CHAPTER 1 INTRODUCTION

LO1-1: Identify the elements of operations and supply chain management (OSCM).

LO1-2: Know the potential career opportunities in operations and supply chain management.

LO1-3: Recognize the major concepts that define the operations and supply chain management field.

The Elements of OSCM

- Clever integration of a great operations-related strategy
- Processes to deliver products and services
- Analytics to support the decisions needed to manage the firm

What Is Operations and Supply Chain Management?

- The design, operation, and improvement of the systems that create and delivery the firm's primary products and services

- Operations and supply chain management (OSCM) is
  - A functional field of business
  - Clear lines management responsibilities
  - Concerned with the management of the entire production/delivery system

Process Steps for Men's Nylon Supplex Parkas

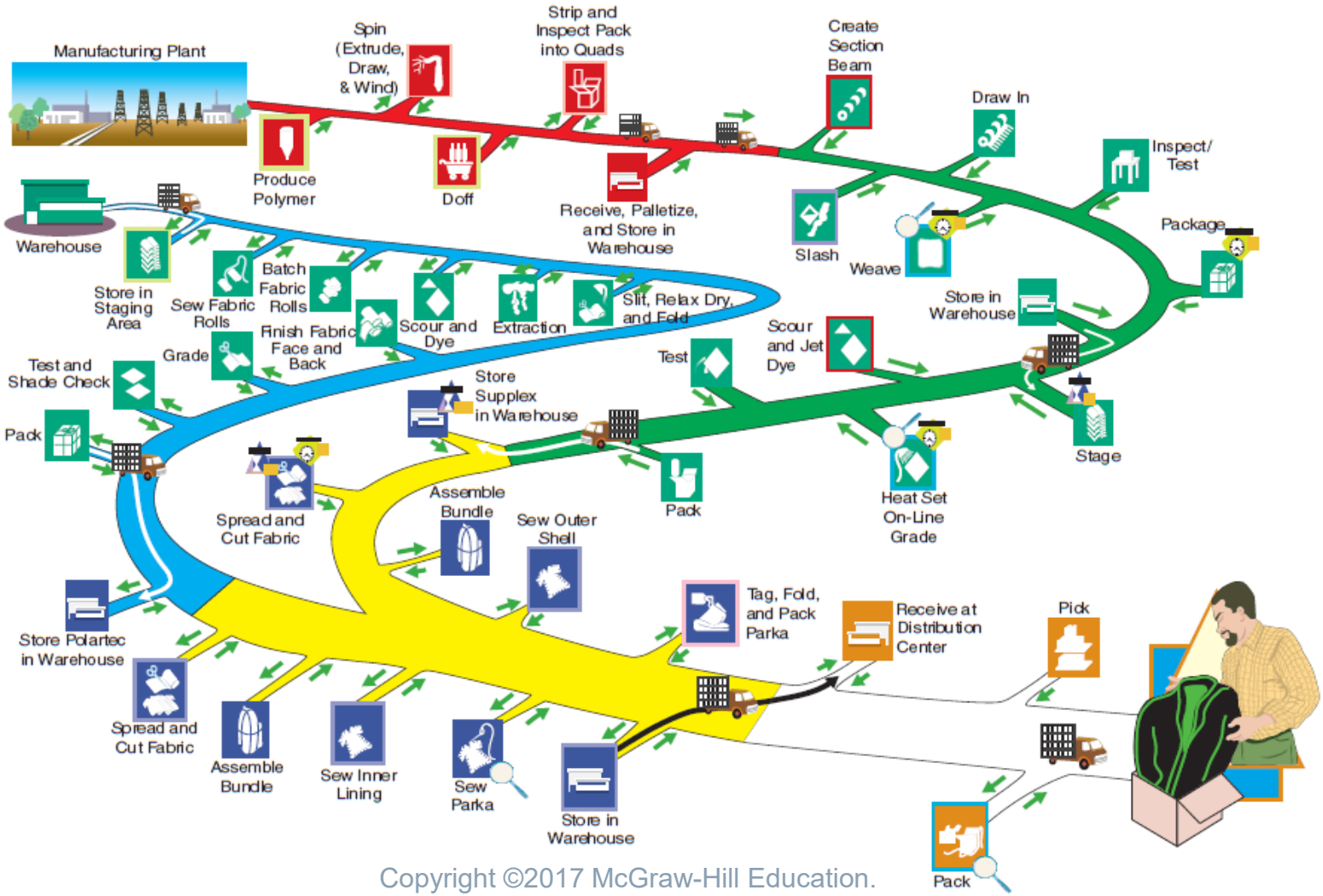


Exhibit 1.1

Questions Answered in Each Section of the OSCM

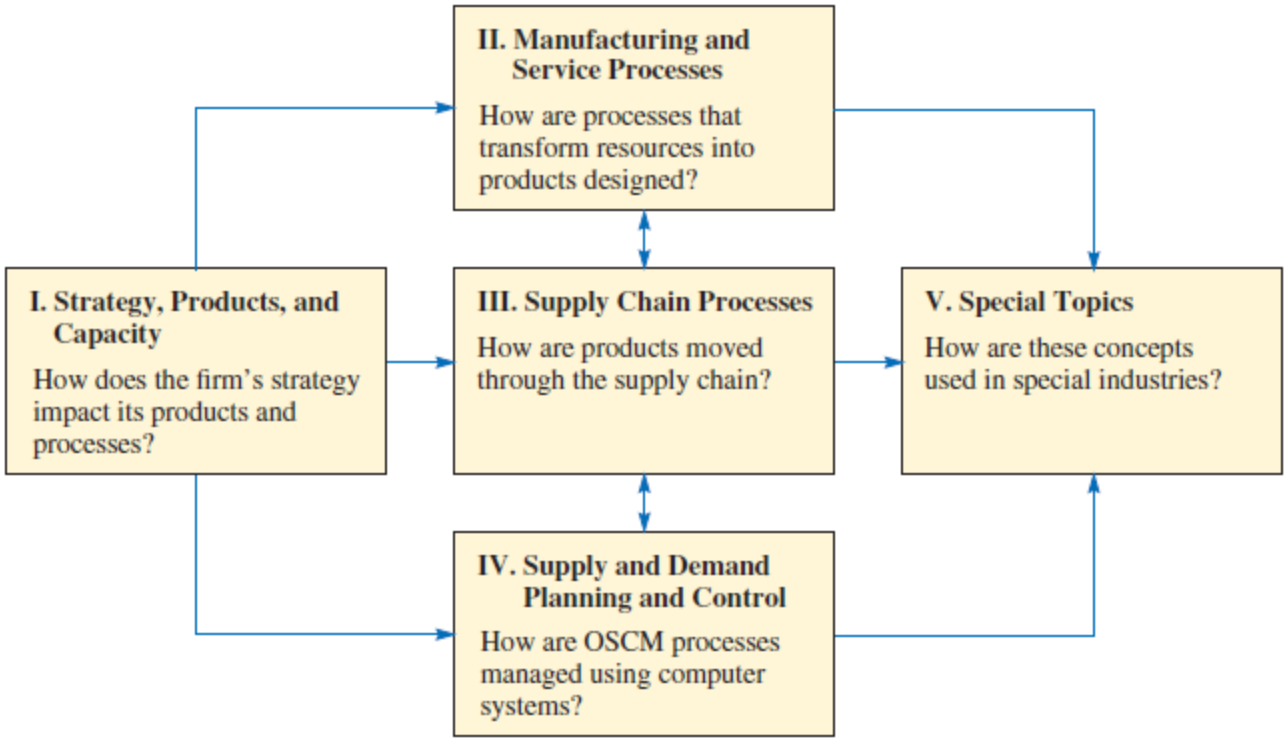


Exhibit 1.2

Operations and Supply Chain Terms

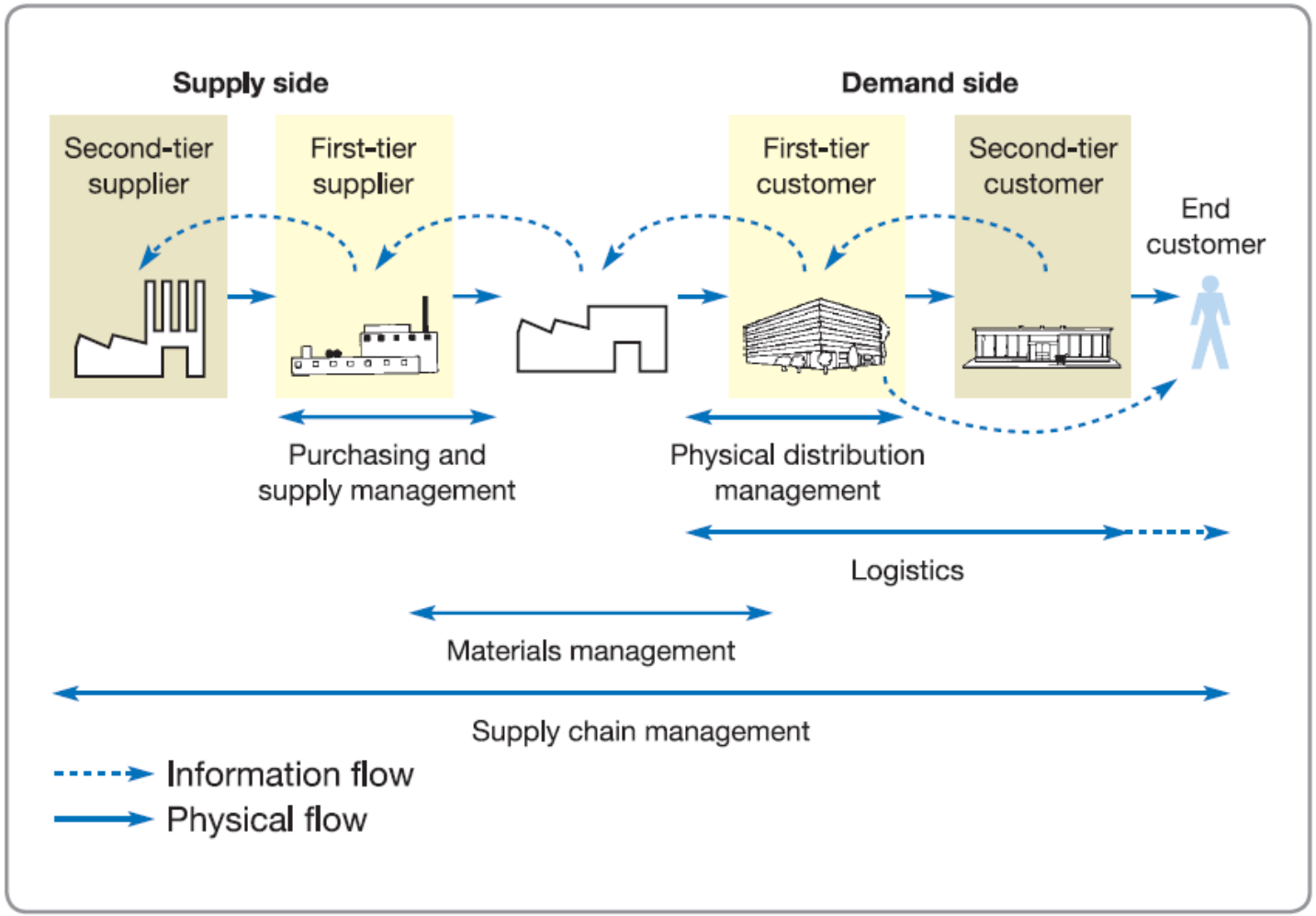
Operations

Manufacturing and service processes used to transform resources into products

Supply Chain

Processes that move information and material to and from the firm

Different parts of a Supply Chain



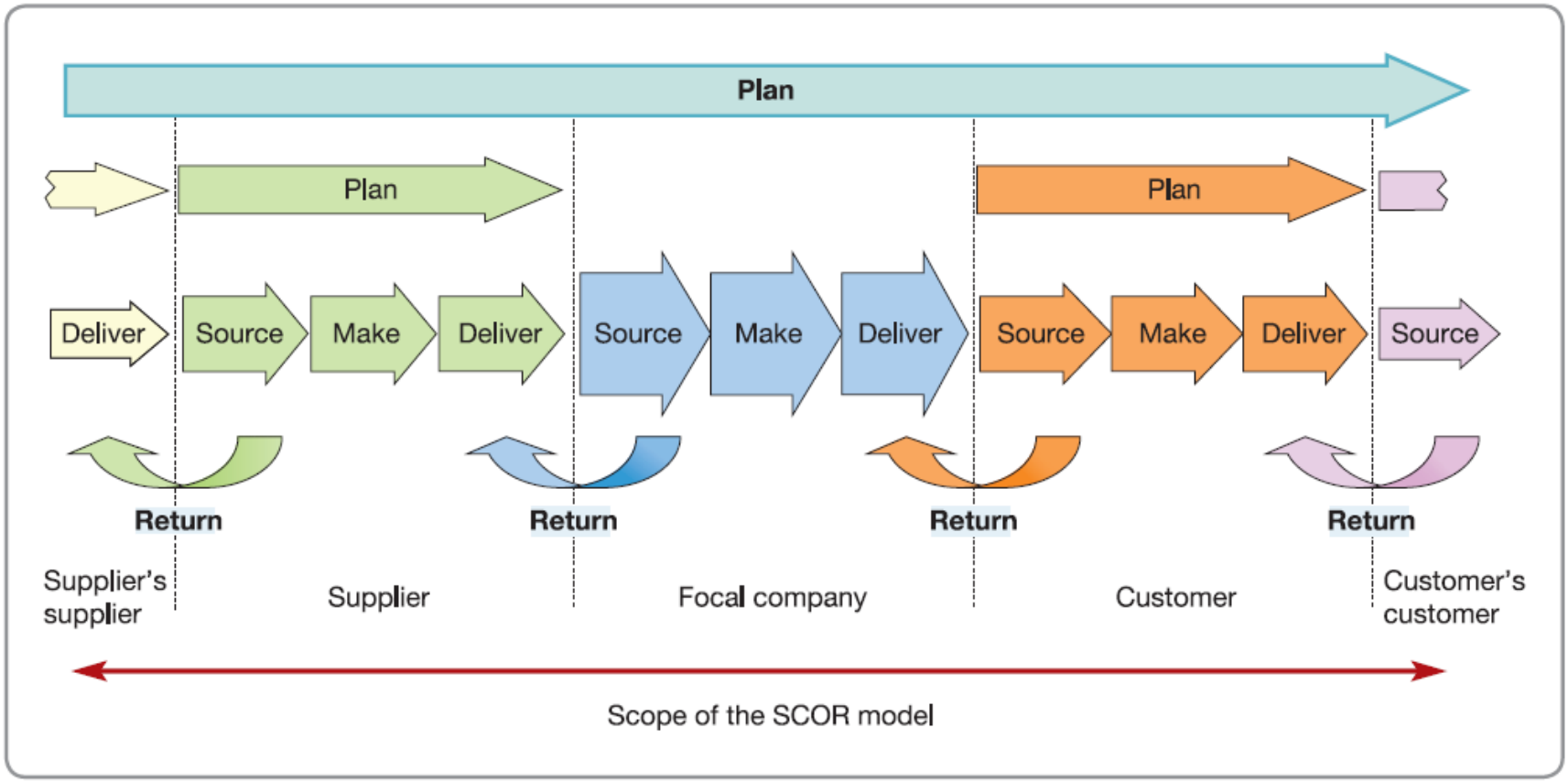
Basic Principles that Guide the Design of Transformation Processes

- How different types of processes are organized
- How to determine the capacity of a process
- How long it should take to make a unit
- How the quality of a process is monitored
- How information is used to make decisions

Process Activities

- **Planning** – processes needed to operate an existing supply chain
- **Sourcing** – selection of suppliers that will deliver the goods and services needed to create the firm's product
- **Making** – producing the major product or service
- **Delivering** – logistics processes such as selecting carriers, coordinating the movement of goods and information, and collecting payments from customers
- **Returning** – receiving worn-out, excess, and/or defective products back from customers

Business process modelling



Supply Chain Processes

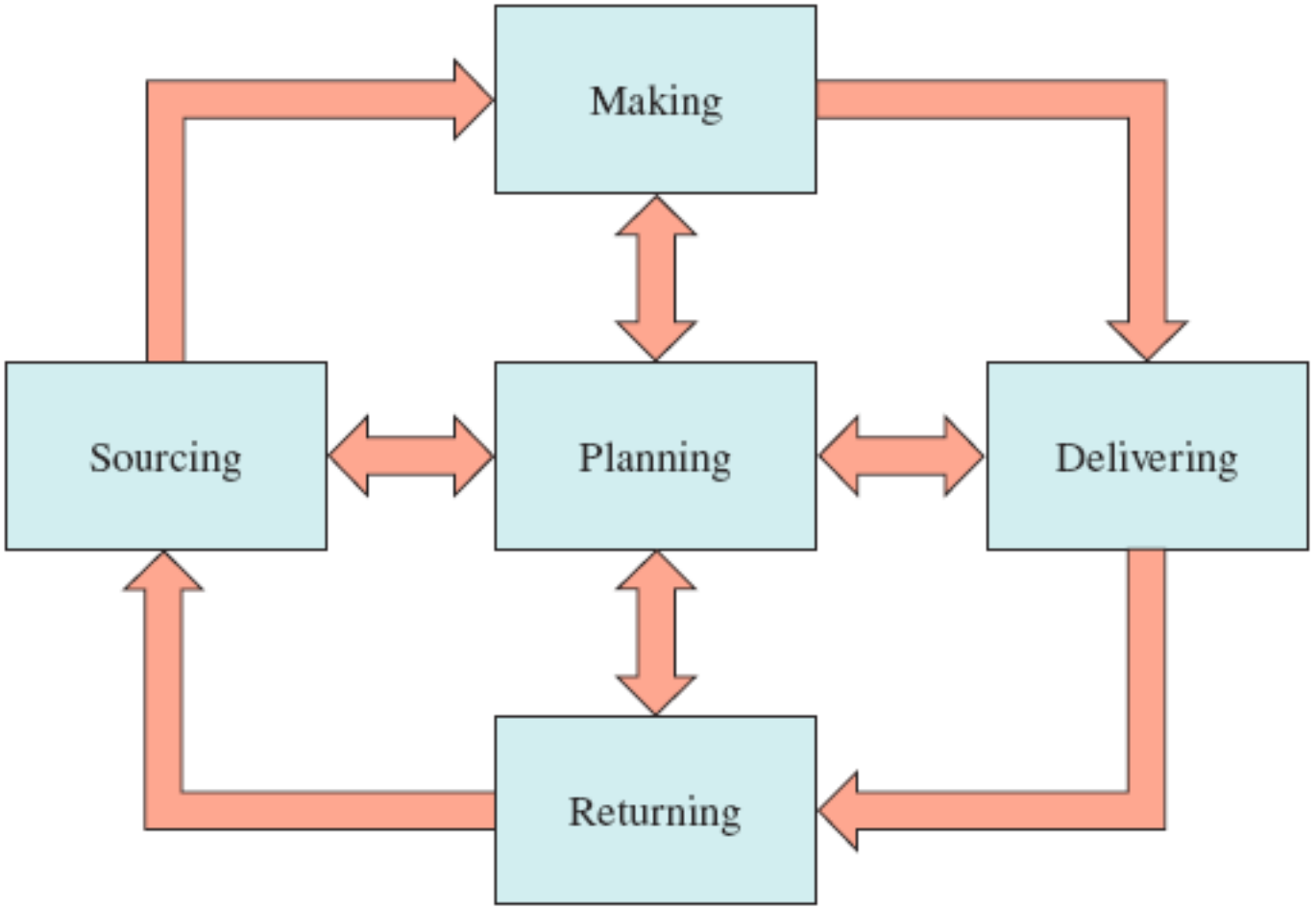


Exhibit 1.3

Differences Between Services and Goods

- Services are intangible
- Services require some interaction with the customer
- Services are inherently heterogenous
- Services are perishable and time dependent
- Services are defined and evaluated as a package of features

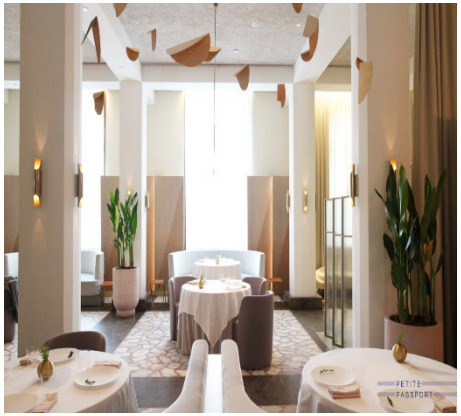
Package of features

- **Supporting facility -** location, decoration, layout, architectural appropriateness, supporting equipment
- **Facilitating goods -** variety, consistency, quantity of the physical goods that go with the service
- **Explicit services -** training of service personnel, consistency of service performance, availability and access to the service, and comprehensiveness of the service
- **Implicit services -** attitude of the servers, atmosphere, waiting time, status, security, and convenience

Package of features








The Goods–Services Continuum

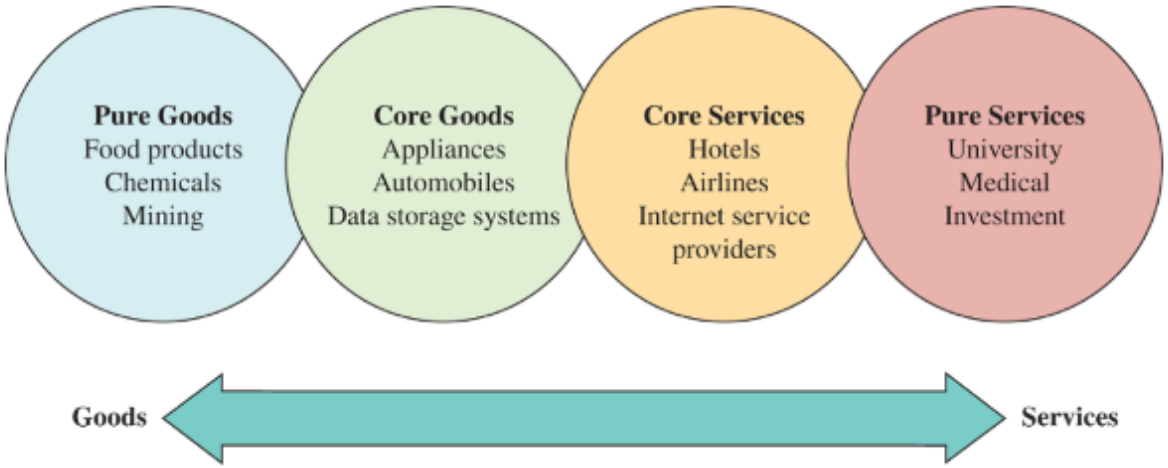


Exhibit 1.4

Servitization Strategies

- Servitization refers to a company building services activities into its product offering for its current users
  - Maintenance, spare parts, training, and so on
- Success starts by drawing together the service aspects of the business under one roof
- The immediate advantage is a closer relationship with customers

Careers in OSCM

- OSCM careers specialize in managing the planning, production, and distribution of goods and services
- Operations and supply chain manager works with people to figure out the best way to deliver the goods and services of the firm
- OSCM jobs are hands-on, working with people and figuring out the best way to do things

OSCM Specialist Areas

- Product design
- Purchasing
- Manufacturing
- Service operations
- Logistics
- Distribution

Possible Careers in OSCM

Plant manager	Hospital administrator	Branch manager	Department store manager
Call center manager	Supply chain manager	Purchasing manager	Quality control manager
Business process improvement analyst	Lean improvement manager	Project manager	Production control analyst
	Facilities manager	Chief operating officer	

Time Line Depicting When Major OSCM Concepts Became Popular

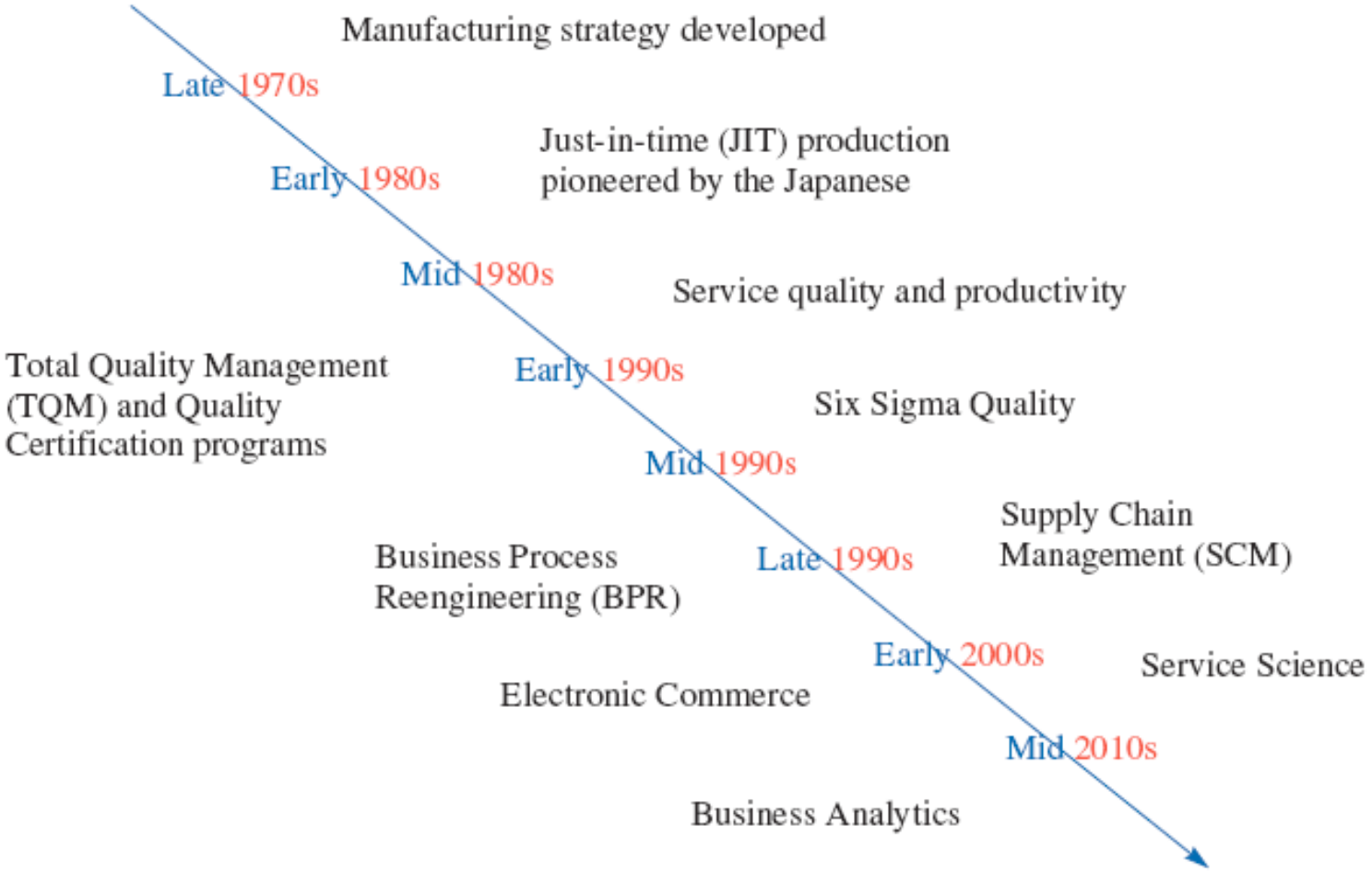


Exhibit 1.5

The Major Concepts that Define the OSCM Field

- Manufacturing strategy paradigm
- Lean manufacturing, JIT, and TQC
- Service quality and productivity
- Total quality management and quality certification
- Business process reengineering
- Six sigma quality
- Supply chain management
- Electronic commerce
- Sustainability and the triple bottom line
  - Business strategy that includes social, economic and environmental criteria
- Business analytics

Current Issues in Operations and Supply Chain Management

1. Coordinating the relationships between mutually supportive but separate organizations
2. Optimizing global supplier, production, and distribution networks
3. Managing customer touch points
4. Raising senior management awareness of OSCM as a significant competitive weapon
5. Sustainability and the triple bottom line

Efficiency, Effectiveness, and Value

- **Efficiency** - doing something at the lowest possible cost
- **Effectiveness** - doing the right things to create the most value for the company
- **Value** - quality divided by price
  - **Quality** - the attractiveness of the product, considering its features and durability

How Does Wall Street Evaluate Efficiency?

