle on another process

Summary

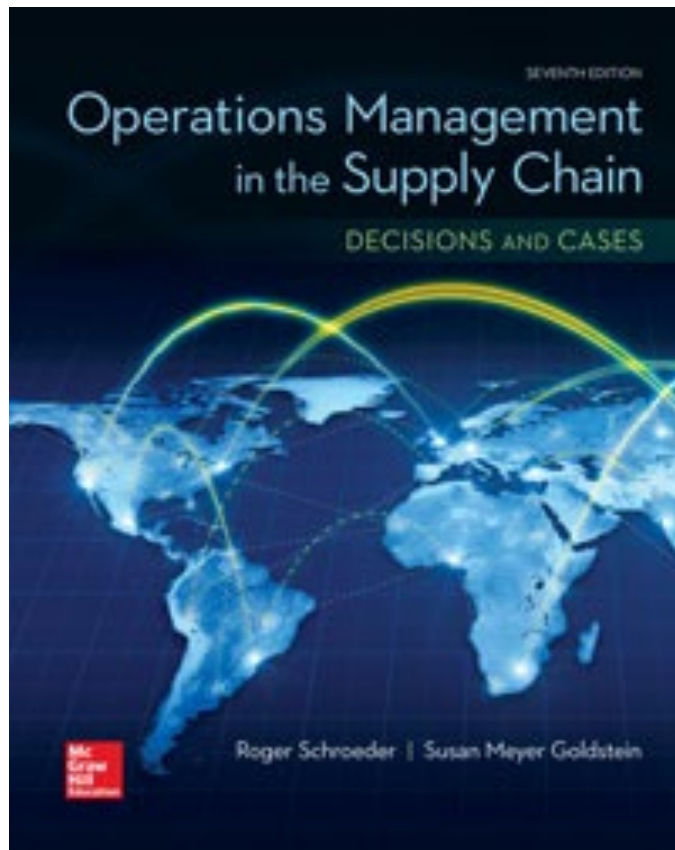
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End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 4

Process Selection

Learning Objectives

- 4.1 Contrast and compare the five types of product-flow processes.
- 4.2 Describe the differences among order fulfillment processes.
- 4.3 Explain how companies should make process selection decisions.
- 4.4 Correctly place examples of products on the diagonal of the product-process matrix.
- 4.5 Describe the features of focused operations.
- 4.6 Discuss the advantages and disadvantages of mass customization and 3D Printing.
- 4.7 Contrast pollution prevention, control and practices.

Product-Flow Characteristics

- Types of Product Flow
 - Continuous process
 - Assembly line
 - Batch flow
 - Job shop
 - Project

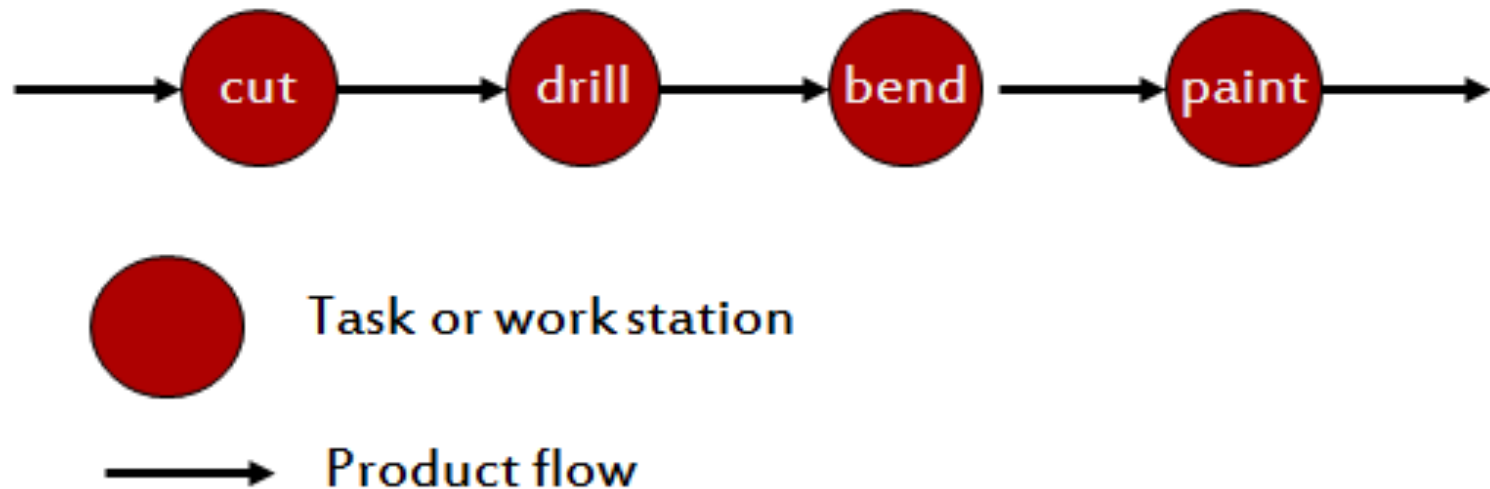
Product-Flow Characteristics: Continuous Process

- Highly standardized and automated
- Flexibility limited
- High volumes of production
- Commodity products
- Low cost is the 'Order Winner'
- Process industries (sugar, paper, oil, electricity, *etc.*)

Product-Flow Characteristics: Assembly Line

- Linear sequence of operations (often paced)
- Large capital investment, use of automation
- Very efficient
- High-volume, standardized products
- Low flexibility to product and volume changes
- Discrete products (autos, appliances, computers, *etc.*)

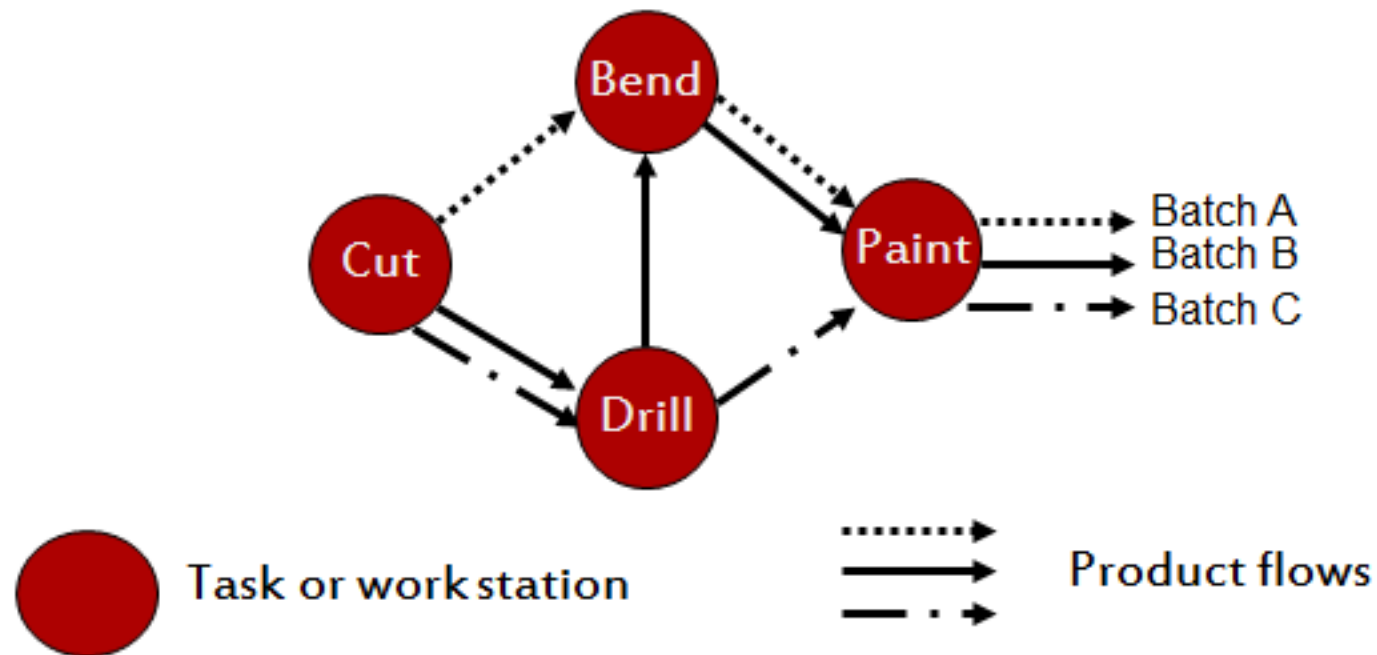
Assembly Line: Metal Bracket (Figure 4.1)



Product-Flow Characteristics: Batch Flow

- Production of batches or lots
- Batches flow as a unit (set) from one work center to another
- Process layout of work centers (by tasks)
- Flow is jumbled and intermittent
- Flexible labor and equipment (general purpose)
- Low to high volume, variety of products
- Many types of products (furniture, dishes, boats)

Batch Flow: Three Metal Brackets (Figure 4.2)



Product-Flow Characteristics: Job Shop

- **Customized** to customer order
- Production of small batches or lots
- Layout/flow similar to Batch Flow
- Flexible labor and equipment (general purpose)
- Many types of made-to-order products (plastic parts, machine components, sheet metal parts, custom signs, artificial limbs, *etc.*)

Product-Flow Characteristics: Project

- Production of customized single products
- Labor and materials brought to site
- Planning, scheduling challenges
- Little automation, general purpose equipment
- Highly skilled and flexible labor
- Unique, one of a kind products (bridges, building construction, large aircraft, *etc.*)

Throughput Ratio: Process efficiency

$$TR = \frac{\text{Total processing time for the job}}{\text{Total time in operations}} \times 100\%$$

Typically:

90-100% in Continuous Process and Assembly Line

10-20% in Batch Flow and Job Shop

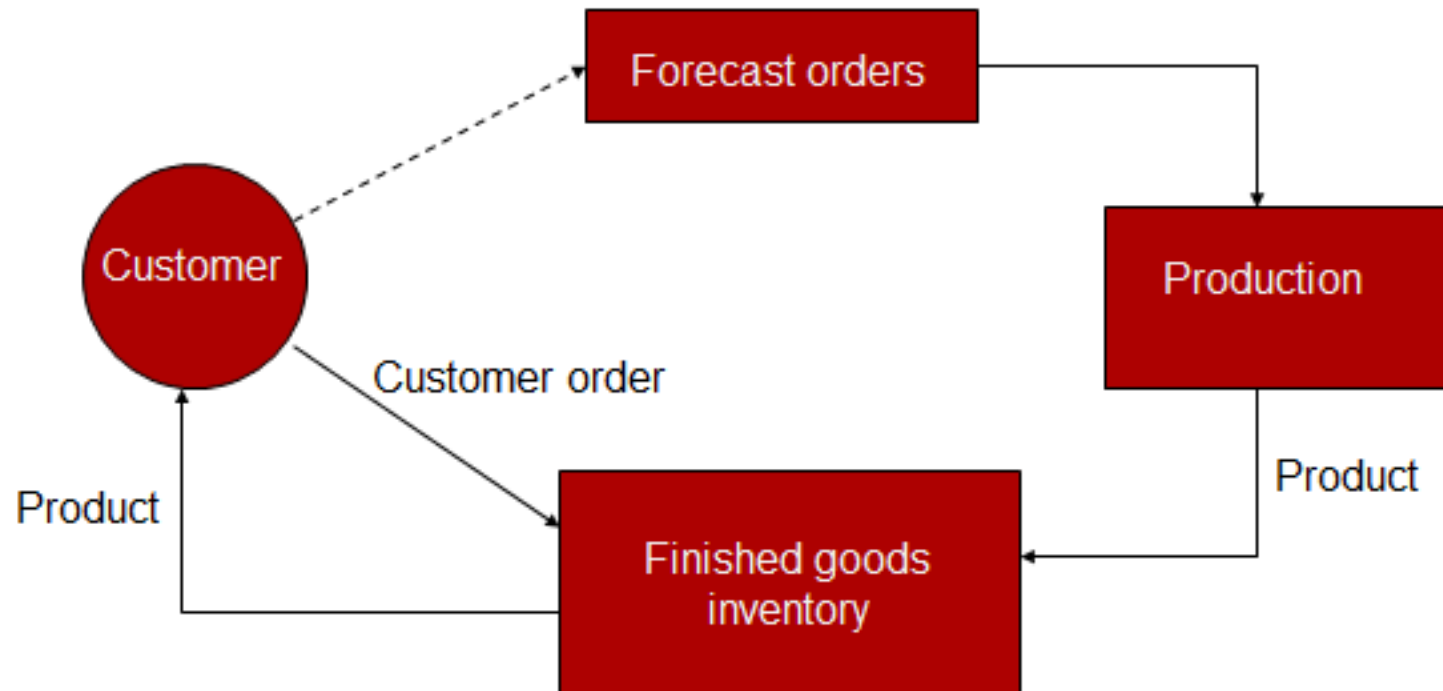
Order Fulfillment

- Make-to-Stock (MTS)
- Make-to-Order (MTO)
- Assemble-to-Order (ATO)

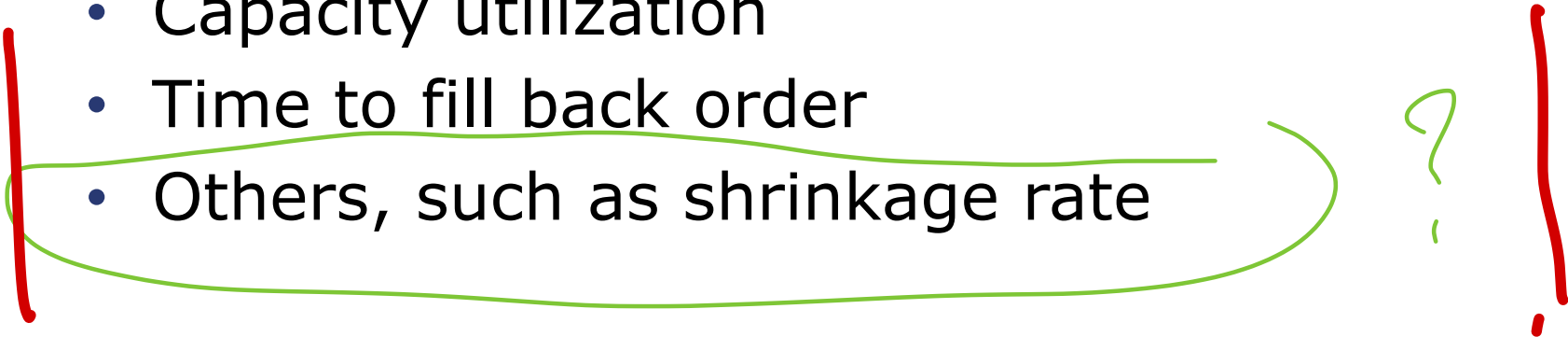
Make-to-Stock (MTS)

- Produce finished goods according to production schedule
- Customer buys from inventory
- Advantage: faster fulfillment of customer demand, lower cost, smooth production rate
- Disadvantage: inventory holding costs, slower to respond to changes in customer preferences

Make-to-Stock (Figure 4.3)



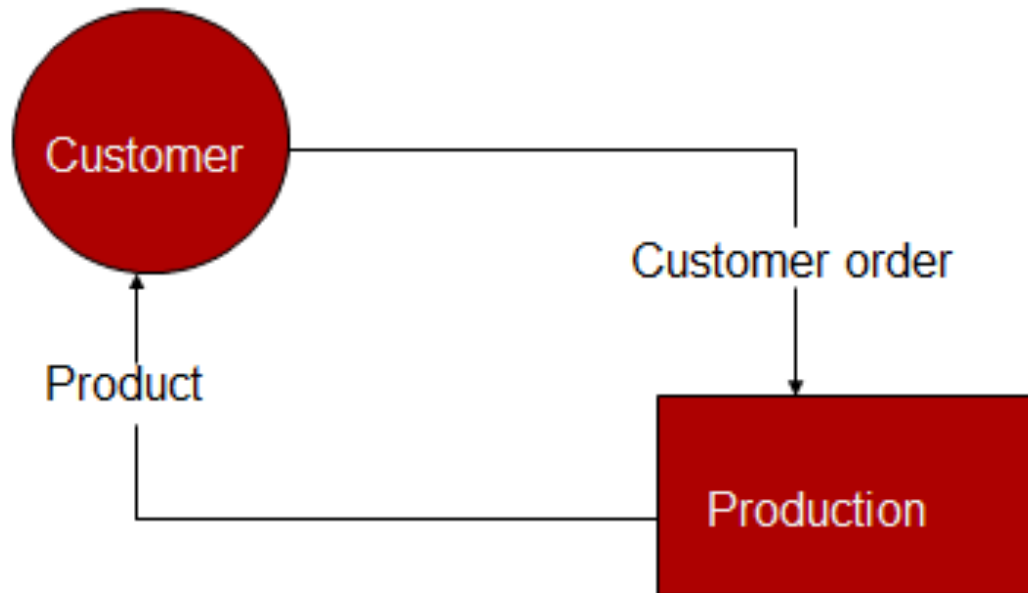
MTS Performance Measures

- Service level (orders filled when requested)
 - Inventory replenishment time
 - Inventory turnover (sales/avg. inventory)
 - Capacity utilization
 - Time to fill back order
 - Others, such as shrinkage rate
- 

Make-to-Order (MTO)

- Start production after customer orders
- No finished goods inventory
- Advantage: higher flexibility to customize order; no finished goods inventory costs
- Disadvantage: intermittent production (i.e., lumpy demand pattern), slower response to customer demand

Make-to-Order (Figure 4.3)



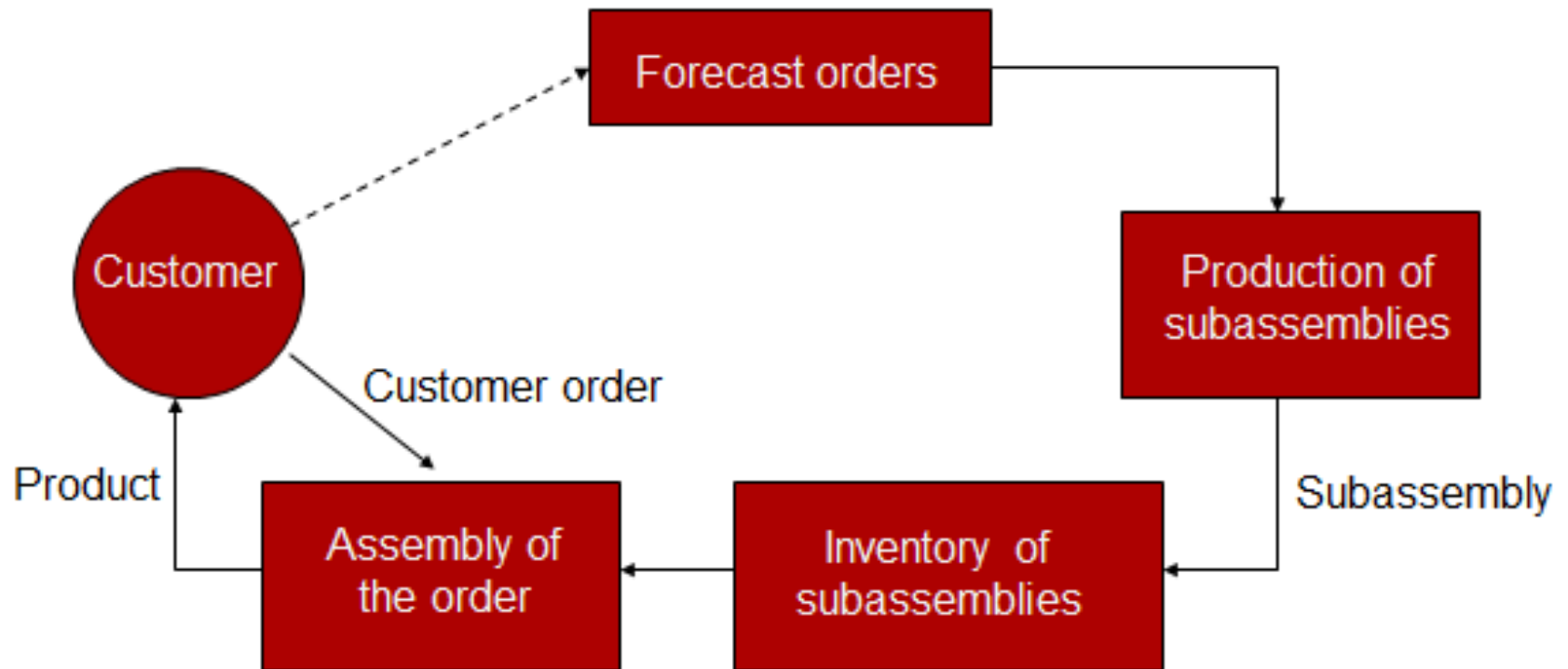
MTO Performance Measures

- Lead time
- Orders completed on time (%)
 - Customer request date
 - Promise date

Assemble-to-Order (ATO)

- Produce parts and subassemblies (modules); complete production when customer places order
- Advantage: less finished goods inventory, faster fulfillment of customer order
- Disadvantage: work-in-process inventory

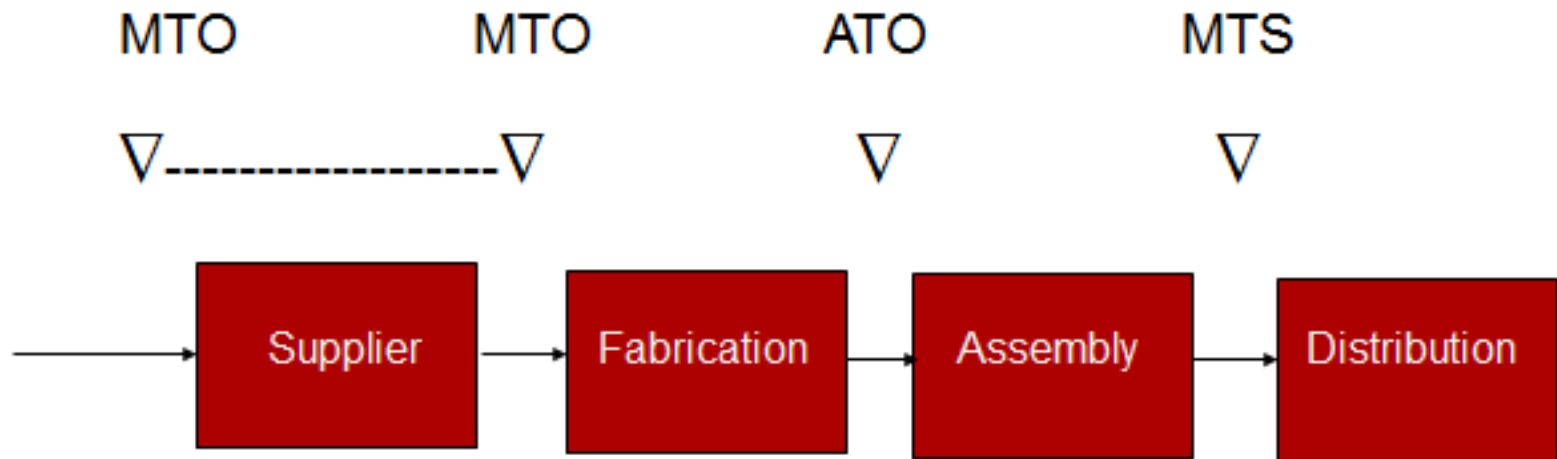
Assemble-to-Order (Figure 4.3)



MTS and MTO Comparison

<i>Characteristics</i>	<i>Make-to-Stock</i>	<i>Make-to-Order</i>
Product	Producer-specified Low variety Inexpensive	Customer-specified High variety Expensive
Objectives	Balance inventory, capacity, and service	Manage delivery lead times and capacity
Main operations challenges	Forecasting Planning production Control of inventory	Delivery promises Delivery time

Order Penetration Point (Figure 4.4)



Process Selection Decisions

- Process characteristics (produce when? produce how?)
 - When: MTS, MTO, ATO
 - How: Continuous process, Assembly line, Batch flow, Job shop, Project
- Factors affecting process choice
 - Market conditions
 - Capital requirements
 - Availability and cost of labor
 - Technology options

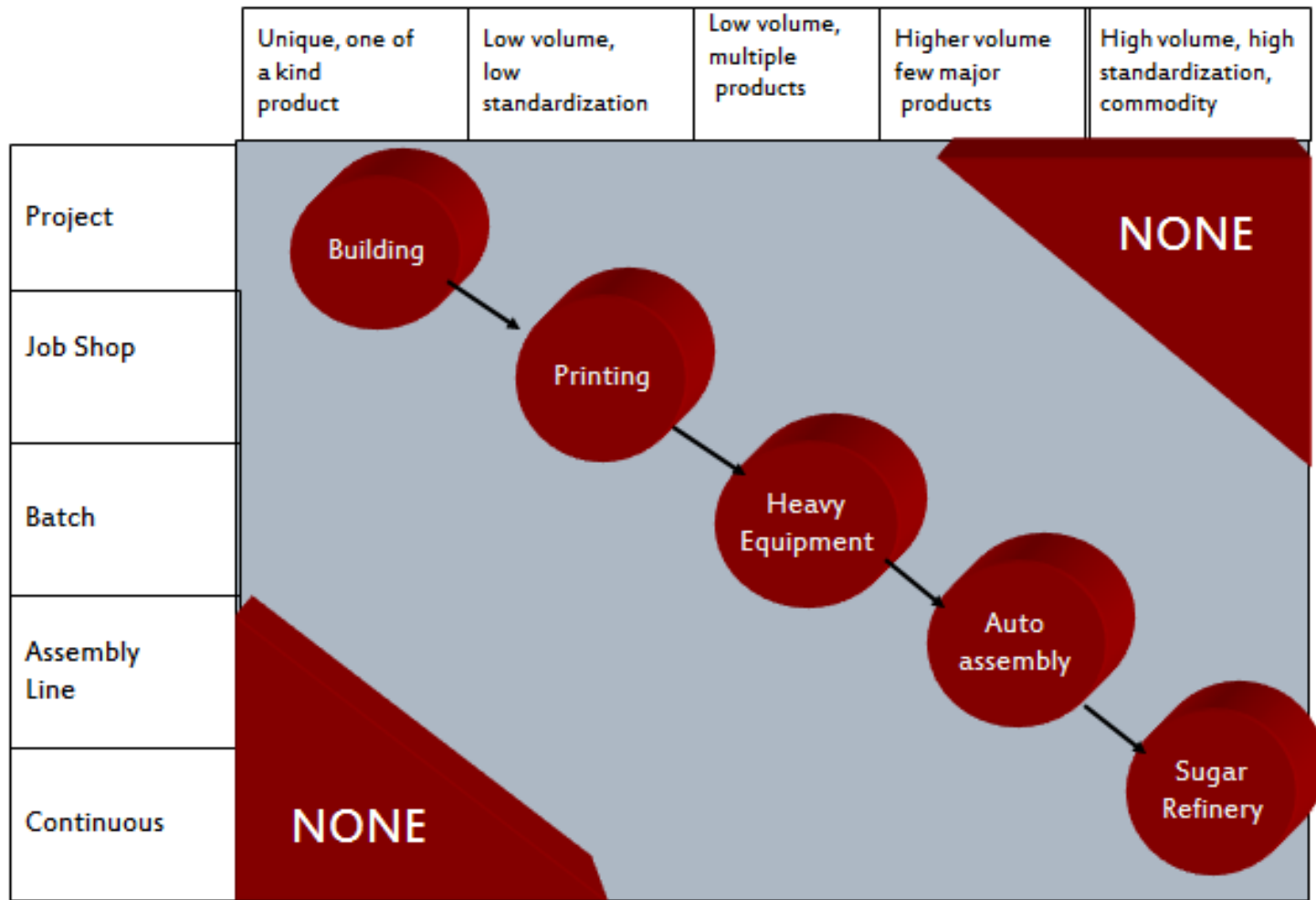
Process Characteristics Matrix (Table 4.2)

<i>Characteristics</i>	<i>Make-to-Stock</i>	<i>Make-to-Order or ATO</i>
Continuous and Assembly Line Flow	Automobile assembly Oil refinery Cannery Cafeteria	Automobile assembly Dell computers Electronic components Fast food
Batch and Job Shop	Machine shop Wine Glassware factory Costume jewelry	Machine shop Restaurant Hospital Custom jewelry
Project	Speculation homes Commercial paintings Noncommissioned art	Buildings Movies Ships

Product-Process Strategy

- Strategy must consider product characteristics and process capabilities.
- Product life cycle:
 - Often begins in Job Shop, then Batch Flow, then Continuous/Assembly Line.
- Example: Bread was first produced by hand in individual units in traditional bakeries, and is now produced in very large batches in modern automated bakeries.