- Earnings growth is largely a function of profitability
- Profits can be increased through higher sales or lower cost
- Highly efficient firms usually do well during recessions
- **Benchmarking** - a process in which one company studies the processes of another company (or industry) to identify best practices

Summary

- Processes are used to implement the strategy of the firm
- Analytics are used to support the ongoing decisions needed to manage the firm
- OSCM people specialize in managing the production of goods and services
- OSCM jobs are hands-on and require working with others and figuring out the best way to do things
- The chief operating officer (COO) works with the CEO and company president to determine the company's competitive strategy
- COOs determine an organization's location, its facilities, which vendors to use, and how the hiring policy will be implemented
- Many of the concepts that form the OSCM field have their origins in the Industrial Revolution in the 1800's

Questions

1. The pipeline-like movement of the materials and information needed to produce a good or service
2. A strategy that meets the needs of shareholders and employees and that preserves the environment
3. The processes needed to determine the set of future actions required to operate an existing supply chain
4. The selection of suppliers
5. A type of process where a major product is produced or a service provided
6. A type of process that moves products to warehouses or customers
7. Processes that involve the receiving of worn-out, defective, and excess products back from customers and support for customers who have problems
8. A type of business where the major product is intangible, meaning it cannot be weighed or measured

Questions Continued

9. Refers to when a company builds service activities into its product offerings
10. Means doing something at the lowest possible cost
11. Means doing the right things to create the most value for the company.
12. A philosophy that aggressively seeks to eliminate causes of production defects
13. An approach that seeks to make revolutionary changes as opposed to evolutionary changes (which is advocated by total quality management).
14. An approach that combines TQM and JIT
15. A program to apply the latest concepts in information technology to improve service productivity

Chapter 2 Strategy

LO2–1: Know what a sustainable business strategy is and how it relates to operations and supply chain management.

LO2–2: Define operations and supply chain strategy.

LO2–3: Explain how operations and supply chain strategies are implemented.

LO2–4: Understand why strategies have implications relative to business risk.

LO2–5: Evaluate productivity in operations and supply chain management.

Sustainable Strategy

- The firm's strategy describes how it will create and sustain value for its current shareholders
  - Shareholders – individuals or companies that legally own one or more shares of stock in the company
  - Stakeholders – individuals or organizations who are directly or indirectly influenced by the actions of the firm
- Adding a sustainability requirement means meeting value goals without compromising the ability of future generations to meet their own needs
- Triple bottom line – evaluating the firm against social, economic, and environmental criteria

Triple Bottom Line

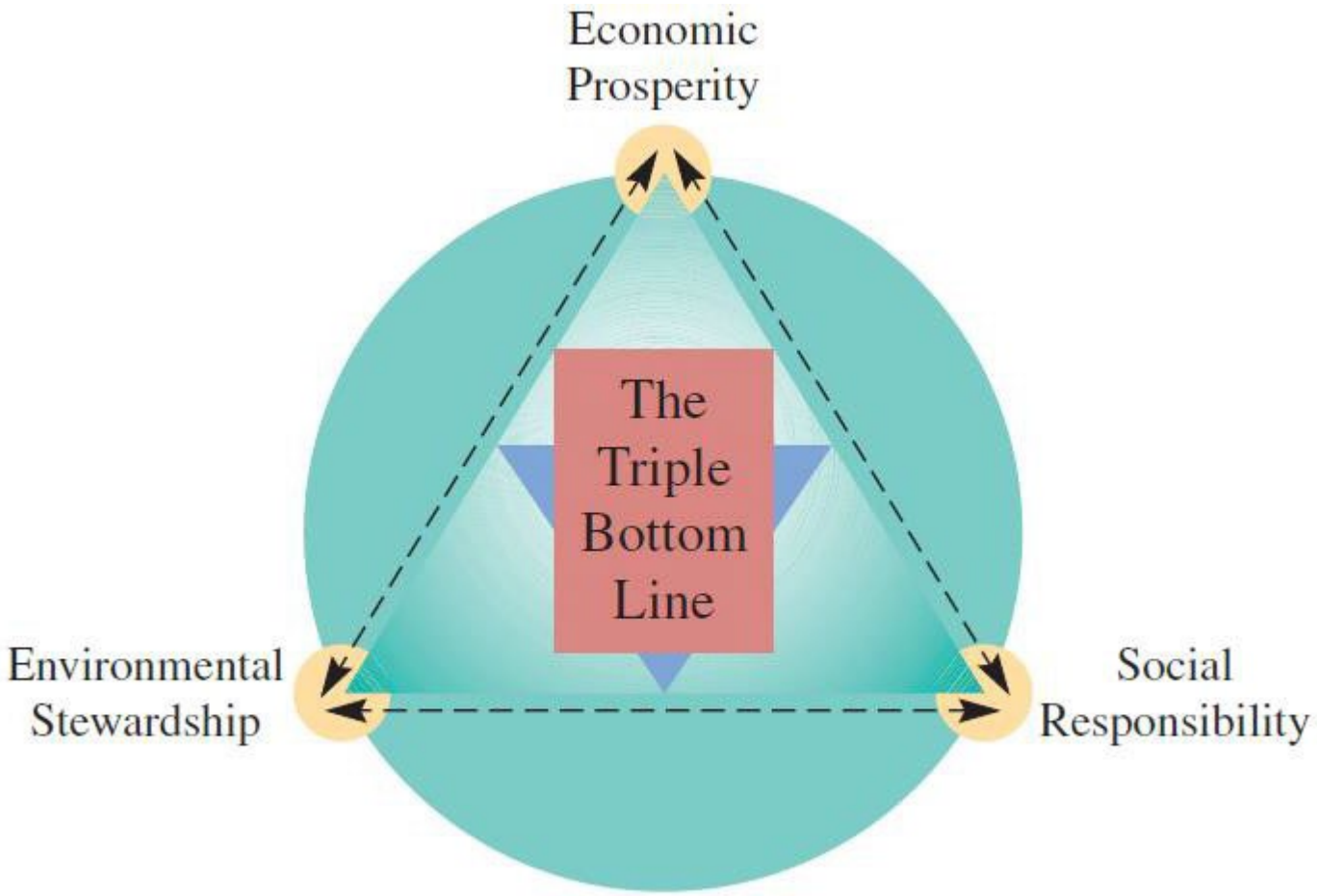
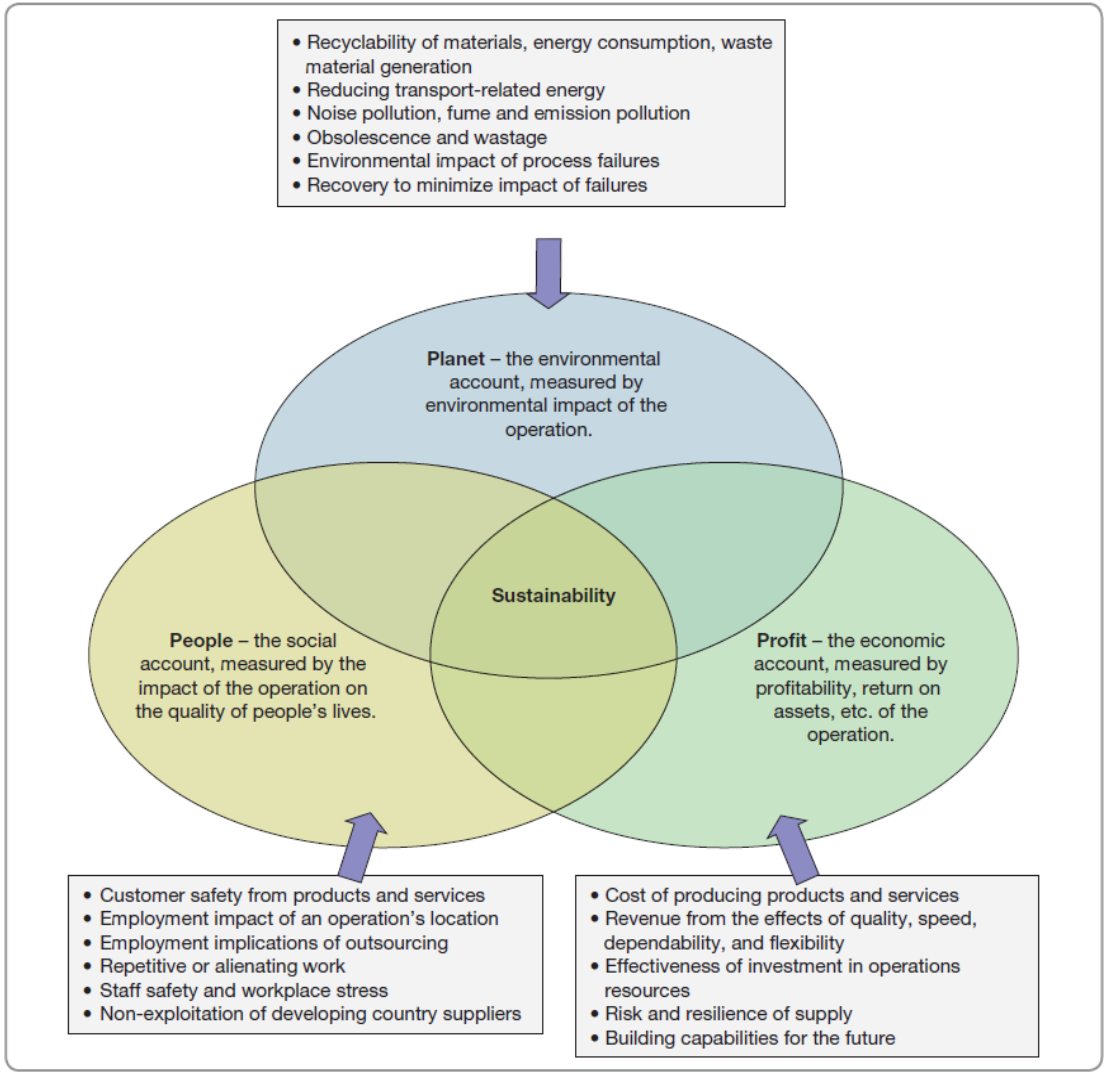


Exhibit 2.1

Triple Bottom Line



What is Operations and Supply Chain Strategy?

- **Operations and supply chain strategy**: setting broad policies and plans for using the resources of a firm – must be integrated with corporate strategy
  - Corporate strategy provides overall direction and coordinates operational goals with those of the larger organization
  - Can be viewed as part of a planning process that coordinates operational goals with those of the larger organization

- **Operations effectiveness**: performing activities in a manner that best implements strategic priorities at a minimum cost

Formulating an Operations and Supply Chain Strategy

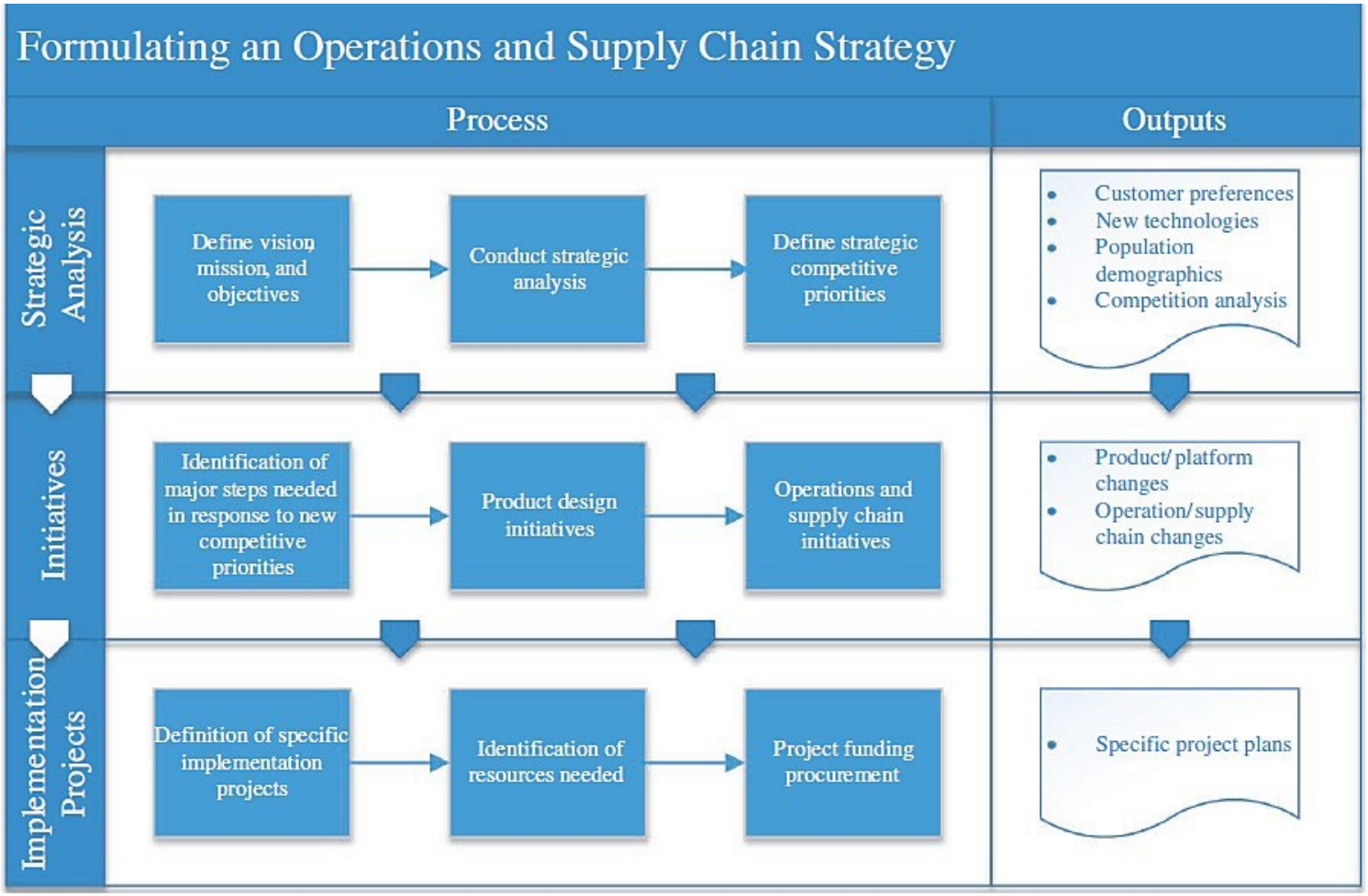


Exhibit 2.2

Competitive Dimensions

Cost/Price

- Make the product or deliver the service cheap

Quality

- Make a great product or delivery a great service

Delivery Speed

- Make the product or deliver the service quickly

Delivery Reliability

- Deliver it when promised

Coping with Changes in Demand

- Change its volume

Flexibility and New-Product Introduction Speed

- Change it

Other Product-Specific Criteria: "Support It"

Technical liaison and support

- A supplier may be expected to provide technical assistance for product development

Meeting a launch date

- A firm may be required to coordinate with other firms on a complex project

Supplier after-sale support

- An important competitive dimension may be the ability of a firm to support its product after the sale

Environmental impact

- This dimension is related to environmental/green criteria

Other dimensions

- These typically include such factors as colors available, size, weight, location of the fabrication site, customization available, and product mix options

Trade-Offs

- Management must decide which parameters of performance are critical and concentrate resources on those characteristics
- For example, a firm that is focused on low-cost production may not be capable of quickly introducing new products
- Straddling: seeking to match a successful competitor while maintaining its existing position
  - It adds features, services, or technology to existing activities
  - Often a risky strategy

Order Winners and Order Qualifiers

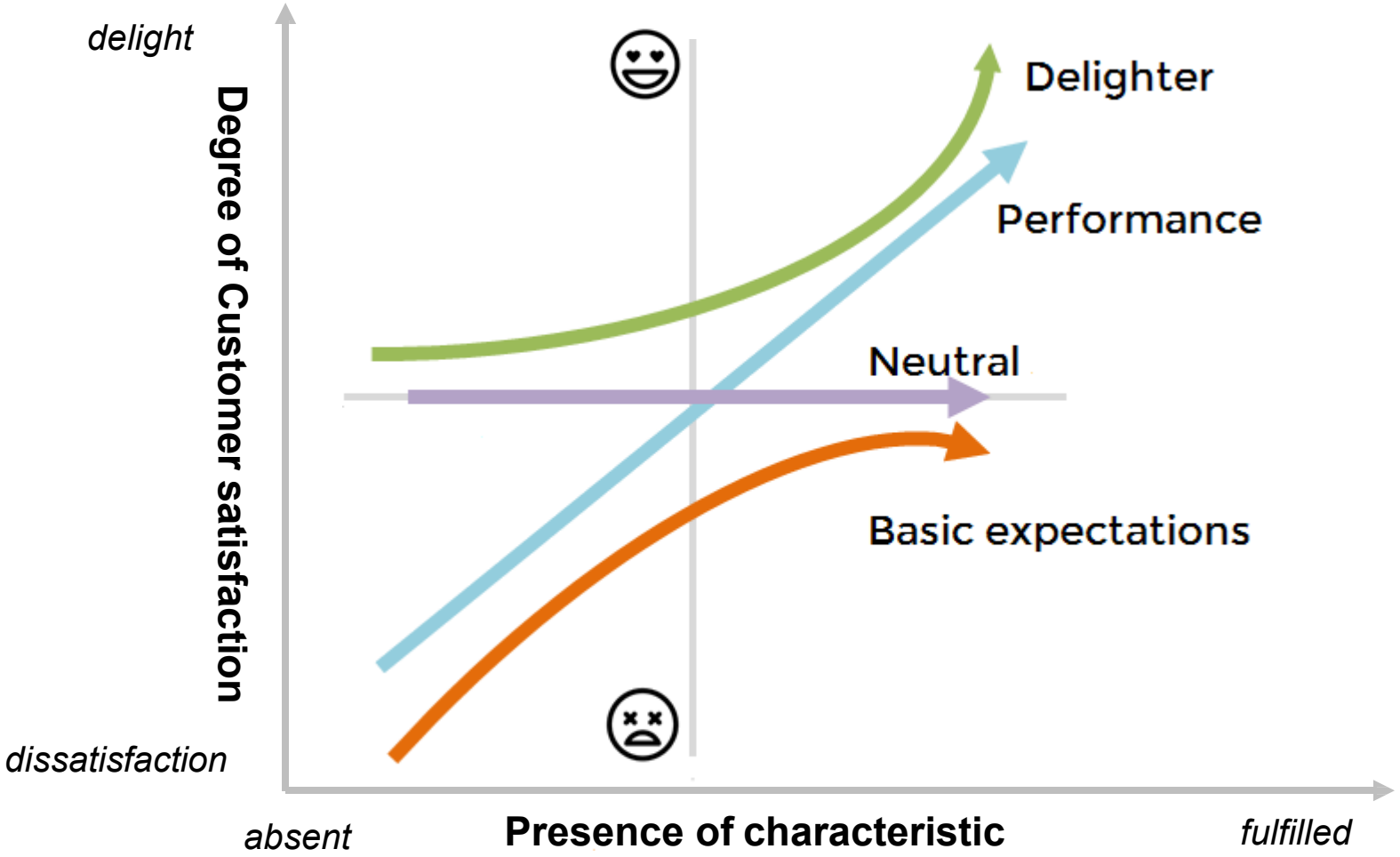
- **Order winners**: criteria used by customers to differentiate the products and services of one firm from those of other firms
  - Features that customers use to determine which product to ultimately purchase
- **Order qualifiers**: those dimensions that are necessary for a firm's products to be considered for purchase by customers
  - Features customers will not forego

What is the Kano Model?

- The Kano model is a theory of product development and customer satisfaction developed in the 1980s by Professor Noriaki Kano.

- The *Kano Model*, is based upon the following premises:
  - Customers' **Satisfaction** with our product's features depends on the **level of Functionality** that is provided (how much or how well they're implemented);
  - **Features can be classified into four categories**;

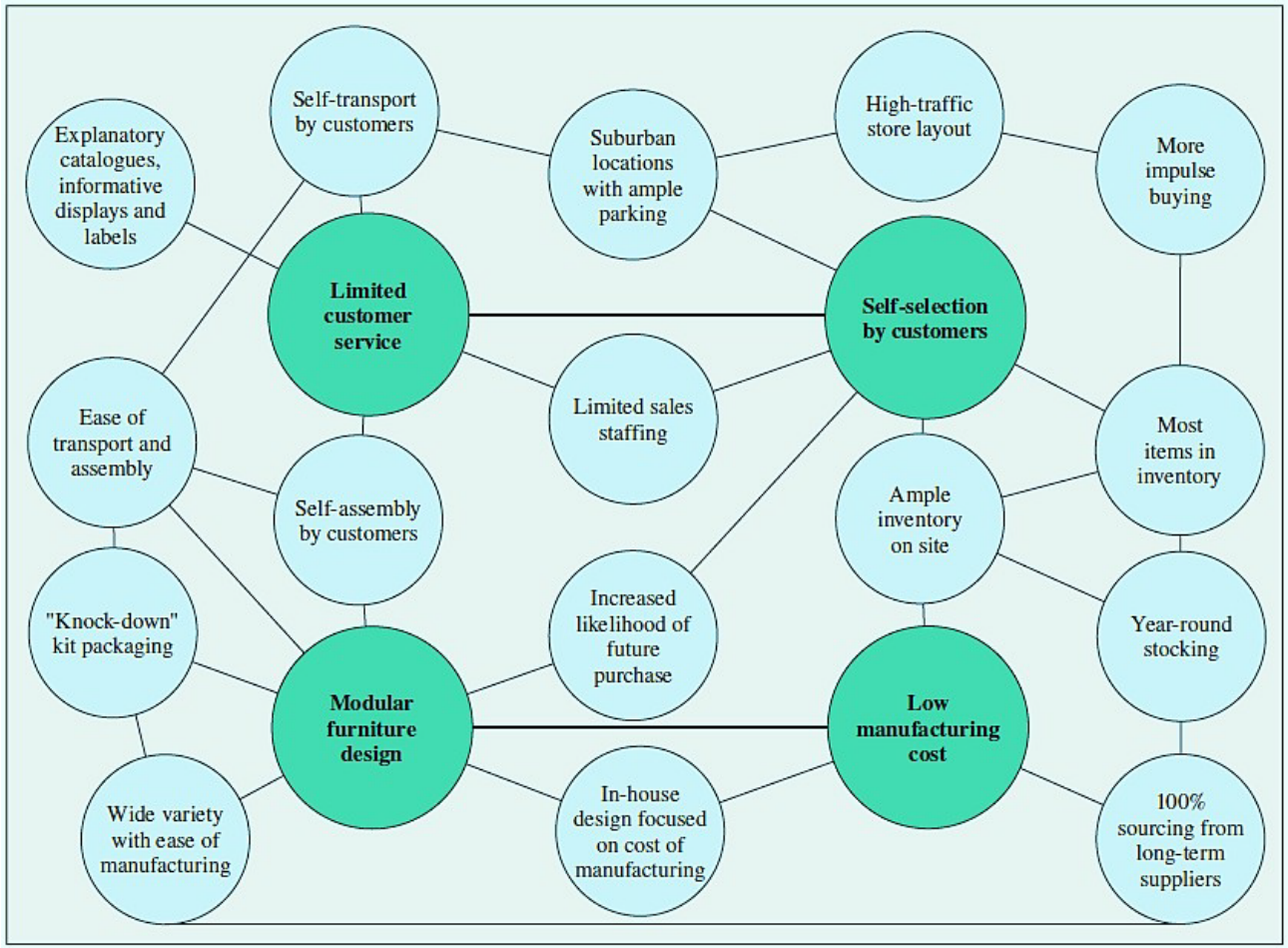
Kano Model



Strategies are Implemented Using Operations and Supply Chain Activities

- All operations activities relate to one another
- To be efficient, the firm must minimize total cost without compromising customers' needs
- Consider GAME
  - Targets low cost buyers
  - Displays assembled product for viewing
  - Sells low-cost, modular, ready-to-assemble furniture
  - Stores stock the products in boxes
  - Customers pick their own boxes from shelves

Activity-system maps



Assessing Risk Associated with OSCM Strategy

- All strategies have an inherent level of risk
  - Uncertainty in the environment causes supply chain planners to evaluate the relative riskiness of their strategies

- **Supply chain risk**: the likelihood of a disruption that would impact the ability of a company to continuously supply products or services
  1. Supply chain coordination risks are associated with the day-to-day management of the supply chain
  2. Disruption risks are caused by natural or manmade disasters

Supply Chain Risk Examples

- Corona Virus
- Corruption risk
  - can occur at any point along the supply chain
- Load shedding – Stages 1- 5
  - Mining industry - supply reliance on Eskom on their ability to self-generate.

Supply Chain Risk Examples

	Supplier-Related	Internal	Customer-Related
Disruptions	▪ Supplier of a key part shuts down plant for a month or at a key part of the production cycle ▪ Supplier capacity drops by 20% overnight	▪ Key plant shuts down unexpectedly for one month ▪ Capacity at a key plant drops by 20% overnight	▪ Demand goes up by 20% ... for all products ... for a key product ... across the board ▪ Demand goes *down* by 20% under conditions above
Delays	▪ Purchase orders of key parts or raw materials delayed by month	▪ Distribution or production orders delayed by a month	▪ Customer orders delayed by a month
Systems	▪ Supplier's order-entry system goes down for a week	▪ Key customer's procurement system inside your company goes down for a week ▪ Company's inventory/accounts system goes down for a week	▪ Order entry system not working for a week ▪ Key customer's procurement system inside your company goes down for a week ▪ Credit card information stolen from hacked e-commerce system
Information Processing	▪ Supplier rations supplies by 20% ▪ Supplier increases minimum order size by 20% then 100%	▪ To take advantage of volume discounts, company begins to order in quantities twice as large as usual, but half as frequently, which impacts supplier's ability to forecast	▪ Key customer begins to order in batches that are twice as large as usual but less frequent (the impact of forecasting)
Intellectual Property	▪ Key supplier redesigns parts and creates own product		
Procurement	▪ Supplier delays in processing returns by twice as long ▪ Supplier forced to increase price of key components by 20% ▪ Transportation costs go up 20% overnight	▪ Unforeseen cash squeeze requires month-long delays in paying key suppliers	
Receivables			▪ Key customer withholds payments one month longer than usual ▪ 20% of receivable payments delayed by one month

https://sloanreview.mit.edu/article/managing-risk-to-avoid-supplychain-breakdown/.

Risk Mitigation Framework

1. Identify the sources of potential disruptions
   - Focus on highly unlikely events that would cause a significant disruption to normal operations
2. Assess the potential impact of the risk
   - Here the goal is to quantify the probability and the potential impact of the risk
   - Could be based on financial impact, environmental impact, ongoing business viability brand image/reputation, potential human lives, and so on
3. Develop plans to mitigate the risk
   - A detailed strategy for minimizing the impact of the risk could take many different forms, depending on the nature of the problem

Risk Assessment

Risk Assessment

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Activity:

Venue:

Risk type	Risk description	Severity	Likelihood	Risk score	Action type	Action	Notes

Version 1.0

Signed: Date: 2022/03/10 Revision date: 2017/02/17

Risk Mitigation Strategies

Risk	Risk Mitigation Strategy
Natural disaster	Contingency planning (alternate sites, etc.) insurance
Country risks	Hedge currency, produce/source locally
Supplier failure	Use multiple suppliers
Network provider failure	Support redundant digital networks
Regulatory risk	Up-front and continuing research; good legal advice, compliance
Commodity price risks	Multisource, commodity hedging

Risk Mitigation Strategies Continued

Risk	Risk Mitigation Strategy
Logistics failure	Safety stock, detailed tracking and alternate suppliers
Inventory risks	Pool inventory, safety stock
Major quality failure	Carefully select and monitor suppliers
Loss of customers	Service/product innovation
Theft and vandalism	Insurance, security precautions, knowledge of likely risks, patent protection, etc.

Risk Assessment Matrix

	Natural/ manmade disasters	Country risks	Supplier failure	Network provider failure	Regulatory risk	Commodity price risks	Logistics failure	Inventory risks	Quality risks
Outsourcing									
Sole sourcing									
Lean practices									
Distribution hubs									

High impact

Moderate impact

Exhibit 2.4 (Partial)

Productivity Measurement

- Productivity is a measure of how well resources are used
- $Productivity = \frac{Outputs}{Inputs}$
- Productivity is a relative measure
  - Must be compared to something else to be meaningful
    - Operations can be compared to each other
    - Firms can be compared to other firms or themselves over time
- Partial productivity measures compare output to a single input
- Multifactor productivity measures compare output to a group of inputs
- Total productivity measures compare output to all inputs

Partial Measures of Productivity

Business	Productivity Measure
Restaurant	Customers (meals) per labor hour
Retail store	Sales per square foot
Chicken farm	Pounds of meat per pound of feed
Utility plant	Kilowatt hours per ton of coal
Paper mill	Tons of paper per cord of wood

Summary

- A strategy that is sustainable needs to create value
- Shareholders are equity owners in the company
- Stakeholders are individuals and organizations that are influenced by the firm
- Operations and supply chain strategy involves setting the broad policies for using a firm's resources
  - Coordinates operational goals with those of the larger organization
- Strategies are implemented through a set of activities designed to deliver products and services in a manner consistent with the firm's overall business strategy
- Operations and supply chain strategies need to be evaluated relative to their riskiness
- Supply chain disruptions are unplanned and unanticipated events that disrupt the normal flow of goods and materials
  - Supply chain coordination risks and disruption risks
- Productivity measures are used to ensure that the firm makes the best use of its resources

Practice Exam

1. A strategy that is designed to meet current needs without compromising the ability of future generations to meet their needs
2. The three criteria included in a triple bottom line
3. The seven operations and supply chain competitive dimensions
4. It is probably most difficult to compete on this major competitive dimension
5. This occurs when a company seeks to match what a competitor is doing while maintaining its existing competitive position

Practice Exam Continued

6. A criterion that differentiates the products or services of one firm from those of another
7. A screening criterion that permits a firm's products to be considered as possible candidates for purchase
8. A diagram showing the activities that support a company's strategy
9. A measure calculated by taking the ratio of output to input

CHAPTER 11: PROCESS MAPPING AND ANALYSIS

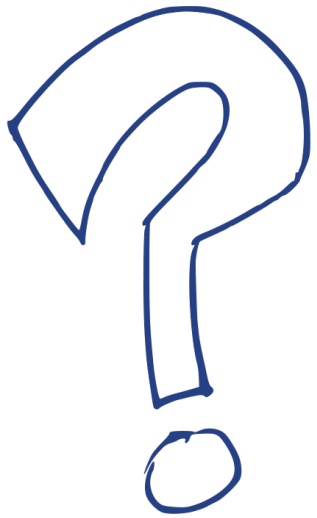
LO11–1: Evaluate why it is important to map processes.

LO11–2: Compare different types of processes.

LO11–3: Explain how jobs are designed.

LO11–4: Analyze manufacturing, service, and logistics processes to ensure the competitiveness of a firm.

What is a process?



Process Analysis

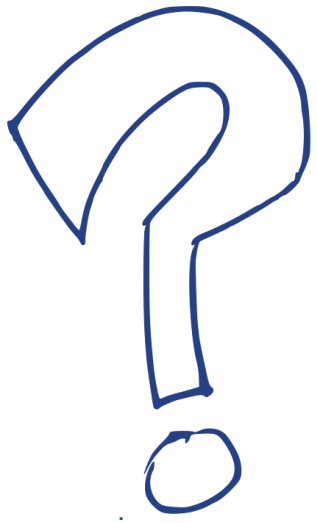
- **Process**: any part of an organization that takes inputs and transforms them into outputs
  - A process that does not match the needs of the firm will punish the firm every minute that the firm operates
- The output of many processes are services

Some inputs are transformed resources

Some inputs are transforming resources

Outputs are products and services that add value for customers

Why do we map processes?



Why do we map processes?

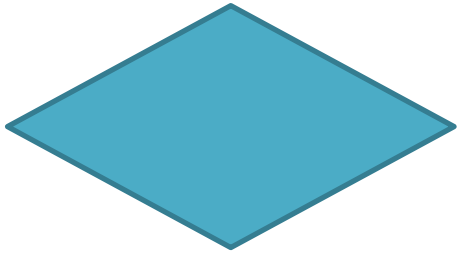
- Understand current processes
- Identify wasteful activities
- Identify relationships and process dynamics
- Design and Anticipate effects of new processes
- Forecast resource requirements

Why do we map processes?

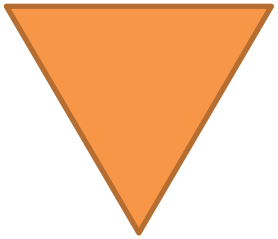
- Standardisation
- Maintain process quality (e.g. ISO9000)
- Highlight deviations and process quality issues
- Provide a foundation for improvement

Flowchart Elements

Task or operation



Decision point

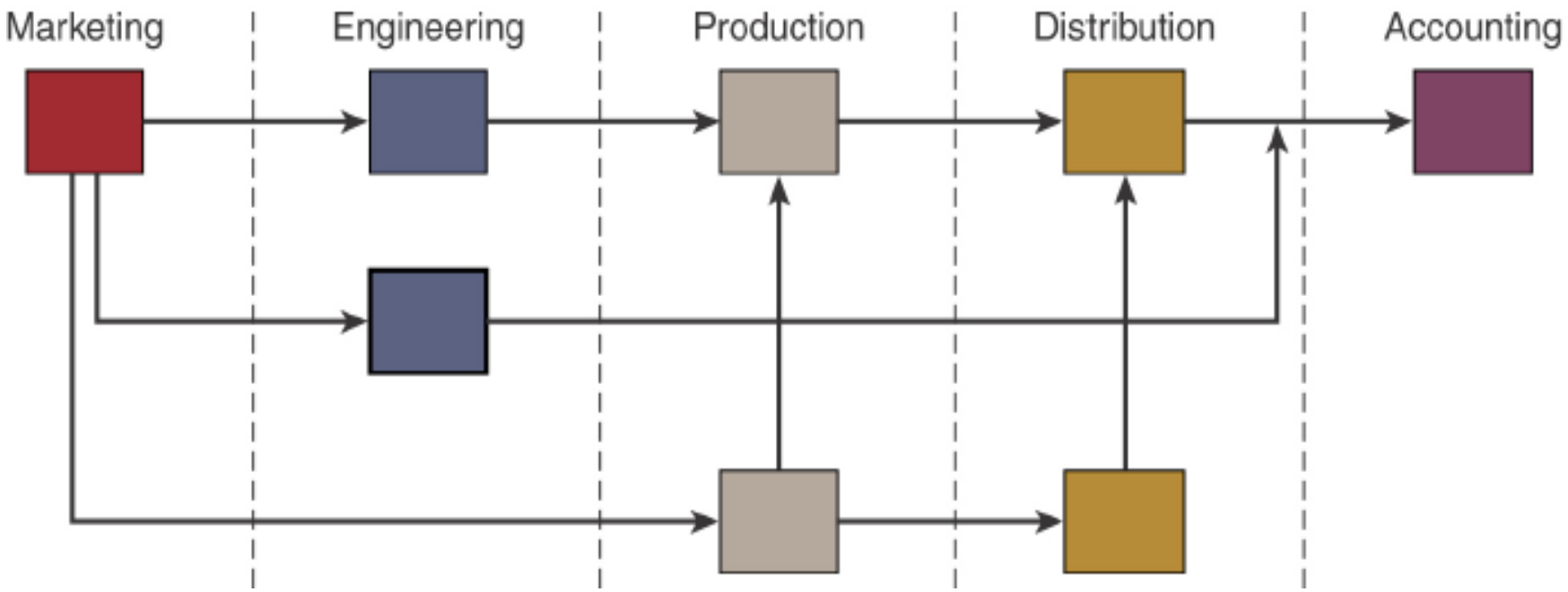


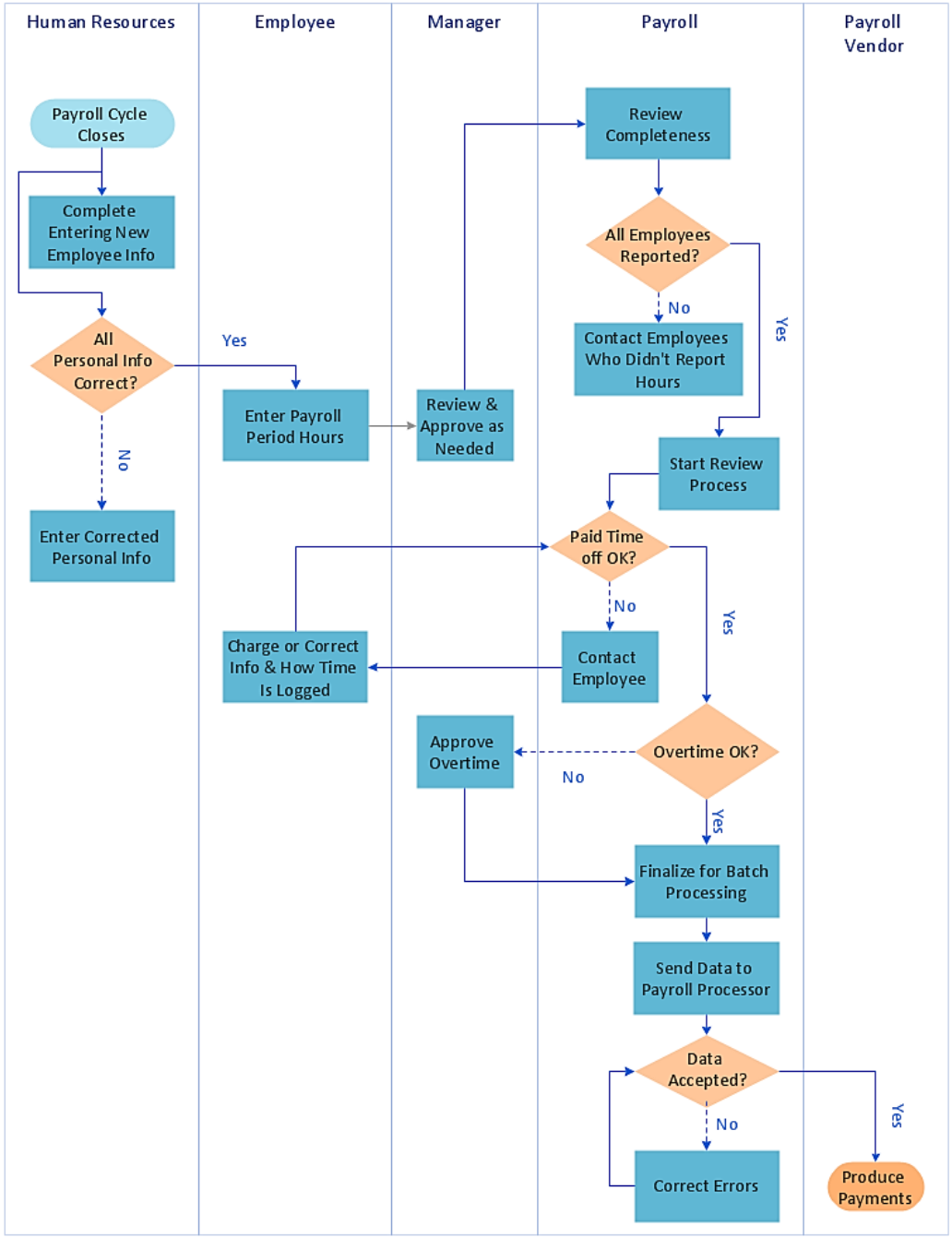
Queue or stockpile

Material or customer flow

Mapping by Functional Area

- Separating a diagram into different horizontal or vertical bands (functional area) is useful.
- It is an ideal methodology by which to begin analyzing a process





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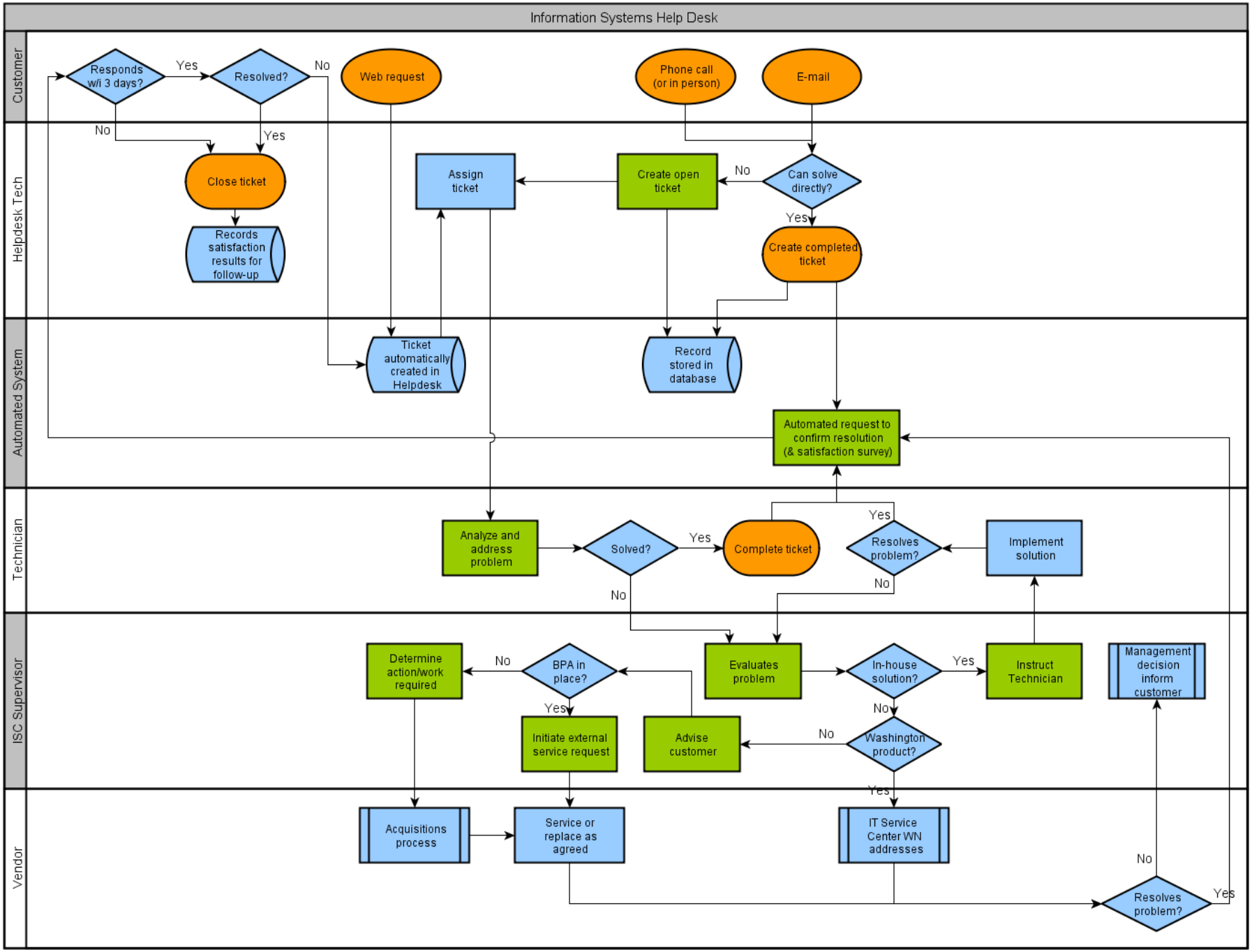

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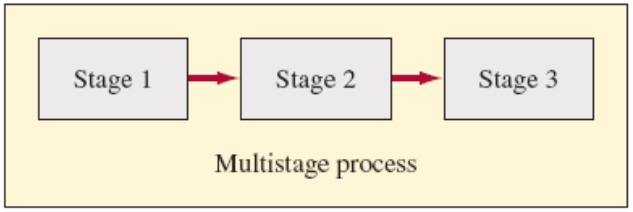
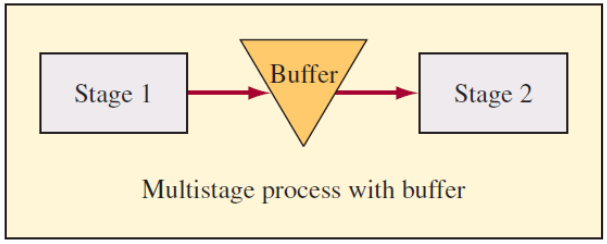
Types of Processes

- One way to categorize a process is single-stage or multiple-stage
- **Single-stage**: all of the activities could be collapsed and analyzed using a single cycle time to represent the speed of the process
- **Multiple-stage**: has multiple groups of activities that are linked through flows
- **Stage**: multiple activities that have been pulled together for analysis purposes



Buffering, Blocking, and Starving

- **Buffer**: a storage area between stages where the output of a stage is placed prior to being used in a downstream stage
- **Blocking**: occurs when the activities in a stage must stop because there is no place to deposit the item
- **Starving**: occurs when the activities in a stage must stop because there is no work
- **Bottleneck**: stage that limits the capacity of the process



Multistage process with buffer

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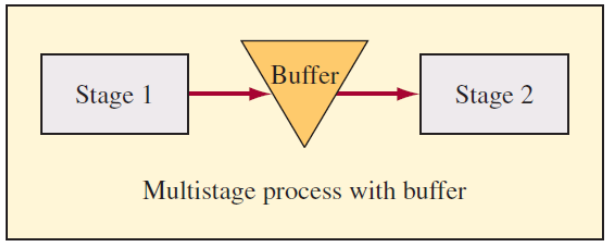
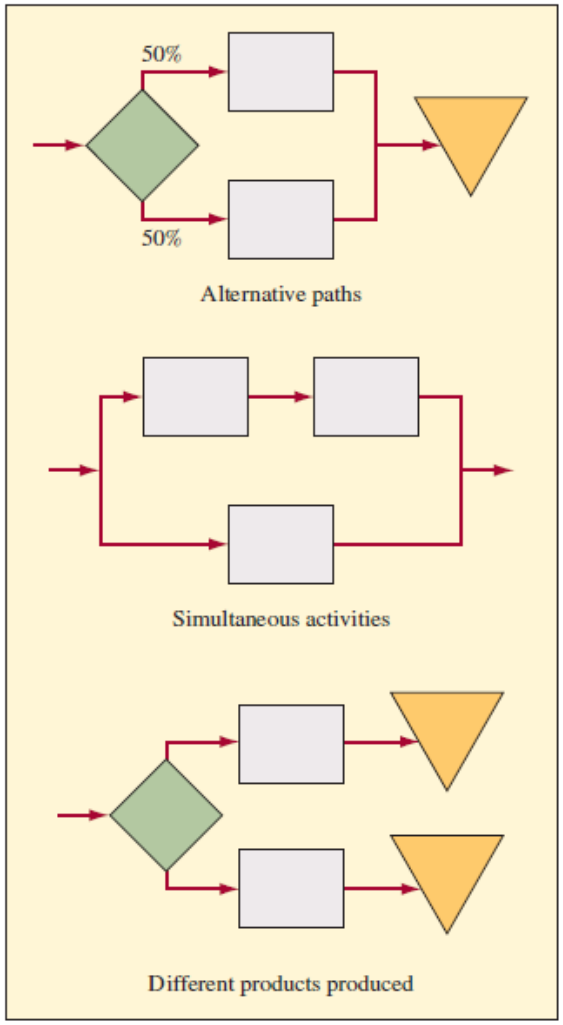


Multistage process with buffer

Process Concepts



Make-to-Stock versus Make-to-Order

Make-to-order

- Only activated in response to an actual order
- Both work-in-process and finished goods inventory kept to a minimum
- Response time is slow

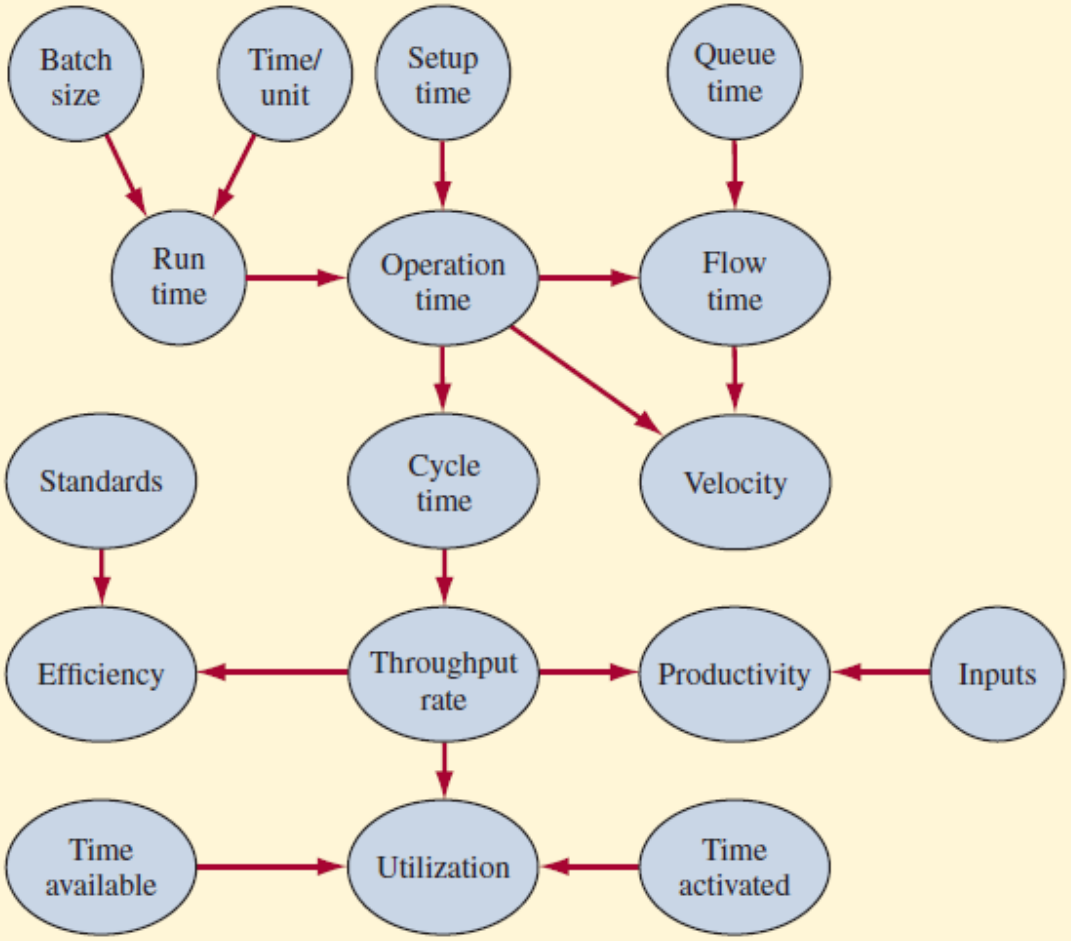
Make-to-stock

- Process activated to meet expected or forecast demand
- Customer orders are served from target stocking level

Hybrid

- Combines the features of both make-to-order and make-to-stock

Measuring Process Performance



$$\text{Operation time} = \text{Setup time} + \text{Run time}$$

$$\text{Flow time} = \text{Average time for a unit to move through the system}$$

$$\text{Velocity} = \frac{\text{Value-added time}}{\text{Flow time}}$$

$$\text{Cycle time} = \text{Average time between completion of units}$$

$$\text{Throughput rate} = \frac{1}{\text{Cycle time}}$$

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Standard output}}$$

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

$$\text{Utilization} = \frac{\text{Time activated}}{\text{Time available}}$$

Exhibit 11.3

Measuring Process Performance Terms

- **Cycle time**: the average successive time between completions of successive units
- **Throughput Time:** Time for unit to move through system
- **Throughput Rate:** the output rate that the process is expected to produce over a period of time
- **Utilization**: the ratio of the time that a resource is actually activated relative to the time that it is available for use
- **Run time**: is the time required to produce a batch of parts

Measuring Process Performance Terms
Continued

- **Setup time**: the time required to prepare a machine to make a particular item
  - In practice, setup time is often not included in the utilization of the process
- **Operation time**: the sum of the setup time and run time for a batch of parts that are run on a machine
- **Flow time**: includes the time the unit spends actually being worked on, together with the time spent waiting in a queue
  - In practice, the term cycle time is often used to mean flow time
- **Value-added time**: the time in which useful work is actually being done on the unit

Job Design Decisions

- **Job design**: the function of specifying the work activities of an individual or group in an organizational setting
- Objective is to develop job structures that meet the requirements of the organization and its technology
  - Also that satisfy the jobholders' personal and individual requirements
- Work measurement methods are used to determine the most efficient means of performing a given task, as well as to set reasonable standards for performing it

Behavioral Considerations in Job Design

Specialization of labor

- Made high-speed, low-cost production possible
- Greatly enhanced standard of living
- Adverse effects on workers

Job enrichment

- Making job more interesting to the worker
- **Horizontal enrichment**: worker performs a greater number of variety of tasks
- **Vertical enrichment**: worker is involved in planning, organizing, and inspecting work

Four Basic Work Measurement Techniques

- Direct methods
  1. Time study: uses a stopwatch to time the work
  2. Work sampling: entails recording random observations of a person or teams at work
- Indirect methods
  3. Predetermined motion-time data system: sums data from tables of generic movement times developed in the laboratory to arrive at a time for the job
  4. Elemental data: sums times from a database of similar combinations of movements to arrive at job time

Summary

- A process takes inputs and transforms them into outputs that create value for the organization
  - A company may have literally thousands of different processes
- Understanding a process usually starts with a flowchart
- With multistage process, it is useful to buffer the activities by placing inventory between the activities
- The bottleneck is the activity or stage that limits the capacity of the process
- A process that is only activated after an actual order arrives is called make-to-order
- Make-to-stock processes supply inventory from which actual customer orders are filled
- Job design is the study of how work activities are designed for workers

Questions

1. This is a part of an organization that takes inputs and transforms them into outputs
2. This is the ratio of the time that a resource is activated relative to the time it is available for use
3. This is when one or more activities stop because of a lack of work.
4. This is when an activity stops because there is no place to put the work that was just completed.
5. This is a step in a process that is the slowest compared to the other steps
   - This step limits the capacity of the process
6. This refers to the fixed timing of the movement of items through a process

Questions

7. This is the time it takes a unit to travel through the process from beginning to end. It includes time waiting in queues and buffers.
8. This is when a job is increased vertically or horizontally.
9. What are the four basic work measurement techniques?

CHAPTER 14: VALUE STREAM MAPPING

LO14–1: Analyze supply chain processes using value stream mapping.

i. Describe the basic building blocks of a value stream map

ii. Define a step–by-step approach for creating current and future state maps

iii. Provide tips for creating VSM

LO14–2: Introduce lean concepts.

Lean Production

- Specify what creates ***value*** from the customers perspective
- Identify all *value-added(VA)* steps across the whole ***value stream*** ,eliminating *non-value added(NVA)* steps
- Make those actions that create value ***flow***
- Only make what is ***pulled*** by the customer just-in-time
- Strive for ***perfection*** by continually removing successive layers of waste

Value added vs. Non-value added: Examples

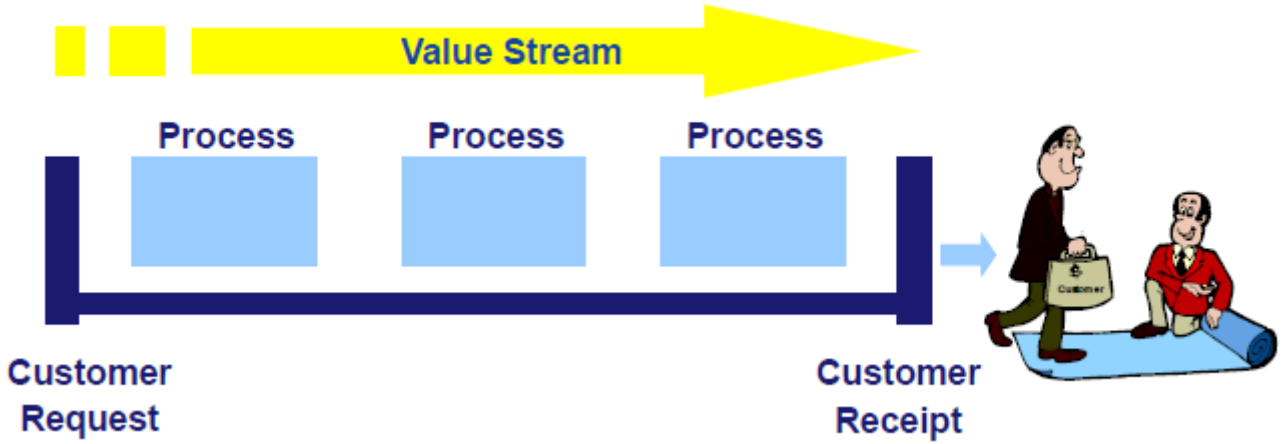
Department	Role	VA Activity	NVA Activity
Operating Room	Surgeon	Operating on patient	Waiting for delayed procedure or performing unnecessary procedure
Pharmacy	Pharmacy technician	Creating an intravenous formulation	Reprocessing medications that were returned from patient units
Inpatient unit	Nurse	Administering medications to a patient	Copying information from one computer system to another
Radiology	Radiology technician	Performing magnetic resonance imaging procedure	Performing medically unnecessary procedure
Laboratory	Medical technologist	Interpreting test result	Fixing broken instrument

Value added vs. Non-value added: Examples

Department	"Product"	VA Activity	NVA Activity
Emergency room	Patient	Being evaluated or treated	Waiting to be seen
Clinical laboratory	Patient specimen	Being centrifuged or tested	Waiting to be moved as a batch
Pharmacy	Prescription	Medication being formulated or prepared	Being inspected multiple times
Perioperative services	Sterilized instruments	Time when instruments are being sterilized	Instruments being sterilized repeatedly without ever being used from a standard kit
Nutrition services	Patient food tray	Time when food is being cooked and tray is being assembled	Being reworked because tray was done incorrectly

Value Stream Defined as

- Value Stream: All of the activities, required to fulfill a customers request from order to delivery (and beyond to cash received



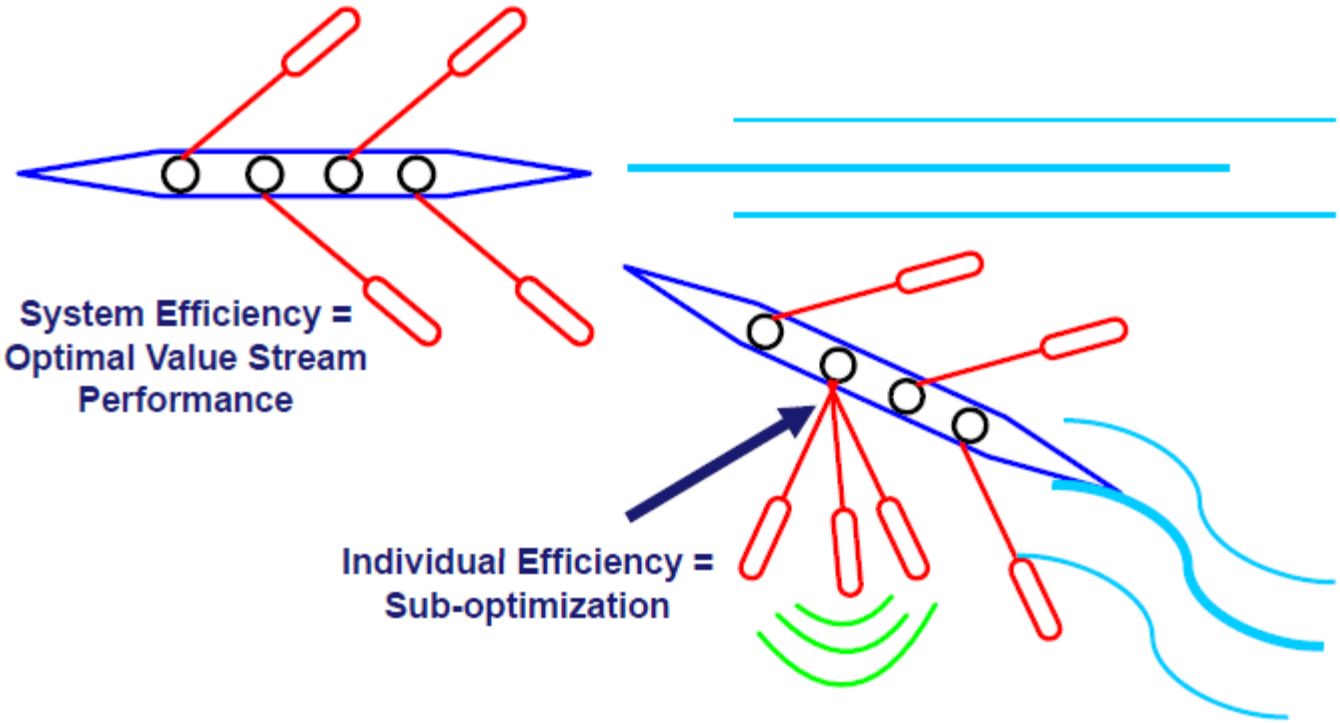
Value Stream Map (VSM)

- A tool used to improve a process by identifying added value and eliminating waste
- A process map that follows the value creation process
  - “strap yourself to the product (or service) and see where you go”
- A process map with data added
  - Times: processing, wait, cycle
  - Quality: number of rejects
  - Inventory
  - Resources
    - Number of people
    - Space
    - Distance travelled
- Whatever else is useful for analysing the process

Why Value Stream Mapping?