Product-Process Matrix (Figure 4.5)



Focused Operations

- Lack of focus means attempting to accomplish too many goals at one plant or one facility.
- Examples of declining focus: Product/service proliferation, requiring different volumes and different levels of standardization.
- **Focused facility:** Meeting one set of goals.
- **Plant-within-a-plant (PWP):** Separate products/services with differing goals by production lines/areas within the same facility.

Mass Customization

- Strategy to produce products in lot sizes = 1, in high volume.
- Made possible by flexible manufacturing.
- Traditional mass production provides *economies of scale*.
- Mass Customization means using a high volume process (*economies of scale = low unit cost*) to produce relatively custom products (*economies of scope = high variety*).

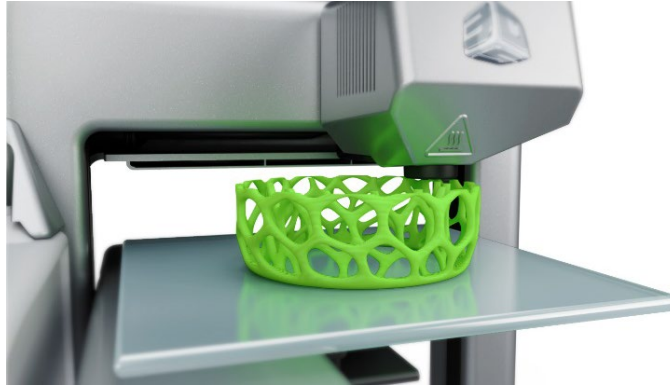
Forms of Mass Customization

- Modular production & assemble-to-order (ATO)
 - e.g., assembling modules for Dell computers
- Fast changeover
 - e.g., zero set-up time at Motorola
- Postponement of options
 - e.g. power supply for Hewlett-Packard printers

3D Printing & Additive Manufacturing (1 of 2)

- Based on digital design model (stored in cloud, not warehouse!)
- Layer plastic, metal, ceramic to build object
 - Normal (real) size
 - Complex shapes and spaces
- Uses: medical implants, aerospace, spare parts, etc.
 - Complements manufacturing for special needs, rather than replacing production facilities
 - Can shorten global supply chain; reduce inventory

3D Printing & Additive Manufacturing (2 of 2)



Environmental Concerns

- Technologies for pollution prevention.
- Technologies for pollution control.
- Infrastructure Systems for pollution practices.
- Other concerns
 - Recycling outputs
 - Recycled inputs
 - Remanufacturing

Cross-Functional Decision Making: Who has a stake in process choice?

- **Marketing** wants fast response to customer demand
- **Finance** provides funds to configure the process
- **HR** finds/creates the properly skilled workers
- **IT** serves various data requirements
- **Accounting** evolves in setting performance measures

Summary

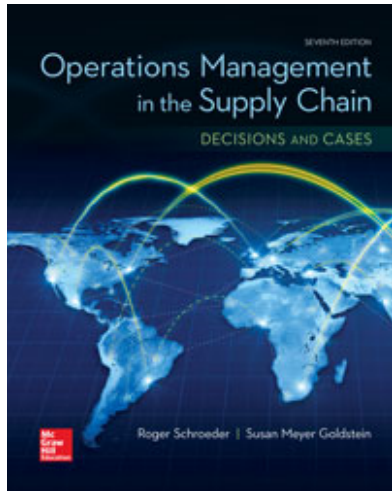
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End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 8

Managing Quality

Learning Objectives (1 of 2)

- 8.1 Explain quality, from a customer perspective.
- 8.2 Characterize product quality based on four dimensions.
- 8.3 Distinguish service quality from product quality based on its distinct measurement.
- 8.4 Apply the quality cycle to a product or service.
- 8.5 Explain how mistake-proofing and the supply chain are integrated with quality management planning.

Learning Objectives (2 of 2)

- 8.6 Attribute how cost of quality is related to financial performance.
- 8.7 Recall the two key quality pioneers and their main ideas.
- 8.8 Compare and contrast ISO 9000 standards and the Baldrige Award criteria.
- 8.9 Articulate some key barriers to successful quality improvement efforts.

Introduction

- Quality is one of the four key objectives of operations (cost, quality, delivery, flexibility)
- Historical development of quality concepts
 - Inspection (early 1900s)
 - Statistics quality control (Shewhart - 1940s)
 - Quality management (1960s)
- Quality is responsibility of everyone in the organization

Comair Flight 5191, Lexington, KY

The Comair Flight 5191 crew began the day by powering up the wrong plane. They took off down the wrong runway. The air traffic controller, working alone in violation of FAA policy, had turned his back to do other duties. Investigators are uncovering a series of mistakes before the plane crashed, killing 49 people.”

Source: www.cnn.com, 2006

Quality involves the entire organization and the supply chain.

Definition of Quality

- *Meeting, or exceeding, customer requirements now and in the future.*
- *i.e., The product or service is fit for the customer's use.*
- *Only the customer can determine quality.*

Dimensions of Product Quality

- Quality
 - Availability
 - Field Service
 - Quality of Design
 - Quality of Conformance

Quality of Design

- Determined before the product is produced
- Responsibility of cross-functional product design team
- Translates the “wishes” of customers into specifications
- Depends on market research, design concept, product specifications

Quality of Conformance

- Producing a product (or service) that meets specifications
- Even 'cheap' products can have high conformance quality
- May not be durable, but conformance quality is achieved if they match their design

The “Abilities”

- **Availability**

- Continuity of usefulness to customers (operational)

- **Reliability**

- Useful product/service time until failure
- Mean time before failure (MTBF)

- **Maintainability**

- Restoration of product/service after failure
- Mean time to repair (MTTR)

$$Availability = \frac{Uptime}{Uptime + Downtime}$$

$$Availability = \frac{MTBF}{MTBF + MTTR}$$

Availability Example

- A piece of medical testing equipment is typically used for 3 hours and then requires one hour of maintenance.
- → Calculate the machine's availability.

$$\text{Availability} = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

- MTBF = 3 hours
- MTTR = 1 hour
- Availability = $3 / (3 + 1) = .75$
- The machine's average availability is 75%.

Field Service

- Warranty and repair/replacement of the product after it has been sold
- Also called customer service, sales service, or just “service”
- Dimensions
 - Promptness
 - Competence
 - Integrity

Different Types of Quality (Figure 8.1) (1 of 2)

- Customer satisfaction (Fitness for use)
 - Quality of design
 - Quality of market research
 - Quality of concept
 - Quality of specification
 - Quality of conformance
 - Technology
 - Employees
 - Management

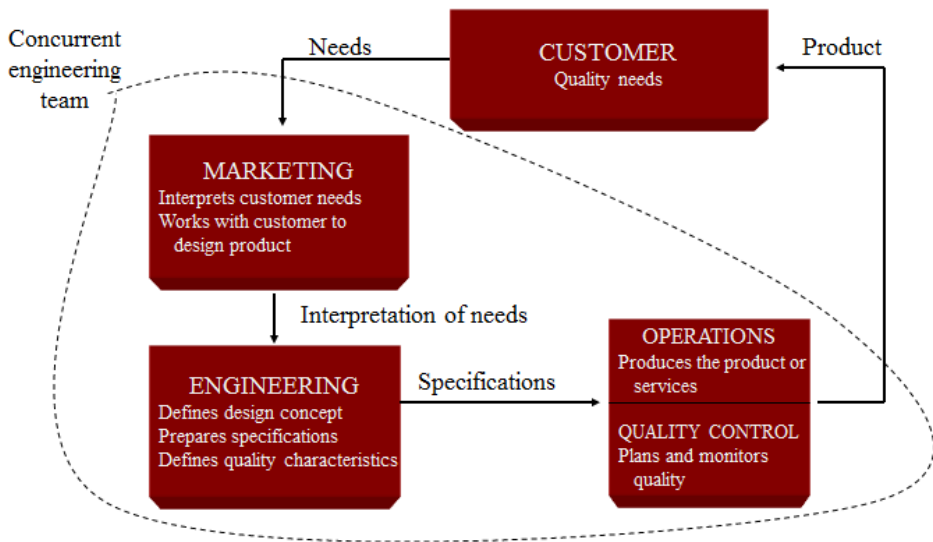
Different Types of Quality (Figure 8.1) (2 of 2)

- Availability
 - Reliability
 - Maintainability
 - Logistical support
- Field service
 - Promptness
 - Competence
 - Integrity

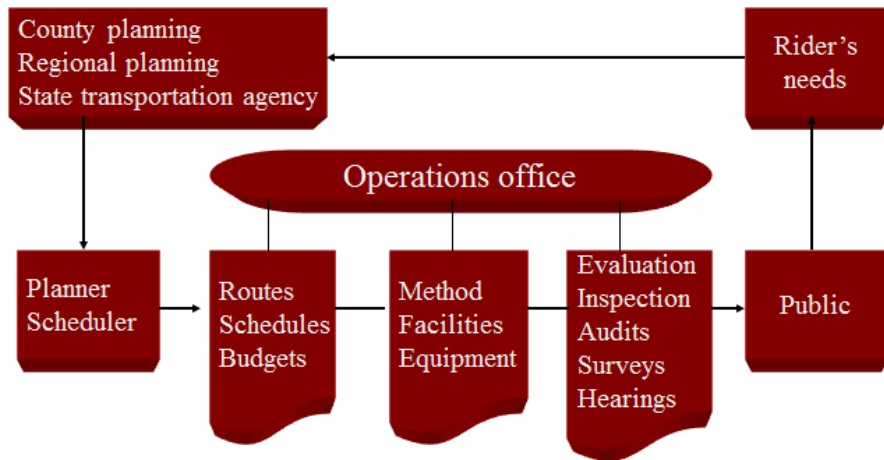
Service Quality

- Includes explicit and implicit service characteristics
- Measures are perceptual/subjective
- **SERVQUAL** is most popular measure
 - Tangibles: appearance
 - Reliability: promised service
 - Responsiveness: prompt, helpful
 - Assurance: knowledge, courtesy
 - Empathy: caring, individualized

The Quality Cycle (Figure 8.2)



Quality Cycle in Mass Transit System (Figure 8.3)



Quality Improvement Through the Quality Cycle

1. Define quality attributes on the basis of customer needs
2. Decide how to measure each attribute
3. Set quality standards
4. Establish appropriate tests for each standard
5. Find and correct causes of poor quality
6. Continue to make improvements

Poka-Yoke (poh-kah yoh-kay) (1 of 2)

- Developed at Toyota in the 1960s
- Means '**mistake proofing**'
- Design the product and process so that mistakes cannot occur or are immediately detectable
- Examples
 - In manufacturing, 2 parts are notched to only fit together one way
 - For consumers, snow blower requires that two hand levers be held during operation (so no hands can be in the dangerous moving parts!)

Poka-Yoke (poh-kah yoh-kay) (2 of 2)



Suppliers Role in Quality

- Involve in product design
 - Prevent design defects; help select materials
- Supplier certification
 - Planning and control system for quality
- Manage rolled yield (cumulative defect rate)
 - 10 parts (1% defects in each)
 - Rolled yield = $(.99)^{10} = .90$
 - 90% quality yield for final product

Cost of Quality

- **Control costs**

- Prevention

- Training, data management, planning

- Appraisal

- Incoming materials inspection, final good inspection

- **Failure costs**

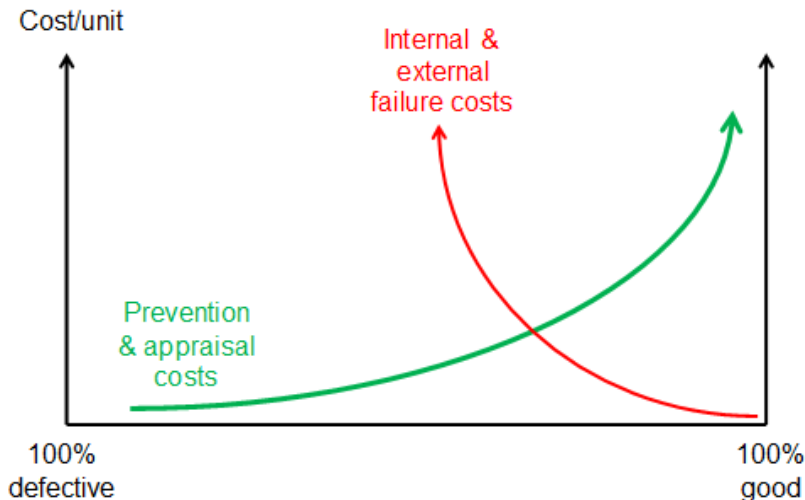
- Internal failure

- Scrap, rework, downtime

- External failure

- Warranty, returns, complaints

Cost of Quality Trade-offs (Figure 8.5)



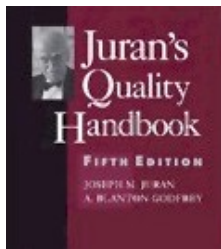
Quality Pioneer: W. Edwards Deming

- 14 Management Principles
- Do not sacrifice quality for short-term profit
- Emphasis on continuous improvement
- PDCA Wheel
 - Plan, do, check, act
- *<http://www.deming.org/>*



Quality Pioneer: Joseph Juran

- Quality “Trilogy”—planning, control and improvement
- Solve “the vital few” quality problems
- Stressed quality control methods
- “*Quality Handbook*”
- <http://www.juran.com>



ISO 9000 Standards (1 of 2)

- Guidelines for designing, manufacturing, selling, and servicing products. Est. 1987.
- Selecting an ISO 9000 certified supplier provides some assurance that supplier follows accepted quality practices.
- Required of suppliers by many manufacturers, especially in Europe.
- *www.iso.org*

ISO 9000 Standards (2 of 2)

Airports can be ISO 9000 certified



Hotels can be ISO 9000 certified



ISO 14000 Standards

- Standards covering **environmental management systems**, environmental auditing, evaluation of environmental performance, environmental labeling, and life-cycle assessment.
- Intent is to help organizations improve their environmental performance through documentation control, operational control, control of records, training, statistical techniques, and corrective and preventive actions.
- *ISO 26000 – social responsibility*
- *ISO 31000 – risk management*

Malcolm Baldrige Award

- Est. 1987 to promote better quality management practices and improved quality results by U.S. industry.
- Award criteria have become standard for “best quality practice” in U.S.
- Given to at most 3 organizations in each of 6 categories: manufacturing, service small business, health care, education, nonprofit.
- ~~www.baldrige.gov~~



Baldrige Criteria Categories

1. Leadership
2. Strategy
3. Customers
4. Measurement, Analysis, and Knowledge Management
5. Workforce
6. Operations
7. Results

Why Some Quality Improvement Efforts Fail

- Requires change in values and management philosophy
- Focus on short-term financial results
- “Blame the employee” syndrome
- Belief in “trade-offs” (quality vs. cost)
- Management interference with teamwork
- Reward systems
- Supplier quality problems

Summary (1 of 2)

- 8.1 Explain quality, from a customer perspective.
- 8.2 Characterize product quality based on four dimensions.
- 8.3 Distinguish service quality from product quality based on its distinct measurement.
- 8.4 Apply the quality cycle to a product or service.
- 8.5 Explain how mistake-proofing and the supply chain are integrated with quality management planning.

Summary (2 of 2)

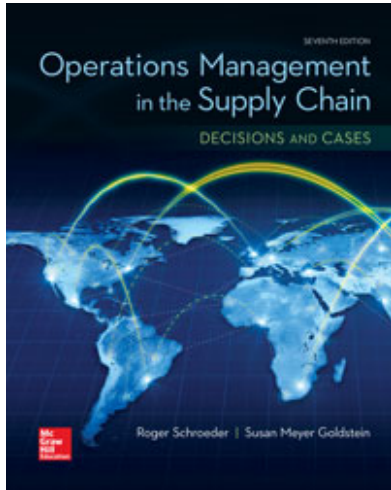
- 8.6 Attribute how cost of quality is related to financial performance.
- 8.7 Recall the two key quality pioneers and their main ideas.
- 8.8 Compare and contrast ISO 9000 standards and the Baldrige Award criteria.
- 8.9 Articulate some key barriers to successful quality improvement efforts.

End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

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Chapter 9

Quality Control and Improvement

Learning Objectives

- 9.1 Describe the steps in designing a quality control system.
- 9.2 Design a process control system using control charts.
- 9.3 Define and calculate process capability.
- 9.4 Apply continuous improvement concepts using the seven quality tools.
- 9.5 Explain Six Sigma and the DMAIC process.
- 9.6 Differentiate lean and Six Sigma.

Design of Quality Control Systems

- Break down production process into subprocesses and identify **internal customers**.
- Identify **critical control points** where inspection or measurement should take place.
- Use **operator inspection** when possible, placing responsibility for quality on workers.

Designing Quality Control Systems

1. Identify critical points for inspection and testing
 - Incoming materials & services
 - Work in process
 - Finished product or service
2. Decide on the type of measurement
 - Variables: continuous scale
 - Attributes: discrete count, or good/bad
3. Decide on the amount of inspection to be used
4. Decide who should do the inspection

Types Of Measurement

- Variables measurement
 - Product/service characteristic that can be measured on a continuous scale
- Length, size, weight, height, time, velocity, temperature
- Attributes measurement
 - Product/service characteristic evaluated with a discrete choice:
- Good/bad, pass/fail, count of defects

Process Quality Control (1 of 2)

- Principles of Process Control:
 - Every process has random variation.
 - Production processes are not usually in a state of control.
- “State of Control” - What does it mean?
 - Unnecessary variation has been eliminated.
 - Remaining variation is due to random causes.

Process Quality Control (2 of 2)

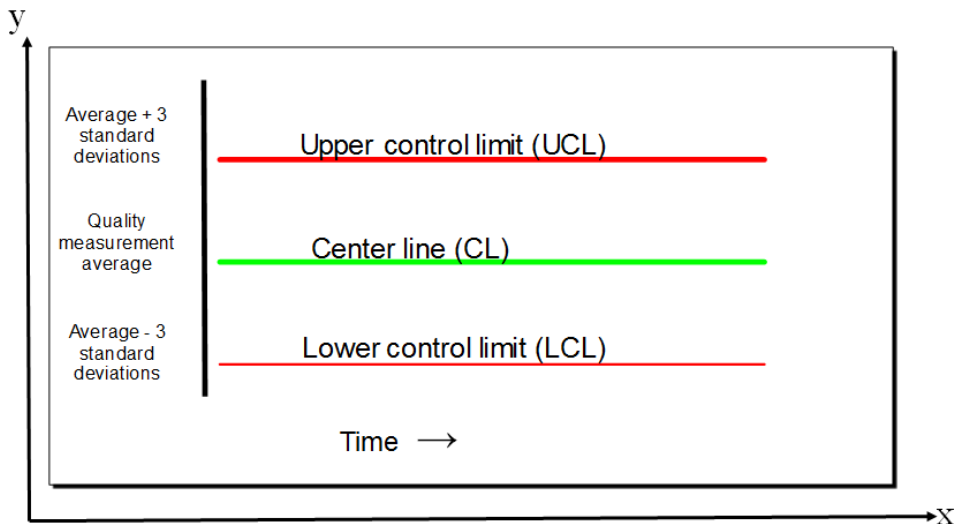
- **Assignable** (special) cause variation

- Can be identified and corrected
- Could be due to machine, worker, materials, etc.

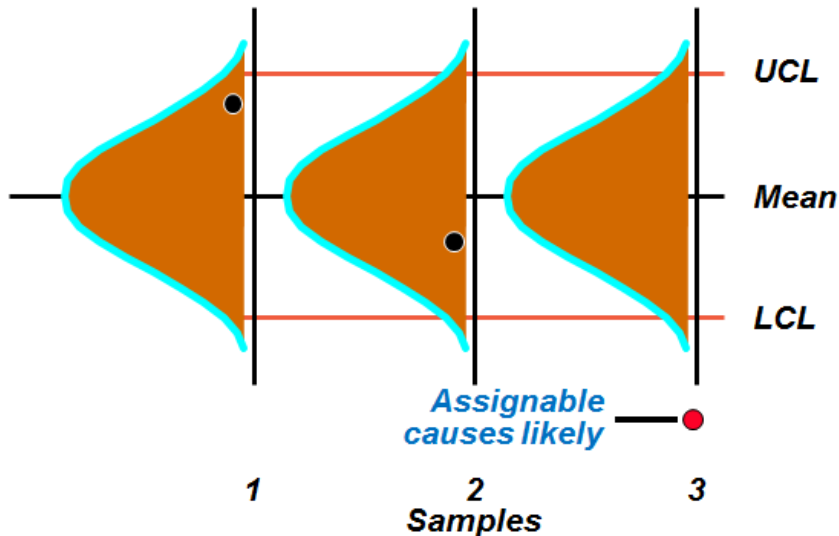
- **Common** (random) cause variation

- Reasonable, acceptable variation
- Within 3 standard deviations ($\pm 3\sigma$) of mean
- Cannot be changed unless process is redesigned

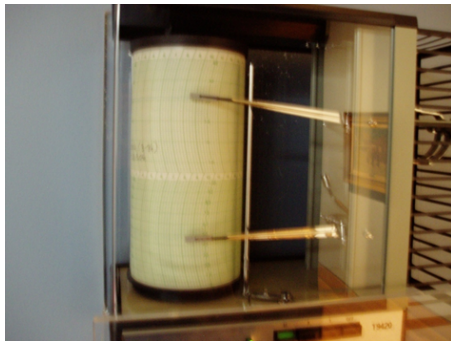
Quality Control Chart



Normal Distribution on Control Chart



Control Limits - Application



Temperature & Humidity Control in a Museum

□ *Monitor for unexpected readings*

Attribute Control [3σ]

- p -chart

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$



- Calculate center line = mean proportion defective across many samples
- Calculate upper and lower control limits

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Variables Control [3 σ]



- $\bar{x}$ -chart
- Calculate center line = mean of sample means
- Calculate upper and lower control limits

$$\bar{\bar{X}} \pm A_2 \bar{R}$$

- R -chart
- Calculate center line = mean of sample ranges
- Calculate upper and lower control limits

$$UCL = D_4 \bar{R}$$

$$LCL = D_3 \bar{R}$$

Using Quality Control Charts (1 of 2)

- If an observation (data point) is **outside** $\pm 3\sigma$ and/or a pattern is detected, the process is **NOT in a state of control**.
- Very likely something is wrong.
- Conclude an assignable cause of variation may exist.
- Signal to take action to eliminate assignable cause:
 - Find it, understand its cause, fix it so it does not occur again!

Using Quality Control Charts (2 of 2)

- How large should sample be?
 - Large enough to detect defects
 - Variables can use smaller sample sizes
- How frequently to sample?
 - Depends upon cost, production rate
- Process control vs. ~~Process capability~~
 - Is the process capable of producing to specification?
 - Are the specifications appropriate?

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Process Capability Index Examples (Figure 9.3)

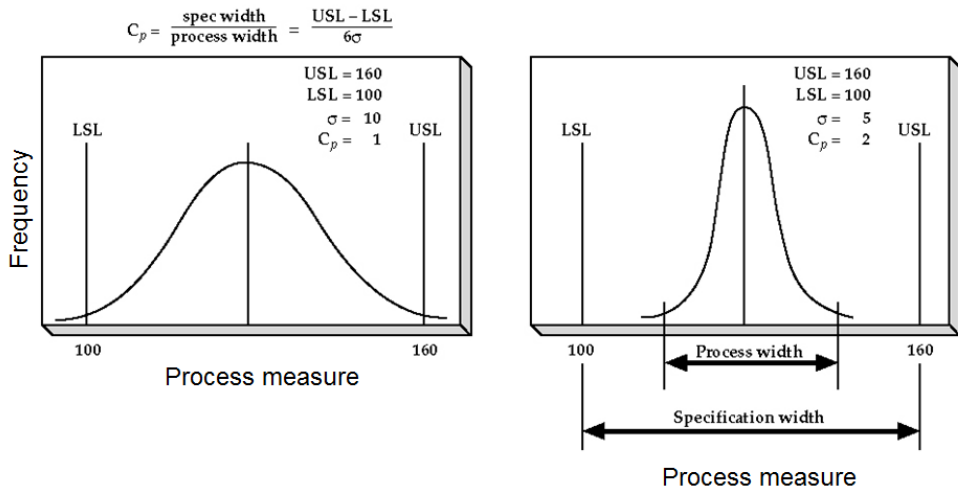
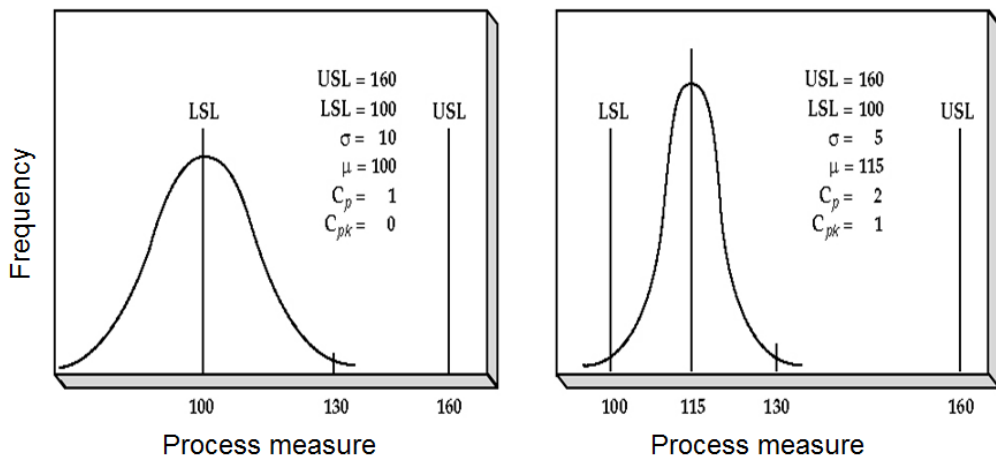


Figure 9.4

Computation of C_{pk}



Continuous Improvement

- When process is not meeting customer specifications.
- Work on processes with strategic importance and low process capability first!
- Use seven tools of quality control.

Seven Tools of Quality Control (1 of 2)

(see Figure 9.5)

- Flowchart
- Check Sheet
- Histogram
- Pareto Chart
- Cause-and- Effect (fishbone, Ishikawa) Diagram
- Scatter Diagram
- Control Chart

Seven Tools of Quality Control (2 of 2)

A battery manufacturer in NW Ohio in 6 weeks, using only the 7 tools of quality, decreased defectives from 7.2 per 100 to 2.6 per 100.

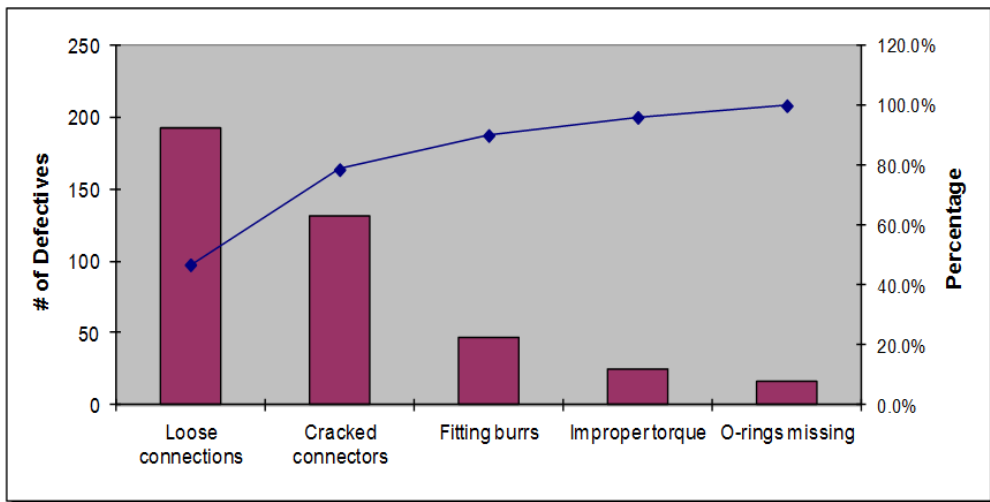
Pareto Analysis

Table 9.4

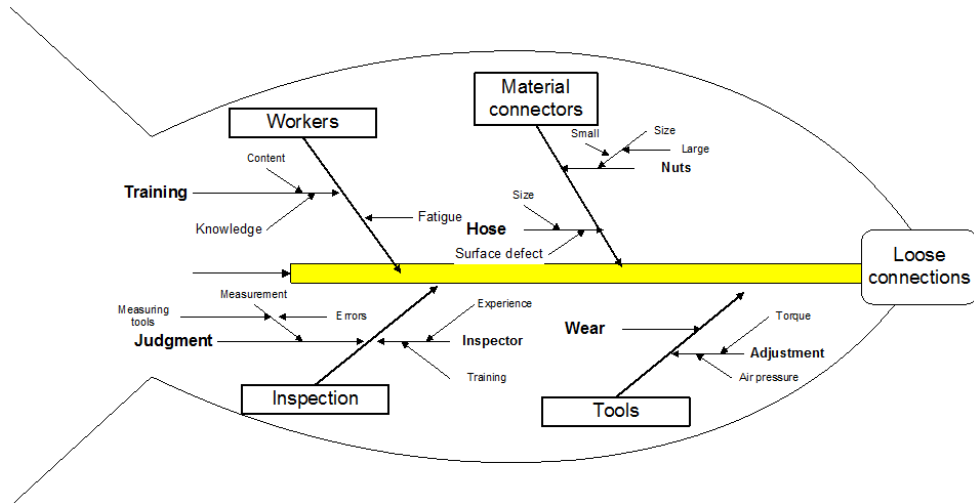
Defect Items	# of Defectives	Percent Defective	Cumulative Percentage
Loose connections	193	46.8%	46.8%
Cracked connectors	131	31.8%	78.6%
Fitting burrs	47	11.4%	90.0%
Improper torque	25	6.1%	96.1%
O-rings missing	<u>16</u>	<u>3.9%</u>	100%
Total	412	100.0%	

Note: 40% (2) of the sources cause 78.6% of the defects

Pareto Diagram (Figure 9.6)



Cause-and-Effect (Fishbone, Ishikawa) Diagram (Figure 9.7)



Six-Sigma Quality

Quality means
 Excellence

- Pioneered by Motorola in 1980s
- Philosophy of 3.4 defects per million
- Most process are 4 sigma (4σ): e.g., payroll records, prescriptions, baggage handling, restaurant bills
- Airline fatalities are 6.4 sigma
- IRS tax advice is less than 2 sigma

Six Sigma Process

refer to 6 sigma

Process Improvement steps (**DMAIC**):

1. Define – select process
2. Measure – measure relevant variables
3. Analyze – determine root causes and alternatives
4. Improve – change process
5. Control – ensure improvements not lost over time

Six Sigma Quality

- Uses project/team approach
- Strategic process is selected for improvement
- Cross-functional team is formed
- '**Black belt**' leader is chosen
- The team uses the DMAIC method (and quality tools) to find root causes and improve the process

6 sigma → Quality → Defects / process
ISO 9000 → process

Lean and Six Sigma



- Complementary approaches to improvement
 - *Lean* seeks to eliminate waste (non-value-added)
 - *Six Sigma* seeks to eliminate defects
 - *Lean* uses part-time leaders and all employees
 - *Six Sigma* uses full-time leaders and selected employees
 - *Lean* requires limited training
 - *Six Sigma* requires extensive training and experts
 - *Lean* focuses on simpler projects
 - *Six Sigma* takes on complex projects
 - *Lean* projects may last a week or less
 - *Six Sigma* projects may last for months

Summary

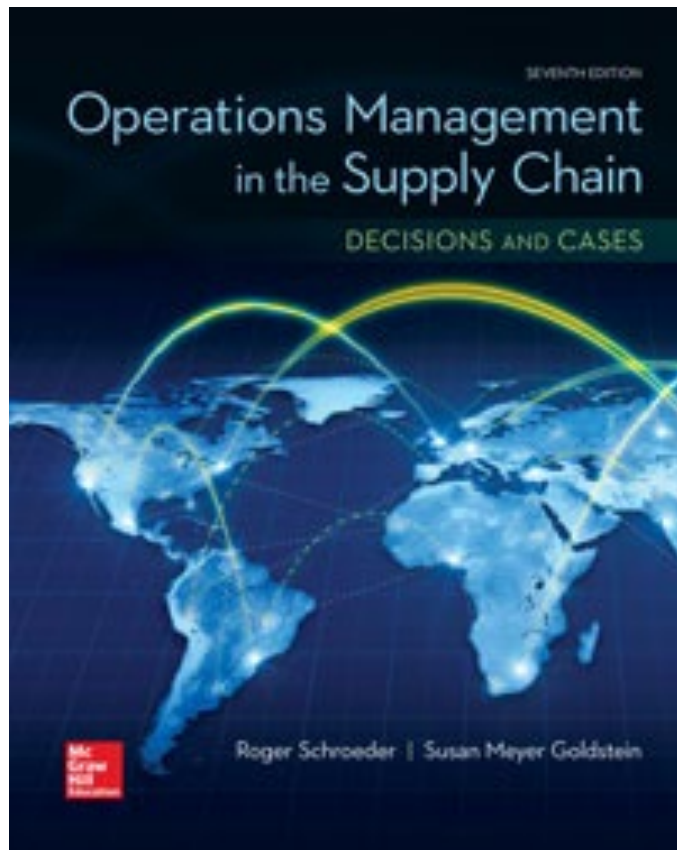
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End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

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Chapter 10

Forecasting

Learning Objectives

- 10.1 Describe why forecasting is important.
- 10.2 Describe the four common methods of qualitative forecasting.
- 10.3 Calculate a moving average and exponential smoothing forecast, and explain when they should be used.
- 10.4 Evaluate forecast accuracy using a variety of methods.
- 10.5 Carry out causal forecasting.
- 10.6 Evaluate factors that impact forecasting method selection.
- 10.7 Explain the benefits and costs of CPFR

Forecasting for Decision Making

- Forecasting demand for operations output
 - Forecasting: what we think demand will be
 - Planning: what we think demand should be
 - Demand: may differ from sales
- Forecasts are used in all functional areas: marketing, finance, human resources, etc.
- Forecasts are necessary for operations decision areas: process design, capacity planning, inventory management, scheduling

Use of Forecasting: Operations Decisions

	Time Horizon	Accuracy Required	Number of Forecasts	Management Level	Forecasting Method
Process design	Long	Medium	Single or few	Top	Qualitative or causal
Capacity planning, facilities	Long	Medium	Single or few	Top	Qualitative or causal
Aggregate planning	Medium	High	Few	Middle	Causal and time series
Scheduling	Short	Highest	Many	Lower	Time series
Inventory management	Short	Highest	Many	Lower	Time series

Use of Forecasting: Marketing, Finance, & HR

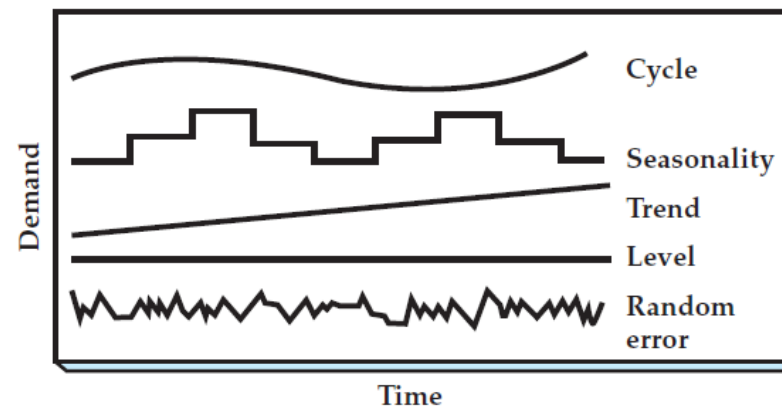
	Time Horizon	Accuracy Required	Number of Forecasts	Management Level	Forecasting Method
Long-range marketing programs	Long	Medium	Single or few	Top	Qualitative
Pricing decisions	Short	High	Many	Middle	Time series
New product introduction	Medium	Medium	Single	Top	Qualitative and causal
Cost estimating	Short	High	Many	Lower	Time series
Capital budgeting	Medium	Highest	Few	Top	Causal and time series
Labor planning	Medium	Medium	Few	Lower	Qualitative and time series

'Qualitative' Forecasting Methods

- Based on managerial judgment when there is a lack of data available. No specific model.
- Major methods:
 - Delphi technique
 - Market surveys
 - Life-cycles analogy
 - Informed judgment (naïve models)

Time-Series Forecasting

- Components of data:
 - Level - average
 - Trend - general direction (increasing/decreasing)
 - Seasonality - short term recurring cycles
 - Cycle - long term business cycle
 - Error - random or irregular component



Moving Average

- Assumes no trend, seasonality, or cycle
- Simple moving average:

$$A_t = \frac{D_t + D_{t-1} + \dots + D_{t-N+1}}{N}$$

$$F_{t+1} = A_t$$

- Weighted moving average:

$$F_{t+1} = A_t = W_1 D_t + W_2 D_{t-1} + \dots + W_N D_{t-N+1}$$

Moving Average Example

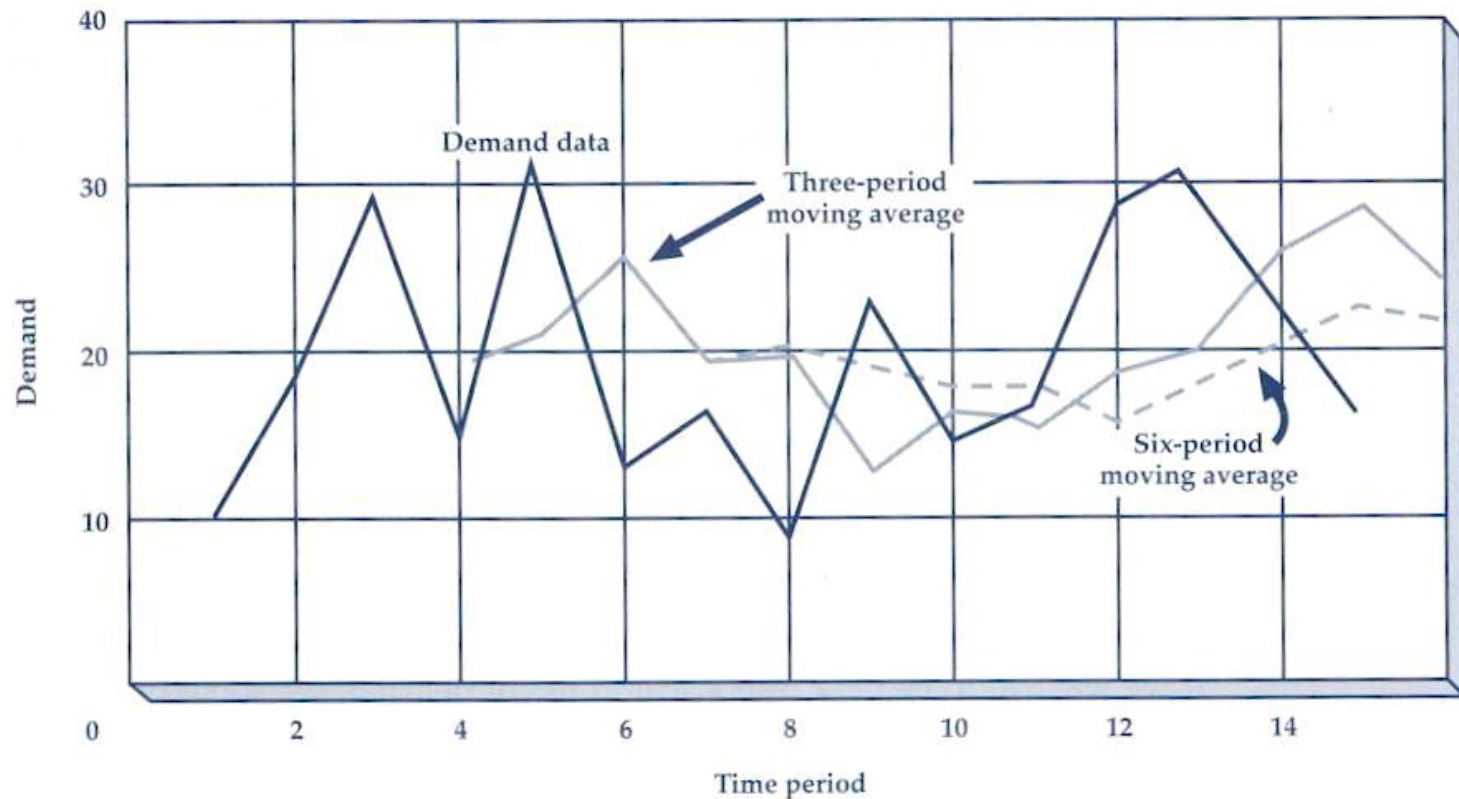
<u>Period</u>	<u>Actual Demand</u>	<u>Forecast</u>
1	10	
2	18	
3	29	
4	-	19

- **Compute three period moving average for Period 4** (number of periods is forecaster's decision)

$$F_4 = A_3 = (29 + 18 + 10)/3 = 19$$

$$F_5 = (\text{actual demand for period 4} + 29 + 18)/3$$

Time-Series Data (Figure 10.2)



Note: The forecast is smoother as the number of periods in the moving average increases.

Exponential Smoothing

- The new average is computed from the old average:

$$A_t = \alpha D_t + (1 - \alpha)A_{t-1}$$

- The value of the smoothing constant (α) is a choice. It determines the extent to which the new forecast weights recent demand (smooths random variation).

Alpha (α) ranges between 0 and 1, and is usually 0.1 - 0.2.

Simple Exponential Smoothing

- Forecast:

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

F = forecast of demand

D = actual demand

t = time period

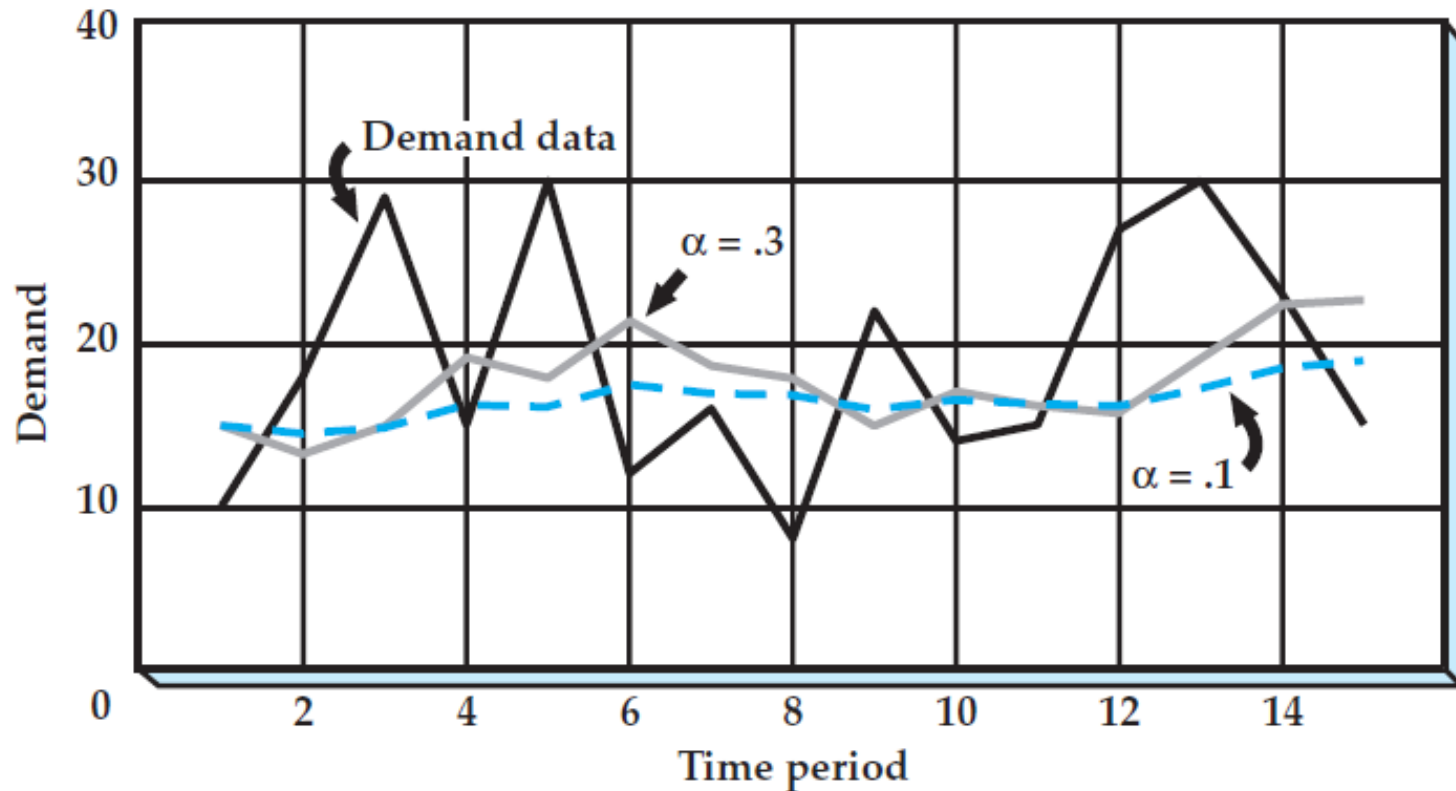
- Assumes no trend, seasonality, or cycle
- Note: we are adjusting F_t to get F_{t+1}

Exponential Smoothing Example

- The **Sept. forecast** was 15, but **Sept. actual** sales were 13. Use alpha (α) of 0.2.
 - What is the **October forecast**?

$$\begin{aligned}\text{October forecast} &= \text{Sept. forecast} + \\ &\quad \alpha(\text{Sept. actual} - \text{Sept. forecast}) \\ &= 15 + 0.2(13 - 15) \\ &= 15 - 0.4 = \underline{\mathbf{14.6}}\end{aligned}$$

Time-Series Data (Figure 10.3)



Note : The forecast is smoother as the value of alpha (α) is reduced.

Forecast Accuracy

In addition to the forecast, firms should estimate forecast accuracy:

- To monitor erratic demand observations or “outliers”
- To determine when the forecasting method is no longer tracking actual demand
- To determine the parameter values that provide the forecast with the least error

Measures of Forecast Accuracy

- Cumulative sum of forecast errors (CFE)
- Mean square error (MSE)
- Mean absolute deviation (MAD)
- Mean absolute percentage errors (MAPE)
- Tracking Signal (TS)

Forecast Accuracy: Formulas

Cumulative sum of forecast errors CFE = $\sum_{t=1}^n e_t$

Mean square error MSE = $\frac{\sum_{t=1}^n e_t^2}{n}$

Mean absolute deviation MAD = $\frac{\sum_{t=1}^n |e_t|}{n}$

Mean absolute percentage errors MAPE = $\frac{\sum_{t=1}^n \left| \frac{e_t}{D_t} \right| 100}{n}$

Tracking signal TS = $\frac{CFE}{MAD_t}$

Advanced Time-Series Forecasting

- Adaptive exponential smoothing
 - Smoothing coefficient (α) is varied
- Mathematical models
 - Linear or nonlinear
- Box-Jenkins method
 - Requires about 60 periods of past data

Causal Forecasting Methods

- Cause-and-effect model, using a data set of other variables to predict demand (forecast).
- Examples:
 - Use population and location characteristics to forecast restaurant sales.
 - Use supply chain data on inventory levels to forecast sales of new generation products such as cell phones.

Causal Forecasting Models

- The general regression model:

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

- Other forms of causal model:
 - Econometric
 - Input-output
 - Simulation models

Example of Causal Model

$$Y_t = a + b(t)$$

I_t	D_t	F_t
34.6	120	121.15
35.7	124	123.786
36.3	119	125.224
35.2	124	122.588
35.7	125	123.786
36.4	130	125.464
37.6		128.34
Intercept (a)	38.230937	
Slope (b)	2.3965142	

D_t = actual sales in year t

F_t = forecasted sales

I_t = median family income (000's)

$F_7 = 38.23 + 2.397(7) = 128.34 = \text{forecast for Period 7}$

Selecting a Forecasting Method

- Use or decision characteristics
 - Scheduling decision? Facility expansion?
 - Short range? Long range?
- Data availability
 - Quantity and quality
- Data pattern
 - Level? Unstable?

Collaborative Planning, Forecasting, and Replenishment (CPFR)

- Aim is to achieve more accurate forecasts
- Share information across supply chain with customers and suppliers
- Compare forecasts
 - If discrepancy, look for reason
 - Reach a consensus forecast
- Works best in B2B with few customers (e.g., a small number of large retailers)

Summary

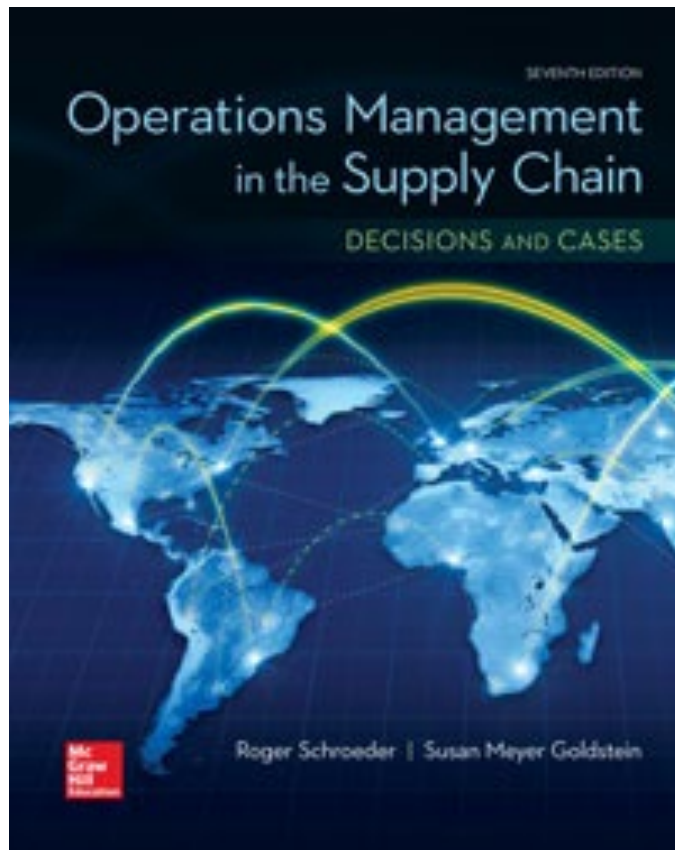
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End of Presentation

Operations Management in the Supply Chain

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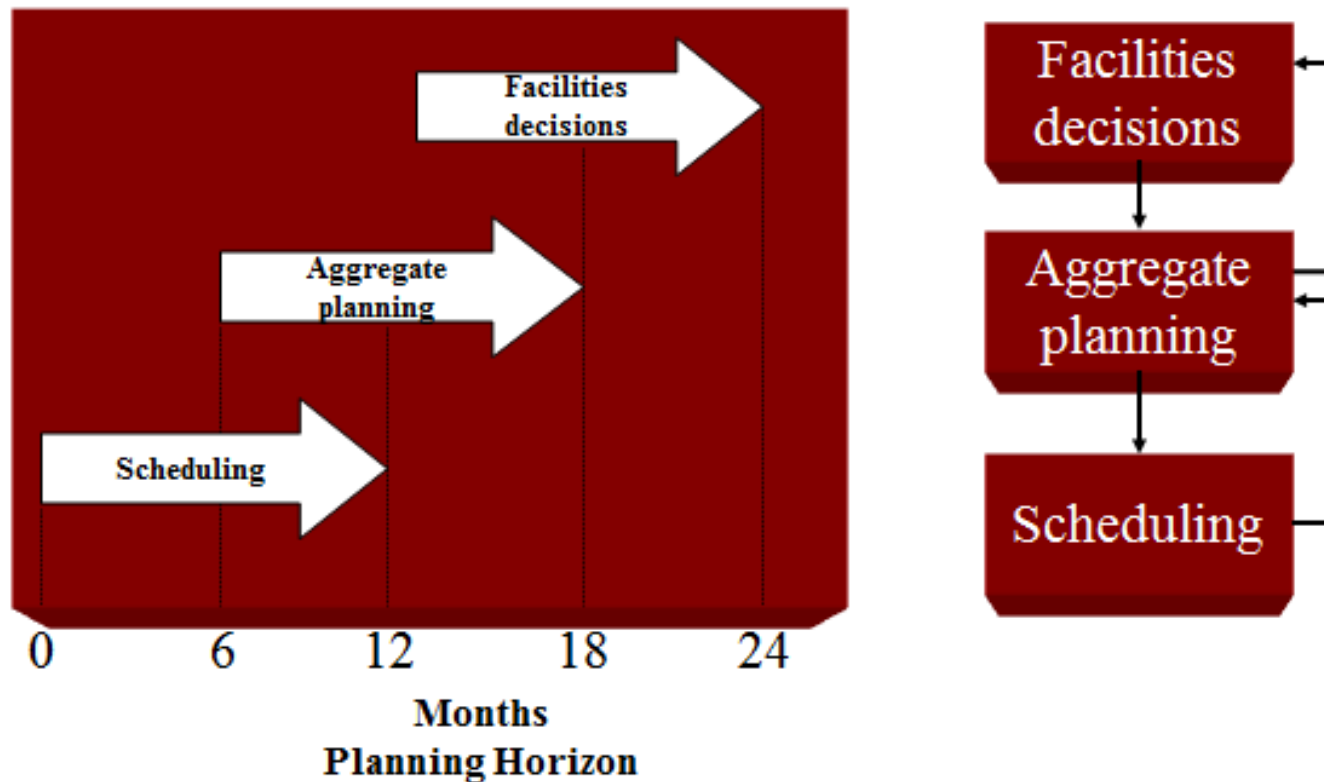
Chapter 11

Capacity Planning

Learning Objectives

- 11.1 Define capacity and utilization
- 11.2 Illustrate with an example a facilities strategy that considers: amount, size, timing, location and type.
- 11.3 Explain how S&OP is done.
- 11.4 Identify the demand and supply options that are available for S&OP
- 11.5 Contrast and compare the chase and level strategies
- 11.6 Define the various costs associated with aggregate planning
- 11.7 Create an alternative strategy for the Hefty Beer Company example

Hierarchy of Capacity Decisions



Months Planning Horizon

Definition of Capacity

Maximum output that can be produced over a given period of time.