- To set a strategy before dividing into tactics
  - The future state VSM is a macro level blueprint for change; road map
- Enables us to SEE the process
- Promotes system thinking/seeing the whole
  - Helps us avoid sub-optimizing

VSM Goal: Systems Efficiency



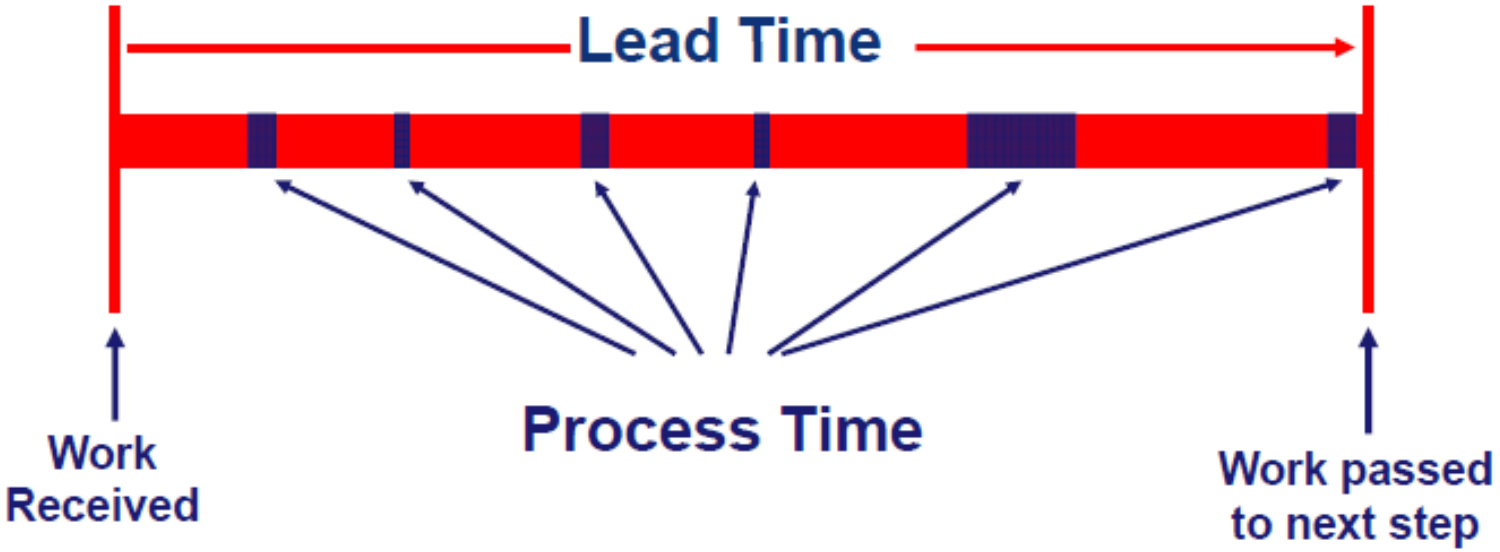
Why Value Stream Mapping? (Cont..)

- Shows the linkage between information and material flow
- Makes the disconnects and obstacles to flow visible at a *macro level*
- Metrics-based decision making:
  - What are you going to do to affect numbers?

Key Metrics: Time

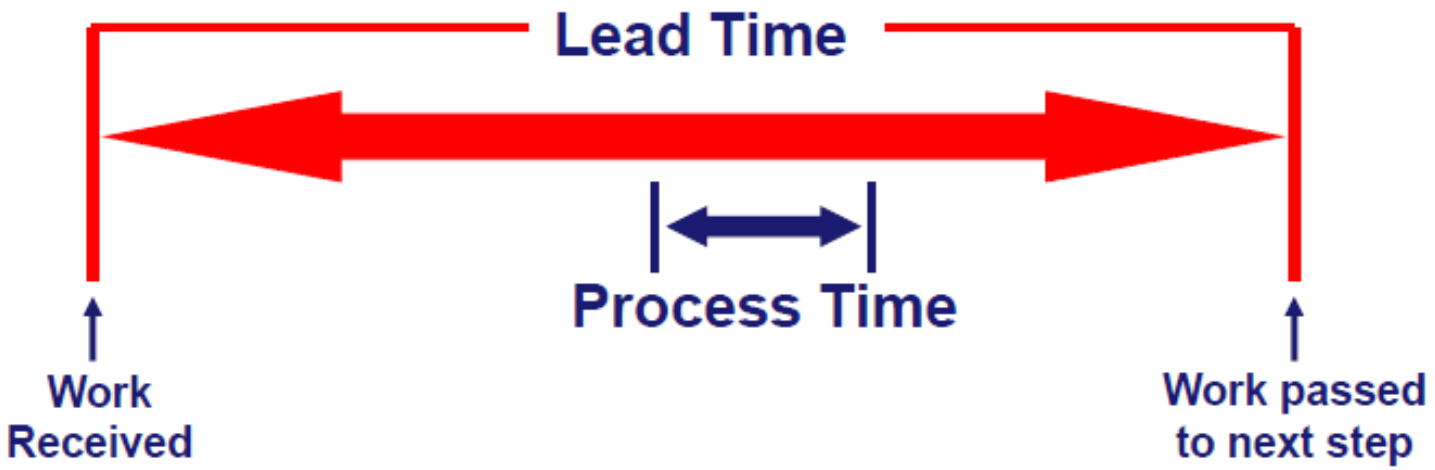
- Process time (PT)
  - The time it takes to actually perform the work, if one is able to work on it uninterrupted
  - Includes task-specific doing, talking, and thinking
  - aka "touch time," work time, cycle time
- Lead time (LT)
  - The elapsed time from the time work is made available until it's completed and passed on to the next person or department in the chain
  - aka throughput time, turnaround time, elapsed time
  - Includes Process Time, not merely waiting time.

Lead Time vs. Process Time (Scenario 1)



LT = PT + Waiting / Delays

Lead Time vs. Process Time (Scenario 2)



LT = PT + Waiting / Delays

Key Metrics: Time

- Takt Time = Demand Rate
  - Pace of processing to match pace of customer need.
  - Rate for completing work based on customer need.
  - Takt time = $\frac{\text{Effective working time per shift}}{\text{Customer requirement per shift}}$
  - One eight hour shift over which 30 patients where administered treatment.
    - 420 minutes/30 patient visits = 14 minutes per patient
  - What resources will be needed to meet demand?

VSM Abbreviations

- C/O – changeover time or setup time to begin new task
- P/T (C/T) – process or cycle time = time to complete a task
  - VAT – value-added time or the time needed to complete a required task
  - NVA – non-value-added time = PT – VAT
- W/T – wait or queue time for next process step to begin
- L/T – lead time, or the total time from when a task is started within a work center until it leaves work center.
- FTQ or FTT – First time quality or first time through quality yield

- Note: Service time units: seconds, minutes, hours, days, months > depends on application

Steps for Creating a VSM

- Define customer value and the process
  - “Walk” the process to identify tasks and flows
  - Identify value-added and waste process steps
- Create the “current state” VSM
  - Gather data on resources, time, quality for each step
- Analyse map to determine opportunities for improvement
  - Identify bottlenecks and other flow impediments
  - Brainstorm actions to eliminate waste and add value
- Create a “future-state” map to visualize the desired and realistic next state
- Create action plans to move toward future state

Value Stream Mapping Symbols

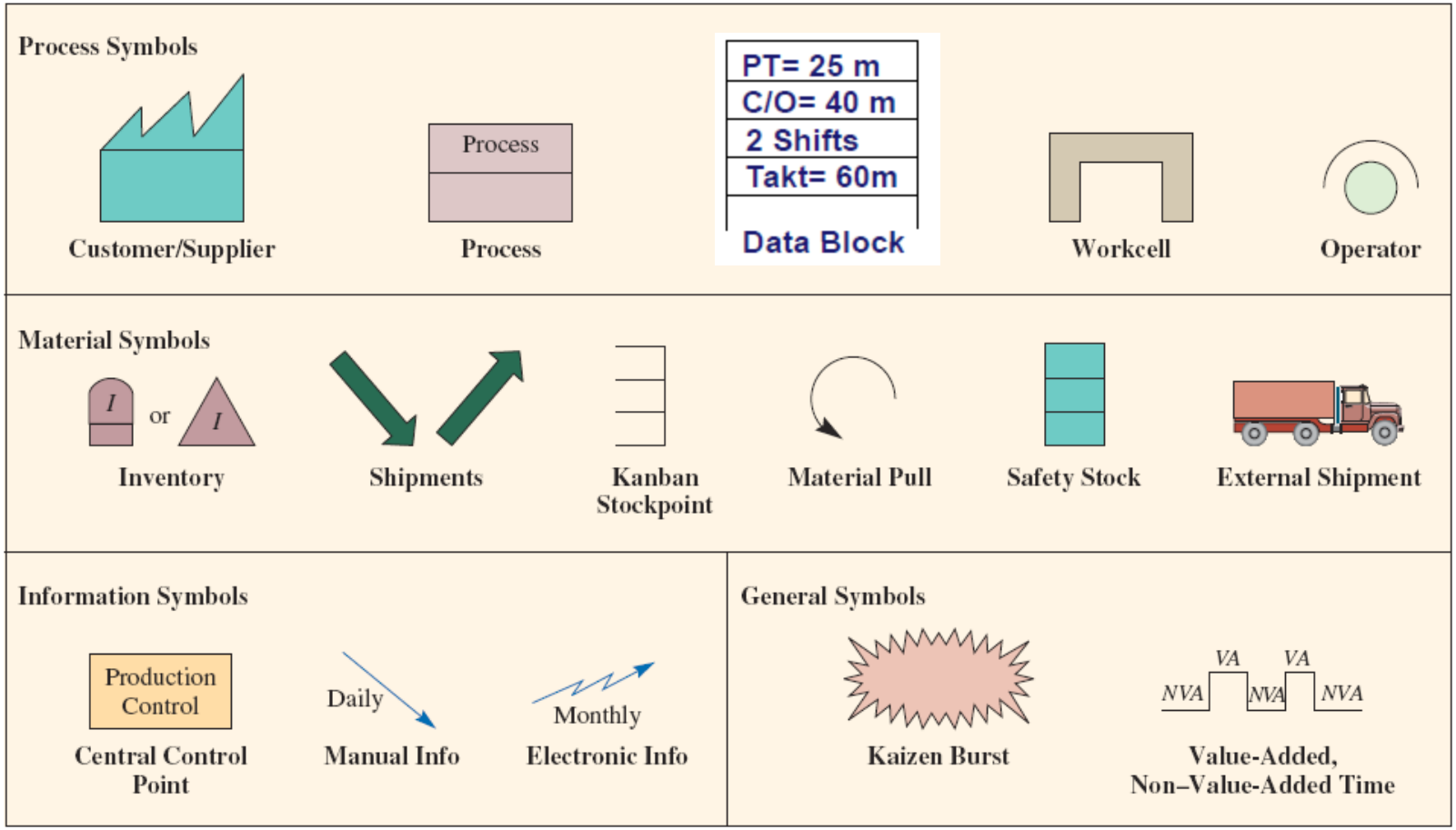


Exhibit 14.3

Manufacturing Process Map

Current State Map

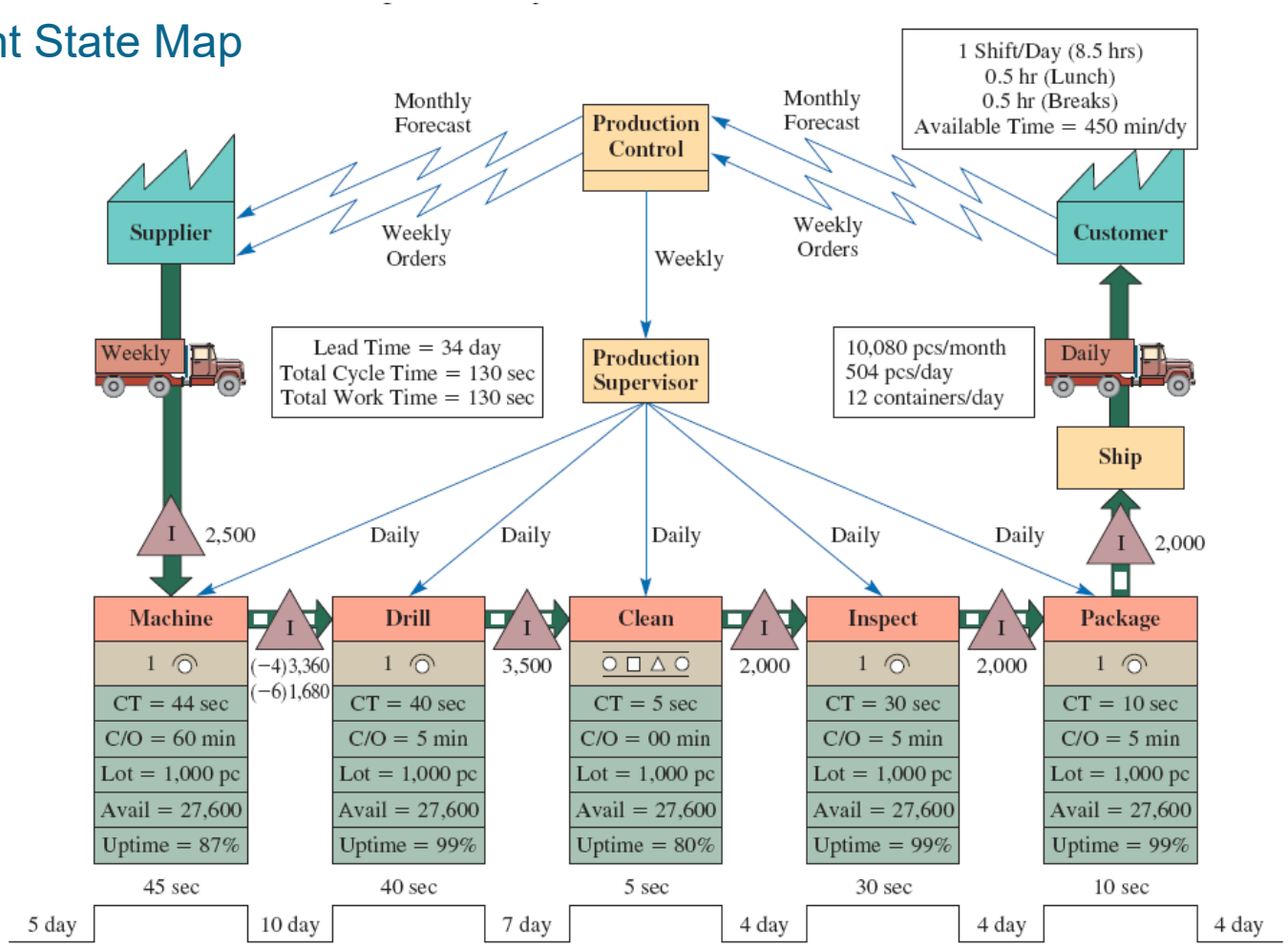
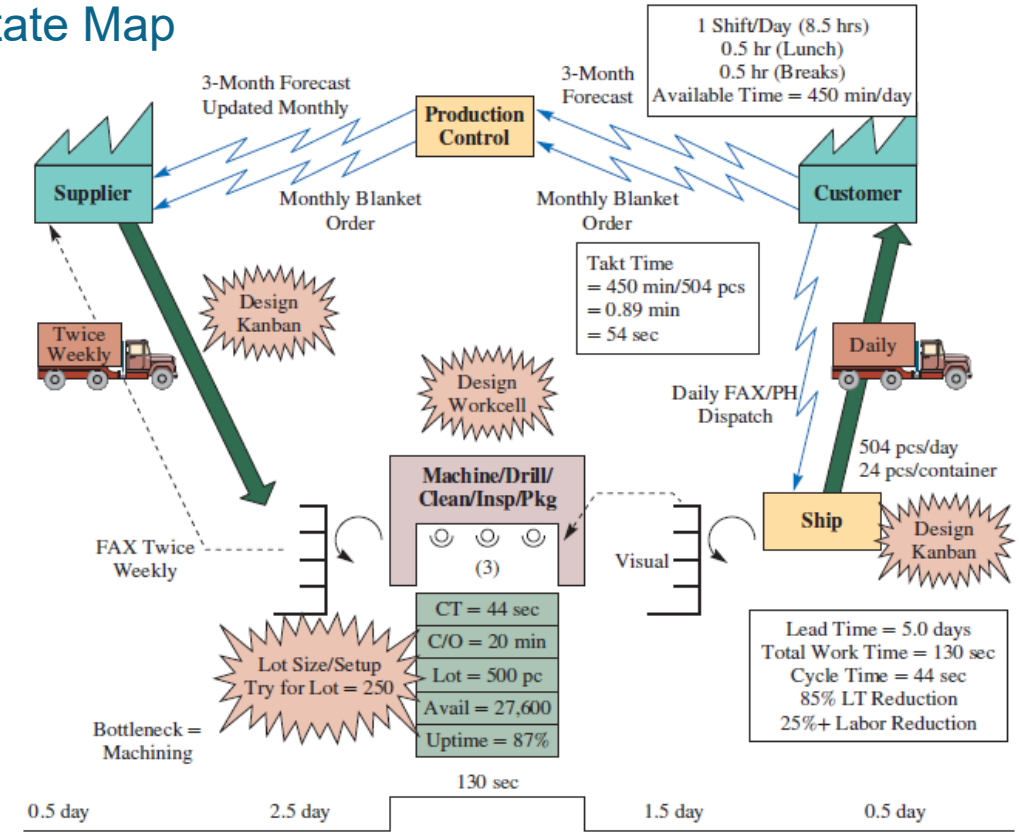


Exhibit 14.2

Manufacturing Process Map

Future State Map



Kaizen is the Japanese philosophy that focuses on continuous improvement. The Kaizen bursts identify specific short-term projects (often referred to as “Kaizen events”) that teams work on to implement changes to the process.

Exhibit 14.2

Tips for Creating a VSM

- Involve entire team
- Actually walk the process - follow the material and information through the process, starting at the beginning
- Use Post-it notes and butcher paper
- Use symbols or icons that are meaningful to the process but common enough to be understood by all involved

Summary

- Lean production involves improving processes by eliminating waste (non–value-adding activities)
  - Muda (waste), Muri (overburden) and Mura (unevenness)
- Lean concepts can be applied to virtually all the processes in the supply chain
  - Key areas include production layout, the scheduling of production, and the design of the supply chain
- Value stream mapping is a flowcharting tool used to visualize flows through a process
  - The goal is to identify ways to “lean” a process by eliminating waste and creating value for the customer
- Lean concepts can be successfully applied by all organizations.

CHAPTER 11: PROCESS ANALYSIS

LO11–4: Analyze manufacturing, service, and logistics processes to ensure the competitiveness of a firm.

Pacing

- A process can be either paced or nonpaced
- **Pacing**: having a fixed time for the movement of items through the process
- In a serial process, the movement of items through each activity is often paced in some mechanical way in order to coordinate the line
- Dividing the time available to produce a certain product by customer demand for the product calculates the required cycle time for a process
  - Manufacturer needs to produce 1,000 automobiles
  - A shift is 420 minutes
  - $Cycle\ time = \frac{420\ minutes}{1{,}000\ automobiles} \times 60\ {}^{seconds}/_{minute} = 25.2\ seconds$

Production Process Mapping and Little's Law

Total average value of inventory

- Sum of the value of raw materials, work-in-process, and finished goods inventory

Inventory turns

- Cost of goods sold divided by the average inventory value

Days-of-supply

- Inverse of inventory turns scaled to days

Little's law

- There is a long-term relationship among inventory, throughput, and flow time
- Inventory = Throughput rate x Flow time

What Goes Into a Process Must Come out of the Process

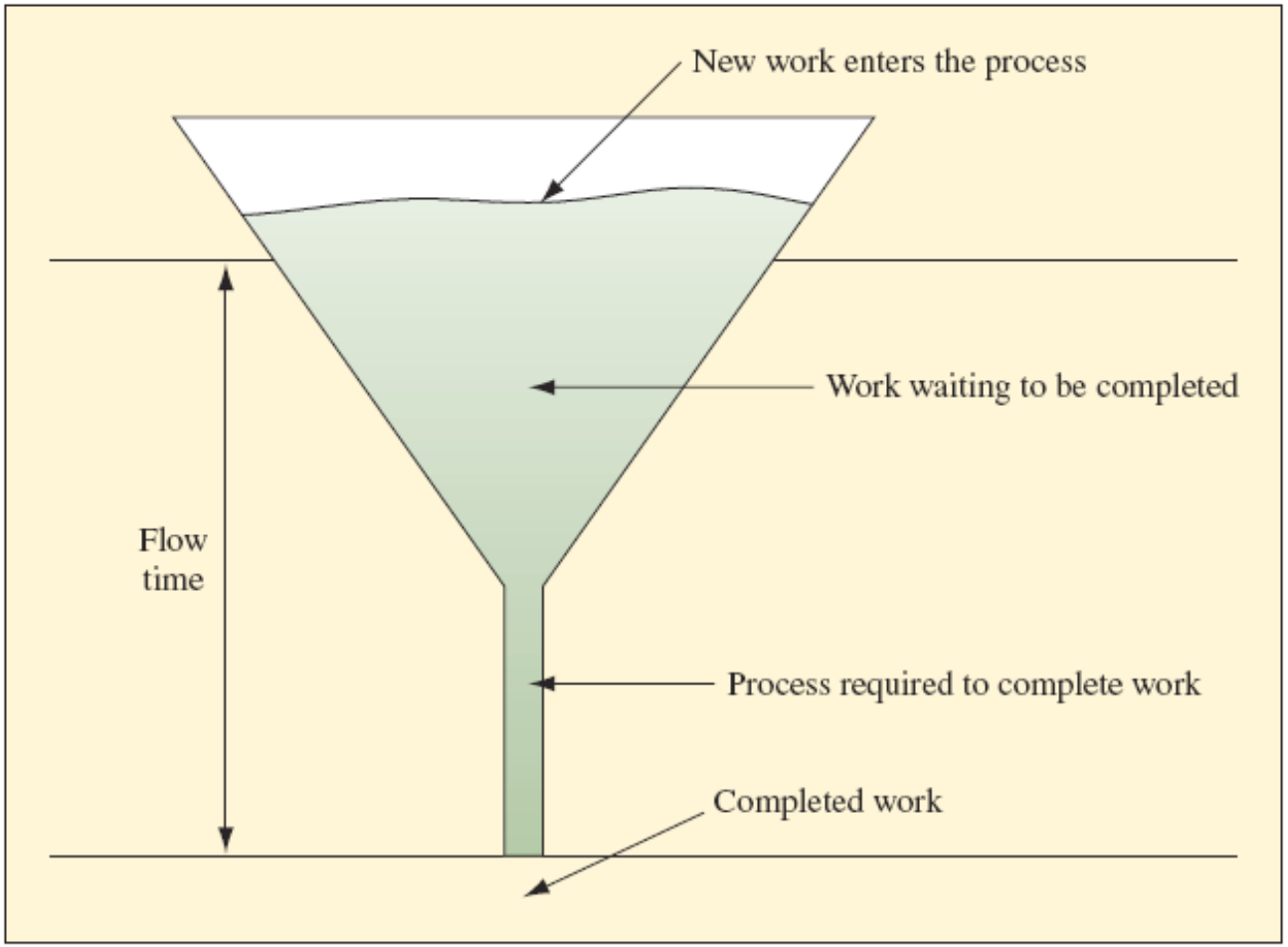


Exhibit 11.6

Example 11.1: Car Batteries

- Average cost $45
- 12 hours to make a car
- Assembles 200 cars per 8-hour shift
  - Currently one shift
- Holds on average 8,000 batteries in raw material inventory

Example 11.1: Average Inventory

- WIP = Throughput x Flow time
- WIP = 25 batteries x 12 hours
- WIP = 300 batteries

- Total = 8,000 + 300 = 8,300 batteries

Example 11.1: Value and Flow Time

- Value = 8,300 x $45 = $373,500

- Flow time = Inventory/Throughput
- Flow time = 8,000/200 = 40 days

Example 11.2: Bread Making

- Two steps are required
  1. Prepare the dough and bake the loaves (bread making)
  2. Packaging the loaves
- Bread is made in batches of 100 loaves
  - Completes a batch every hour, which is the cycle time
  - Slower process so is the bottleneck
- Packaging needs only 0.75 hour to place the 100 loaves in bags
  - Has 75 percent utilization

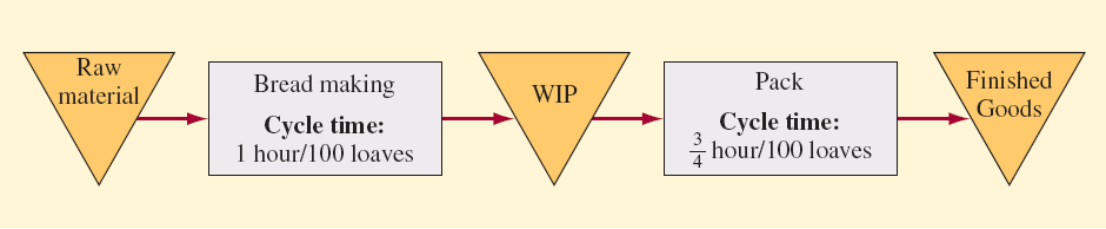


Exhibit 11.5A

Example 11.2: Bread Making

- Suppose we have two bread making lines
  - Cycle time on each is still one hour to make 100 loaves
- Bread making runs two shifts
  - Produces 200 x 8 x 2 = 3,200
- Packaging runs three shifts
  - Produces 133.3 x 8 x 3 = 3,200
- Capacities are roughly equal

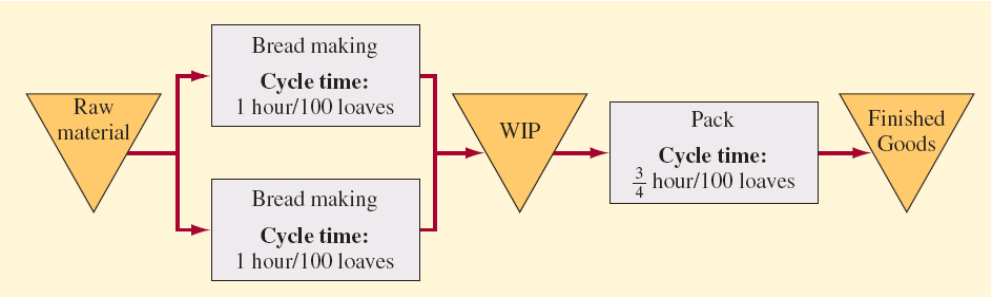


Exhibit 11.5B

Example 11.3: A Restaurant

- Consider the restaurant in the casino
- Managers have set up a buffet arrangement where customers serve themselves
- Buffet is continually replenished to keep items fresh
- To further speed service a fixed amount is charged for the meal
- Customers take an average of 30 minutes to get their food and eat
- They typically eat in groups (or customer parties) of two or three to a table
- The restaurant has 40 tables
  - Each table can accommodate four people
- What is the maximum capacity of this restaurant?