- Theoretical capacity
 - Labor availability and overtime
 - Physical assets, delayed maintenance, etc.
 - Can be used for short-term demand spikes
- Effective capacity
 - Used for planning
 - Subtracts maintenance downtime, shift breaks, absenteeism, etc.

Capacity Utilization

$$Utilization = \frac{\text{Actual output}}{\text{Capacity}} \times 100\%$$

→ Utilization is seldom 100%.

→ Estimates capacity usage and 'busyness.'

A production facility that builds 1000 cars during the time it can actually produce 1200 cars has utilization = $1000/1200 = 83\%$

A doctor who is busy working for 6 hours during an 8 hour shift has utilization = $6/8 = 75\%$

Facilities Decisions

- How much capacity is needed?
- How large should each facility be?
- When is the capacity needed?
- Where should the facilities be located?
- What type of facilities/capacity are needed?

Facilities Strategy

- How much? Amount of capacity
 - Size of capacity cushion
- How large? Size of facilities
 - Economies/diseconomies of scale
- When? Timing of facility decisions
 - Preemptive, wait-and-see
- Where? Location of facilities
 - Variety of factors to consider
- What type? Types of facilities
 - Product-focused, market-focused, process-focused, general-purpose

Factors Affecting Facilities Strategy

- Predicted demand
- Cost of facilities
- Likely behavior of competitors
- Business strategy
- Global considerations

How Much? Strategies for Capacity Cushion

- **Capacity cushion** = $100\% - \text{utilization}$
- Three strategies:
 - *Large* cushion (e.g., make-to-order)
 - *Moderate* cushion (cost of running out balanced with cost of excess capacity)
 - *Small* cushion (e.g., make-to-stock)

How Large? Selecting Facility Size

- **Economies of scale**
 - Production costs are not linear
 - Overhead costs spread over more units
- **Diseconomies of scale**
 - Increased transportation costs
 - Cost of more bureaucracy
 - Increased organizational complexity

When? Timing of Facility Additions

- **Preemptive Strategy**
 - Build capacity ahead of need
 - Positive capacity cushion
- **Wait-and-see Strategy**
 - Small or negative capacity cushion
 - Lower-risk strategy

Where? Facility Location

- Quantitative Factors
 - ROI, NPV
 - Transportation, Taxes
 - Lead times
- Qualitative Factors
 - Language, norms
 - Worker and customer attitudes
 - Proximity to customers, suppliers, competitors



What Type? Types of Facilities

- Product-focused (55%)
 - One family of products/services (e.g., computers)
- Market-focused (30%)
 - Located near sales (e.g., electricity, bakeries)
- Process-focused (10%)
 - Few technologies (e.g., computer chips, MRI center)
- General purpose (5%)
 - Several products/services (e.g., furniture, banking)

Sales & Operations Planning (S&OP)

- **Matching supply & demand** over a medium time range
- Time horizon of about 12 months
- ***Aggregated demand*** for one or few categories of product. Demand may fluctuate or be uncertain.
- Possible to change both supply and demand
- Variety of management objectives
- Facilities are fixed (cannot be expanded or reduced) during this timeframe

Cross-Functional Nature of S&OP

- Budgeting: closely tied to aggregate plan
- HR: workforce availability
- Operations: capacity/inventory planning
- Accounting: cost analysis
- Finance: capital investments
- Marketing: sales plan

Demand Management

- **Influence demand through:**
 - Pricing
 - Advertising and promotion
 - Backlogs or reservations (shift demand)
 - Development of complementary offerings
 - Seasonal products/service spread demand
 - Lawn mower, snow blower
 - Ski resort, mountain biking

Supply Management

- **Influence (control) supply through:**
 - Hiring and layoff of employees
 - Using overtime and undertime
 - Using part-time or temporary labor
 - Carrying inventory
 - Outsourcing/subcontracting
 - Cooperative arrangements
 - Share capacity during demand peaks
 - e.g., airlines, hotels, utilities

Aggregate Planning Strategies

- **Level** Strategy
 - Constant workforce size
 - Inventory as buffer
- **Chase** Strategy
 - Vary workforce size
 - Produce to meet demand
 - Typical for services

Aggregate Planning Costs

- Hiring and firing costs (**Chase** Strategy)
- Overtime and undertime costs (**Chase**)
- Subcontracting costs (**Chase**)
- Part-time labor costs (**Chase**)
- Inventory-carrying costs (**Level** Strategy)
- Cost of stockout or back order (**Level**)

Aggregate Planning - Level Strategy

Aggregate Planning Costs: Level Workforce

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
<i>Resources</i>													
Regular workers	45	45	45	45	45	45	45	45	45	45	45	45	
Overtime (%)	0	0	0	0	0	0	0	0	0	0	0	0	
Units Produced	450	450	450	450	450	450	450	450	450	450	450	450	5400
Sales Forecast	300	300	350	400	450	500	650	600	475	475	450	450	5400
Inventory (end of month)	200	350	450	500	500	450	250	100	75	50	50	50	
<i>Costs</i>													
Regular time	\$180	###	###	###	###	###	###	###	###	###	###	###	\$2,160
Overtime	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hire/Layoff	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25
Inventory carrying	24	42	54	60	60	54	30	12	9	6	6	6	363
Total Cost	\$229	###	###	###	###	###	###	###	###	###	###	###	\$2,548

Aggregate Planning - Chase Strategy

Aggregate Planning Costs: Chase Demand

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
<i>Resources</i>													
Regular workers	30	30	35	40	45	50	65	60	48	47	45	45	
Overtime (%)	0	0	0	0	0	0	0	0	0	0	0	0	
Units Produced	300	300	350	400	450	500	650	600	480	470	450	450	5400
Sales Forecast	300	300	350	400	450	500	650	600	475	475	450	450	5400
Inventory (end of month)	50	50	50	50	50	50	50	50	55	50	50	50	
<i>Costs</i>													
Regular time	\$120	###	###	###	###	###	###	###	###	###	###	###	\$2,160
Overtime	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hire/Layoff	40.0	0.0	25.0	25.0	25.0	25.0	75.0	20.0	48.0	4.0	8.0	0.0	295
Inventory carrying	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.6	6.0	6.0	6.0	72.60
Total Cost	\$166	###	###	###	###	###	###	###	###	###	###	###	\$2,527.60

Summary

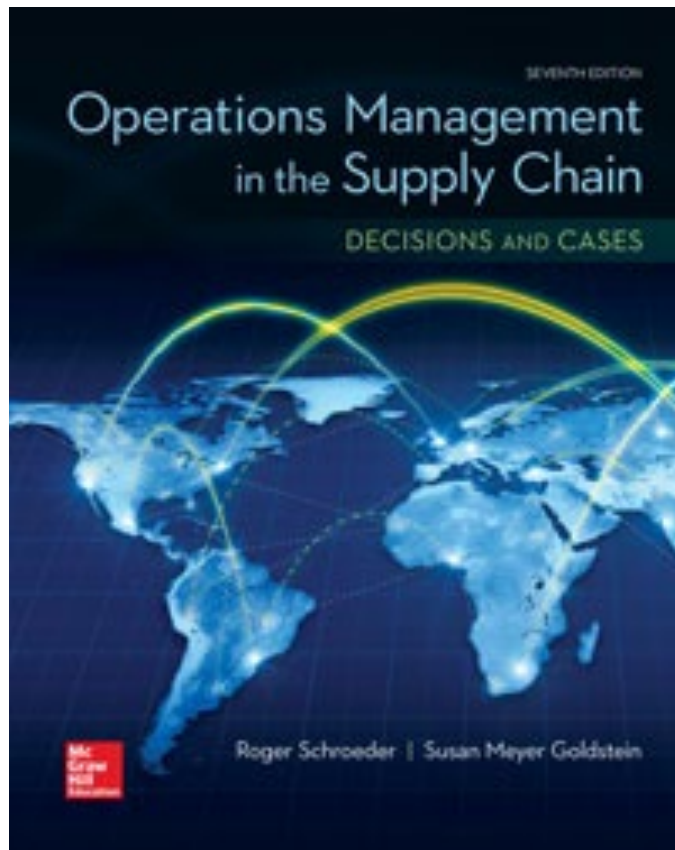
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End of Presentation

Operations Management in the Supply Chain

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Chapter 12

Scheduling Operations

Learning Objectives

- 12.1 Describe the concept of batch scheduling.
- 12.2 Construct a Gantt chart.
- 12.3 Create work schedules using forward and backward scheduling.
- 12.4 Explain the implications of the theory of constraints for scheduling.
- 12.5 Compare various dispatching rules.
- 12.6 Describe the important factors to consider when designing a scheduling system.

Scheduling Operations

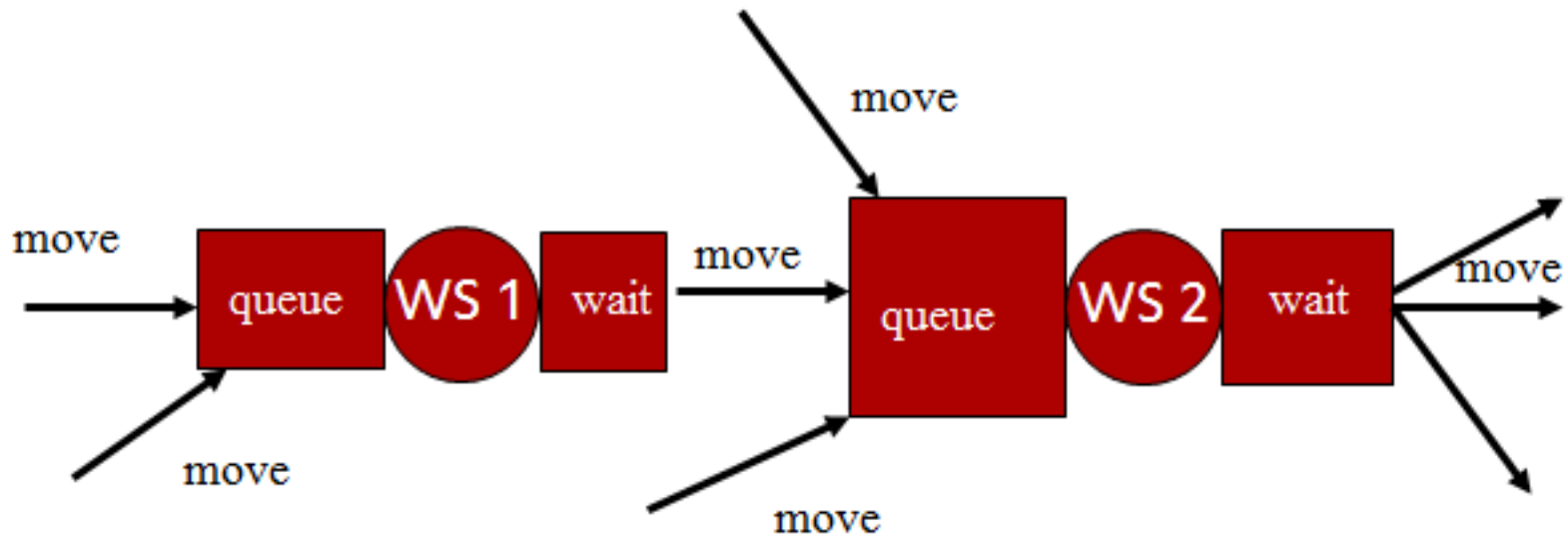
- Most detailed and most constrained decisions in capacity planning hierarchy
- Results in a time-phased plan (by hour, week)
- Allocation of resources (workers, machines) to tasks
- Trade-offs (conflicting objectives)
 - High efficiency
 - Low inventories
 - Good customer service

Batch Scheduling

- Network of queues, as job moves from work station to work station
 - job = manufacturing parts, customer, paperwork
 - work station = machine, room, facility, worker
- Customers or jobs spend most of their time at work stations waiting to be processed
- Typical for actual work to be 5-20% of total throughput time

Batch Processing

move → queue → process → wait → move...



WS = work station

“move” = movement of work: parts, customers, paperwork, etc.

Challenges of Batch/Job Shop Scheduling

- Variety of jobs processed
- Different routing and processing requirements of each job
- Number of different job orders in the facility at any one time
- Competition for common (constrained) resources

Gantt Charting

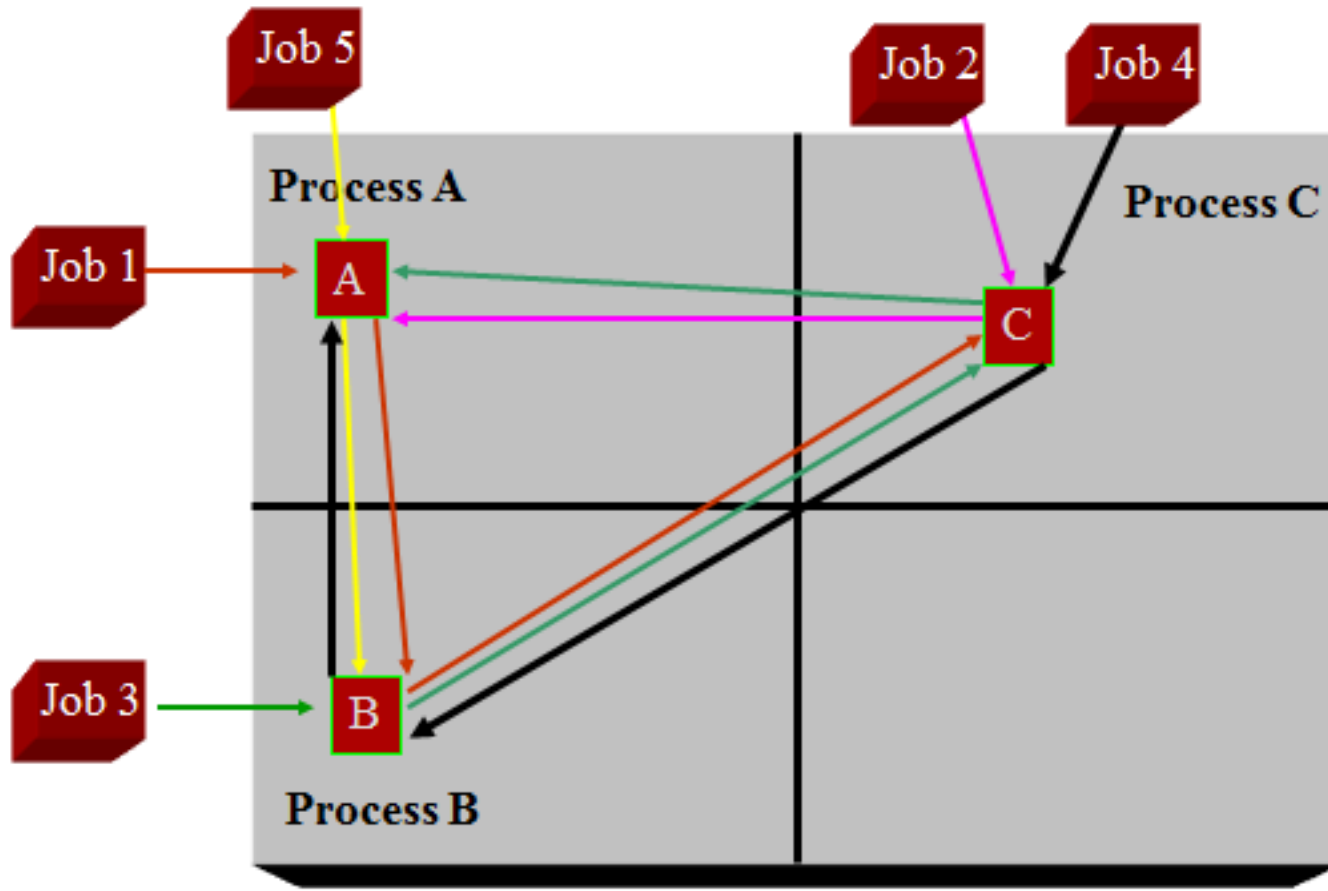
- Scheduling multiple jobs thru a set of work centers, minimizing completion time
- Machine performance measures:
 - Makespan = total time to complete a set of jobs
 - Machine utilization = percent of makespan time machine (or person) is used.
- Used to monitor progress of jobs
- Optimal schedule can be computationally intensive for multiple jobs/multiple machines

Job Data for Scheduling Example

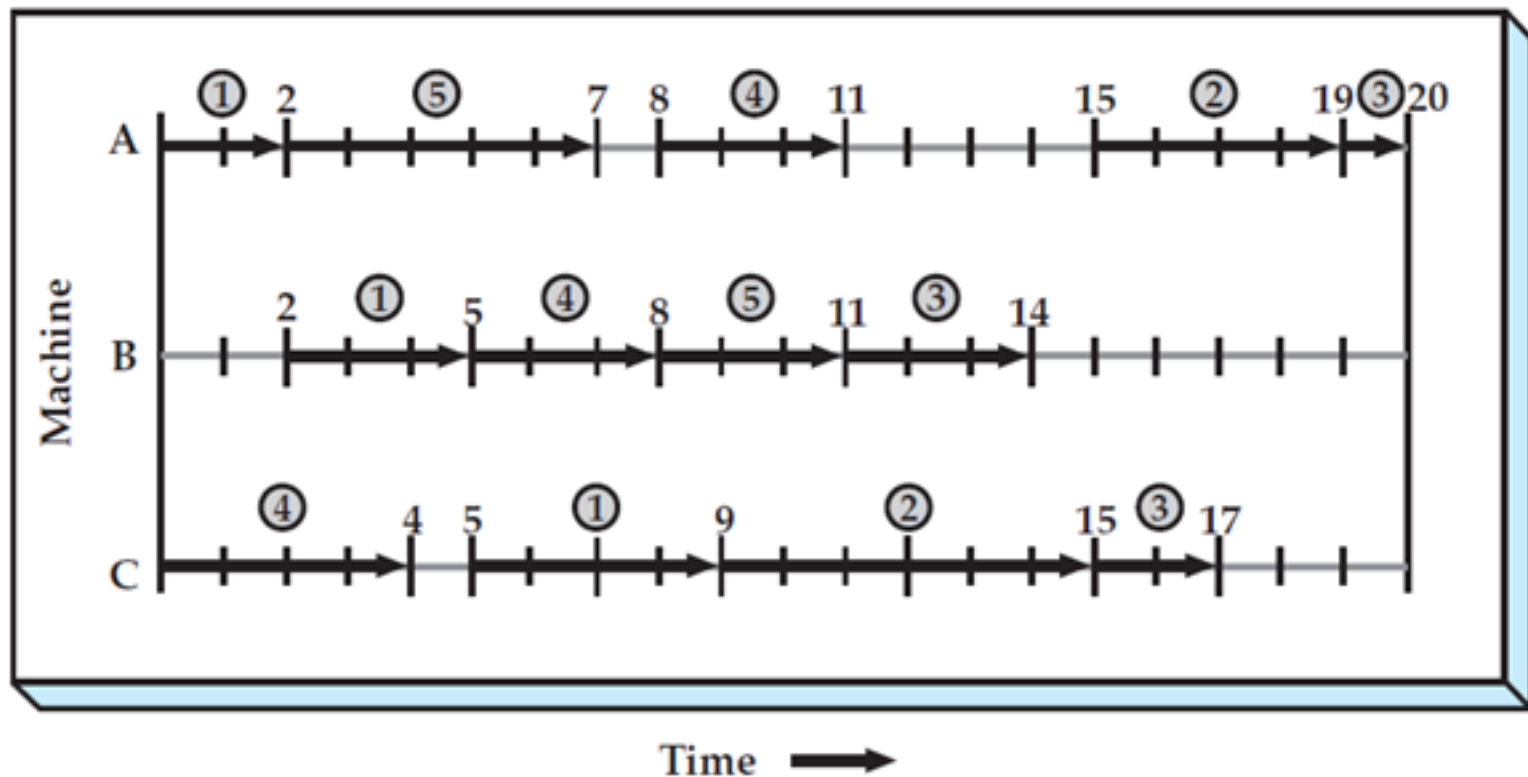
Job	Work center / Machine hours	Due date
1	A/2, B/3, C/4	3
2	C/6, A/4	2
3	B/3, C/2, A/1	4
4	C/4, B/3, A/3	4
5	A/5, B/3	2

Scheduling Example

In what sequence should the jobs be done?



Gantt Chart for Example (1 of 2)



Gantt Chart for Example (2 of 2)

Machine idle (hr)

A	5
B	8
C	4
	17

Makespan = 20 hr

Job	Job waiting time (hr)	Delivery time (hr)
1	0	9
2	9	19
3	14	20
4	1	11
5	3	11

Shop Performance Measures

- Machine Efficiency: Makespan or machine utilization
- Customer: Delivery times of the jobs (minimizing job waiting time is complementary measure)

Change the job sequence from 1, 4, 5, 2, 3 to improve efficiency and/or delivery times to the customer.

Machine(s) could be added to improve both efficiency and delivery times.

Conclusions About Batch Scheduling

- Performance is highly sequence dependent.
- Waiting time depends upon job interference in the schedule and available capacity.
- Finding optimal schedules is challenging, but good heuristics are available.

Finite Capacity Scheduling

- Scheduling jobs onto work stations, but not exceeding the capacity of any given resource.
- Used to identify bottlenecks.
- **Forward** scheduling
 - To determine completion date for all orders.
- **Backward** scheduling
 - Work backward from due date to determine start dates for orders.

Theory of Constraints (TOC) (1 of 3)

- Proposed by Goldratt in *The Goal* (1983)
- Goal is to make money from operations
- Production does not have value until it is sold!
- Key elements:
 - **Throughput** = sales minus cost of raw materials
 - **Inventory** = raw materials value
 - **Operating expenses** = cost of labor and overhead

Theory of Constraints (TOC) (2 of 3)

- Constraint is anything slowing down production ... *a bottleneck*.
 - Machine or workstation
 - Market
 - Procurement system
- The **bottleneck** determines the capacity of the system.
- Implication: *Operations manager should focus on bottleneck to increase capacity and throughput (and make more money).*

Theory of Constraints (TOC) (3 of 3)

- The **bottleneck** should be scheduled to achieve maximum throughput.
- Non-bottlenecks should be scheduled to keep the bottleneck busy.
- A work-in-process queue should always be in front of the bottleneck.
- Non-bottleneck resources may be idle.
- Find ways to relieve or reduce the bottleneck.

Priority Dispatching Rules

- Which job should be processed next?
 - Rule for selecting the next job from the queue
- Common in services:
 - **First come, first served**
 - Priority rule (first-class customers first)
 - Preemptive rule (most severe patient treated next)
- Common in manufacturing:
 - Critical ratio** = $\frac{\text{remaining time until due date}}{\text{remaining processing time}}$
 - Shortest processing time (quickest job)

Planning and Control Systems

- What delivery date should be promised?
- Where is the bottleneck?
- When should each activity or task be started?
- How is on-time job completion ensured?
- Sometimes referred to as:
 - *Advanced Planning & Scheduling (APS)*

Summary

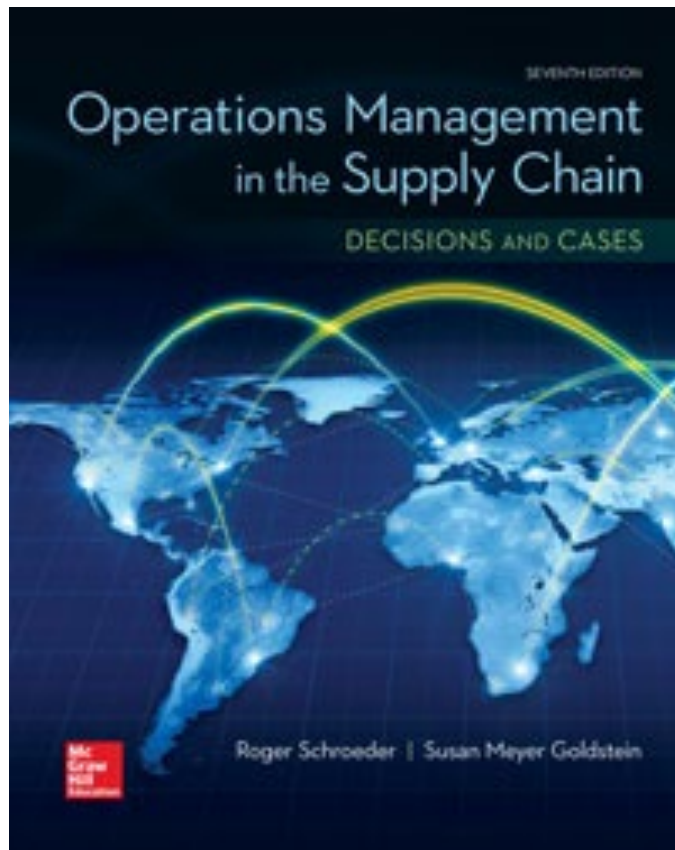
- 12.1 Describe the concept of batch scheduling.
- 12.2 Construct a Gantt chart.
- 12.3 Create work schedules using forward and backward scheduling.
- 12.4 Explain the implications of the theory of constraints for scheduling.
- 12.5 Compare various dispatching rules.
- 12.6 Describe the important factors to consider when designing a scheduling system.

End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 13

Project Planning and Scheduling

Learning Objectives (1 of 2)

- 13.1 Explain the nature of tradeoffs among the three objectives of project management
- 13.2 Describe the four activities included in project management
- 13.3 Distinguish the advantages and disadvantages of a network over a Gantt chart for project scheduling
- 13.4 Calculate the ES, EF, LS, LF for an example network

Learning Objectives (2 of 2)

- 13.5 Explain the significance of the critical path and slack.
- 13.6 Calculate the cost of crashing a network by one or two days.
- 13.7 Contrast and compare the use of constant-time and CPM networks.

What is a Project?

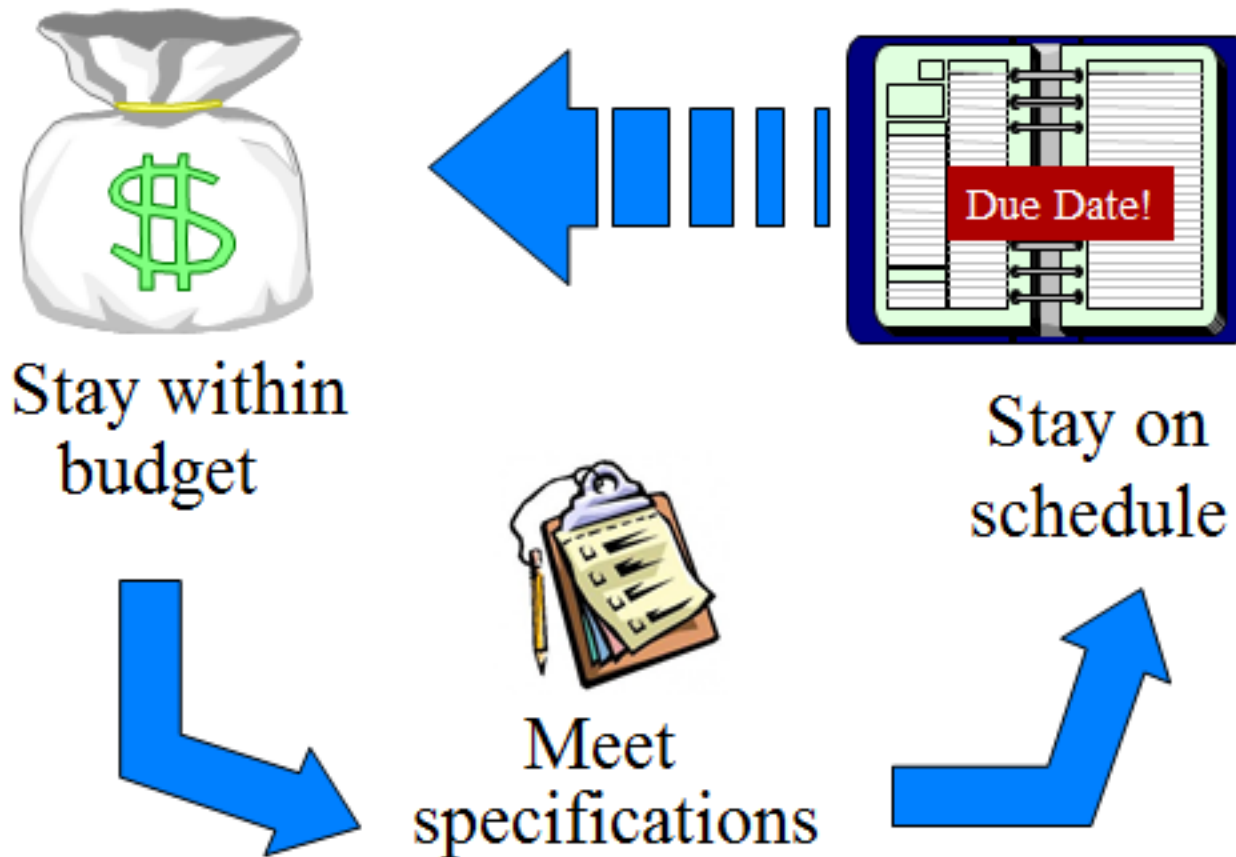
- “A temporary endeavor undertaken to create a unique product/service/result.” - Project Mgmt Institute (PMI)
- Unique item or event; often a single unit.
- Begins and ends; not ongoing activity.
- Work often done on-site.
- Resources (materials, labor) are brought to the project.

Examples of Projects

- Building construction
- Bridge construction
- Aircraft carrier
- R&D project
- Audit
- Equipment installation
- New product introduction
- Opening/closing a facility
- Making a movie
- Fund-raising campaign
- Ad campaign
- Software installation



Objectives and Tradeoffs



Project Management Activities & Decisions

- Control
 - Planning
 - Scheduling
 - Closing

Planning Activities & Decisions

- Identify the project customer
- Establish the end product/service
- Set project objectives
- Estimate total resources and time required
- Decide on the form of project organization
- Make key personnel appointments
- Define major tasks required
- Establish a budget

Scheduling Activities & Decisions

- Develop a detailed **work-breakdown structure**
- Estimated time required for each task
- Sequence tasks in proper order
- Develop a start/stop time for each task
- Develop detailed budget for each task
- Assign tasks to people, subcontractors, etc.

Control Activities and Decisions

- Monitor actual time, cost, and performance
- Compare planned to actual figures
- Determine whether corrective action is needed
- Evaluate alternative corrective actions
- Take appropriate ***corrective actions***

Closing Activities and Decisions

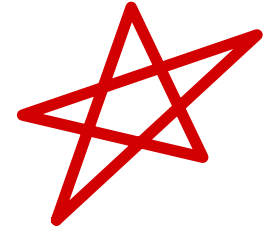
- Finish all work
- Close contracts
- Pay all accounts payable
- Turn the project over to the owners
- Reassign personnel and equipment

PMI Body of Knowledge

- Integration
- Scope
- Time management
- Costs
- Quality management
- Human resources
- Communications
- Risk
- Procurement

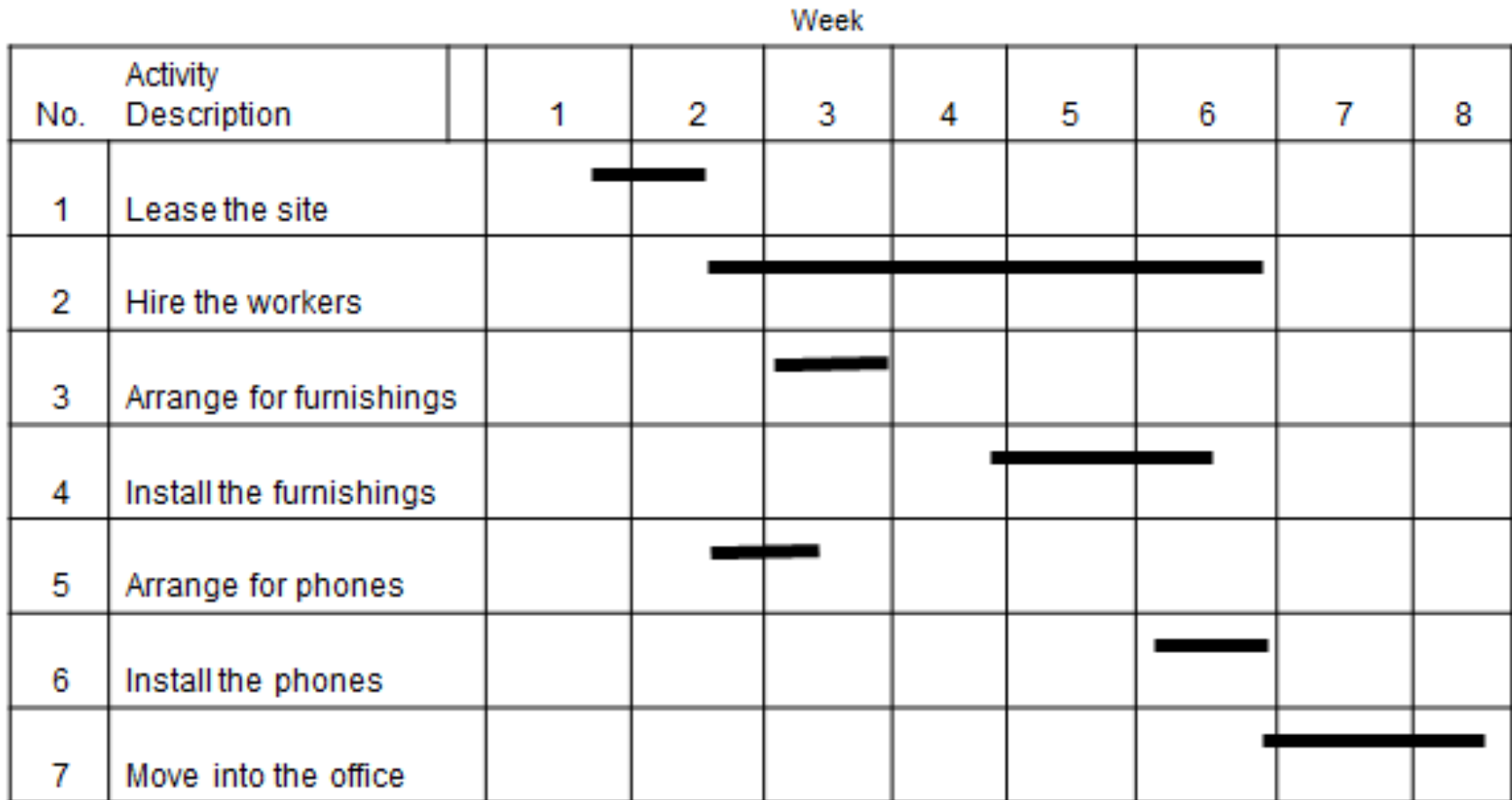
Project Management Institute's required areas of knowledge for certification as a Project Manager.

Scheduling Methods



- Gantt Chart
 - Bar charts
 - Does not show interdependencies of activities
 - Visual & easy to understand
- Network Method
 - Graphs or networks
 - Shows precedence relations
 - More complex, difficult to understand, and costly than Gantt charts

Gantt Chart Project Example (Figure 13.2)



Constant-Time Networks

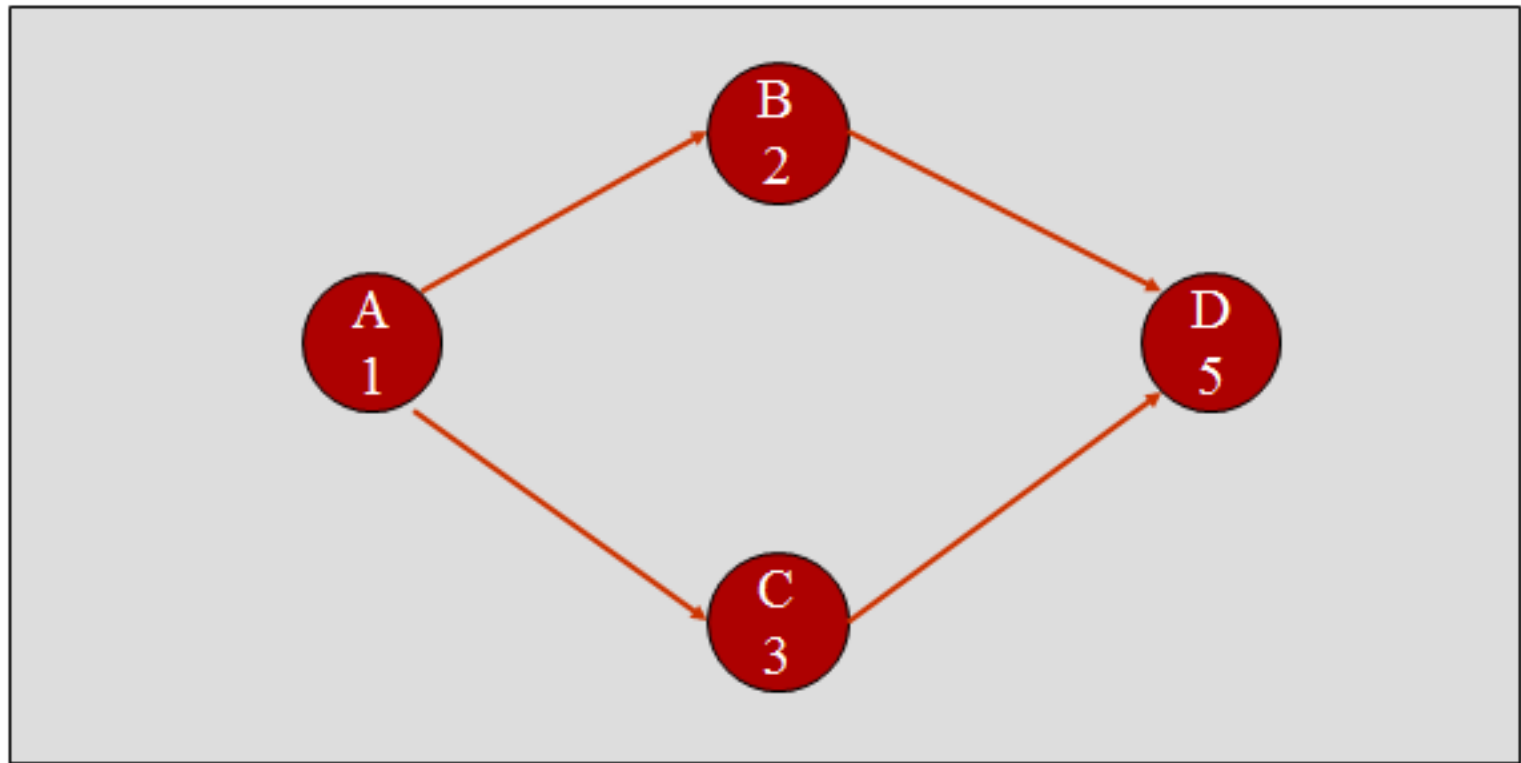
- Activity times assumed to be constant
- Activities represented by nodes
- Arrows show precedence relationships
- Notation used to calculate start and finish times:
 - $ES(a)$ = early start of activity A (constrained by predecessors)
 - $EF(a)$ = early finish of activity A (constrained by early start time)
 - $LS(a)$ = late start of activity A (constrained by late finish time)
 - $LF(a)$ = late finish of activity A (without delaying successors)

Example: Write a Business Report (Table 13.4)

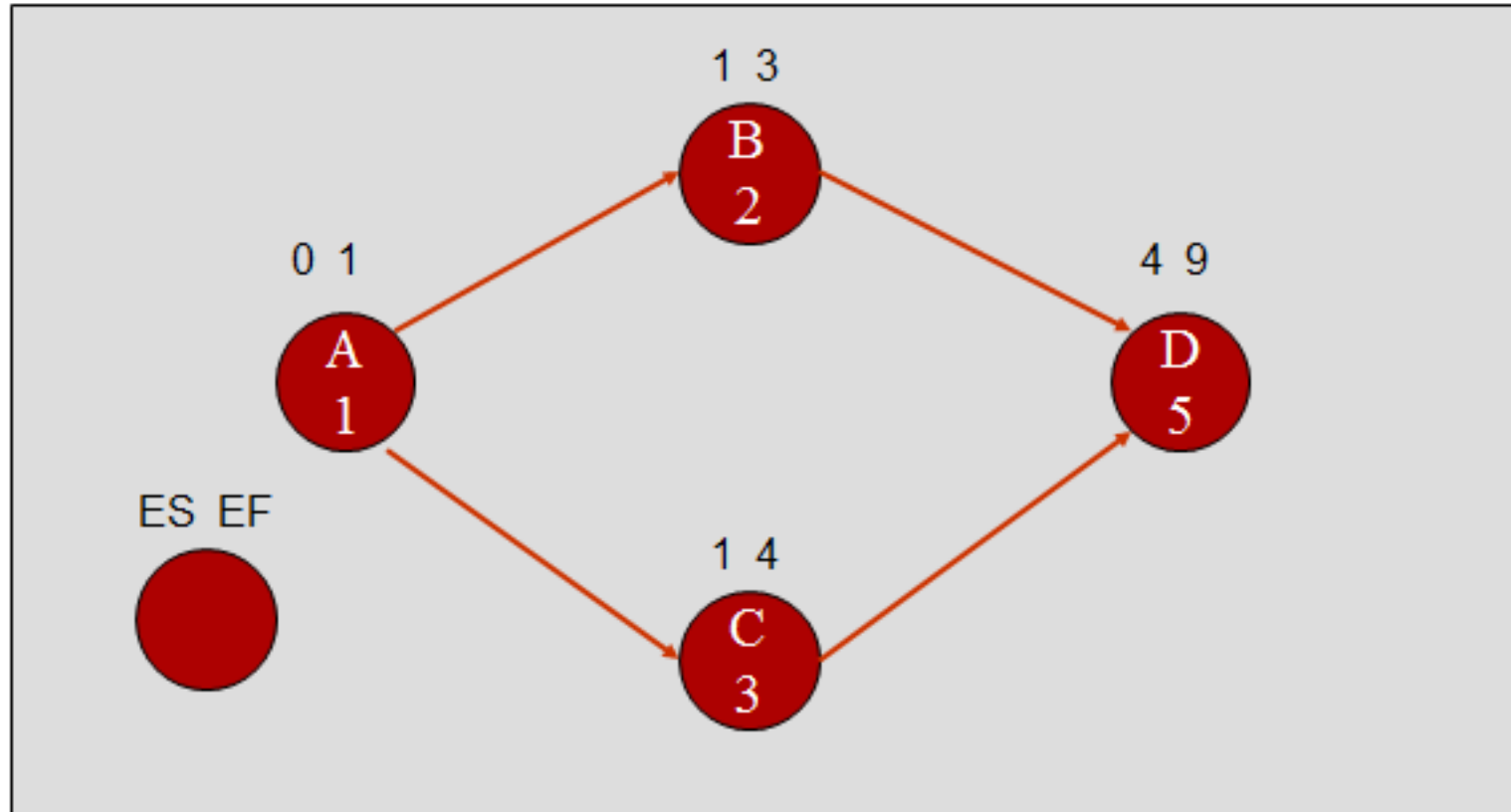


<u>Activity</u>	<u>Description</u>	<u>Immediate Predecessors</u>	<u>Duration in Days</u>
A	Decide on topic	None	1
B	Collect data	A	2
C	Search the Internet	A	3
D	Write the report	B and C	5

Network Diagram: Write a Business Plan (Figure 13.3)



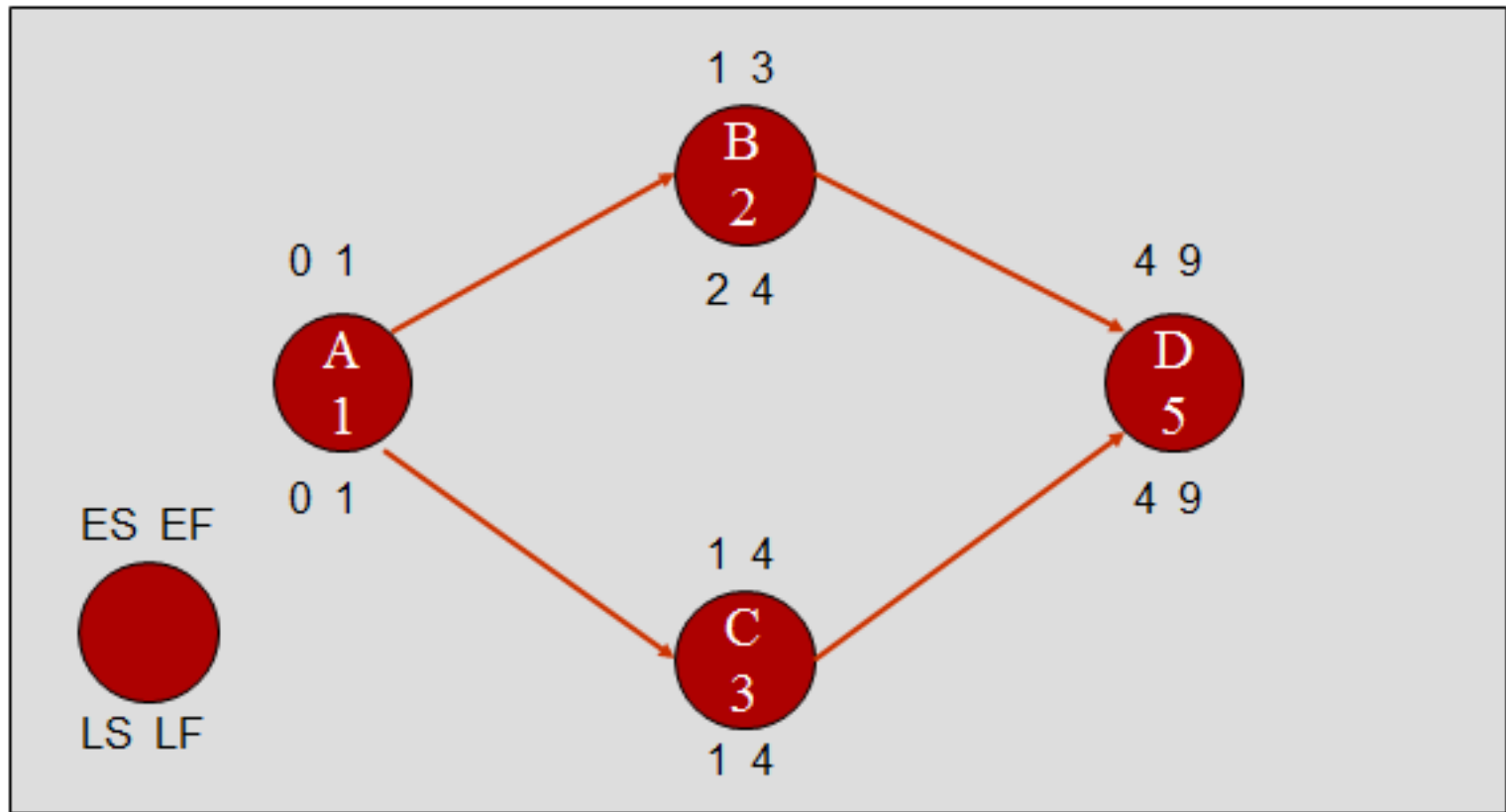
Forward Pass: Write a Business Plan (Figure 13.4)



Calculating ES, EF, LS, LF, Completion Time

- Forward Pass:
- **ES (a)** = 0 for the starting activities
- **EF (a)** = $ES(a) + t(a)^*$
- **ES (a)** = Max [EF(all predecessors of a)]
- **Project completion time** = Max [EF(all ending activities)]
- Backward pass:
- **LF (a)** = Min [LS(all successors of a)]
- **LS (a)** = $LF(a) - t(a)^*$
- * *t(a)* denotes the duration of activity a

Forward and Backward Pass: Write a Business Plan (Figure 13.5)



Critical Path

- Critical Path = longest path in the network
 - All activities for which $ES = LS$ and $EF = LF$
 - Length of critical path is equal to the project completion time
 - Any delay on critical path delays the project (unless 'corrective actions' are taken)
 - Critical path in example (above) is A-C-D

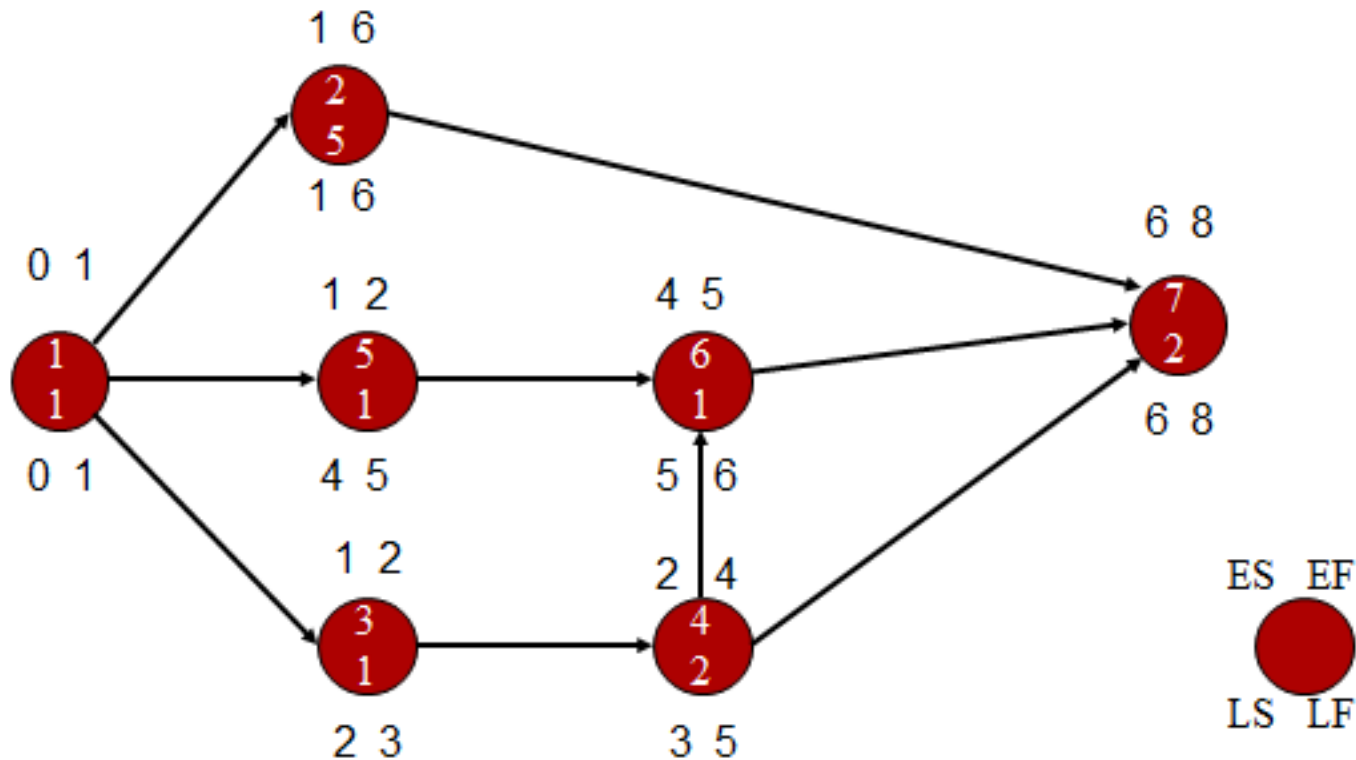
Slack

- Slack time is the time a path may be delayed without delaying the project.
- Paths not on the critical path have slack.
- $\text{Slack} = \text{LS} - \text{ES} = \text{LF} - \text{EF}$

Precedence and Times for Opening a New Office (Table 13.5)

<u>Activity</u>	<u>Description</u>	<u>Immediate Predecessors</u>	<u>Activity Time</u>	<u>Computed Slack</u>
1	Lease the site	None	1	0
2	Hire the workers	1	5	0
3	Arrange the furnishings	1	1	1
4	Install the furnishings	3	2	1
5	Arrange for phones	1	1	3
6	Install the phones	4, 5	1	1
7	Move into the office	2, 6, 4	2	0