Example 11.3: Solution Approach

- Utilization
  - The restaurant can accommodate 160 people at a time
  - It might be more convenient to measure the capacity in terms of customer parties because this is how the capacity will be used
    - If the average customer party is 2.5 individuals, then the average seat utilization is 62.5 percent when the restaurant is operating at capacity
- Cycle time
  - When operating at capacity, 0.75 minute
    - 30 minutes/40 tables
  - On average, a table would become available every 0.75 minute or 45 seconds
- Capacity
  - The restaurant could handle 80 customer parties per hour
    - 60 minutes/0.75 minute/party

Example 11.3: Challenges in Restaurant Problem

- The problem with this restaurant is that everyone wants to eat at the same time
- Management has collected data and expects the profile below for customer parties arriving during lunch, which runs from 11:30 am until 1:30 pm
- Customers are seated only until 1:00 pm

Time	Parties Arriving
11:30–11:45	15
11:45–12:00	35
12:00–12:15	30
12:15–12:30	15
12:30–12:45	10
12:45–1:00	5
Total parties	110

Example 11.3: Restaurant Continued

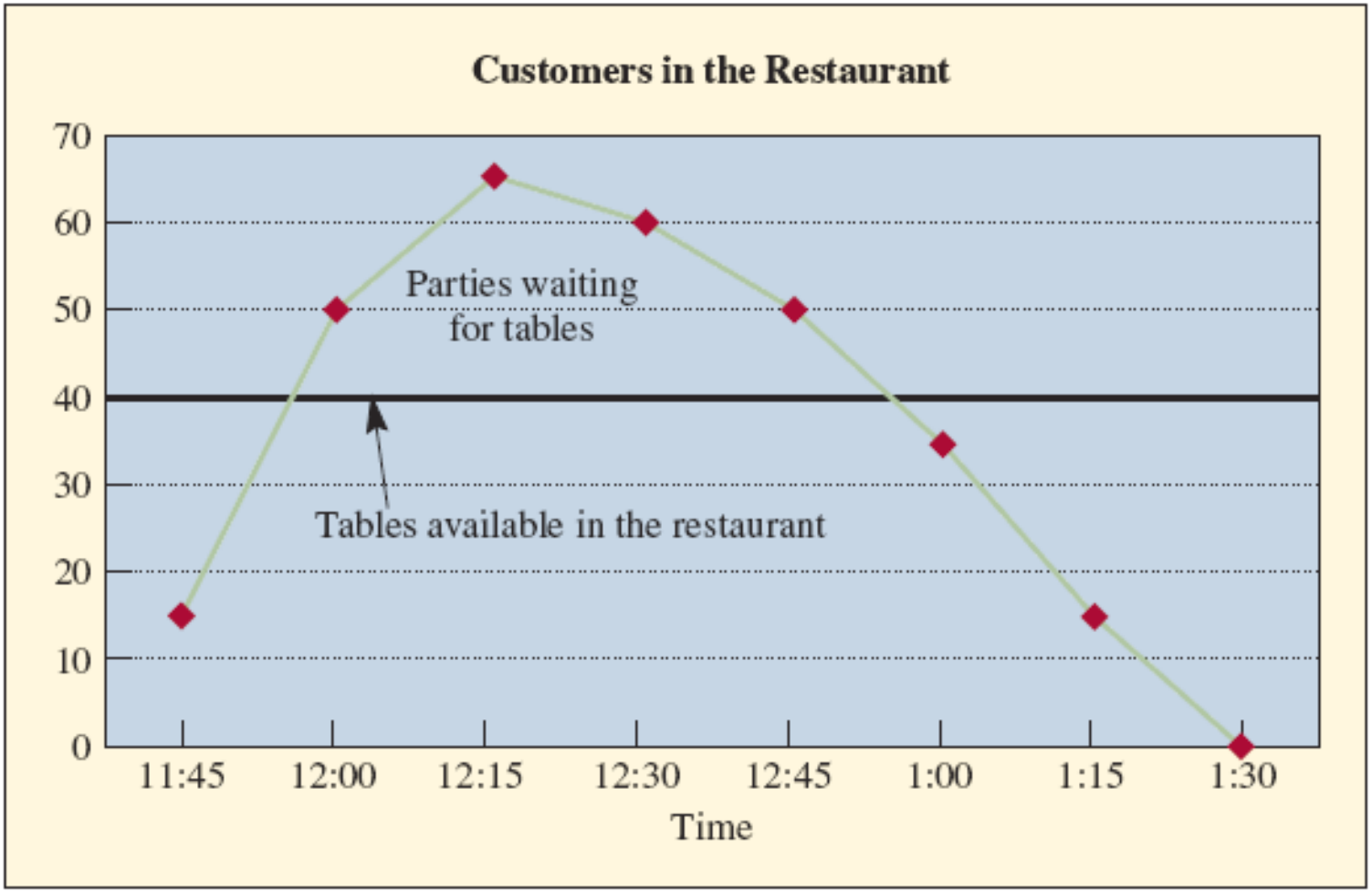
- Restaurant operates for two hours for lunch
- The capacity is 80 customer parties per hour
- A simple way to analyze the situation is to calculate how the system looks at the end of each 15-minute interval
- The key is to look at the cumulative numbers
  - The difference between cumulative arrivals and cumulative departures gives the number of customer parties in the restaurant
- Because there are only 40 tables, when the cumulative difference through is greater than 40, a waiting line forms
- Cycle time for the entire restaurant is 45 seconds per customer party at this time
- The last party will need to wait for all of the earlier parties to get a table, so the expected waiting time is the number of parties in line multiplied by the cycle time

Example 11.3: Restaurant Continued

- In the table below, when the cumulative number of parties is 50, there are 10 parties waiting to be seated
- The average wait time is 10 x 45 seconds = 7.5 minutes
- During 12:00 to 12:15
  - Parties that arrived during 11:30 to 11:45 would have left
  - The cumulative number of parties at the end of 12:15 = 50
    - Number at the end of 12:00 + 30 (arrivals during 12:00 to 12:15) – 15 (departures during 12:00 to 12:15) = 65

Time Period	Parties Arriving during Period (Cumulative)	Parties Departing during Period (Cumulative)	Parties Either at Table or Waiting to Be Served (at End of Period)	Tables Used (at End of Period)	Customer Parties Waiting (at End of Period)	Expected Waiting Time (at End of Period)
11:30–11:45	15	0	15	15		
11:45–12:00	35 (50)	0	50	40	10	7.5 minutes
12:00–12:15	30 (80)	15	65	40	25	18.75 minutes
12:15–12:30	15 (95)	20 (35)	60	40	20	15 minutes
12:30–12:45	10 (105)	20 (55)	50	40	10	7.5 minutes
12:45–1:00	5 (110)	20 (75)	35	35		
1:00–1:30	0 (110)	35 (110)				

Example 11.3: Customers in the Restaurant



Example 11.4: The Balabus ("Tourist Bus") in Paris

- Two hours for the route during peak traffic
- Route has 60 stops
- Each bus has seating capacity of 50
  - Another 30 passengers can stand
- Busy much of the day

Example 11.4: Initial Analysis

- With one bus, maximum wait is two hours
- If bus is halfway through cycle, wait is one hour
- Average wait is one hour
  - In general, average wait is ½ cycle time
- If two buses used…
  - Cycle time is one hour
  - Average wait is 30 minutes
- For a two-minute wait…
  - Need four-minute cycle time
  - Need 30 buses (120 minutes/4 minute cycle time)

Example 11.4: Capacity

- Each bus has total capacity of 80 passengers
  - 50 seated
  - 30 standing
- 30 buses can accommodate…
  - 1,500 seated
  - 2,400 total

Example 11.4: Detailed Analysis

Time	Number of Customers	Average Time on Bus	Load (Passenger Hours)	Minimum Number of Buses Needed	Buses Needed for All Passengers to Be Seated
8:00–9:00 A.M.	2,000	45 minutes	1,500	18.75	30
9:00–10:00 A.M.	4,000	30 minutes	2,000	25	40
10:00–11:00 A.M.	6,000	30 minutes	3,000	37.5	60
11:00 A.M.–12:00 NOON	5,000	30 minutes	2,500	31.25	50
12:00–1:00 P.M.	4,000	30 minutes	2,000	25	40
1:00–2:00 P.M.	3,500	30 minutes	1,750	21.875	35
2:00–3:00 P.M.	3,000	45 minutes	2,250	28.125	45
3:00–4:00 P.M.	3,000	45 minutes	2,250	28.125	45
4:00–5:00 P.M.	3,000	45 minutes	2,250	28.125	45
5:00–6:00 P.M.	4,000	45 minutes	3,000	37.5	60
6:00–7:00 P.M.	3,000	45 minutes	2,250	28.125	45
7:00–8:00 P.M.	1,500	45 minutes	1,125	14.0625	22.5
TOTALS	42,000		25,875		

Example 11.4: Conclusion

- With 30 buses, many will stand
- During morning and afternoon rush, not all customers can be accommodated
  - Need at least 40 buses during rush hours
- With 40 buses all the time…
  - 24,000 seat-hours available
    - 40 buses x 12 hours x 50 seats per bus
  - 25,875 seat-hours needed
    - 107.8 percent utilization
    - 7.8 percent of customers must stand

Process Flow Time Reductions

1. Perform activities in parallel
2. Change the sequence of activities
3. Reduce interruptions

Summary Continued

- Little's law is a mathematical formula that captures the relationship between the amount of inventory of all types in the process
- Job design is the study of how work activities are designed for workers
- A key design decision is the amount of specialization that a job entails
- Trade-offs exist between the quality and relative productivity of a process
- A fundamental concept is that what goes into a process must come out of the process in some form
- Coordinating the inputs and outputs is important to having a good process

CHAPTER 16: GLOBAL SOURCING AND PROCUREMENT

LO16–1: Explain what strategic sourcing is.

LO16–2: Explain why companies outsource processes.

LO16–3: Analyze the total cost of ownership.

Strategic Sourcing

- **Strategic sourcing**: the development and management of supplier relationships to acquire goods and services in a way that aids in achieving the immediate needs of the business
- In the past, sourcing was another name for purchasing
- As a result of globalization, sourcing implies a more complex process suitable for products that are strategically important

Strategic Sourcing Continued

- **Specificity**: refers to how common the item is and, in a relative sense, how many substitutes might be available
  - Commonly available products can be purchased using a relatively simple process
- **Request for proposal (RFP)**: used for purchasing items that are more complex or expensive and where there may be a number of potential vendors
- **Vendor-managed inventory**: when a customer actually allows the supplier to manage an item or group of items for them (given freedom to replenish as they see fit)

Sourcing Design Matrix

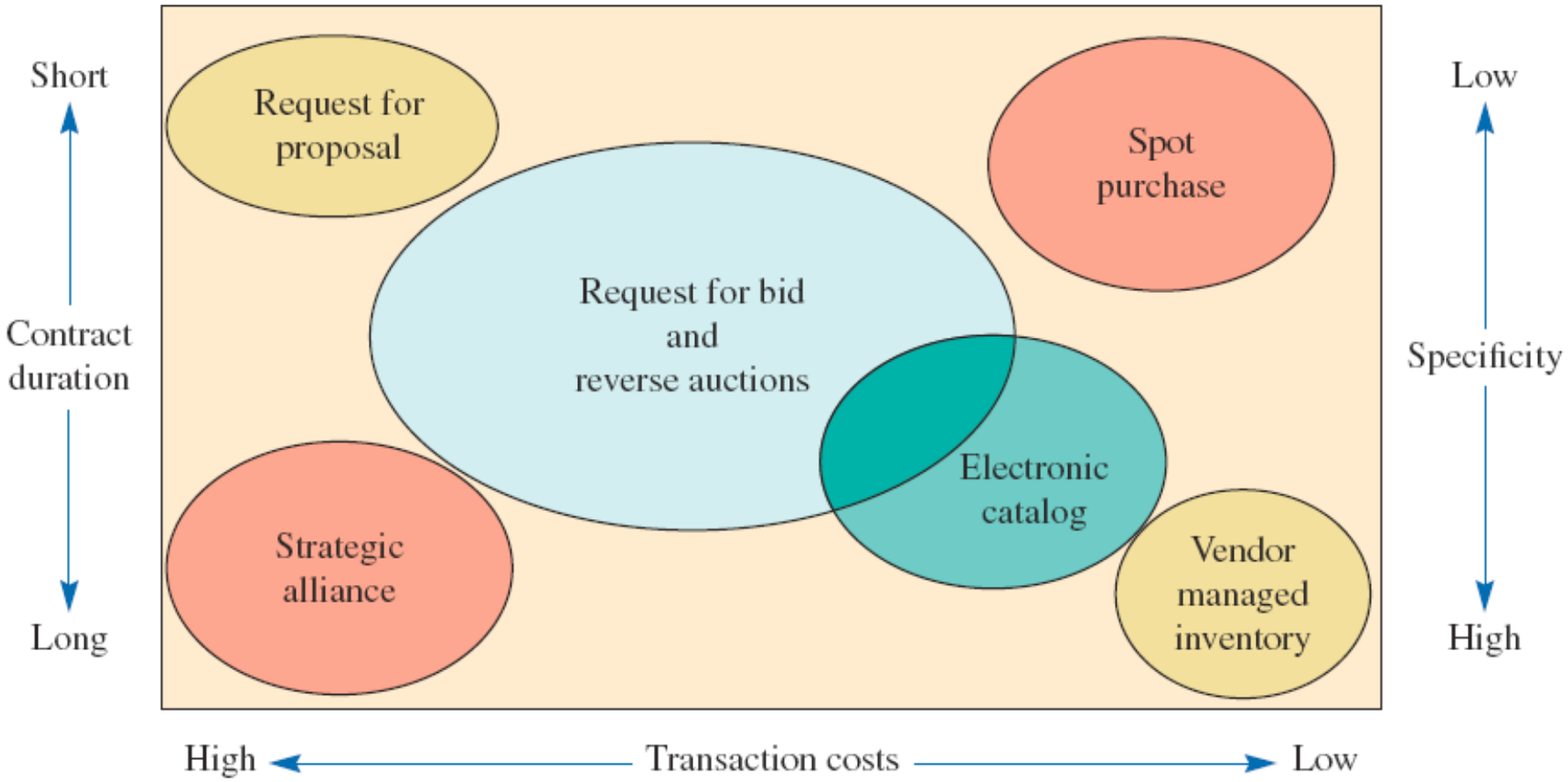


Exhibit 16.1

The Bullwhip Effect

- **Bullwhip effect**: phenomenon of variability magnification as we move from the customer to the producer in the supply chain
  - A slight change in consumer sales ripples backward as magnified oscillations upstream, like the result of a flick of a bullwhip handle
- **Forward buying**: retailers responding to a temporary price cut by stocking up
- **Continuous replenishment**: inventory is replaced frequently, as part of an ongoing process

Increasing Variability of Orders Up the Supply Chain

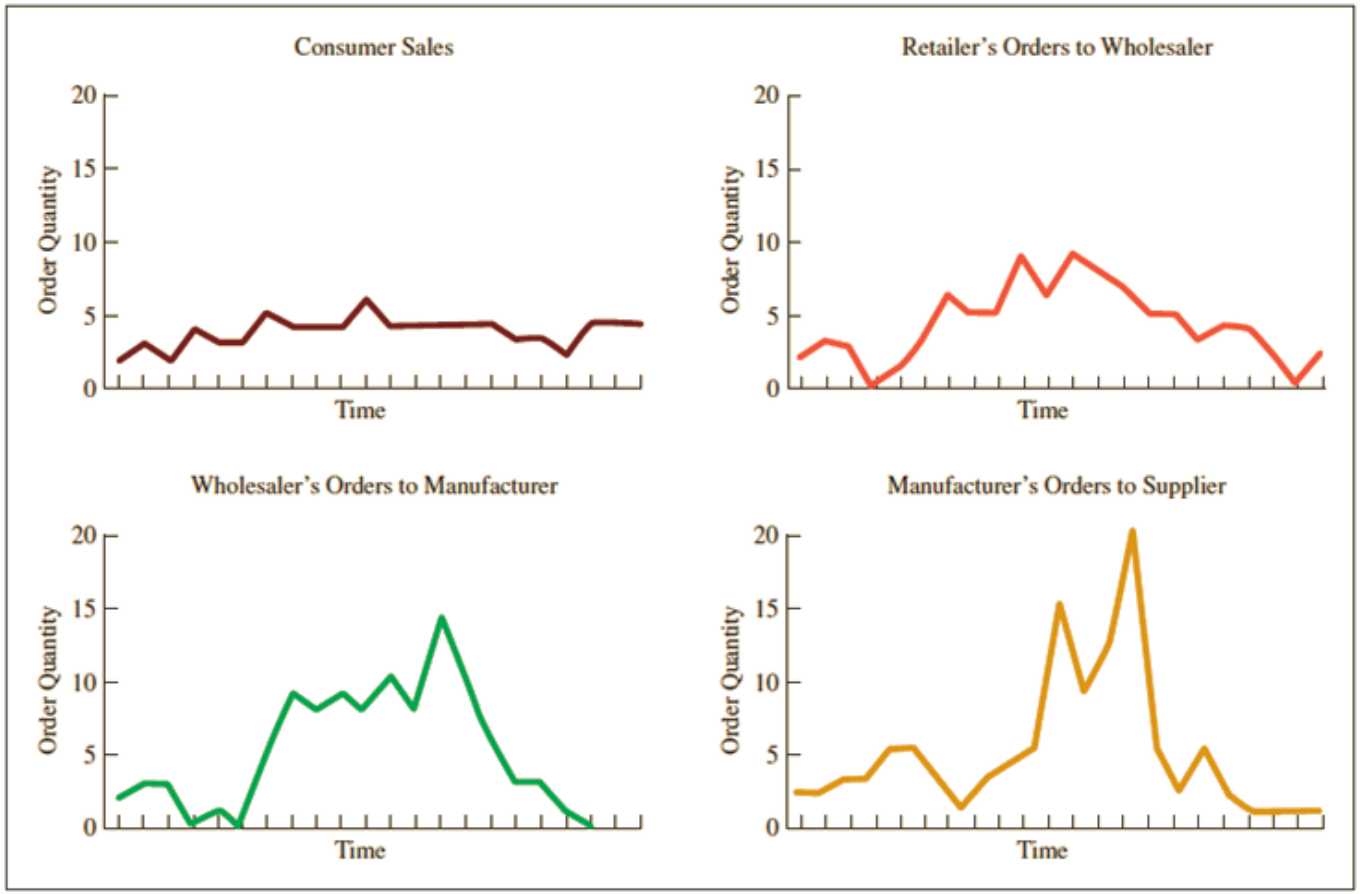


Exhibit 16.2

Functional Products

- **Functional products**: the staples that people buy in a wide range of retail outlets, such as grocery stores and gas stations
- Product life cycle of more than two years
- Contribution margin of 5 to 20 percent
- Only 10 to 20 product variations
- An average forecast error of only 10 percent
- Lead time for make-to-order products of from six months to one year

Innovative Products

- Innovation can enable a company to achieve higher profit margins
- Newness of the innovative products makes demand for them unpredictable
- Typically have a life cycle of just a few months
  - Imitators quickly erode the competitive advantage that innovative products enjoy
  - Companies are forced to introduce a steady stream of newer innovations
- The short life cycles and the great variety typical of these products further increase unpredictability

Product and Process Uncertainty Characteristics

	Product (Demand) Characteristics			Manufacturing (Supply) Process Characteristics	
	Functional	Innovative		Stable	Evolving
Demand	Predictable	Unpredictable	Breakdowns	Few	Higher
Product Life	Long	Short	Process Yield	High	Lower
Inventory Value	Low	High	Quality Problems	Few	More
Product Variety	Low	High	Supply Sources	Many	Few
Volume	High	Low	Process Changes	Few	Many
Stock-out Cost	Low	High	Lead Time	Dependable	Difficult to predict

Exhibit 16.3

Supply Chain Uncertainty Framework

		Product (Demand) Characteristics	
		Functional	Innovative
Manufacturing (Supply) Process Characteristics	Stable	**Efficient Supply Chain** Grocery, basic apparel, food, oil and gas	**Responsive Supply Chain** Fashion apparel, low-end computers, seasonal products
	Evolving	**Risk-Hedging Supply Chain** Hydroelectric power, food dependent on weather	**Agile Supply Chain** Cellphones, high-end computers, semiconductors

Exhibit 16.4

Four Types of Supply Chain Strategies

1. **Efficient supply chains**: utilize strategies aimed at creating the highest cost efficiency
2. **Risk-hedging supply chains**: utilize strategies aimed at pooling and sharing resources in a supply chain to share risk
3. **Responsive supply chains**: utilize strategies aimed at being responsive and flexible
4. **Agile supply chains**: utilize strategies aimed at being responsive and flexible to customer needs

Outsourcing

- **Outsourcing**: moving some of a firm's internal activities and decision responsibility to outside providers
- Allows a company to create a competitive advantage while reducing cost
- An entire function may be outsourced, or some elements of an activity may be outsourced, with the rest kept in-house

Reasons to Outsource and the Resulting Benefits

Financially Driven Reasons
Improve return on assets by reducing inventory and selling unnecessary assets. Generate cash by selling low-return entities. Gain access to new markets, particularly in developing countries. Reduce costs through a lower cost structure. Turn fixed costs into variable costs.
Improvement-Driven Reasons
Improve quality and productivity. Shorten cycle time. Obtain expertise, skills, and technologies that are not otherwise available. Improve risk management. Improve credibility and image by associating with superior providers.
Organizationally Driven Reasons
Improve effectiveness by focusing on what the firm does best. Increase flexibility to meet changing demand for products and services. Increase product and service value by improving response to customer needs.

Exhibit 16.5

Logistics Outsourcing

- **Logistics**: the management functions that support the complete cycle of material flow
  - Purchase and internal control of materials
  - Planning and control of WIP
  - Purchasing, shipping, and distribution of finished product
- Emphasis on lean inventory means there is less room for delivery errors
- Logistics companies have complex computer tracking technology that reduces the risk in transportation and allows the logistics company to add more value to the firm
- Third-party logistics providers track freight to tell customers exactly where its drivers are and when deliveries will be made

A Framework for Structuring Supplier Relationships

	Do not outsource	Outsource
Coordination characteristics	Coordination and interfaces are not well defined. The information and coordination is specific to each job. Immature technology and a need for "expert" knowledge that has been obtained by experience.	Standardized interfaces, required information is highly codified and standardized (prices, quantities, delivery schedules, etc.).
Investment is strategic assets characteristics	Significant investments in highly specialized assets are needed. The investments cannot be easily recovered if the relationship terminates. Long-term investments in specialized R&D, and lengthy learning curves.	Assets are commonly available from a large number of potential customers or suppliers.
Intellectual property characteristics	Weak intellectual property protection. Easy-to-imitate technology when access is given.	Strong intellectual property protection Difficult-to-imitate technology

Exhibit 16.6

Green Sourcing

- Being environmentally responsible has become a business imperative
- Many firms are looking to their supply chains to deliver “green” results
- Financial results can often be improved through going green
- A comprehensive green sourcing effort should assess how a company uses items that are purchased internally
- It is also important to reduce waste

Green Sourcing Process

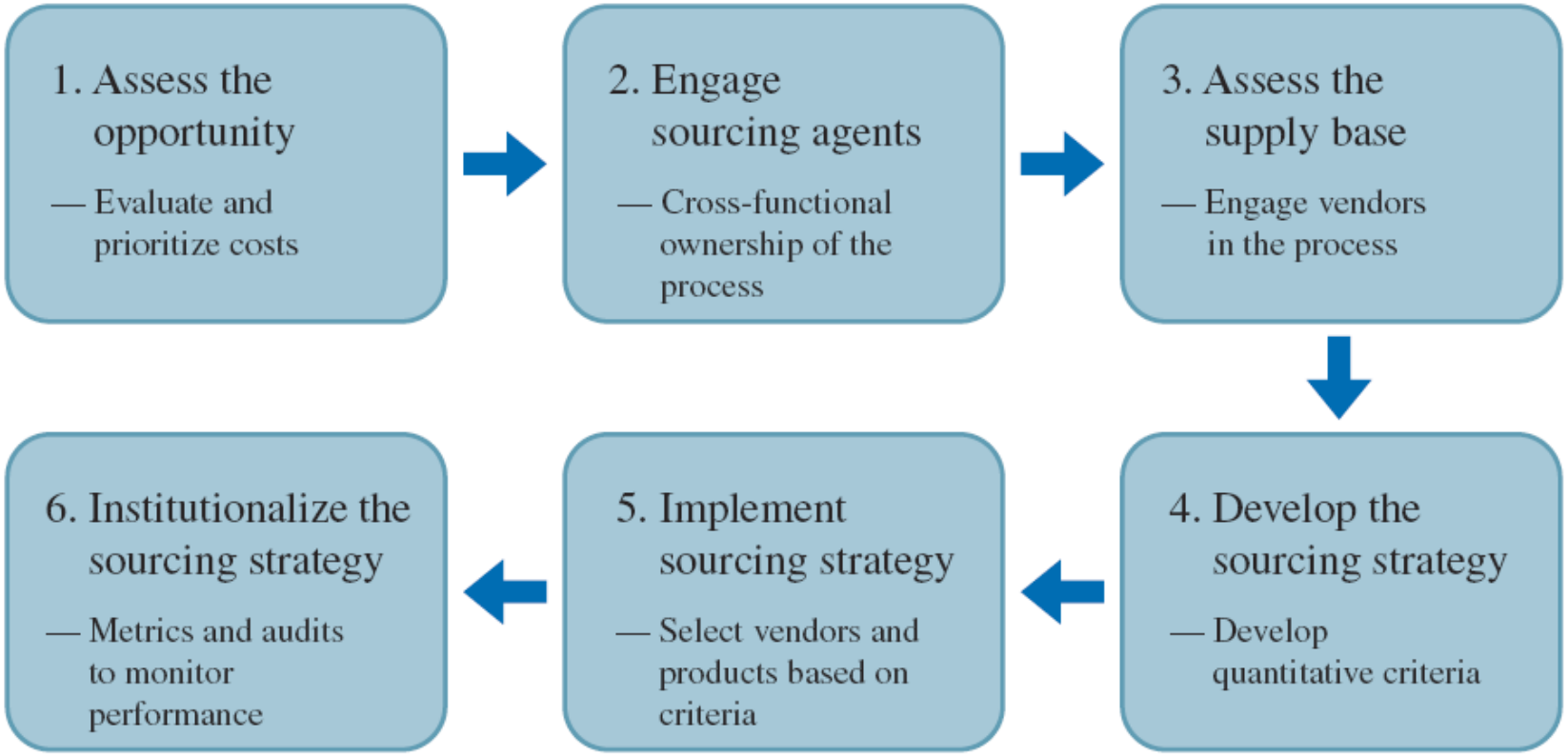


Exhibit 16.7

Total Cost of Ownership

- **Total cost of ownership (TCO)**: an estimate of the cost of an item
- Includes all the costs related to the procurement and use of an item, including any related costs in disposing of the item
- Can be applied to internal costs or more broadly to costs throughout the supply chain

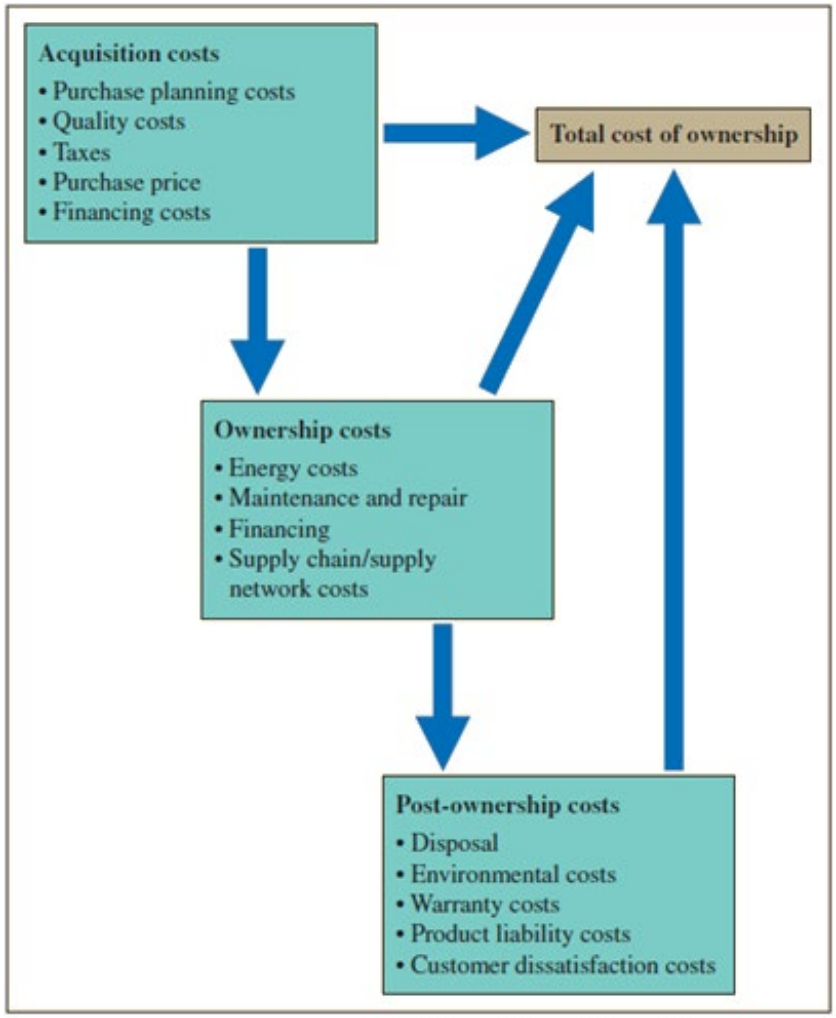


Exhibit 16.8

Summary

- Sourcing is a term that captures the strategic nature of purchasing in today's global and Internet-connected marketplace
- The bullwhip effect is when changes in demand are magnified as they move from the customer to the manufacturer
- Supply chains can be categorized based on demand and supply uncertainty characteristics
  - Four types of supply chains are identified: (1) efficient, (2) risk-hedging, (3) responsive, and (4) agile
- Costs can generally be categorized into three areas
  - (1) acquisition costs, (2) ownership costs, and (3) post-ownership costs

Questions

1. Refers to how common an item is or how many substitutes might be available
2. When a customer allows the supplier to manage inventory policy for an item or group of items
3. A phenomenon characterized by increased variation in ordering as we move from the customer to the manufacturer in the supply chain
4. Products that satisfy basic needs and do not change much over time
5. Products with short life cycles and typically high profit margins
6. A supply chain that must deal with high levels of both supply and demand uncertainty

Questions Continued

7. In order to cope with high levels of supply uncertainty, a firm would use this strategy to reduce risk
8. Used to describe functions related to the flow of material in a supply chain
9. When a firm works with suppliers to look for opportunities to save money and benefit the environment
10. Refers to an estimate of the cost of an item that includes all costs related to the procurement and use of an item, including the costs of disposing after its useful life

Gaining Control: Exploring Push v Pull Manufacturing

InSync Solutions Paper | 1

synchrono manufacturing software

Contents

Introduction

As the economy begins to refocus, so too do manufacturers. More and more analysts and industry experts are writing about "the factory of the future" and the enablement of demand-driven systems to drive velocity and on-time production while effectively managing the inevitable constraints. Legacy ERP and Push-based MRP systems are hard-pressed to support the Lean and demand-driven Pull-based production environments of today. And while Pull-based systems are more and more becoming a way to bridge the old and the new, they require a shift in philosophy as well as a shift in IT systems. Flexible, plug-in solutions like Kanban systems, however, are a seemingly efficient (and non-disruptive) way to bridge the gap for those looking to gain greater control by implementing or expanding upon Lean principles.