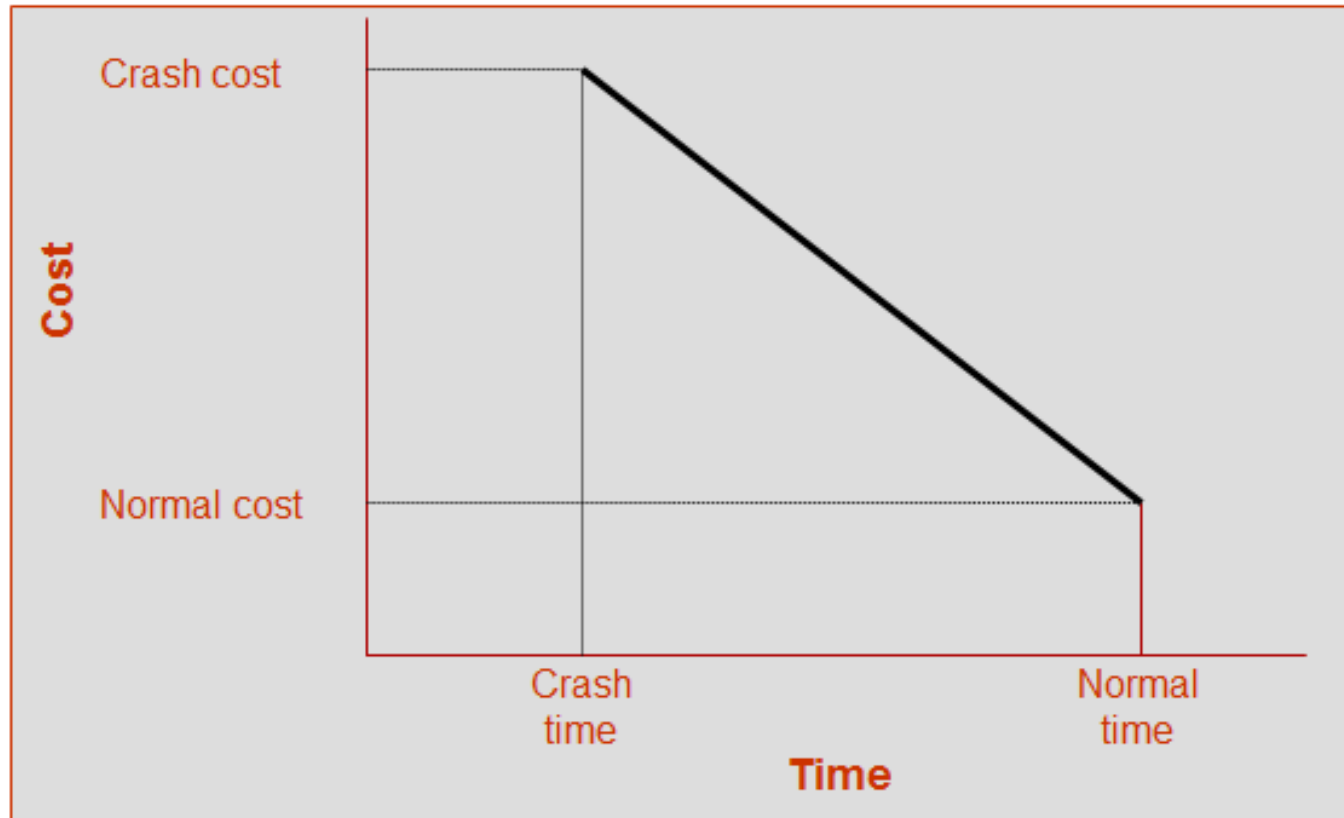
Network: Open a New Office (Figure 13.6)



Critical Path Method

- **Critical Path Method (CPM)**
- Developed to start-up/shutdown plants
- Activity times can be compressed by spending more \$
- Requires single time estimate for each activity
- Looks at time/cost trade-offs
 - Normal activity time
 - Normal cost
 - Crash time
 - Crash cost

Time-Cost Relationship in CPM (Fig. 13.8)



Use of Project Management Concepts

- Scheduling is only part of a **complete** approach to project management
- Trade-off between sophistication and cost of methods
- Choice between constant-time, CPM or more advanced techniques
- Choice of project management software packages
 - *e.g.*, Microsoft Project

Summary (1 of 2)

- 13.1 Explain the nature of tradeoffs among the three objectives of project management
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Summary (2 of 2)

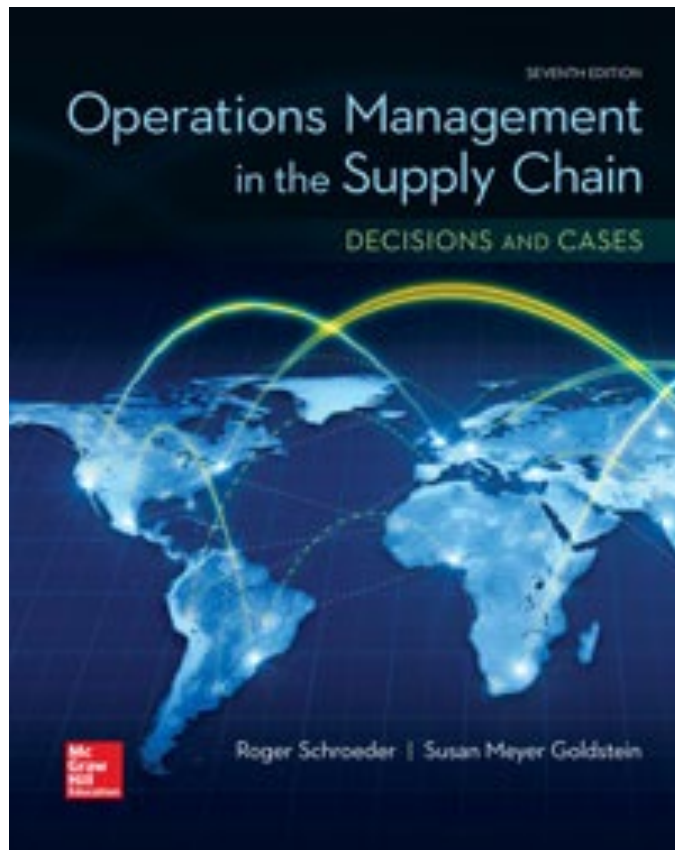
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End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 14

Independent Demand Inventory

Learning Objectives

- 14.1 Define inventory types and the purpose of inventory.
- 14.2 Explain the costs incurred by inventory.
- 14.3 Differentiate between independent and dependent demand.
- 14.4 Calculate the economic order quantity and identify the underlying assumptions.
- 14.6 Recall the uses of periodic and continuous review systems.
- 14.7 Describe how inventory and service level are related.
- 14.8 Define Vendor Managed Inventory and the ABC system.

Definitions

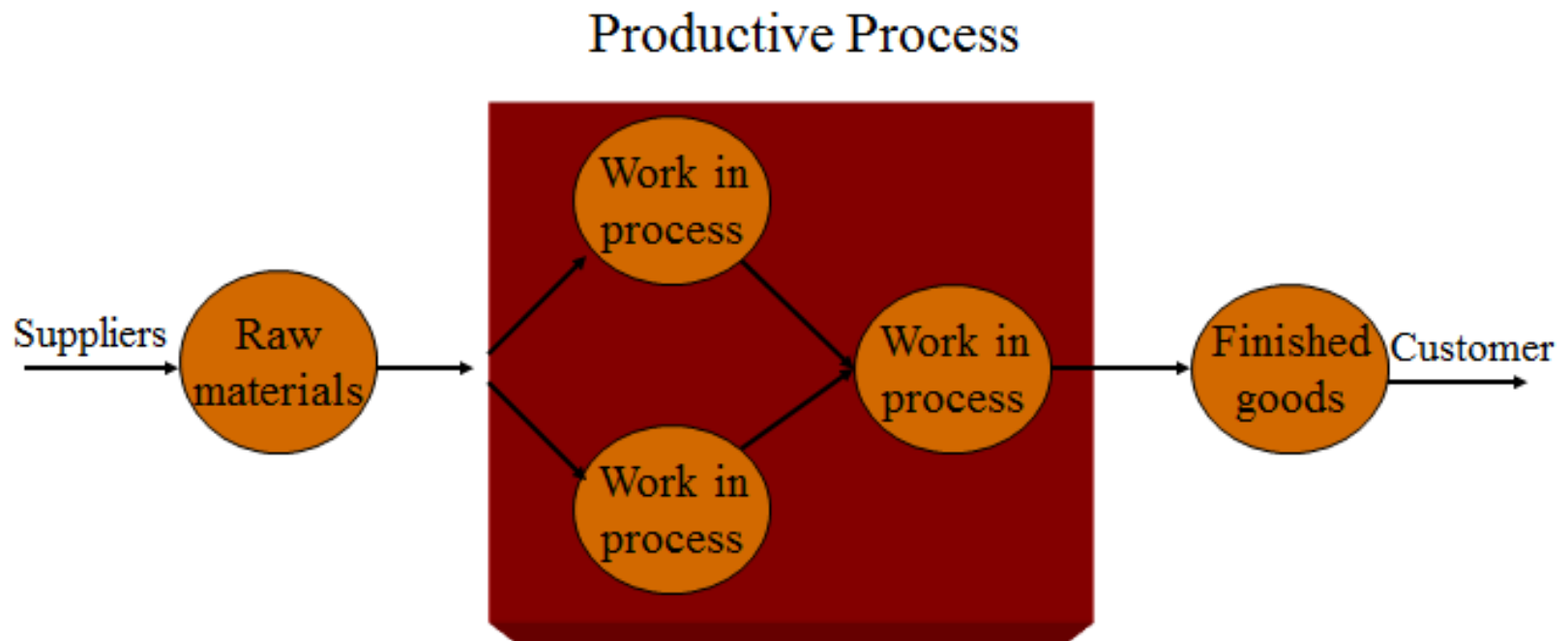
- **Inventory:** A stock of materials used to facilitate production or satisfy customer demands.
- Types of inventory
 - **Raw materials**, purchased parts (RM)
 - **Work in process** (WIP)
 - **Finished goods** (FG)

Inventory Management Technologies

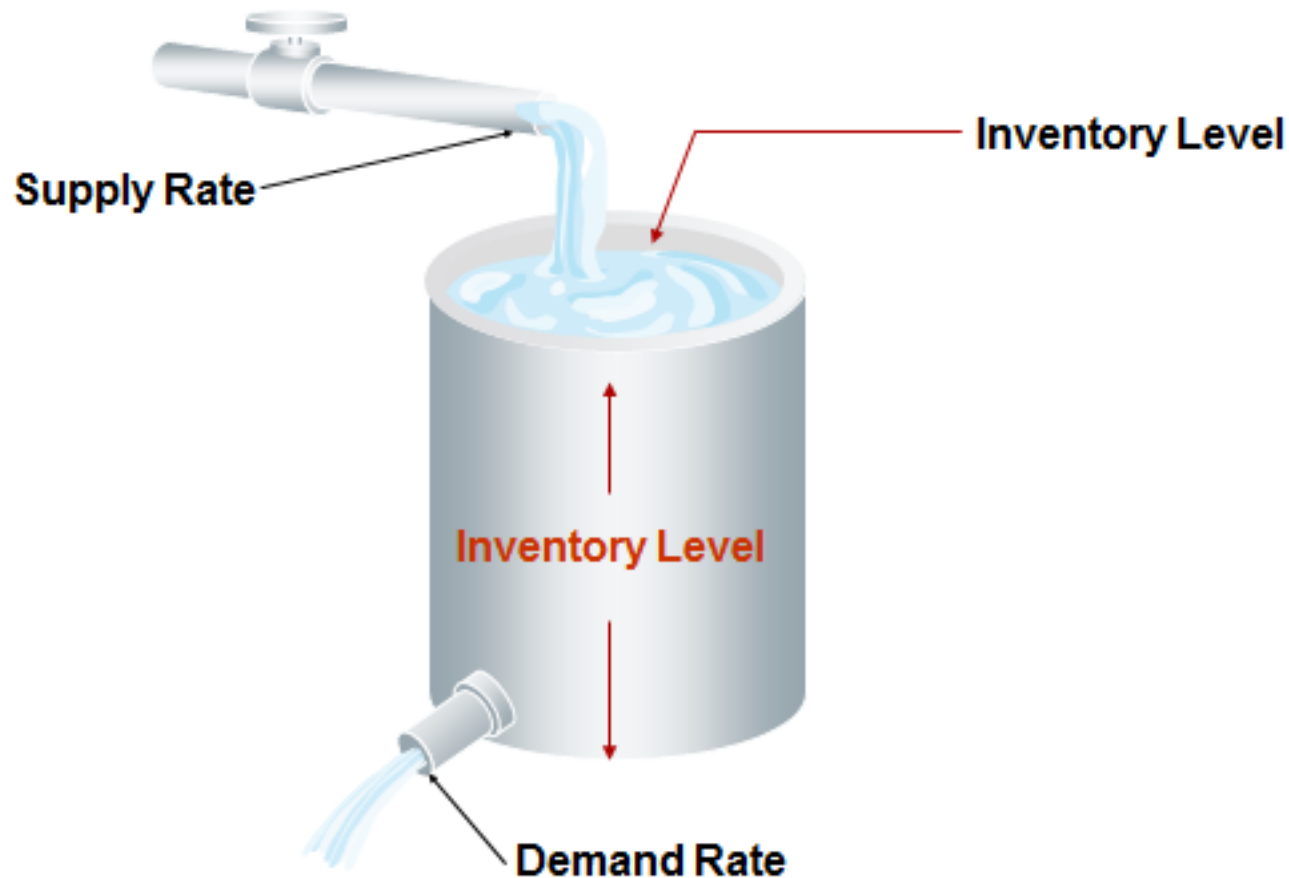
- Bar coding
- Point of sale (POS) data
- Radio-frequency identification (RFID)



Materials-Flow Process (Figure 14.1)



Water Tank Analogy for Inventory (Figure 14.2)



Purpose of Inventories

- To protect against *uncertainties* - demand, supply, lead times, schedule changes
 - **Safety stock**
- To allow economic production and purchase
 - **Cycle inventory**
- To cover anticipated changes in demand/supply
 - **Anticipation inventory**
- To provide for transit
 - **Pipeline inventory**

Costs of Inventory (1 of 3)

- **Item cost**
 - Expressed as cost per unit or SKU
 - Quantity discounts possible
- **Ordering (or setup) cost**
 - Paperwork, electronic entry, worker time for ordering
 - Worker time for setup, downtime
 - Transportation costs
 - Typically a fixed cost per order (or setup)

Costs of Inventory (2 of 3)

- **Carrying (or holding) cost**
 - Cost of capital (market rate or internal rate of return)
 - Cost of storage (space, insurance, taxes)
 - Cost of obsolescence, deterioration, and loss (shrinkage)
 - Estimated U.S. average is **35%** of SKU cost per year.
 - Businesses often use cost of capital (understated).

Costs of Inventory (3 of 3)

- **Stockout cost**

- Back order costs (expressed as a fixed cost per backorder or as a function of aging of backorders)
- Lost income
- Customer dissatisfaction; loss of future sales

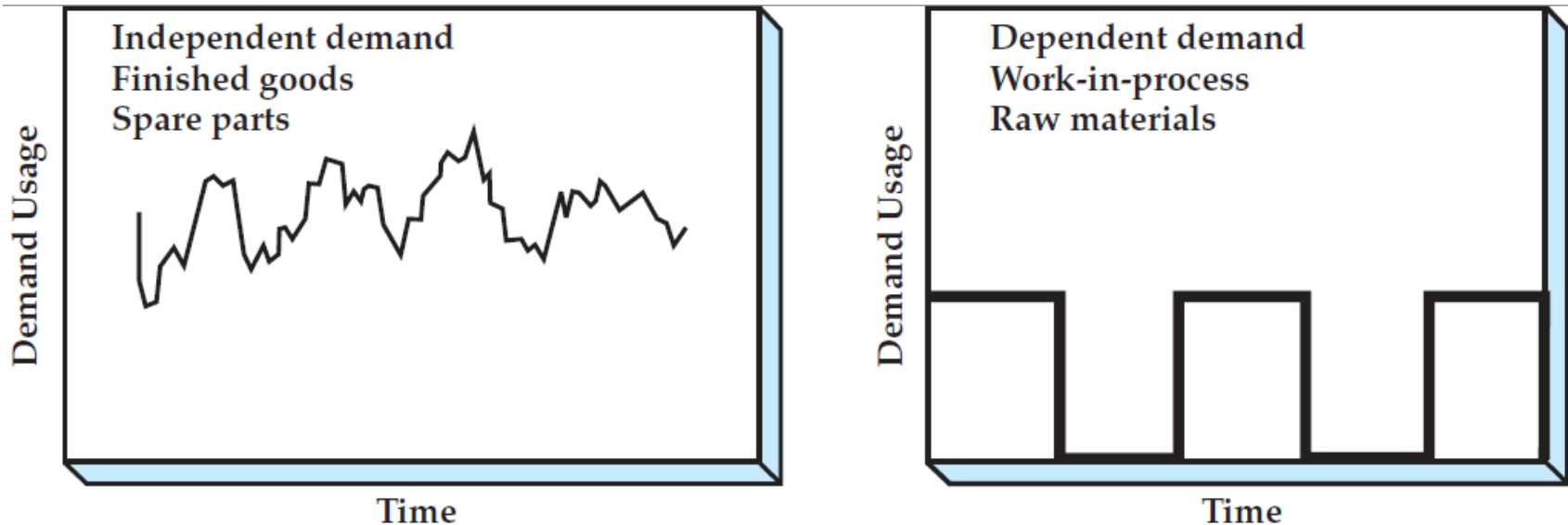
Distribution of 35% Carrying Cost:

- Cost of capital: 9-20%
- Obsolescence: 2-5%
- Storage: 2-5 percent
- Material handling: 1-3%
- Shrinkage: 1-3%
- Taxes & insurance: 1-3%

Types of Demand

- **Independent demand** (this chapter)
 - Finished goods, spare parts
 - Based on market demand, independent of other items
 - Requires forecasting
- **Dependent demand**
 - Components/parts of the finished (parent) products
 - Demand is a *known* function of (parent) independent demand items
 - Calculate instead of forecast

Demand Patterns (Figure 14.4)



- The first graph - A pattern plus random influences
- The second graph - 'Lumpy' due to production lots

Economic Order Quantity (EOQ)

- Answers question: “How much should we order?”
- Used for *independent demand* items.
- Objective is to find **order quantity** (Q) that minimizes **total cost** (TC) of managing inventory.
- Must calculate for each SKU.
- *Widely used* and *very robust* (i.e., works well in a variety of situations, even when its assumptions do not perfectly hold).

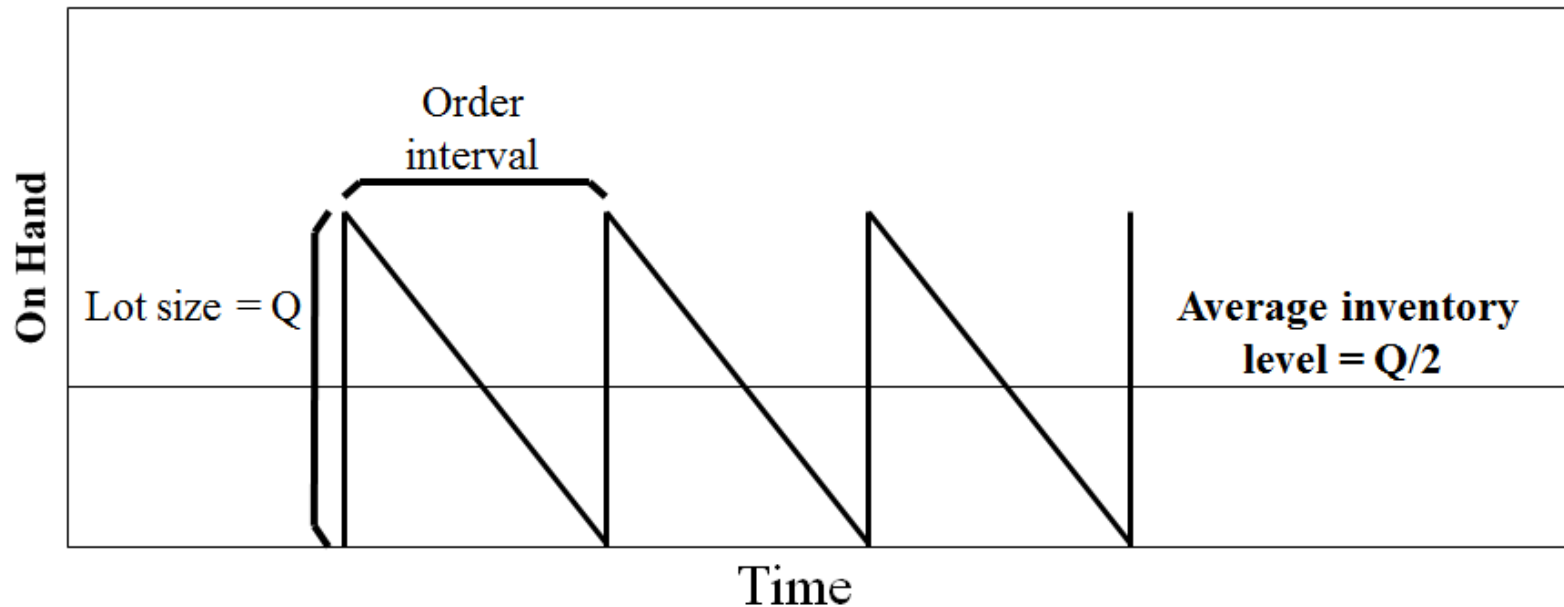
EOQ Assumptions

1. Demand rate is constant, recurring, and known.
2. Lead time is constant and known.
3. No stockouts allowed.
4. Items are ordered or produced in a lot or batch, and the lot is received all at once.
5. Costs are constant:
 - Unit cost (no quantity discounts).
 - Carrying cost is constant per unit.
 - Ordering (setup) cost per order.
6. Item is a single product or SKU; demand not influenced by other items.

EOQ Lot Size Intuition

- Trade-off between ordering frequency (*i.e.*, order size) and inventory level.
 - Frequent orders (small lot sizes) lead to lower average inventory level, *i.e.*, **higher total ordering costs** and **lower total holding costs**.
 - Less frequent orders (large lot sizes) lead to higher average inventory level, *i.e.*, **lower total ordering costs** and **higher total holding costs**.

EOQ Inventory Levels (Figure 14.5)



Notation in EOQ Calculation

D = Demand rate, units per year

S = Cost per order placed or setup cost,
dollars per order

C = Unit cost, dollars per unit

i = Carrying rate, percent of dollar value per
year

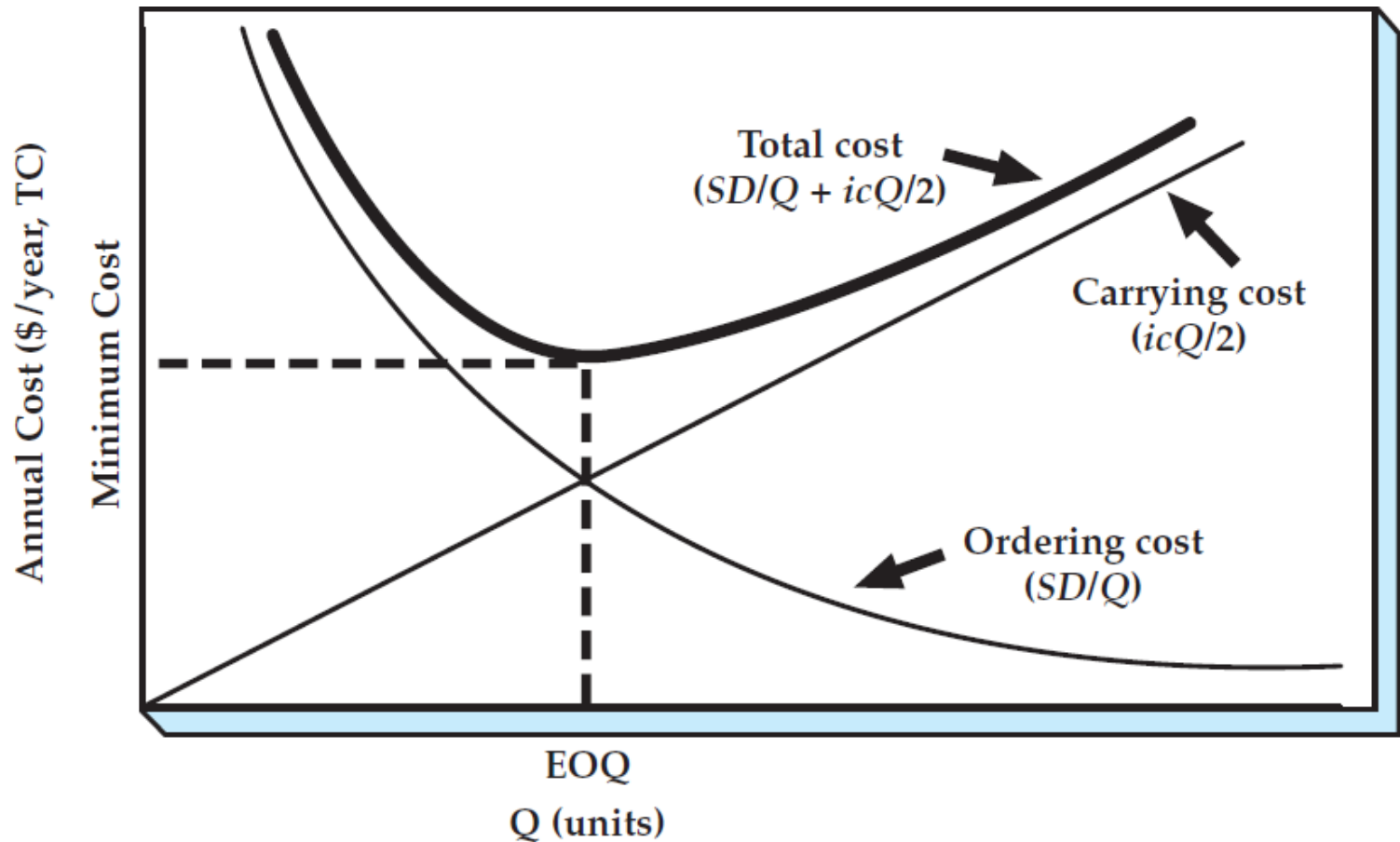
Q = Lot size, units

TC = Total of ordering cost plus carrying cost,
dollars per year

Cost Equations in EOQ

- **Ordering cost** per year = (cost per order) × (orders per year) = **SD/Q**
- **Carrying cost** per year = (annual carrying rate) × (unit cost) × (average inventory level) = **$iCQ/2$**
- Total annual cost (TC) = ordering cost per year + carrying cost per year = **$SD/Q + iCQ/2$**

Total Cost of Inventory (Figure 14.6)



EOQ Formula

At the EOQ,
ordering costs = holding costs

$$S^*(D/Q) = iC^* (Q/2)$$

$$EOQ = Q = \sqrt{\frac{2SD}{iC}}$$

Note: Although we use *annual* costs, any time period can be used. Just be consistent throughout equation! The same is true for currencies.

EOQ Example (1 of 2)

Demand = 10 cases/week

S = \$12/order

i = 30% per year

C = \$80/case

$$\begin{aligned} \text{EOQ} &= \sqrt{(2SD)/iC} = \sqrt{(2 * 12 * 10 * 52)/(.3 * 80)} \\ &= \mathbf{22.8 \text{ cases/order}} \end{aligned}$$

TC = ordering cost + holding cost

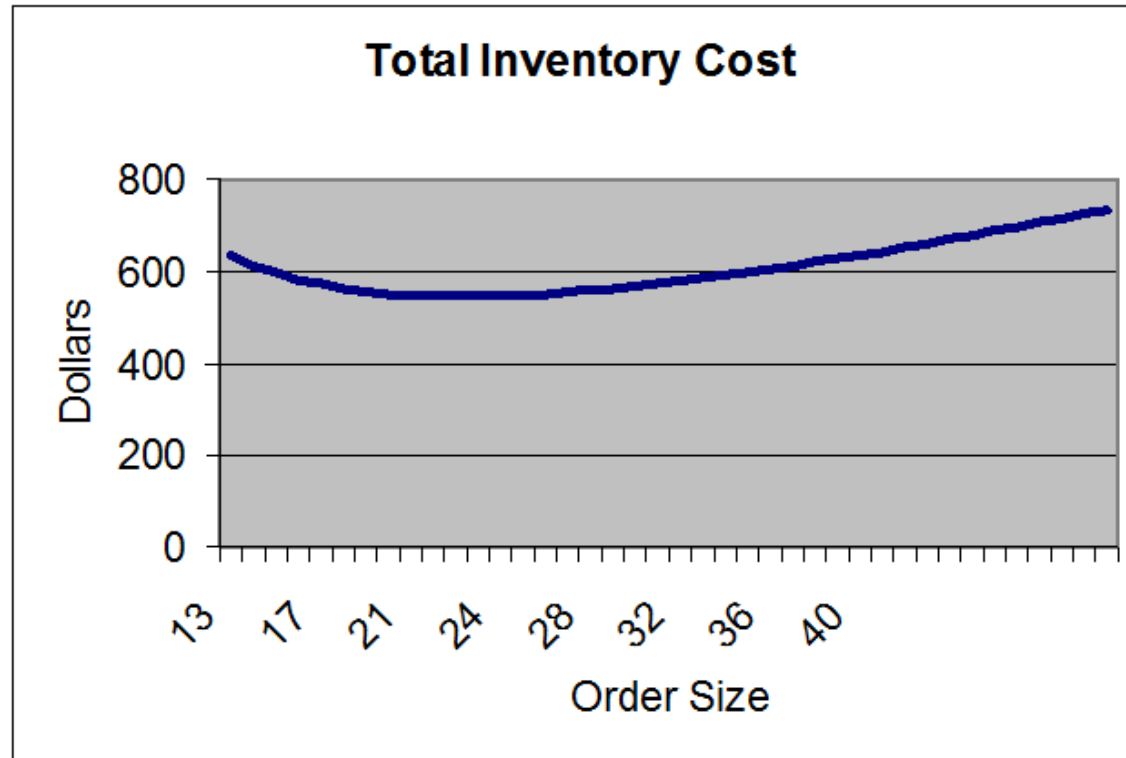
$$= SD/Q + iCQ/2 = 12*520/22.8 + .3*80*22.8/2$$

$$= 273.68 + 273.60 = \mathbf{\$547.28/year}$$

If ordering **22** cases, TC = \$547.64

If ordering **23** cases, TC = \$547.30

EOQ Example (2 of 2)



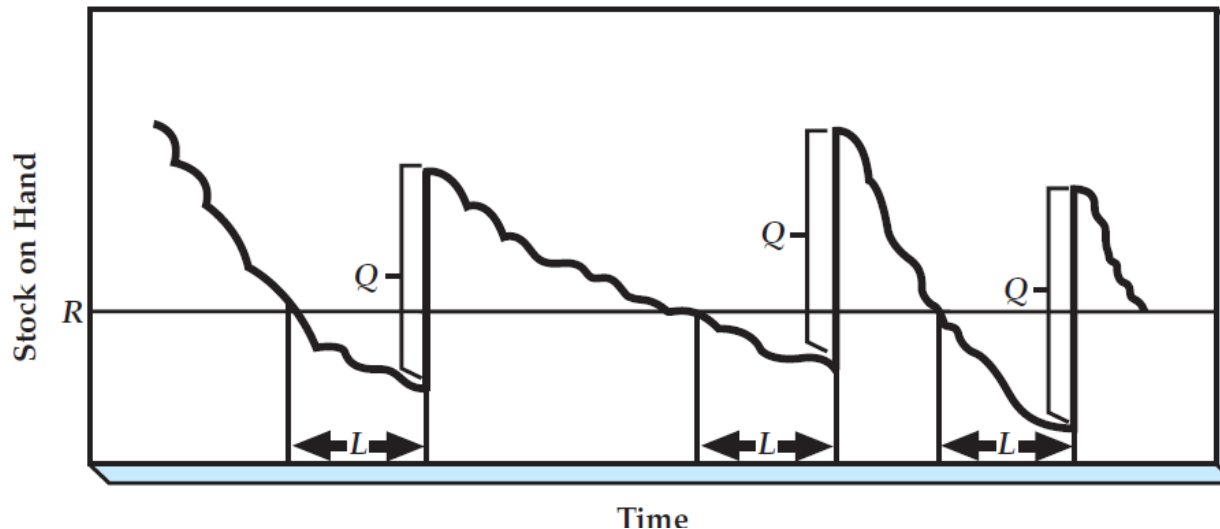
Total cost curve is quite flat *near the optimal EOQ*. Order size need not be exactly the EOQ to get cost advantages.

Continuous Review (Q) System (1 of 3)

- Relax assumption of constant demand. Demand is assumed to be random.
- Check inventory position each time there is demand (i.e., continuously).
- If inventory position drops below **reorder point**, place an order for the EOQ.
- Also called fixed-order-quantity or **Q system** (the fixed order size is EOQ).

Continuous Review (Q) System (2 of 3)

(Figure 14.7)



R = Reorder point
Q = Order quantity
L = Lead time

Continuous Review (Q) System (3 of 3)

Amount to order = EOQ

Order when inventory position = Reorder point

$R = m + s$

R = Reorder point

m = mean demand during lead time

s = safety stock

Reorder point is independent of EOQ!

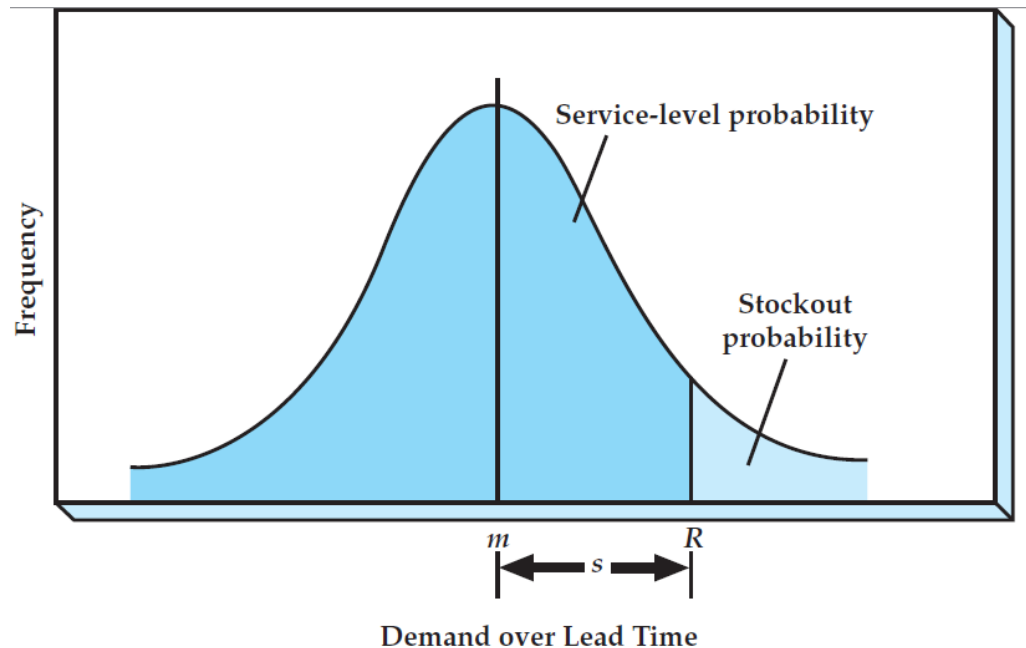
EOQ tells how much to order.

Reorder point tells when to order

Service Level

- When demand is random, reorder point must account for desired service level (fill rate).
- $S = Z \sigma$
 - s = safety stock
 - z = safety factor
 - σ = standard deviation in demand during lead time
- Service level can be defined several ways:
 - Probability all customer orders will be filled while waiting for supply order to arrive.
 - Percentage of demand filled from stock.
 - Percentage of time item is on hand.

Probability Distribution of Demand over Lead Time (Fig. 14.8)



m = mean demand

R = Reorder point

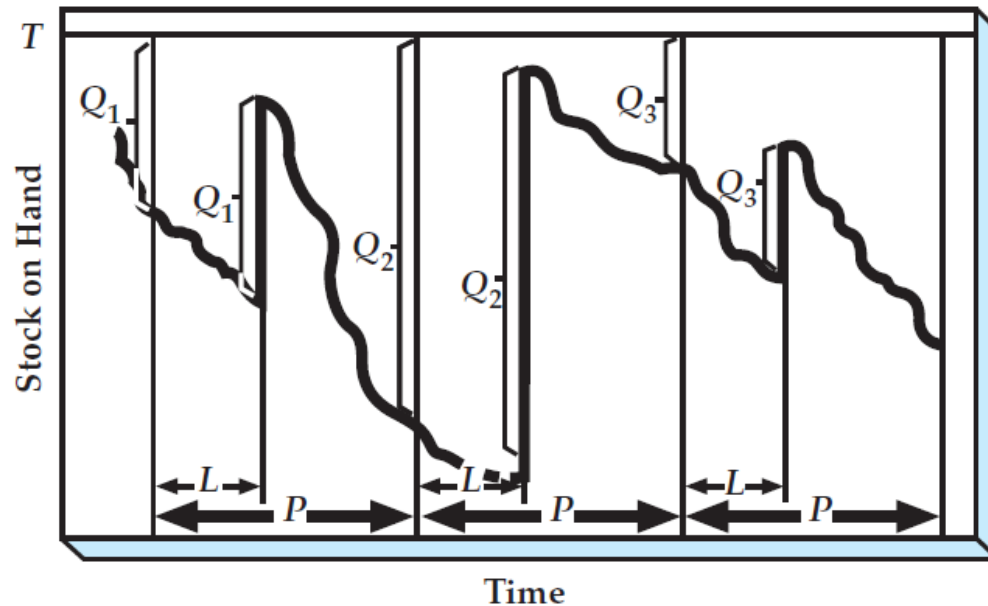
s = safety stock

Periodic Review (P) System (1 of 2)

- Review inventory position at *fixed interval* (**P**). For example, bread delivery truck visits grocery stores on same days each week.
- Inventory brought up to a **target** level.
- Order quantity varies according to demand.
- Also called fixed-order-interval system or **P system**.

Periodic Review (P) System (2 of 2)

(Figure 14.9)



T = target level

Q = order quantities

L = lead time

P = time between orders(period)

Periodic Review (P) System

P = time between orders

$$P = \frac{Q}{D} = \frac{1}{D} \sqrt{\frac{2SD}{iC}} = \sqrt{\frac{2S}{iCD}}$$

$$T = m' + s'$$

where

T = target inventory level

m' = average demand over $P + L$

s' = safety stock to cover $P + L$

P System Service Level

Safety stock must cover a longer interval ($P + L$).

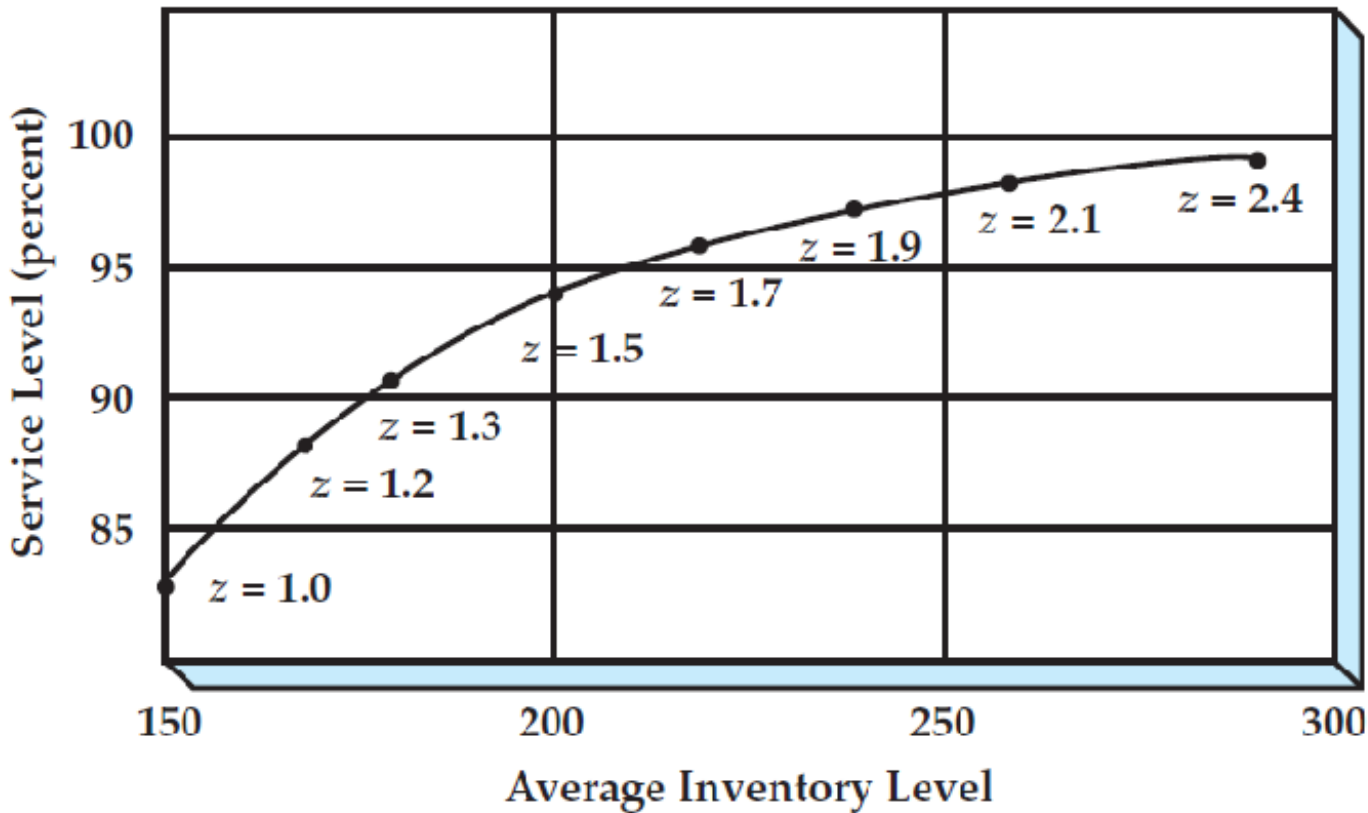
$$s' = z\sigma'$$

where

z = safety factor

σ' = the standard deviation of demand over $P + L$

Service Level versus Inventory Level (Fig. 14.10)



Using P and Q System in Practice

- Use P system when orders must be placed at specified intervals.
- Use P systems when multiple items ordered from the same supplier (joint-replenishment).
- Use Q system for expensive items; P for inexpensive.
- P requires more safety stock (and is more likely to stockout) since the system cannot respond quickly to increased demand.
- Either may be more costly:
 - P in safety stock, Q in monitoring costs

P and Q Systems at Home

- P system: You go to the grocery store on the same day every week.

“What will we need for the next week?”

- P carries more inventory and is more likely to run out since it cannot respond quickly to increases in demand.
- Q system: You go to the grocery store each time you need something.

“What do we need?”

- Q may require more unplanned trips to the store.

Vendor Managed Inventory (VMI)

- Supply chain management initiative passing responsibility for managing inventory stocks to vendors (suppliers).
- Vendor must have access to buyer's demand forecast and inventory records.
- Managed through contractual arrangement.
- Supply chain partners share cost savings of collaboration.

ABC Inventory Management

- Based on Pareto concept (**80/20 rule**) and total usage in dollars of each item.
- Classification of **A**, **B**, and **C** items based on usage.
- Purpose is to set effort priorities to manage different SKUs, i.e., to allocate scarce management resources.

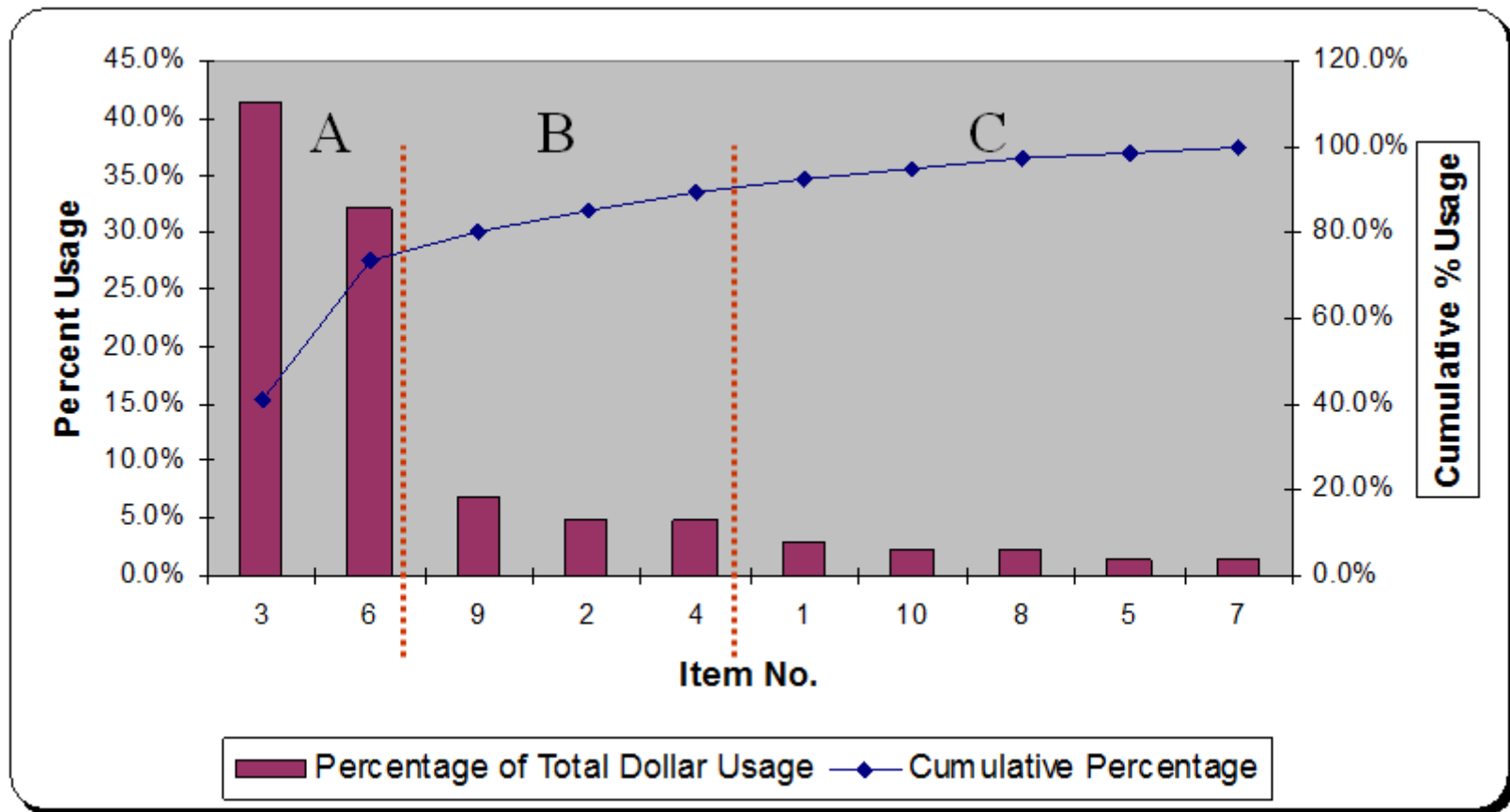
ABC Inventory Classification

- **A** items: 20% of SKUs, 80% of dollars
- **B** items: 30% of SKUs, 15% of dollars
- **C** items: 50% of SKUs, 5% of dollars
- Three classes is arbitrary; could be any number.
- Percentages are approximate.
- Danger:
 - Dollar use may not reflect importance of a particular SKU! Some *critical but low value items* may be classified as **A**.

Annual Usage of Items by Dollar Value (Table 14.4)

<i>Item</i>	<i>Annual Usage in Units</i>	<i>Unit Cost</i>	<i>Dollar Usage</i>	<i>% of Total Dollar Usage</i>
1	5,000	\$ 1.50	\$ 7,500	2.9%
2	1,500	8.00	12,000	4.7%
3	10,000	10.50	105,000	41.2%
4	6,000	2.00	12,000	4.7%
5	7,500	0.50	3,750	1.5%
6	6,000	13.60	81,600	32.0%
7	5,000	0.75	3,750	1.5%
8	4,500	1.25	5,625	2.2%
9	7,000	2.50	17,500	6.9%
10	3,000	2.00	6,000	2.4%
Total			\$ 254,725	100.0%

ABC Chart for Table 14.4



Summary

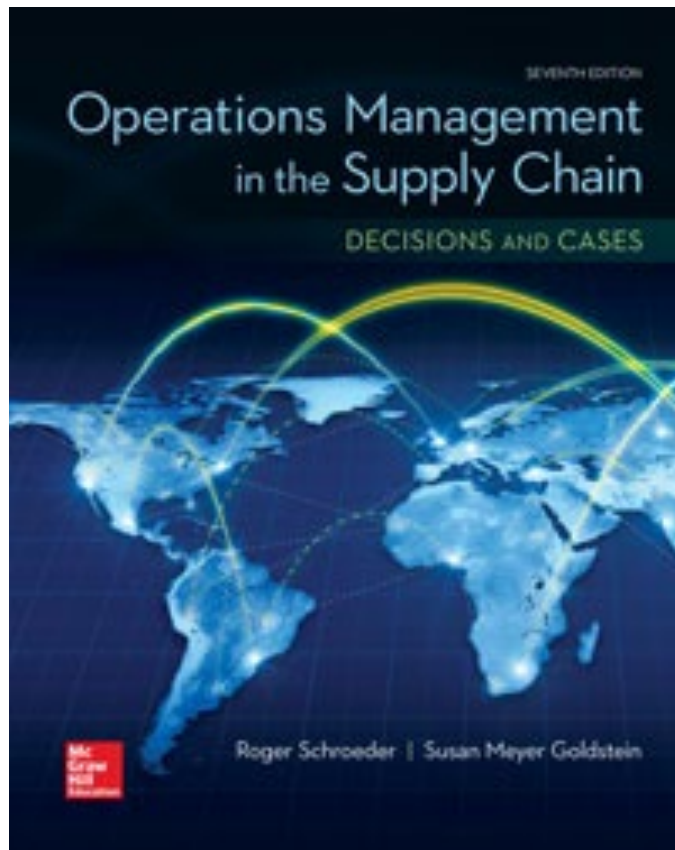
- 14.1 Define inventory types and the purpose of inventory.
- 14.2 Explain the costs incurred by inventory.
- 14.3 Differentiate between independent and dependent demand.
- 14.4 Calculate the economic order quantity and identify the underlying assumptions.
- 14.6 Recall the uses of periodic and continuous review systems.
- 14.7 Describe how inventory and service level are related.
- 14.8 Define Vendor Managed Inventory and the ABC system.

End of Presentation

Operations Management in the Supply Chain

Decisions and Cases

Seventh Edition



Chapter 15

Material Requirements Planning and ERP

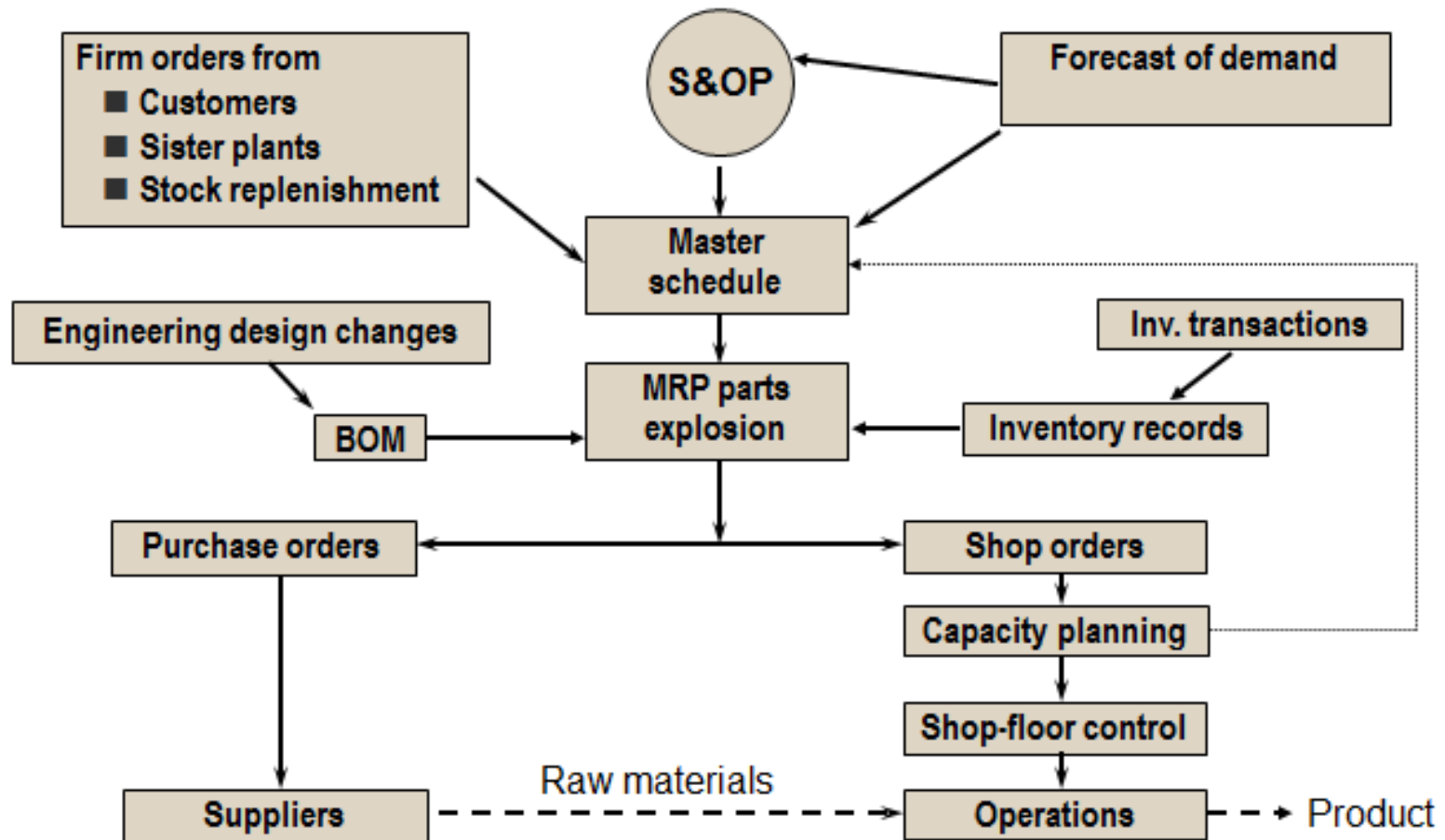
Learning Objectives

- 15.1 Recall the elements, inputs and outputs of an MRP system.
- 15.2 Contrast and compare MRP versus order-point systems.
- 15.3 Construct a materials plan given the gross requirements.
- 15.4 Describe in detail each element of an MRP system.
- 15.5 Discuss DRP and different ways to deal with uncertain demand.
- 15.6 Explain the five requirements for a successful MRP system.
- 15.7 Describe what an ERP system does.