This is the first in a series of papers exploring the nature of Pull-based manufacturing systems and specifically, Kanban systems. The focus of this paper is at the system, or workflow level, while subsequent publications will review Pull/Kanban systems from a management, customer and competitive standpoint. After reading this paper, you will have a good understanding of both Pull and Push-based manufacturing systems and your choices for systems within a Pull environment. After reading the collection of papers, you should have a 360-degree perspective of the impact of a Pull/Kanban system in an organization.

Push v. Pull Planning and Execution Systems in Manufacturing

The contrast between Push and Pull-based systems starts at the planning phase. In traditional Push-based MRP/ERP environments, a plan is developed and pushed through the system. The assumption for planning in a Push environment is that everything remains constant; the company has the capacity on hand, along with the inventory and decision support staff to execute the plan. And while seemingly proactive, the plan often becomes obsolete before it is executed as it cannot easily accommodate changes in market conditions or adjust to variations inherent in manufacturing environments.

The contrast between Push and Pull-based systems starts in the planning phase.

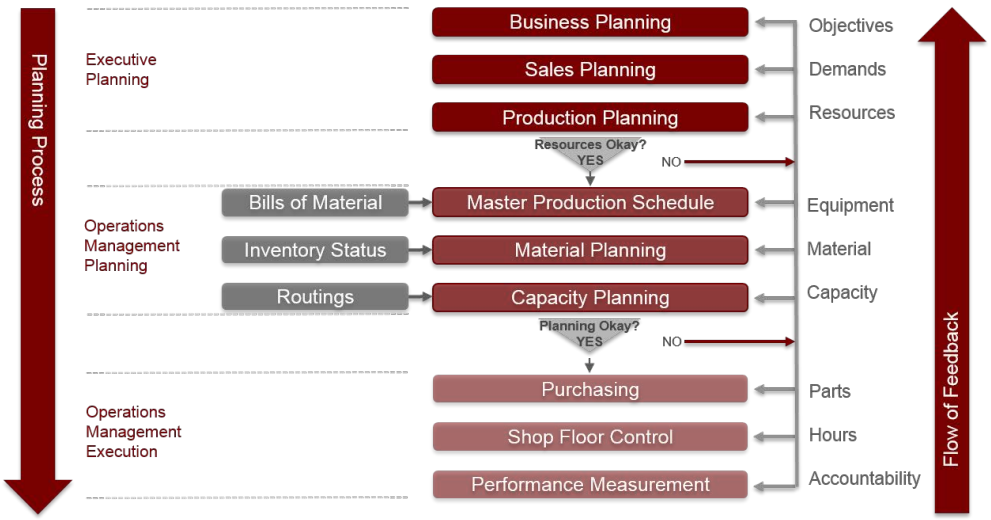
Pull/Kanban systems are driven from a high-level perspective that focuses on capacity and material planning based on actual customer demand. The assumption for planning here is that the design of the system is balanced according to the demands placed on the company.

So while Push-based systems are front-loaded in planning and rigid in execution, Pull-based systems focus on the execution of the customer order and are designed to be agile enough to respond quickly to changes in demand. Next, we'll review both systems in greater detail.

Plan-Driven Push-Based Systems

Planning in a Push environment is most often executed from an MRP or ERP system and starts when senior management sets the near-term and long-term financial goals for the company. These goals create the foundation for the company's business plan. (Figure 1.)

Based on high-level strategic goals, the business plan establishes budgets and identifies resources required to execute the plan. The plan is then handed off to the sales, operations and supply chain teams to validate the goals and determine how they will be met.

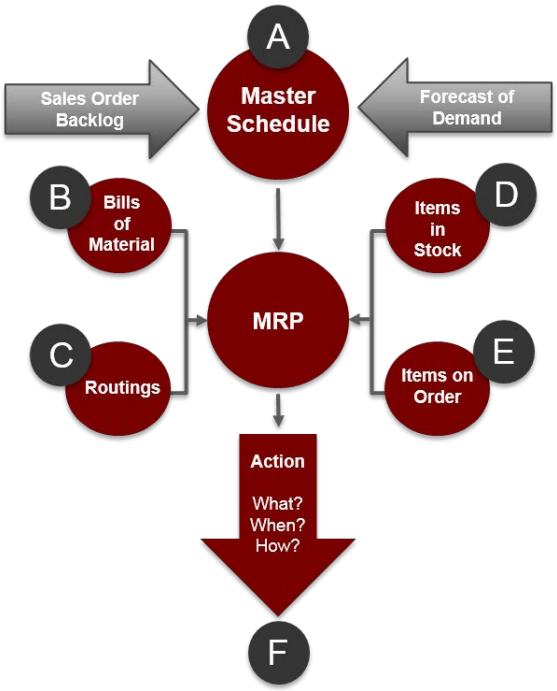


Basic Model for Resource Planning and Control

Figure 1

As would be expected, a large component of the process revolves around forecasting customer demand across the plan's horizon. Methods for forecasting vary greatly in Push environments, ranging from complex modeling techniques to SWAGs on customer demand.

Once developed, the forecast plans are loaded into the MRP/ERP system and a rough cut capacity plan is created to verify if the plans will be able to produce the desired results. The forecast is then joined with actual sales and current activity into a Master Production Schedule. (Figure 2.)



Master Production Schedule

Figure 2

Developing a Master Production Schedule (MPS)

A. **Master Schedule** - what you plan to do.
B. **Bills of Material** - what you need to do it.
C. **Routings** - how you will do it.
D. **Inventory Status** - what you have in stock.
E. **Open Purchase Orders** - what you have on order.

(A)(B)(C)-(D)-(E)=(F)

F. **Planned Work Orders** - what you need to make.
Dispatch List - when you need to make it.
Planned Purchase Orders - what you need to buy.
Purchase Order Action - when you need to buy.

This is an iterative process, but once the plan is agreed upon, the MPS pushes out resource requirements to the production planning and purchasing/ supply chain functions for more detailed planning, resource allocation and spending approvals.

Inventory, open work orders and open purchase orders are taken into account and actions are pushed to purchasing, production control, inventory control and shop floor control personnel in the form of suggestions for new work

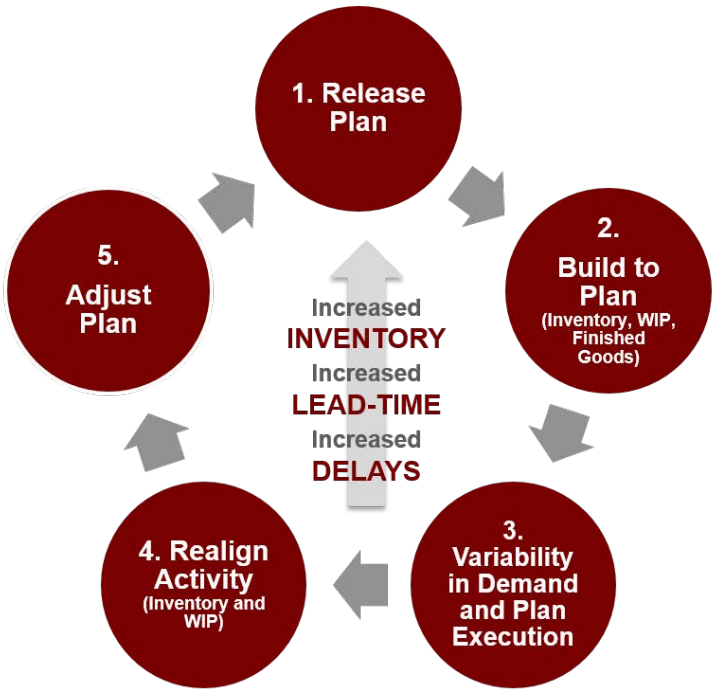
Each time the plan changes, there is a great deal of effort by planning, procurement, supply chain, logistics and shop floor personnel to adjust all work in process and move to the new plan.

orders and purchase orders. If there are work-in-process (WIP) or open orders (purchase orders and work orders), there may be a great deal of adjustment required to the current state to realign resources and activities to accommodate the new plan.

The execution phase follows the planning stage. This is the phase where the rubber hits the road. Here, work is performed through resource dispatch reporting, labor transactions for direct labor, work order completions, purchase order requisitions, purchase order receipts and inventory transactions. Materials are stored, allocated, pulled from stock, issued to manufacturing and returned to stock in a new form.

Material, machines and people are told what to do, when to do it and how much to do. This is dictated by the parameters set up within the item master, purchasing-supplier and routing data within the MRP/ERP system.

Most often there are average values for the lead time of items and process-time calculations throughout the master data. Likewise, there are many queuing and optimization models that assess the average variability of the



Push Planning Cycle

Figure 3

A Brief History of Push-Based Planning Systems

In the 1940's, the government started using computers to help speed up complex calculations; manufacturing was a natural offshoot and led to the digitizing of manufacturing data in the 1950's and 1960's.

MRP was designed to work in complex environments where production times were long and the supply chain was extended. The planning process relied on planning all the levels of production with the Bills of Material for the products, resources to produce and cost allocations to simplify the accounting functions. Prior to MRP, figuring out how much inventory was needed was done entirely by manual calculation, which could take months.

When MRP was written, it was meant to optimize each step and function of the company. The thought being that if each step is optimized, we will have an optimal result. And as computing power grew, so did MRP. First managing just materials, then time-phased materials, capacity and finally, accounting. Today nearly all of a company's transactional, financial and back office data are managed by ERP systems.

Demand, like the weather, becomes more difficult to forecast the further you look into the future. There are many changes that can happen once the plan is put in place and the longer or more diverse the supply chain, the more variation can play upon the plan. This is a key reason why more flexible, Pull-based systems are gaining traction today.

process. Anytime there is some degree of variability in execution outside of the planning parameters, the MRP engine re-plans and makes suggestions to operations (manufacturing and supply chain) to adjust the previous planning orders based on the new current state.

If you have worked in this environment, you are aware that by the time the plan is put in place, variability in actual customer demand and variability in execution to the plan has made it mostly meaningless. The effort then turns reactionary to accommodate actual customer demand and a controlled environment can turn to chaos. (Figure 3.)

Each time the plan changes, there is a great deal of effort by planning, procurement, supply chain, logistics and shop floor personnel to adjust all work in process and move to the new plan. This becomes a perpetual cycle that eventually results in too much for the system - too much investment in inventory, too much expediting and too much overtime and/or premium transportation costs. In the worst cases, the process directly impacts the customer. If customers have no tolerance for missed deliveries, the goals of the financial plan will not be met.

In summary, a Push-based system is a command and control structure for planning and execution that is pushed out from the top. Plan results are adjusted and reported back up the chain. This slow and often arduous feedback loop doesn't offer much flexibility to quickly respond to the inevitable variation in customer demand and execution to the plan. Rather, it often leads to a negative spiral of adding inventory, clogging up production and leading to diminished capacity and loss of control. This is the very opposite of what we are trying to achieve with our systems.

Customer Order-Driven, Pull-Based Kanban Systems

Pull-based systems represent the other end of the spectrum. Pull systems are based on the Toyota Production System (TPS) and its western interpretation, "Lean Manufacturing". The Pull method from TPS is often referred to as a Kanban system – a method for planning, execution and inventory replenishment that enables flow through greater control.

eKanban
The automation of the manual Kanban, Supermarket and K-Loop processes.

K-Loop
The K-Loop is the replenishment model for a Kanban system. It determines how many Kanban Cards are in a process, where they are sourced from and how the demand signal will be communicated.

Supermarket
A grouping of K-Loops that provides immediate access to inventory (raw materials, subassemblies or finished products) at strategic points in the manufacturing process and extended supply chain.

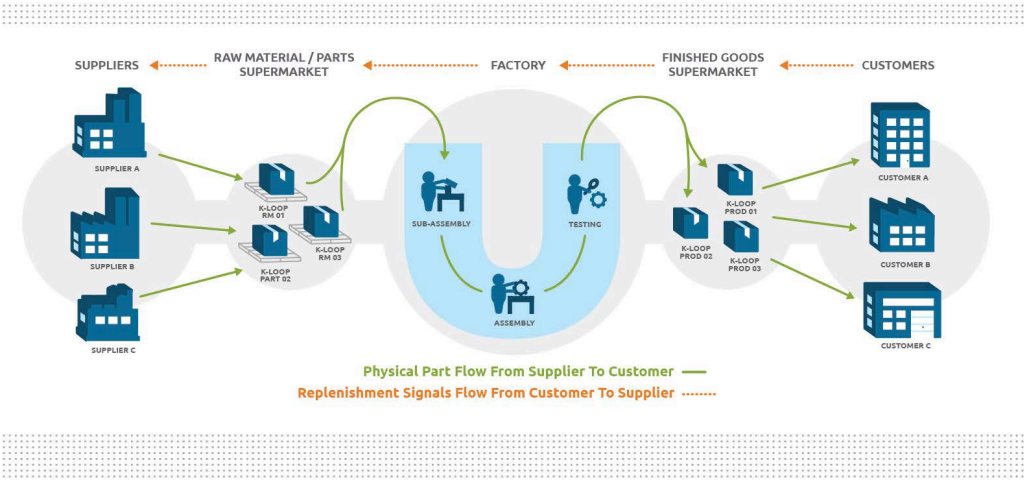
Pull/Kanban systems are based on actual customer demand. And while simple in nature, there is a great deal of effort required to change the system, or set the pieces in place so that the company can be responsive to customer demand. Determining costs and establishing budgets, developing the inventory supplier network and assessing manufacturing capabilities and capacity are still required regardless of the type of planning used. The real difference in a Pull/Kanban-based system is in the execution process.

Under the Push method, charging/feeding the system is done by the forecast. In Pull/Kanban, it is the consumption of inventory that authorizes activity (procurement, supply chain and manufacturing). The activity is authorized when a customer order pulls a part or finished good from inventory. When pulled, a signal is passed from the source of the demand through manufacturing and on to the suppliers for replenishment. The basic assumption for planning here is that the design of the system is balanced according to the demands placed on the company.

This is accomplished through a simple signaling method where K-Loops™ (defined on the next page) are inserted at strategic points in the supply-chain. These strategic points can be between supplier and work cell (raw material), between work cells (semi-finished) and between work cell and customer (finished goods). The K-Loop sends a signal in the form of a Kanban Card. The Kanban Card is the authorization to replenish inventory once it has been consumed. When an inventory/Kanban Card is pulled, the Card is returned to the previous operation or supplier to signal/authorize the holder of the Kanban Card to resupply the inventory. No less and no more.

The supplier process in this environment is considered more of a partnership than an oppositional relationship as both supplier and manufacturer know that they only succeed when the end customer is satisfied.

There are several other important aspects to a Kanban system, but we will limit these to just the essentials for the purpose of this discussion. Two of the more important factors to define are the Supermarket and the K-Loop.



Kanban Process with Raw Material and Finished Goods Supermarkets

Supermarket

The Supermarket is the concept of having inventory available for the internal/ external customer so that they do not have to wait for what they require. For internal customers, the Supermarket should be located close to the area of need, for example, beside the assembly line. The important factor is that suppliers are signaled when usage occurs and are responsible for replenishing what has been pulled. These two signals occur with the use of Kanban Cards. The concept is also useful for external customers pulling the finished product. As such, a company may have several Supermarkets.

K-Loop™

A K-Loop (Kanban-Loop) is the number of Kanban Cards in the replenishment and usage cycle of an item. The K-Loop is created as a closed loop of activity between all involved in the use and supply of materials.

There are many factors that may be used to calculate the size and quantity of Kanban Cards, including:

- Expected demand
- Batch sizes
- Container sizes
- Safety factors
- Service levels
- Supplier lead-times
- Transportation times

Suppliers are signaled when usage occurs and are responsible for replenishing what has been pulled.

The level of control gained allows you to reduce the total amount of inventory.

Also consider the amount of variation in all these factors when determining Kanban Card sizes and the number of Kanban Cards the K-Loop™ will contain.

Reduce Waste and Inventory

With Supermarkets and K-Loops working together to reduce the amount of waste and disruption in the system, the level of control gained allows you to reduce the total amount of inventory. The method is simple to follow and is easily synchronized with actual customer orders. K-Loops are defined for each part/unit to ensure consistency of supply. Both suppliers and work cells are synchronized to maximize flow through the operation and its extended supply chain.

One of the great benefits of the process is the level of control gained through immediate feedback and the ability to make quick adjustments. If demand increases, the Kanban signals increase. In the cases where demand slows, the system slows as the frequency of the Kanban needed is reduced. This process is very nimble in the current state both visually and across the entire supply chain.

There is not a great deal of effort required to adjust/synchronize the system continually as in the Push method. And, unlike the Push system, there is no second guessing of what is a real change versus changes that are just noise. In Pull environments, communication of the change is clear, precise and quickly acted upon.

Insight into the History of Kanban

The Kanban process was developed in Japan during the country's period of reconstruction. Due to a shortage of factory workers, they needed a system that was easy-to-use and produced the desired results, but didn't require an extensive command and control structure to manage. The Kanban system was the result. Efforts in Kanban date back to the late 1940's, and became widely used by Toyota and their suppliers by the late 1950's.

Manual and Electronic Kanbans

In Lean Manufacturing, there are many tools that are part of a Lean journey. A Kanban system is one such tool that represents a visual and functional step in the transition from Push to Pull processing. While there are Kanban systems for a variety of purposes (software development, project management, even personal productivity Kanbans), in the manufacturing world, we make the distinction between manual and electronic – or eKanban software systems.

Manual Kanban Systems

In a manual Kanban system, there are physical Kanban Cards for each unit of inventory (or batch) that are located in item bins, shelves, palettes, etc. The Card indicates a replenishment signal for that item. Typically there is also a

large Kanban board located on the plant floor that tracks work items as they move through the production process. The drawbacks of manual Kanban systems are that they are prone to data entry errors and Cards can be lost or misplaced. Manual Kanbans also have a threshold; it's been recommended that they only be used in environments with less than 200 items to track.

The largest drawback of the manual Kanban system, however, is that it is not automated, nor does it provide real-time demand signals across the organization. As such, communication challenges surface:

- Across departments within a company.
- Between the purchasing organization and suppliers where there are mixed methods (e.g., some products are utilizing Push forecasts while other products are using Kanban signals).
- When parts pass between multiple divisions or locations.

The big difference between a Pull and Push-based system, is that a Kanban system "pulls" inventory and work through the system based upon ACTUAL customer Demand.

Many times, a Kanban system is implemented manually to start. This can help ease the organizational transition to the Pull signaling method for more change-resistant environments and provides the opportunity to implement Kanban as a pilot program to test the process and work out the issues. Usually simple processes are used in this approach. And, like all new processes, there are valuable lessons to be learned:

- How to size the K-Loops (number of Kanbans in the process).
- How to use Spike Kanban Cards when demand increases.
  (A Spike Card is used to quickly increase inventory to account for sudden and temporary increases in demand.)
- When to remove Kanban Cards as demand trends downward.
- Identifying data that is important for monitoring line performance.
- Understanding how changes in supplier performance and lead-times impact K-Loop sizing.

For some, however, the immediate benefits of an eKanban system far outweigh the choice for implementing manually first, then transitioning to an electronic system. Next, we will take a closer look at eKanban software systems.

eKanban Software Systems

Electronic Kanban is a software signaling system that drives the movement of materials within a manufacturing, assembly or warehousing facility. In contrast to the physical Kanban Cards used in a manual Kanban system, eKanban software uses barcodes and electronic messages to signal inventory replenishment.

An eKanban system only requires intervention when there is a problem, greatly reducing the amount of attention required to have the K-Loop function. This is in sharp contrast to an ERP system, where action is required at every stage of the process of planning and execution.

eKanban systems can take the form of a spreadsheet, packaged software or a Cloud-based application. Some eKanban systems are best suited for single sites, but may be adapted to connect multiple sites with additional software. And more robust eKanban software systems with automated identification equipment (bar code transactional systems) can accommodate more complexity. For example, environments with tens of thousands of SKUs, interplant transfers, overseas locations and large, extended internal and external supply chains. When utilized globally - and across multiple company locations - an eKanban system can eliminate the supply chain bullwhip effect (distortion of information from one end of the supply chain to the other) and significantly enhance the benefits and performance of Lean enterprise efforts.

While there is a great benefit in providing a simple method to manage the supply network, some of the more specific benefits of having an eKanban system include the ability to:

- View and track supermarket and kanban status in real-time.
- Make instantaneous adjustments based on demand.
- Communicate across the supplier network in a fast and consistent manner.
- Right-size inventory through automated K-Loop™ sizing that takes into account changes in demand and supply.
- Provide a closed-loop process that can signal where problems need attention.
- Free buyers and planners from the administrative grind of executing the K-loop so they can focus on strategic sourcing, long-term strategy and continuous improvement.

Other benefits are found in the tools that collect data - data used for analysis of performance metrics as well as data used to automate K-Loop adjustments

and Kanban sizing. Analytics can also help supply chain managers to quickly adjust the system to take into account spike demands, increasing demand trends and conversely, decreasing demand trends.

"Kanban is like the milkman. Mom didn't give the milkman a schedule. Mom didn't use MRP. She simply put the empties on the front steps and the milkman replenished them. That is the essence of a pull system"

– Ernie Smith, Lean Event Facilitator in the Lean Enterprise Forum at the University of Tennessee

Gaining Control through Transparent Communications

The best systems are systems where signals are not lost, misunderstood or misinterpreted. That is why Kanban systems are so appealing. The loss of dexterity in manual systems only requires one person to be distracted, one card to be misplaced or turnover of a key individual to create a hole in the process. Systems that have a great deal of human interaction such as manual kanban systems require a stringent system of checks and balances to ensure that communication is always taking place.

We can point to a wealth of case studies that demonstrate the value of eKanban systems. They reduce inventory which can lead to significant cost savings; they shorten lead times, purchase order cycles and more. A hidden and often untold benefit, however, is an elevated level of communication across the plant floor. And while the capabilities of eKanban software packages differ, consider the value of those that provide instantaneous demand signals across the organization and extended supply chain – signals that are visible and can be tracked by all. Everyone is on the same page, even suppliers who have a portal into the system that empowers them to replenish items based on the parameters you have set.

Communication creates control and helps to reduce variability. Next are a couple of examples that illustrate this point.

Minimizing Physical Interactions and Variability

The more physical interactions that occur within the requirements of a supply chain, the greater the distortions that are added to each step that encounters the requirement (e.g., data entry, order policy decisions, stock decisions, transactions and nodes). Given that, each step in the supply chain process attempts to protect itself from variability which can lead to increased inventory, lead-times and delays.

Therefore, the more physical interactions between each step in the supply chain, the greater the distortion of information and requirements. These exaggerations can create artificial problems because the decisions at each stage are constantly second guessed or adjusted based upon incomplete

information. These types of adjustments can create great variation throughout the supply chain when made simultaneously, or when a slight delay in one area has the effect of a greater delay in a later step.

An eKanban system sending real-time demand signals and providing continuous status updates that are visible throughout the plant, can greatly reduce the need for physical interactions and ultimately, variability.

Building Trust in the System

eKanbans can serve to create one source of truth throughout the system. As eKanban signaling is utilized, the amount of variability throughout the process is reduced and each step begins to trust the previous step. This reduces the need to add extra protection everywhere in the supply chain. eKanban communication eliminates the noise of the previous Push signals in the supply chain.

eKanban communications also build trust among suppliers. In a Push environment, there are countless and continuous calls to suppliers to move up orders, move out orders, combine orders and to "really, really please" expedite deliveries – only to call back later and cancel the order. Understandably, at some point, the validity of these requests may be questioned. When communication is fluid and transparent through the use of an eKanban system, interactions with suppliers can turn into more positive and collaborative relationships.

When working well, a Kanban process will yield:

- A significant reduction in the amount of inventory (company inventory and amount of inventory held by suppliers)
- Increased inventory turns.
- Ability to focus improvement efforts.
- Increased goodwill by customers.
- Suppliers experience much less oscillations in demand
- Supplier communication improves greatly.

Summary

Push and Pull are methods both designed to bring control to the supply side of demand. And while ERP takes a top-down approach, Lean Kanban takes a customer demand-based approach. Yet, these two methods can coexist in today's supply chain network. If your organization is slow in adopting a Lean process, eKanban solutions like SyncKanban™ from Synchrono can offer quick results that reinforce the desired outcomes of Lean Manufacturing:

- Optimized inventory levels.
- Reduced purchase order cycles.
- Increased inventory turns.
- Shorter lead times.
- On time performance.
- Real-time communication up and down the supply chain.
- The ability to function in multi-plant, multi-site, multi-distributed environments.
- Leveraging existing MRP/ERP systems and data.
- Reporting tools and analytics for decision-making and monitoring performance.
- Focused Continuous Improvement (CI) efforts.
- Reduced administrative costs in executing the replenishment loop.

eKanban systems offer a tremendous upside in cost savings, organization-wide visibility, increased capacity and on time performance. eKanban systems can offer control and predictability while fostering a culture of moving from supply chain and manufacturing management working in the system to a mode of working on the system.

In this paper, we have explored the nature of Push and Pull systems and more specifically, manual and eKanban systems within a Pull environment. In our next paper in this series, we will explore Pull/Kanban systems from a management perspective, exploring the benefits of a more predictable environment along with the decision-making power gained through a deeper access to data and analytics.

About the Authors.

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John Maher has more than twenty years of experience working in manufacturing environments and has been with Synchrono since the company's inception. John's subject matter expertise in ERP, MRP, APS, supply chain, manufacturing planning and scheduling systems and constraints management drives continuous refinement of the company's Lean and constraints management-based software and services. John is responsible for providing strategic direction for the Synchrono product roadmap and oversees the technology and delivery functions within the organization.

John earned his BBA in production/operations management from University of Wisconsin, Whitewater, and an MBA from the University of Minnesota, Carlson School of Management. He has APICS CPIM certification in production and inventory management and Jonah certification in Theory of Constraints from the Goldratt Institute.

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Rick Denison is a software implementation consultant in Minneapolis/St. Paul, Minnesota. He is an operations and logistics professional with applied knowledge and hands-on experience in leading change in companies through Lean manufacturing, six sigma and TOC techniques. This experience has been obtained through 25 years leading industrial operations in industry and consulting in a diverse range of manufacturing environments and products. Rick has a strong background in process improvement, change management, project management, information systems implementation and profitability analysis. Currently, he is a Senior Implementation Consultant at Synchrono Manufacturing Software.

About SyncKanban.

SyncKanban software from Synchrono keeps instantaneous supply chain signals moving through your organization at lightning speed. This automated, pull-based inventory replenishment system sends signals to suppliers to deliver materials, helping you reduce the costs and waste associated with excess inventory and replenishment process administration. For many, that means up to a 50% reduction in inventories, on-time production, improved cash flow and a distinct competitive advantage. See for yourself; try SyncKanban for free.

About Synchrono.

Synchrono is leading the movement in demand-driven manufacturing software with a portfolio of applications that focus on enterprise and operational management – from supply chain and eKanban to production and execution systems. All delivered through a real-time, dynamic and web-based technology platform.

Bringing Lean and constraints management principles to life, the company's inclusive, yet modular approach allows for continuous, real-time information integration and flow throughout the plant and beyond to the extended supply chain ecosystem. With Synchrono, manufacturers gain visibility across their organization for greater clarity while enterprise-focused tools help control costs and variability driving on-time performance and a clear competitive advantage. Sync with us at www.synchrono.com.

Push and Pull Production Systems

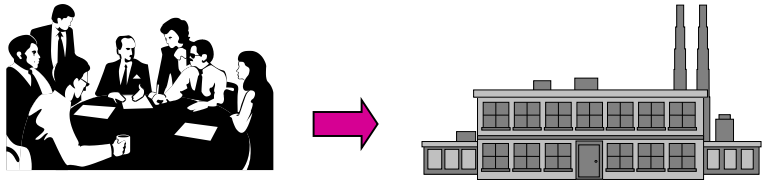
You say yes.
I say no.
You say stop.
and I say go, go, go!

– The Beatles

The Key Difference Between Push and Pull

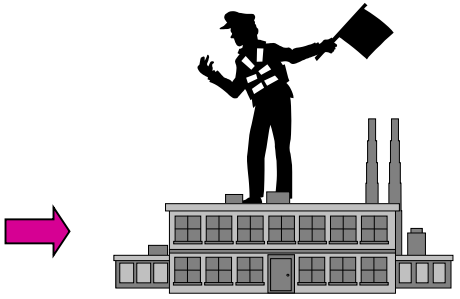
Push Systems: ***schedule*** work releases based on demand.

- inherently due-date driven
- control release rate, observe WIP level



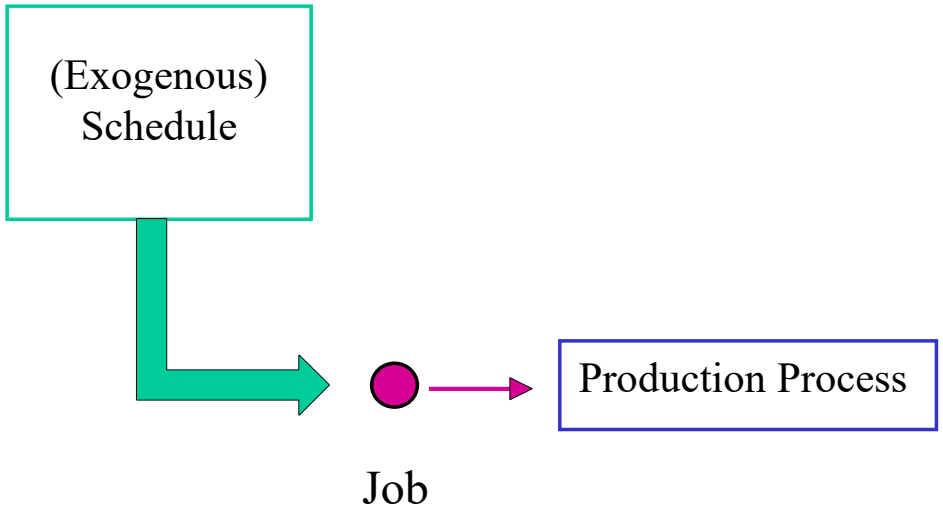
Pull Systems: ***authorize*** work releases based on system status.

- inherently rate driven
- control WIP level, observe throughput



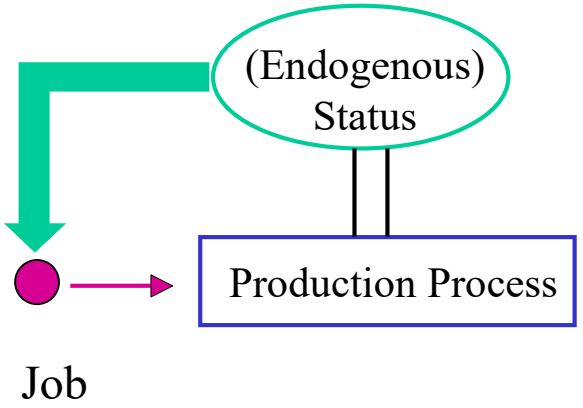
Push vs. Pull Mechanics

PUSH



Push systems are inherently make-to-stock.

PULL



Pull systems are inherently make-to-order.

Push and Pull Examples

Are the following systems essentially push or essentially pull?

- 3@1 copy/printing shop:
- Vending machine:
- "Pure" MRP system:
- Booking Driver's or Learner's license on NATIS:
- Supermarket (goods on shelves):
- Girlhouse/Steakhouse restaurant:
- Greyhound Buses at Parkstation:

Advantages of Pull Systems

Low Unit Cost:

- low inventory
- reduced space
- little rework

High External Quality:

- high internal quality
- pressure for good quality
- promotion of good quality (e.g., defect detection)

Good Customer Service:

- short cycle times
- steady, predictable output stream

Flexibility:

- avoids committing jobs too early
- encourages floating capacity

The Magic of Pull

Pulling Everywhere?

> ***You don't never make nothin' and* send *it no place. Somebody has to come get it.***
>
> – Hall 1983

No! It's the WIP Cap:

- Kanban – WIP cannot exceed number of cards
- "WIP explosions" are impossible

Pull Benefits Achieved by WIP Cap

Reduces Costs:

- prevents WIP explosions
- reduces average WIP
- reduces engineering changes

Improves Quality:

- pressure for higher quality
- improved defect detection
- improved communication

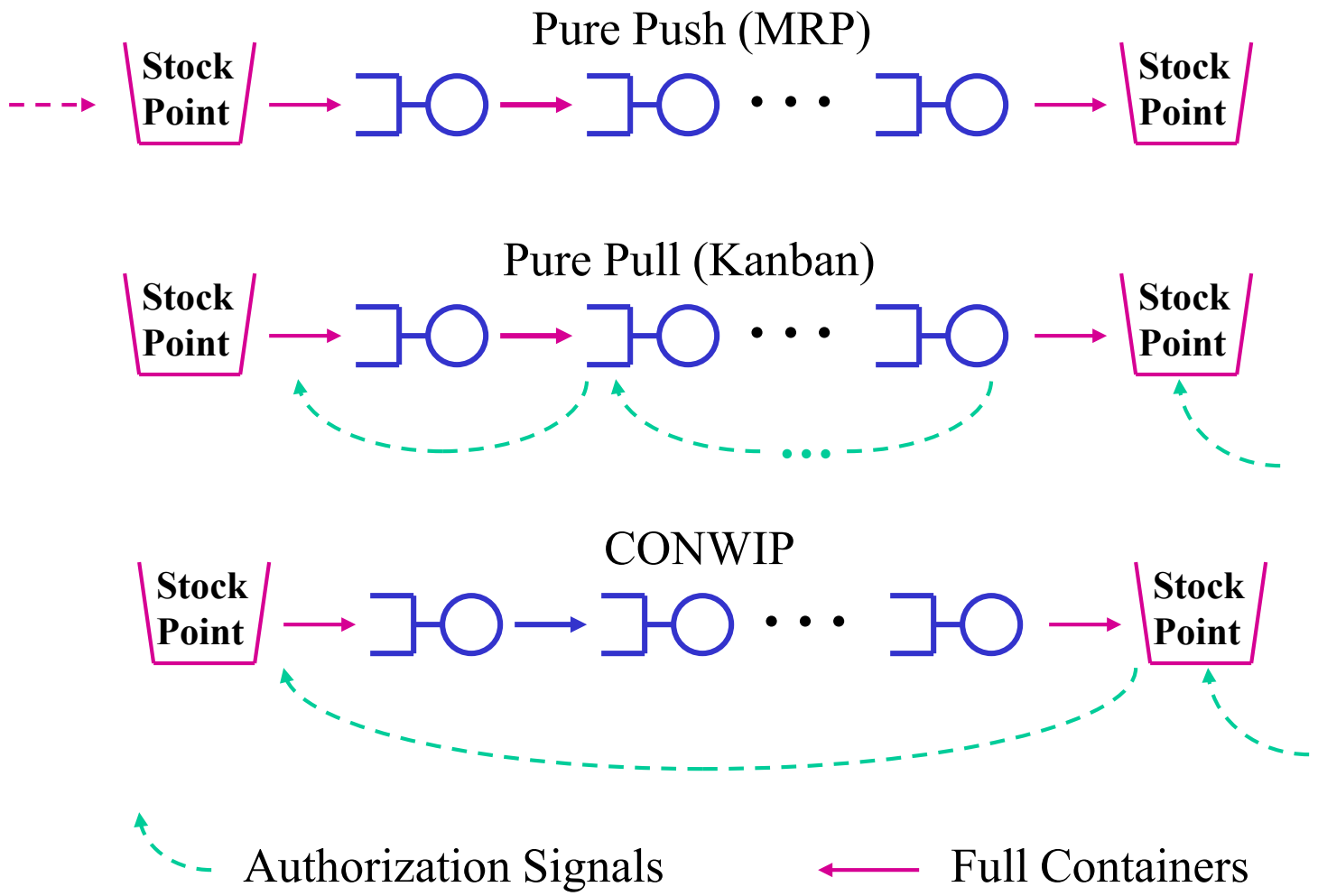
Improves Customer Service:

- reduces cycle time variability
- pressure to reduce sources of process variability
- promotes shorter lead times and better on-time performance

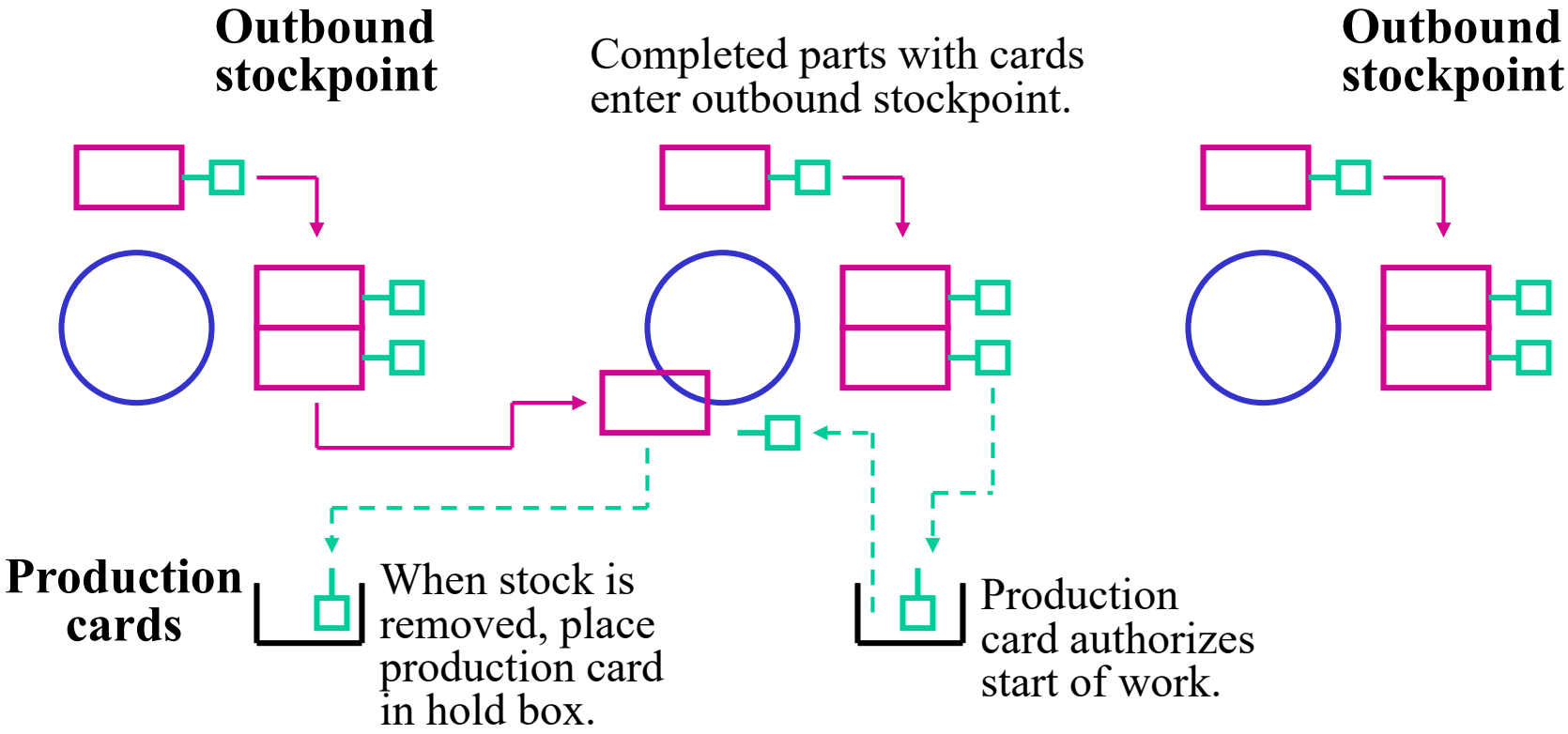
Maintains Flexibility:

- avoids early release (like air traffic control)
- less direct congestion
- less reliance on forecasts
- promotes floating capacity

Push and Pull Line Schematics



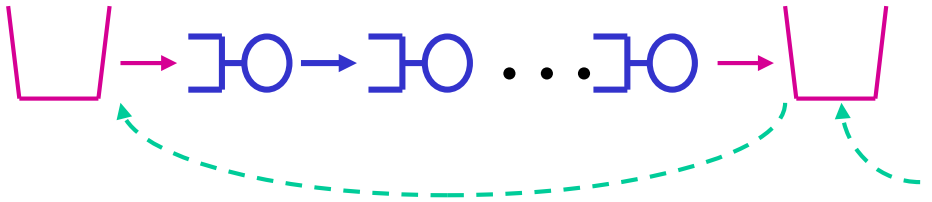
Pulling with Kanban



CONWIP

Assumptions:

1. Single routing
2. WIP measured in units



Mechanics: allow next job to enter line each time a job leaves (i.e., maintain a WIP level of *m* jobs in the line at all times).

Modeling:

- MRP looks like an open queueing network
- CONWIP looks like a closed queueing network
- Kanban looks like a closed queueing network with blocking

CONWIP Vs Pure Push System:

CONWIP exhibits the following advantages over a pure push system:

- The WIP level is **directly observable**, while the release rate in a push system must be set with respect to (unobservable) capacity.
- It requires **less WIP on average** to attain the same throughput.
- It facilitates **working ahead** of a schedule when favorable circumstances permit it.

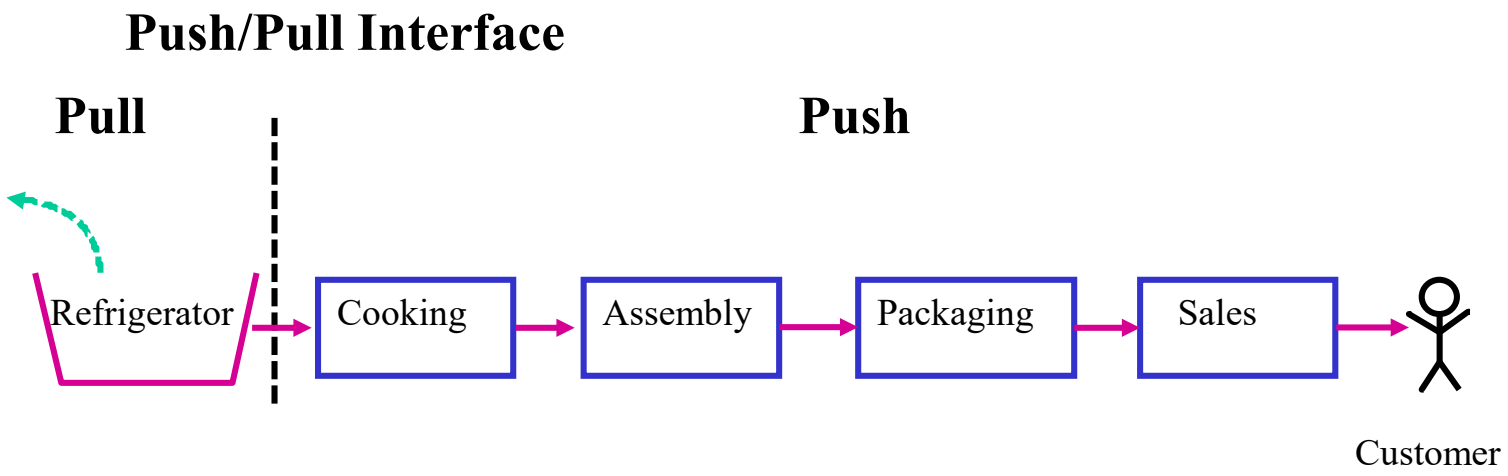
Push/Pull Interface

Concept:

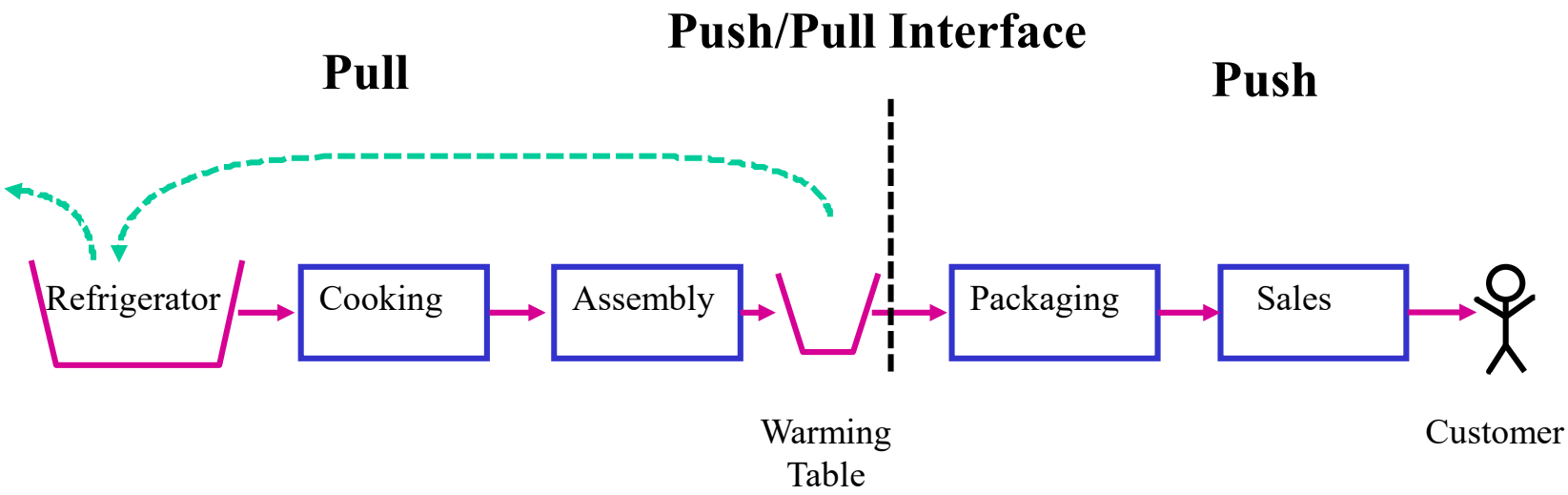
- both push and pull can be used in same system
- dividing point is called the **push/pull interface**

Benefit: eliminate entire portion of cycle time seen by customers by building to stock.

Example - Custom ‘Bunny Chow’ Production Line



Example - Custom 'Bunny Chow' Production Line

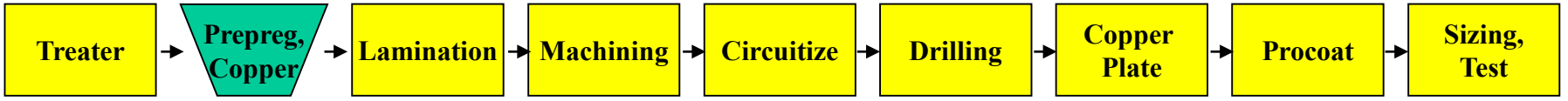


Notes:

- **Push/pull interface can differ by time of day (or season).**
- **Push/pull interface can differ by product.**

Example – Siemens Plant

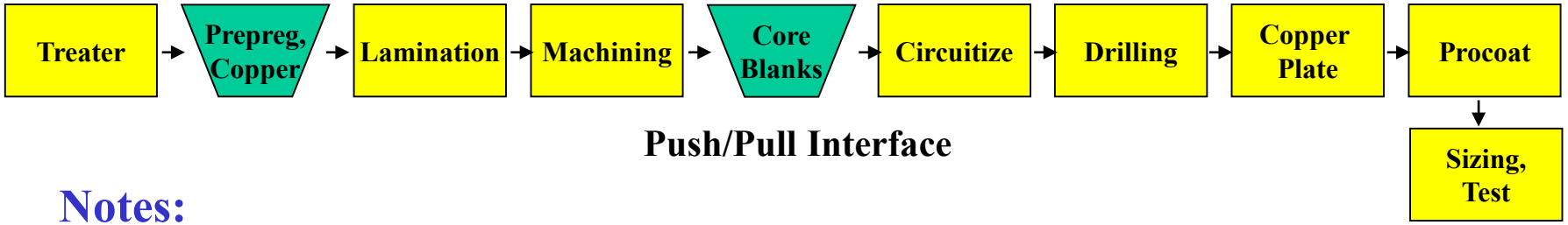
Original Line



Push/Pull Interface

process that gives boards "personality"

Revised Line



Push/Pull Interface

Notes:

- **Moving push/pull interface closer to customer shortens Leadtime seen by customer.**
- **Small number of core blanks presents opportunity to make them to stock.**

Push/Pull Interface Conclusions

Basic Tradeoff:

- responsiveness vs. inventory (time vs. money)
- moving PPI closer to customer increases responsiveness and (usually) inventory

Optimal Position of Push/Pull Interface:

- need for responsiveness
- cost of carrying inventory $\Rightarrow$ product diversification

Levers:

- product design (postponement)
- process design (quick response manufacturing)

Summary

- Push systems schedule the release of work on the basis of demand information, while pull systems authorize the release of work on the basis of inventory status within the system.
- The "magic" of pull systems is that they establish a WIP cap, which prevents producing unnecessary WIP that does not significantly improve throughput.
- The simplest mechanism for establishing a WIP cap is CONWIP (constant work in process), in which the WIP level in a line is held constant by synchronizing releases to departures.

CHAPTER 18: FORECASTING

LO18–1: Understand how forecasting is essential to supply chain planning.

LO18–2: Evaluate demand using quantitative forecasting models.

LO18–3: Apply qualitative techniques to forecast demand.

LO18–4: Apply collaborative techniques to forecast demand.

Forecasting in Operations and Supply Chain Management

- Forecasting is a vital function and affects every significant management decision
  - Finance and accounting use forecasts as the basis for budgeting and cost control
  - Marketing relies on forecasts to make key decisions such as new product planning and personnel compensation
  - Production uses forecasts to select suppliers; determine capacity requirements; and drive decisions about purchasing, staffing, and inventory
- Different roles require different forecasting approaches
  - Decisions about overall directions require *strategic forecasts*
  - *Tactical forecasts* are used to guide day-to-day decisions

Forecasting and Decoupling Point

- **Decoupling point**: Point at which inventory is stored, which allows Supply Chain to operate independently
- The choice of the decoupling point in a supply chain is strategic
- Forecasting helps determine the level of inventory needed at the decoupling points
- The decision will be affected by the error produced in the forecast and the type of product (easily inventoried or easily perishable)

Types of Forecasting

- There are four basic types of forecasts
  1. Qualitative
  2. Time series analysis
  3. Causal relationships
  4. Simulation
- Time series analysis is based on the idea that data relating to past demand can be used to predict future demand
- Chapter focuses on qualitative and time series techniques

Qualitative Forecasting Techniques

- Generally used to take advantage of expert knowledge
- Useful when judgment is required, when products are new, or if the firm has little experience in a new market
- Examples…
  - Market research
  - Panel consensus
  - Historical analogy
  - Delphi method

Time Series Model

Components of Demand

1. Trend
2. Seasonal element
3. Cyclical elements
4. Random variation

Components of Demand

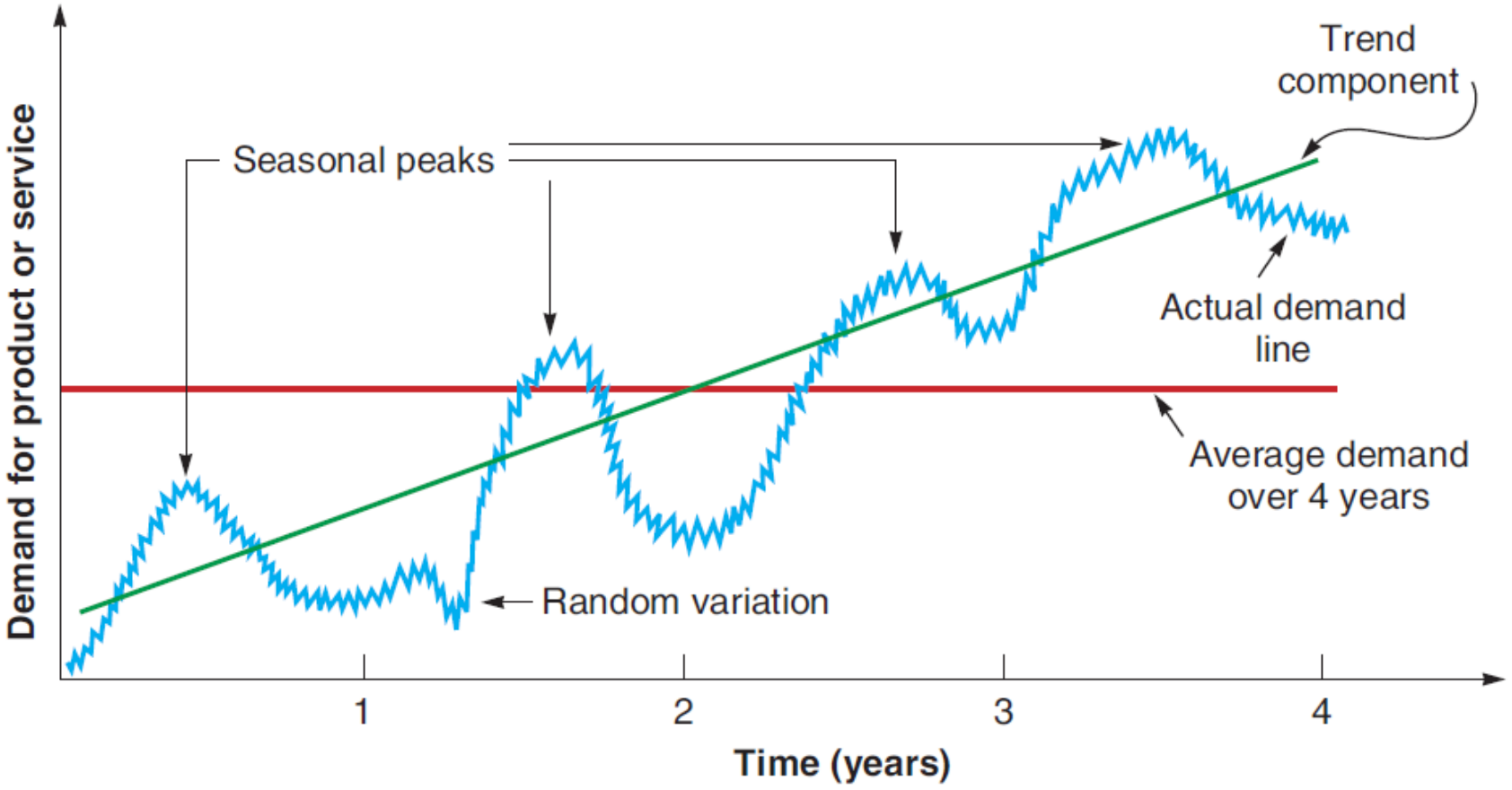


Figure 4.1

Trend Lines

- Identification of trend lines is a common starting point when developing a forecast
- Common trend types include linear, S-curve, asymptotic, and exponential