Materials Requirements Planning (MRP)

- Used to manage **dependent demand** items
 - Raw materials, WIP parts
 - Parts used to make higher-level components
- Driven by the **master schedule** (which is driven by S&OP)
- **Parts explosion** breaks end items into all requirements for components/parts using **bill of materials** (BOM)
- Schedule is offset based on lead times
- **Push system** used because master schedule is constantly changing

Closed Loop MRP System (Figure 15.1)



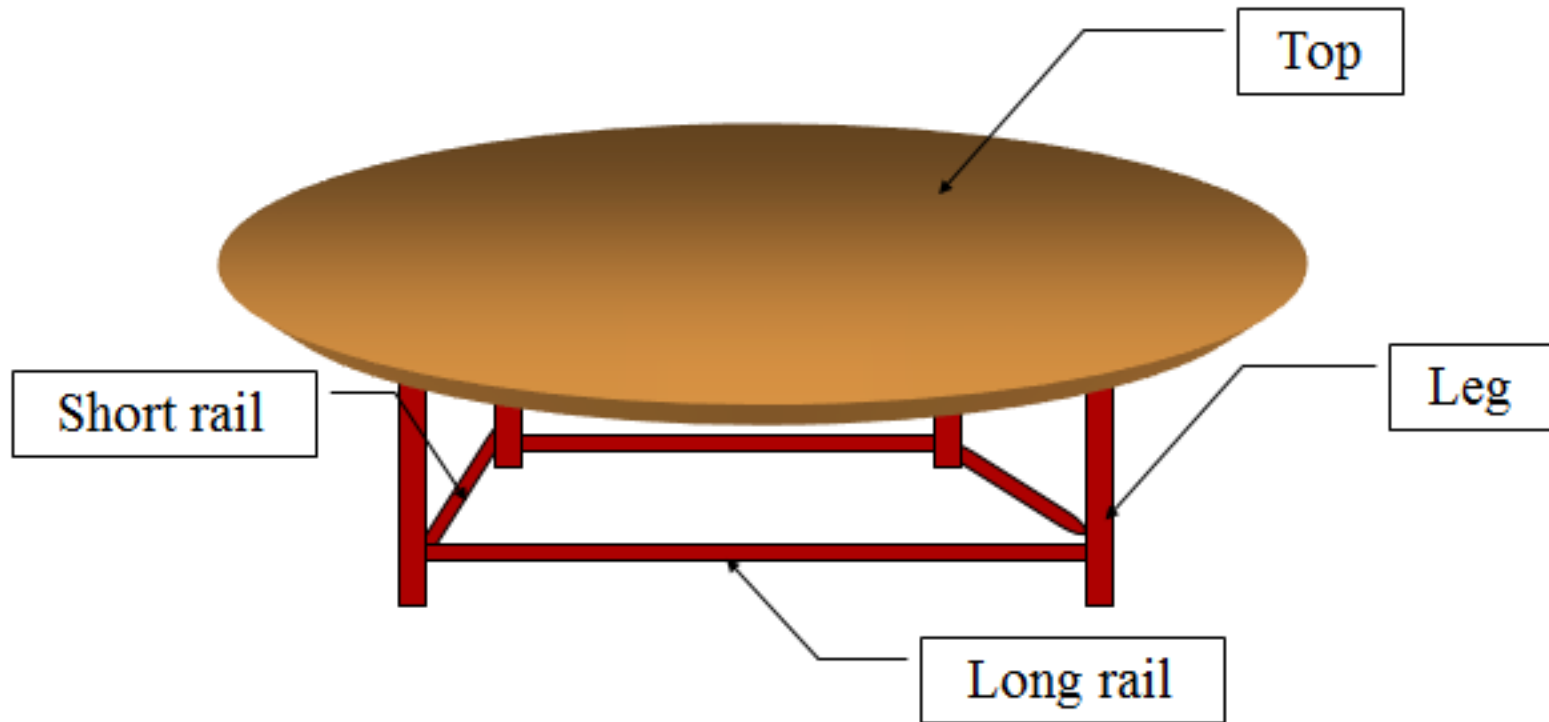
Comparison of MRP & Order-Point Systems

Attribute	MRP	Order Point
Demand	Dependent	Independent
Order philosophy	Requirements	Replenishment
Forecast	Based on master schedule	Based on past demand
Control concept	Control all items	ABC
Objectives	Meet manufacturing needs	Meet customer needs
Lot sizing	Discrete	EOQ
Demand pattern	Lumpy but predictable	Random
Types of inventory	Work in process and raw materials	Finished goods and spare parts

MRP Elements

- Inputs
 - Master schedule
 - Bill of materials (BOM)
 - Inventory records
- Outputs
 - Capacity planning
 - Purchasing
 - Shop-floor control

MRP Example



BOM (Product Structure)

- Table (end item) 1 week
 - Leg assembly (1) 1 week
 - Short rails (2) 1 week
 - Long rails (2) 1 week
 - Legs (4) 1 week
 - Top (1) 2 weeks

Indented BOM

<u>Level Code</u>	<u>Component</u>
0	Table (end-item)
1	Leg assembly (1)
2	Short rails (1)
2	Long rails (2)
2	Legs (4)
1	Top (1)

Materials Plan for BOM Levels 0 and 1 (1 of 2)

		Week: 1	Week: 2	Week: 3	Week: 4	Week: 5	Week: 6
	Tables						
On hand = 50	Gross Requirement				200	150	100
LT = 1 wk	Scheduled Receipts						
Lot size: L4L	Projected Ending Inventory	50	50	50			
Safety Stock = 0	Net Requirement				150	150	100
	Planned order receipts				150	150	100
	Planned order releases			150	150	100	
	Tops						
On hand = 50	Gross Requirement			150	150	100	
LT = 2 wk	Scheduled Receipts		50				
Lot size: L4L	Projected Ending Inventory	50	100				
Safety Stock = 0	Net Requirement			50	150	100	
	Planned order receipts			50	150	100	
	Planned order releases	50	150	100			

Materials Plan for BOM Levels 0 and 1 (2 of 2)

		Week: 1	Week: 2	Week: 3	Week: 4	Week: 5	Week: 6
	Leg Assembly						
On hand = 100	Gross Requirement			150	150	100	
LT = 1 wk	Scheduled Receipts						
Lot size: L4L	Projected Ending Inventory	100	100				
Safety Stock = 0	Net Requirement			50	150	100	
	Planned order receipts			50	150	100	
	Planned order releases		50	150	100		

Materials Plan

On previous slide, note the following:

- Gross requirements in level 0 (Tables) come from the master schedule.
- Gross requirements in level 1 (Tops, Leg assemblies) come from the planned order releases in level 0.
- Planned order releases are offset by the lead times.
- Planned order releases are planned! Actual order releases must take available capacity into account.
- Net requirements are the gross requirements minus the projected ending inventory.

Master Schedule

- Quantities derived from aggregate production plan (product families).
- Frozen within production lead time (so all parts can be obtained).
- Quantities reflect “build” schedule rather than demand forecasts.
- Quantities represent what needs to be produced (infinite capacity assumed)

Bill of Materials [BOM]

- Structured list of all parts and materials
- Must be 100 percent accurate
- Should be one BOM per product per company
- Engineering-change-order (ECO) system used to update BOM as product redesigned

Inventory Records

- Item master data segment
 - Constant info (part number, cost, etc.)
- Inventory status segment
 - Materials plan for each item
- Subsidiary data segment
 - Info on outstanding orders, demand history, etc.
- Records must be accurate
 - **Cycle counting**: physical count of a few items each day, so that all items are counted on a regular cycle

Capacity Planning

- Purpose is to aid management in checking validity of master schedule
 - Is there enough capacity to produce as scheduled?
- Two methods
 - Shop loading: assign work to work centers
 - Finite capacity scheduling: considers resource limitations

Purchasing

- Greatly enhanced by use of MRP
- Past due orders mostly eliminated
- Order expediting mostly eliminated
- Can provide suppliers with reports of planned future orders
- Can use electronic data interchange (EDI) to communicate directly with suppliers

Shop Floor Control

- Purposes
 - Release orders to the shop floor
 - Manage the orders for on-time completion
 - Can use manufacturing execution system (MES)
- Set job priorities (dispatching rules)
- Manage lead times on basis of priority
 - Expedite and de-expedite orders
- Minimize inventory while meeting completion dates

Operating an MRP System

- Should MRP carry **safety stock**?
- How much **safety stock** should be carried?
- **Safety lead time, safety capacity**
- Couple its use downstream with distribution requirements planning (DRP)
- Use upstream to give suppliers visibility into schedule

Required Elements for a Successful MRP System

1. Implementation planning
2. Appropriate and adequate IT support
3. Accurate data
4. Management support
5. User knowledge (all levels of firm)

Enterprise Resource Planning (ERP) Systems

- Extension and integration of all functions through a common database –
Forces standardized systems throughout firm
 - Accounting controls systems
 - Marketing and sales transactions
 - Human resource planning and payroll transactions
- Coordinate decisions along the supply chain
- Major software vendors
 - SAP
 - Oracle

Summary

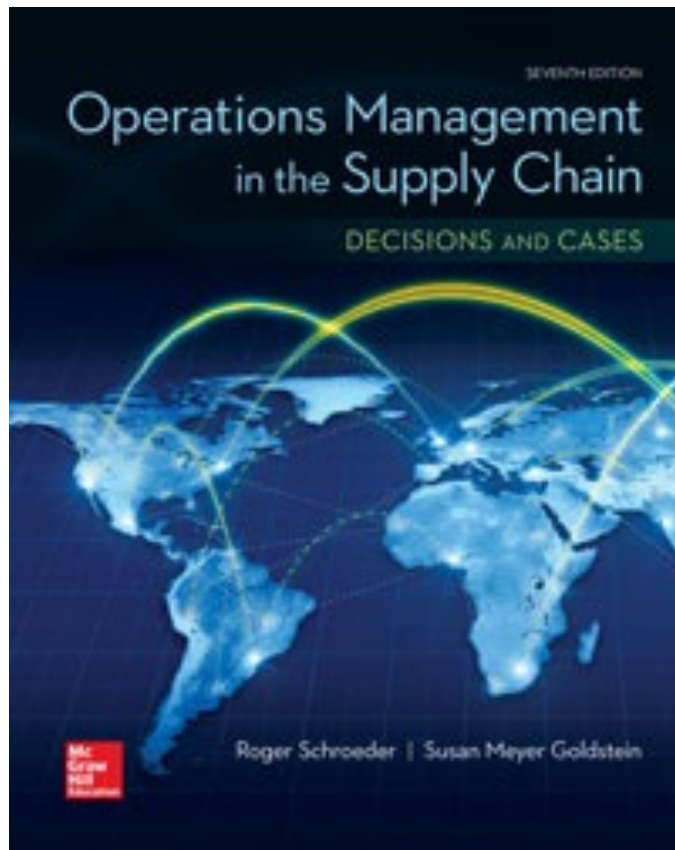
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End of Presentation

Operations Management in the Supply Chain

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Chapter 16

Supply Chain Management

Learning Objectives

- 16.1 Define supply chain and supply chain management.
- 16.2 List five key measures of supply chain performance.
- 16.3 Explain the bullwhip effect and how it can be reduced.
- 16.4 Contrast structural and systems improvements.
- 16.5 Explain the effect of technology on the supply chain.
- 16.6 Define supply chain risk, resilience and how risk can be managed.
- 16.7 Describe supply chain sustainability.

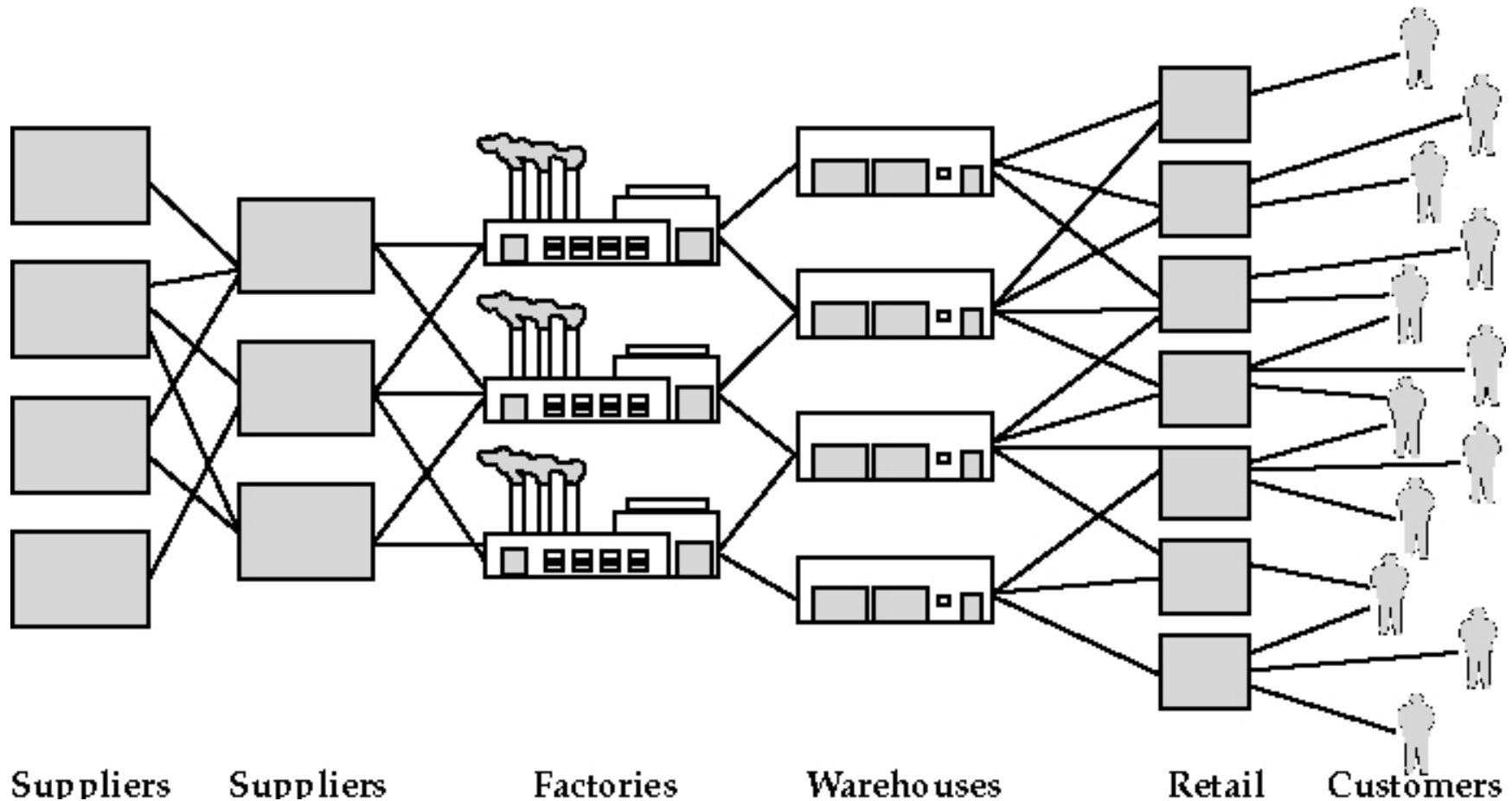
Supply Chain and Supply Chain Management

A **SUPPLY CHAIN** is the set of entities and relationships that cumulatively define materials and information flows both **downstream** toward the customer and **upstream** toward the very first supplier.

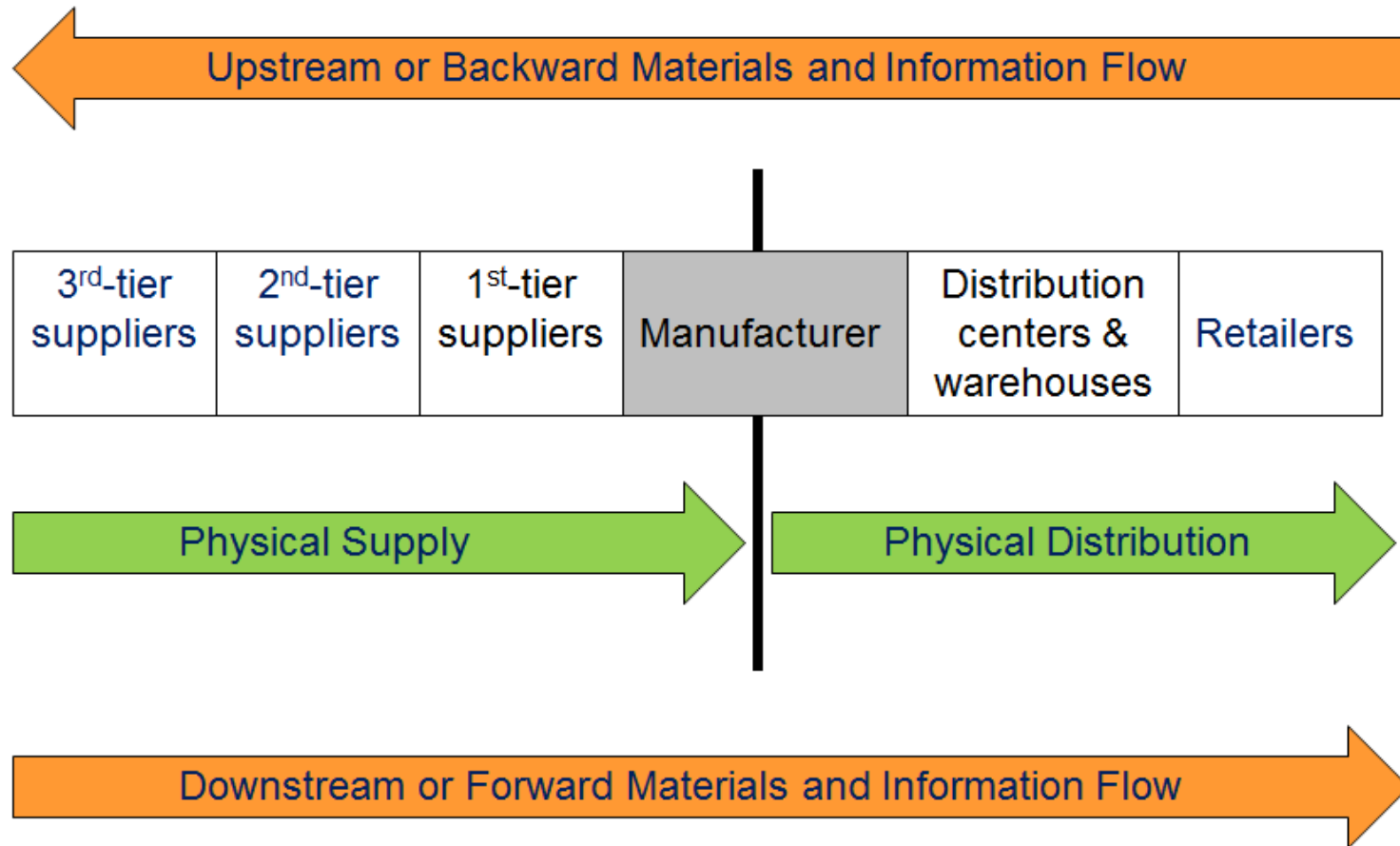
“**Supply chain management** is the design and management of seamless, value-added processes across organizational boundaries to meet the real needs of the end customer.”

--Institute for Supply Management

Typical Supply Chain (Figure 16.1)

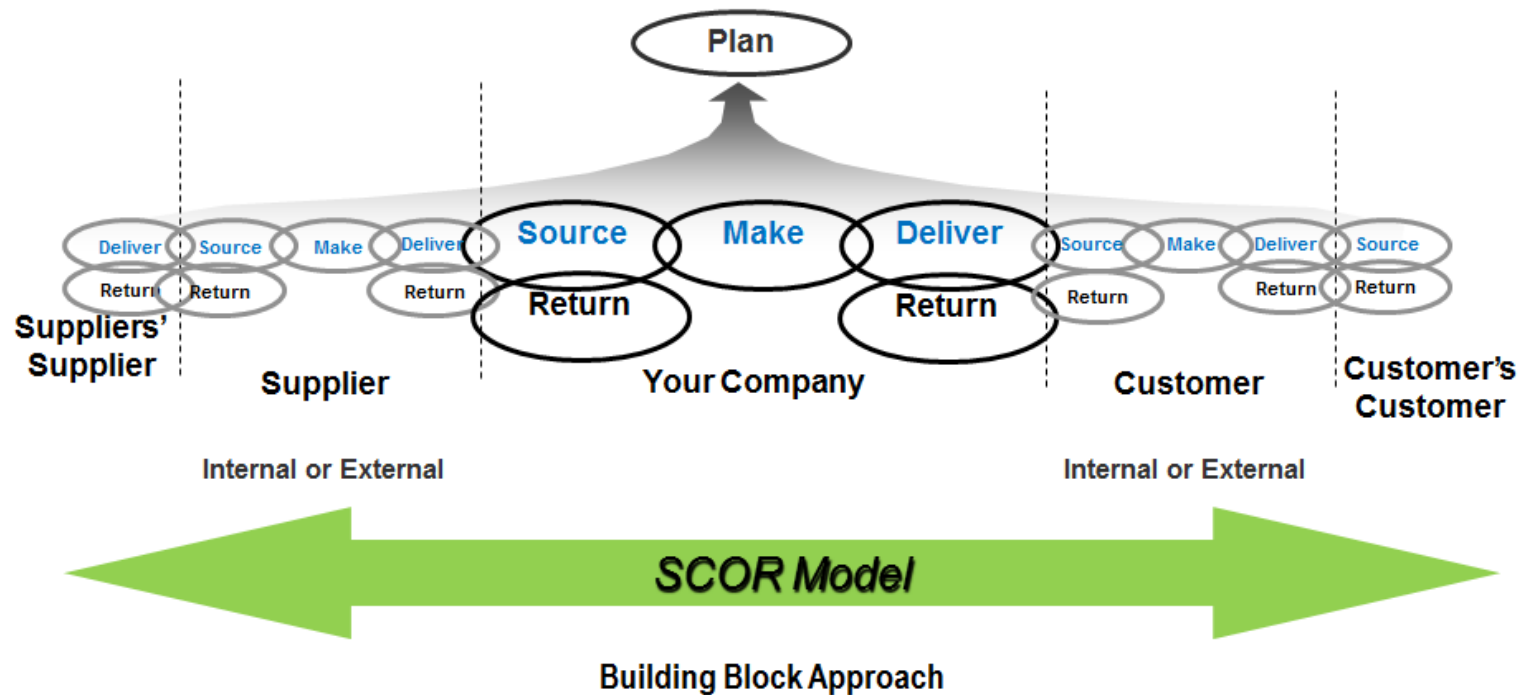


Supply Chain from Manufacturer's Perspective



SCOR

SCOR = **S**upply **C**hain **O**perations **R**eference model
SCOR is founded on five distinct management processes



The Five SCOR Functions

- **Plan.** Coordinate the other functions.
- **Source.** The sourcing function brings inputs into the transformation process from other organizations.
- **Make.** The operations function is responsible for making the product or service.
- **Deliver.** The logistics function is responsible for the movement and storage of goods across organizations in a supply chain.
- **Return.** Return and recycle inputs or products in the supply chain.

Measuring Supply Chain Performance (1 of 3)

- Delivery
 - On time delivery
 - Fill rate
- Quality
 - Product or service performance
 - Conformance to specifications
 - Customer satisfaction

Measuring Supply Chain Performance (2 of 3)

- Flexibility
 - Time to change volume of output by a fixed amount
 - Time to change the mix of products or services
- Time
 - Total supply chain throughput time
 - Cash-to-cash cycle time = Days in inventory + days in accounts receivable - days in accounts payable

Measuring Supply Chain Performance (3 of 3)

- Cost
 - Unit cost = (materials + labor + overhead) / # units
 - Distribution, inventory carrying, accounts receivable
 - Total supply chain cost =
 - Suppliers (materials and components) +
 - Producer (fabrication and assembly) +
 - Logistics (shipping and WIP between firms)

Dynamics: Bullwhip Effect

- Supply chain is a highly interactive system. Decisions in each part of the chain affect the other entities.
- There is an ***accelerator (bullwhip) effect***: Increased variability in upstream orders, resulting in more inventory upstream.
- Even with perfect information, replenishment lead times lead to an accelerator effect.
- Improve supply chain by reducing total replenishment time, share real demand information with all levels.

Improving Supply Chain Performance

- Decisions to improve performance
 - Change structure
 - Decisions that involve investments in bricks and mortar (facilities, new products, technology, etc.)
 - Change systems within a given structure
 - Decisions that involve people, process flow and information systems

Supply Chain Structural Improvements

- Forward and backward integration
- Major process simplification
- Change configuration of factories, warehouses, or retail locations (e.g. fewer plants or locations)
 - Can include supply base reduction, outsourcing, off-shoring
- Major product redesign
 - Postponement, modularity

Supply Chain System Improvements

- Cross-functional teams and partnerships with suppliers and customers to increase coordination.
- Lean Systems for producers, suppliers and distribution
- Integrated information systems downstream and upstream

Technology and Supply Chain Management

- Growth of e-commerce
 - B2B (business-to-business)
 - B2C (business-to-consumer)
- Fundamental processes in supply chains:
 - Order placement process
 - Information before order (Is product available in stock?)
 - Actual order entry
 - Order fulfillment process
 - Direct link to internal operations & suppliers
- Use of analytics to improve supply chains

Supply Chain Risk and Resilience

- **Resilience:** Ability to quickly respond to unexpected disruptions in supply or demand, either natural or manmade.
 - Examples: strike, recession, price change, natural disaster, manufacturing failure, unexpected demand.
- **Risk mitigation***
 - Stage 1: Proactive plan
 - Stage 2: Minimize damage during disruption
 - Stage 3: Post-disruption recovery

*** Each stage requires strategic and operational planning.**

Analysis of Supply Chain Risk (1 of 2)

- **Supply chain risk:** the probability of supply chain disruption.
- Risk can be reduced at each node in the network.
 - Add inventory at the supplier node or firm itself.
 - Use two dispersed suppliers.
 - For a sole source, have quick recovery or second supplier.
- Do not solely focus on the highest spend suppliers. Even small suppliers can add risk.

Analysis of Supply Chain Risk (2 of 2)

- For a given damage scenario and each supplier calculate

T_R = time to recover

PI = performance impact of disruption

T_S = maximum time supplier can match supply and demand
during a disruption, using inventory or alternate supply sources.

Insure that $T_R < T_S$

- Costs of a resilient network can be higher or sometimes lower, depending on the network configuration.
- Some supply chains can be too lean.

Sustainability of the Supply Chain

- **Sustainability:** meeting present needs without sacrificing the needs of future generations.
- Triple bottom line: *environmental, social, financial*
- Rests on the concept that all stakeholders are important
- Sustainable supply chains, beyond firm to all parties in supply chain
- Goals, plans and implementation needed to improve sustainability

Summary

- 16.1 Define supply chain and supply chain management.
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End of Presentation