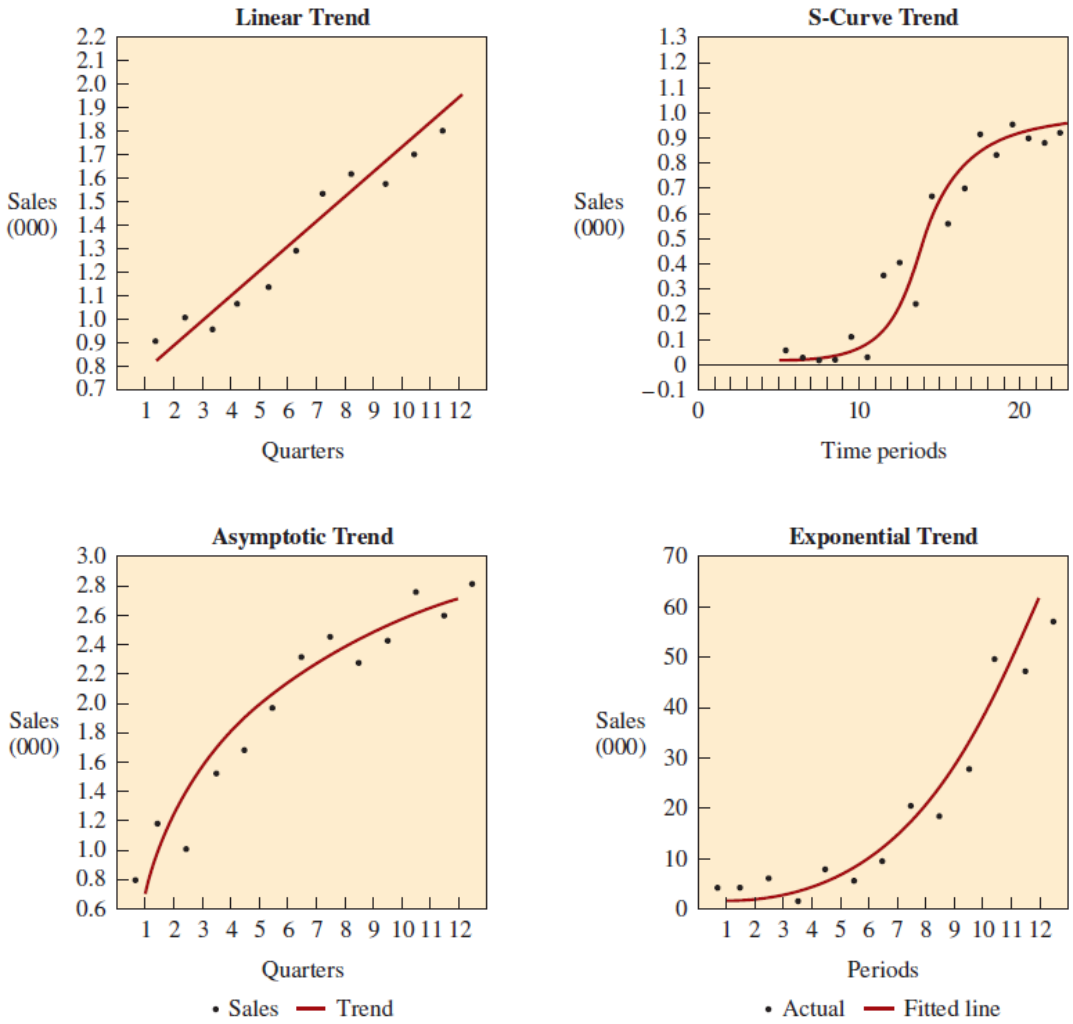


Exhibit 18.2

Time Series Analysis

- **Short term**: forecast under three months
  - Tactical decisions
- **Medium term**: three months to two years
  - Capturing seasonal effects
- **Long term**: forecast longer than two years
  - Detecting general trends
  - Identifying major turning points

Factors Affecting Forecasting Model Selection

1. Time horizon to be forecast
2. Data availability
3. Accuracy required
4. Size of forecasting budget
5. Availability of qualified personnel

A Guide to Selecting an Appropriate Forecasting Method

Forecasting Method	Amount of Historical Data	Data Pattern	Forecast Horizon
Simple moving average	6 to 12 months; weekly data are often used	Stationary only (i.e., no trend or seasonality)	Short
Weighted moving average and simple exponential smoothing	5 to 10 observations needed to start	Stationary only	Short
Exponential smoothing with trend	5 to 10 observations needed to start	Stationary and trend	Short
Linear regression	10 to 20 observations	Stationary, trend, and seasonality	Short to medium
Trend and seasonal models	2 to 3 observations per season	Stationary, trend, and seasonality	Short to medium

Exhibit 18.3

Simple Moving Average

- Forecast is the average of a fixed number of past periods
- Selecting the period length is important
  - Longer periods provide more smoothing
  - Shorter periods react to trends more quickly
- $F_t = \frac{A_{t-1}+A_{t-2}+A_{t-3}+\cdots+A_{t-1}}{n}$
  - F_t = Forecast in the coming period (t)
  - n = Number of periods to be averaged
  - A_{t-1} = Actual occurrence in the just pasted period (t-1)
  - A_{t-2}, A_{t-3}, and A_{t-n} = Actual occurrences two periods ago, an so on

Simple Moving Average – Example

Week	Demand	3 Week	9 Week
1	800		
2	1,400		
3	1,000		
4	1,500	1,067	
5	1,500	1,300	
6	1,300	1,333	
7	1,800	1,433	
8	1,700	1,533	
9	1,300	1,600	
10	1,700	1,600	1,367
11	1,700	1,567	1,467
12	1,500	1,567	1,500
13	2,300	1,633	1,556
14	2,300	1,833	1,644
15	2,000	2,033	1,733
16	1,700	2,200	1,811
17	1,800	2,000	1,800
18	2,200	1,833	1,811
19	1,900	1,900	1,911
20	2,400	1,967	1,933
21	2,400	2,167	2,011
22	2,600	2,233	2,111
23	2,000	2,467	2,144
24	2,500	2,333	2,111
25	2,600	2,367	2,167
26	2,200	2,367	2,267
27	2,200	2,433	2,311
28	2,500	2,333	2,311
29	2,400	2,300	2,378
30	2,100	2,367	2,378

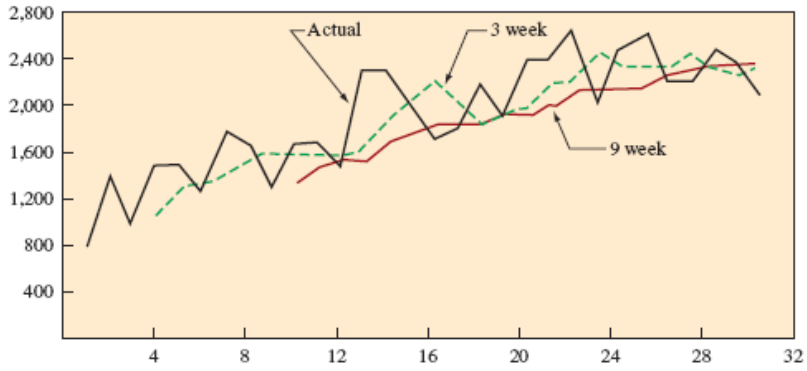


Exhibit 18.4

Weighted Moving Average

- A weighted moving average allows unequal weighting of prior time periods
  - The sum of the weights must be equal to one
  - Often, more recent periods are given higher weights than periods farther in the past

- $F_t = w_1 A_{t-1} + w_2 A_{t-2} + \cdots + w_n A_{t-n}$

  w_1 = Weight to be given to the actual occurrence for period t-1

  w_2 = Weight to be given to the actual occurrence for period t-2

  w_n = Weight to be given to the actual occurrence for period t-n

  n = Total number of prior periods in the forecast

Selecting Weights

- Experience and/or trial-and-error are the simplest approaches
- The recent past is often the best indicator of the future, so weights are generally higher for more recent data
- If the data are seasonal, weights should reflect this appropriately
  - That is, the sales from the same period last time should be weighted the heaviest

Exponential Smoothing

- The most used of all forecasting techniques
- An integral part of computerized forecasting
- Well accepted for six reasons
  1. Exponential models are surprisingly accurate
  2. Formulating an exponential model is relatively easy
  3. The user can understand how the model works
  4. Little computation is required to use the model
  5. Computer storage requirements are small
  6. Tests for accuracy are easy to compute

Exponential Smoothing Model

- Only three pieces of data are required:
  1. Most recent forecast
  2. Actual demand for the forecast period
  3. Smoothing constant alpha (α)
     - Determines the level of smoothing and speed of reaction
- $F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$
  - F_t = The exponentially smoothed forecast for period t
  - F_{t-1} = The exponentially smoothed forecast made for the prior period
  - A_{t-1} = The actual demand in the prior period
  - α = The desired response rate, or smoothing constant

Exponential Smoothing Example (α=0.20)

Week	Demand	Forecast
1	820	820
2	775	820
3	680	811
4	655	785
5	750	759
6	802	757
7	798	766
8	689	772
9	775	756
10		760

$F_2 = F_1 + \alpha(A_1 - F_1)$ =820 + 0.2(820-820)

$F_4 = F_3 + \alpha(A_3 - F_3)$ =811+ 0.2(680-811)

$F_6 = F_5 + \alpha(A_5 - F_5)$ =759+ 0.2(750-759)

$F_8 = F_7 + \alpha(A_7 - F_7)$ =766+ 0.2(798-766)

$F_{10} = F_9 + \alpha(A_9 - F_9)$ =756+ 0.2(775-756)

Exponential Forecasts vs. Actual Demand for Product over Time Showing Forecast Lag

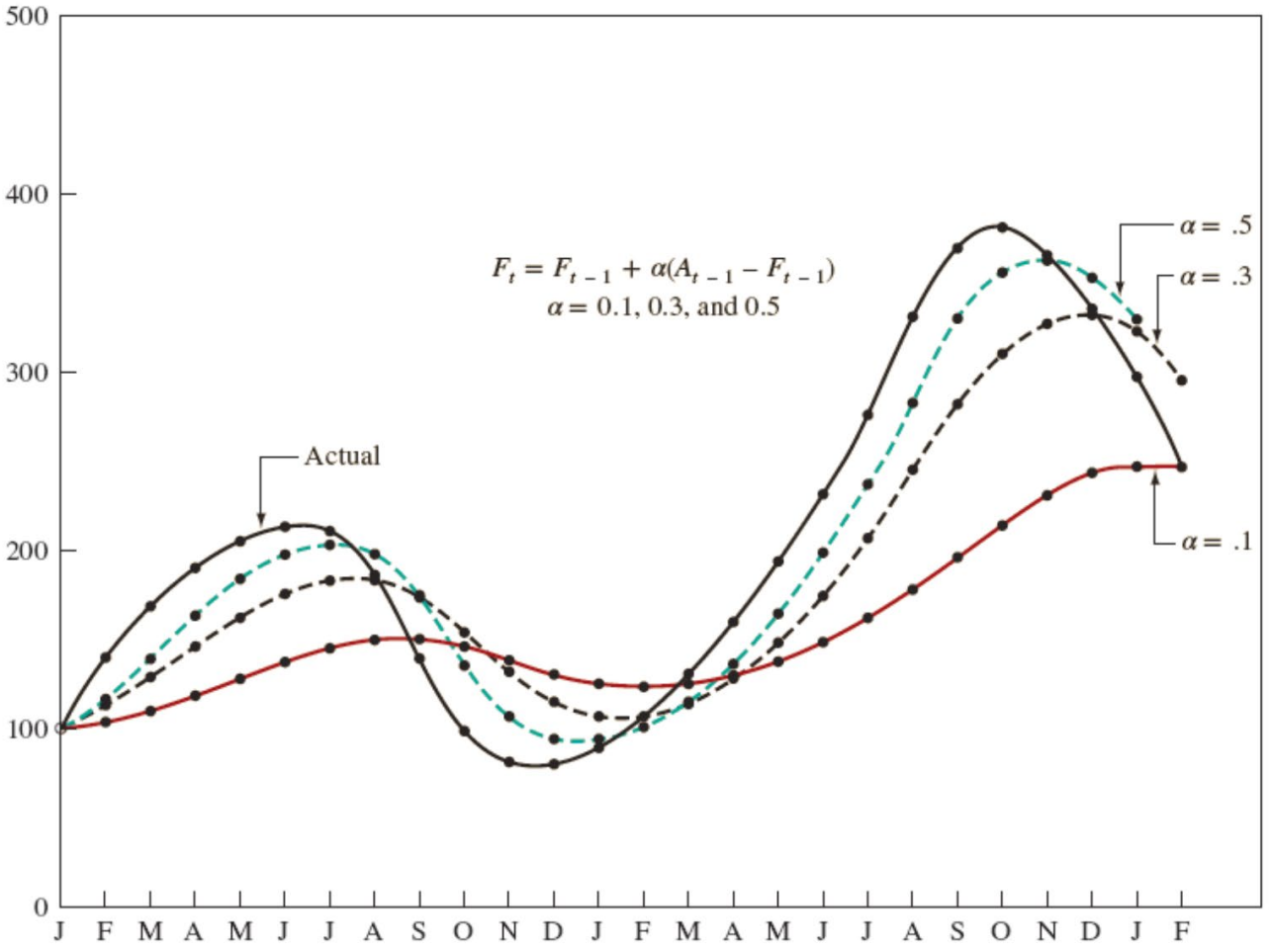


Exhibit 18.5

Exponential Smoothing with Trend

- A trend in data causes the exponential forecast to always lag the actual data
- Can be corrected somewhat by adding in a trend adjustment
- To correct the trend, we need two smoothing constants
  - Smoothing constant alpha (α)
  - Trend smoothing constant delta (δ)

Trend Effects Equations

$$F_t = FIT_{t-1} + \alpha(A_{t-1} - FIT_{t-1})$$
$$T_t = T_{t-1} + \delta(F_t - FIT_{t-1})$$
$$FIT_t = F_t + T_t$$

F_t = The exponentially smoothed forecast that does not include trend for period t

T_t = The exponentially smoothed trend for period t

FIT_t = The forecast including trend for period t

FIT_{t-1} = The forecast including trend made for the prior period

A_{t-1} = The actual demand for the prior period

δ = Smoothing constant (delta)

α = Smoothing constant (alpha)

Example 18.1: Forecast Including Trend

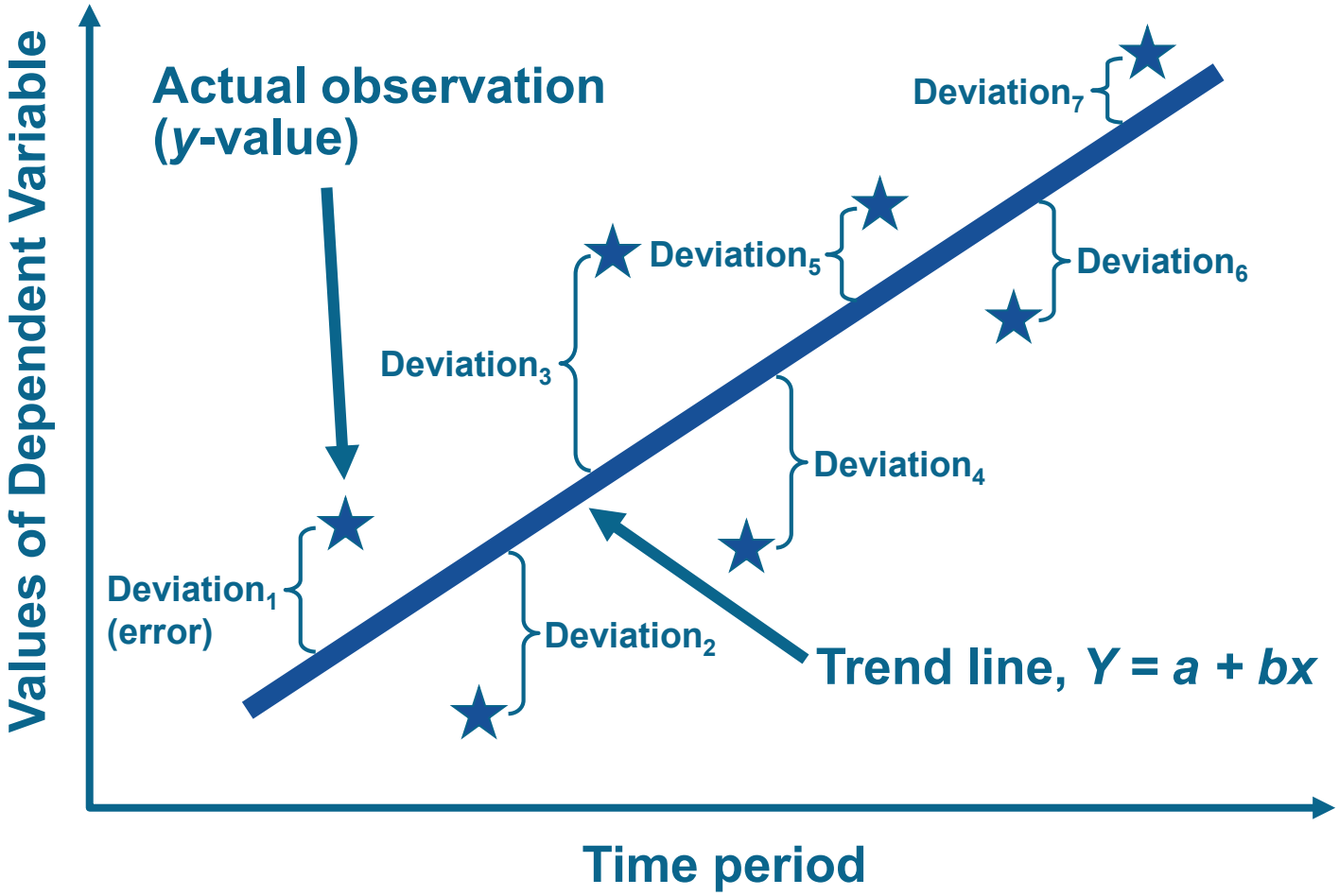
- Previous forecast including trend of 110 units
- Previous trend estimate of 10 units
- Alpha of 0.20
- Delta of 0.30
- Actual demand of 115
- $F_t = FIT_{t-1} + \alpha(A_{t-1} - FIT_{t-1}) = 110 + .2(115 - 110) = 111.0$
- $T_t = T_{t-1} + \delta(F_t - FIT_{t-1}) = 10 + .3(111 - 110) = 10.3$
- $FIT_t = F_t + T_t = 110.0 + 10.3 = 121.3$

- If actual 120, instead of 121.3, forecast for next period is…
- $F_t = FIT_{t-1} + \alpha(A_{t-1} - FIT_{t-1}) = 121.3 + .2(120 - 121.3) = 121.04$
- $T_t = T_{t-1} + \delta(F_t - FIT_{t-1}) = 10.3 + .3(121.04 - 121.3) = 10.22$
- $FIT_t = F_t + T_t = 121.04 + 10.22 = 131.26$

Linear Regression Analysis

- Dependent variable is predicted for given values of the independent variable
- Linear regression is special case that assumes the relationship between the variables can be explained with a straight line
- Useful for long-term forecasting
- $Y = a + bx$
  - Y = Dependent variable computed by the equation
  - y = y variable data point
  - a = Y intercept
  - b = Slope of the line
  - x = x variable data point

Linear Regression - Least Squares Regression Line



Trend projections – least squares

Equations to calculate the regression variables

$$Y = a + bx$$

$$b = \frac{\Sigma xy - n\bar{x}\bar{y}}{\Sigma x^2 - n\bar{x}^2}$$

$$a = \bar{y} - b\bar{x}$$

a = Y intercept
b = Slope of Line
$\bar{y}$ = Average of all *y*s
$\bar{x}$ = Average of all *x*s

x = x value of each data point
y = y value of each data point
n = Number of data points
Y = Value of Dependant variable

Example 18.2: Least Squares Method

Quarter	Sales		Quarter	Sales
1	600		7	2,600
2	1,550		8	2,900
3	1,500		9	3,800
4	1,500		10	4,500
5	2,400		11	4,000
6	3,100		12	4,900

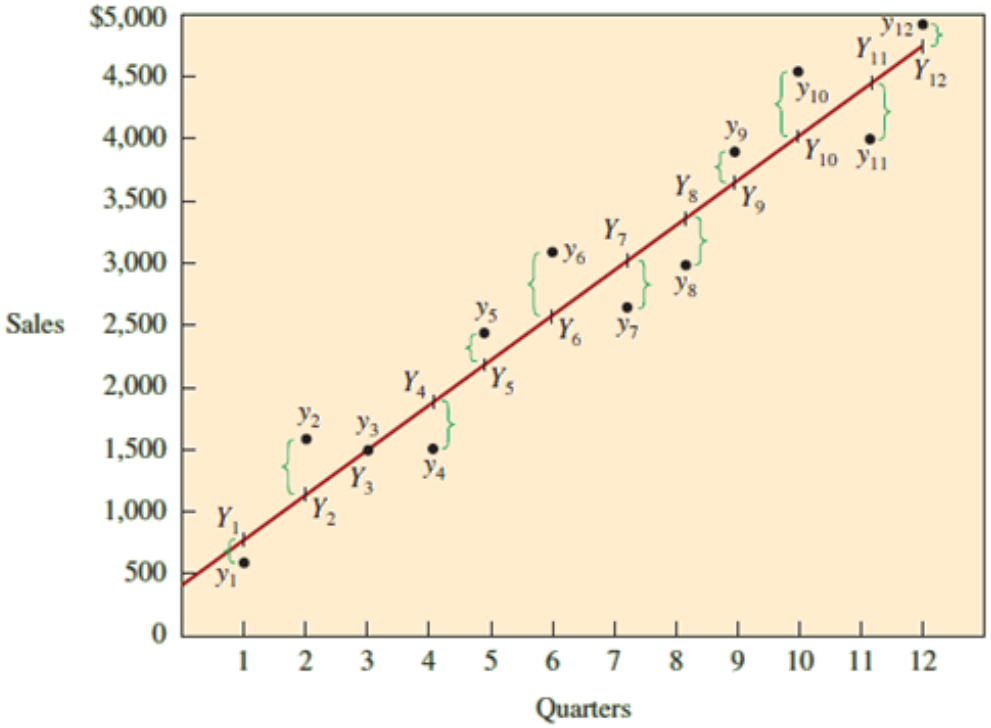


Exhibit 18.6

Example 18.1: Calculating Totals

(1) t	(2) y	(3) $t \times y$	(4) t^2	(5) y^2	(6) y
1	600	600	1	360,000	801.3
2	1,550	3,100	4	2,402,500	1,160.9
3	1,500	4,500	9	2,250,000	1,520.5
4	1,500	6,000	16	2,250,000	1,880.1
5	2,400	12,000	25	5,760,000	2,239.7
6	3,100	18,600	36	9,610,000	2,599.4
7	2,600	18,200	49	6,760,000	2,959.0
8	2,900	23,200	64	8,410,000	3,318.6
9	3,800	34,200	81	14,440,000	3,678.2
10	4,500	45,000	100	20,250,000	4,037.8
11	4,000	44,000	121	16,000,000	4,397.4
12	4,900	58,800	144	24,010,000	4,757.1
78	33,350	268,200	650	112,502,500	

$\bar{t} = 6.5 \quad b = 359.6154$
$\bar{y} = 2{,}779.17 \quad a = 441.6667$
Therefore, $Y = 441.67 + 359.6t$
$S_{yt} = 363.9$

Exhibit 18.7

Example 18.1: Other Calculations

$$a = \bar{y} - b\bar{x} \qquad b = \frac{\sum xy - n\bar{x} \cdot \bar{y}}{\sum x^2 - n\bar{x}^2}$$

where

a = Y intercept
b = Slope of the line
$\bar{y}$ = Average of all ys
$\bar{x}$ = Average of all xs
x = x value at each data point
y = y value at each data point
n = Number of data points
Y = Value of the dependent variable computed with the regression equation

$$Y_1 = a + bt = 441.67 + 359.6 * 1 = 801.3$$

$$Y_2 = a + bt = 441.67 + 359.6 * 2 = 1{,}160.9$$

$$\vdots$$

$$Y_{12} = a + bt = 441.67 + 359.6 * 12 = 4{,}757.1$$

The forecast is extended to periods 13-16

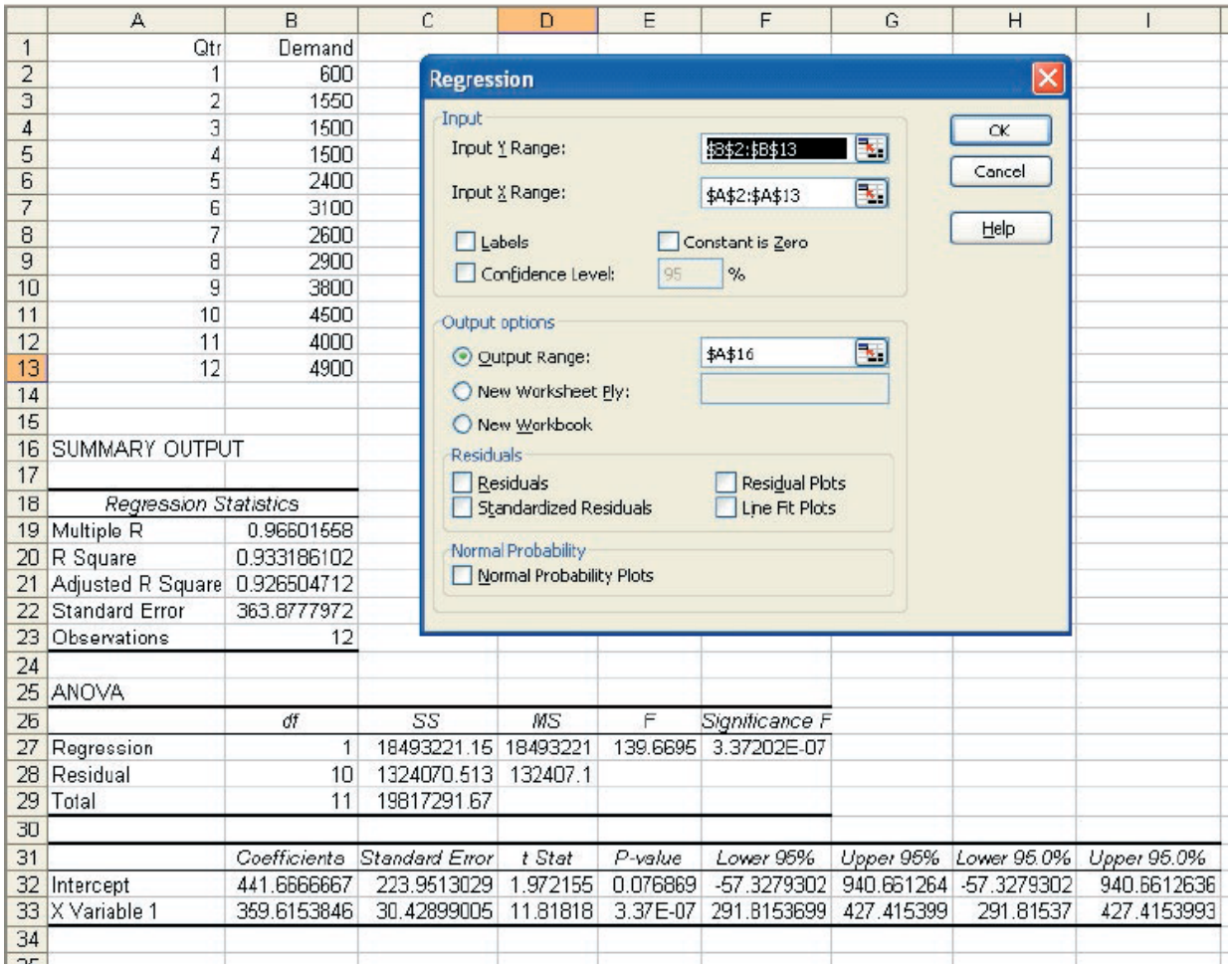
$$Y_{13} = a + bt = 441.67 + 359.6 * 13 = 5{,}116.4$$

$$Y_{14} = a + bt = 441.67 + 359.6 * 14 = 5{,}476.0$$

$$Y_{15} = a + bt = 441.67 + 359.6 * 15 = 5{,}835.6$$

$$Y_{16} = a + bt = 441.67 + 359.6 * 16 = 6{,}195.2$$

Regression with Excel



	A	B	C	D	E	F	G	H	I
1	Qtr	Demand							
2	1	600							
3	2	1550							
4	3	1500							
5	4	1500							
6	5	2400							
7	6	3100							
8	7	2600							
9	8	2900							
10	9	3800							
11	10	4500							
12	11	4000							
13	12	4900							
14									
15									
16	SUMMARY OUTPUT								
17									
18	*Regression Statistics*								
19	Multiple R	0.96601658							
20	R Square	0.933186102							
21	Adjusted R Square	0.926504712							
22	Standard Error	363.8777972							
23	Observations	12							
24									
25	ANOVA								
26		*df*	*SS*	*MS*	*F*	*Significance F*			
27	Regression	1	18493221.15	18493221	139.6695	3.37202E-07			
28	Residual	10	1324070.513	132407.1					
29	Total	11	19817291.67						
30									
31		*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
32	Intercept	441.6666667	223.9513029	1.972155	0.076869	-57.3279302	940.661264	-57.3279302	940.6612636
33	X Variable 1	359.6153846	30.42899005	11.81818	3.37E-07	291.8153699	427.415399	291.81537	427.4153993
34									

Exhibit 18.8

Time Series Decomposition

- Identifying these elements and separating the time series data into these components is known as decomposition
- Seasonal variation may be either additive or multiplicative
  - Additive: Forecast including trend and seasonal = Trend + Seasonal
  - Multiplicative: Forecast including trend and seasonal = Trend × Seasonal factor

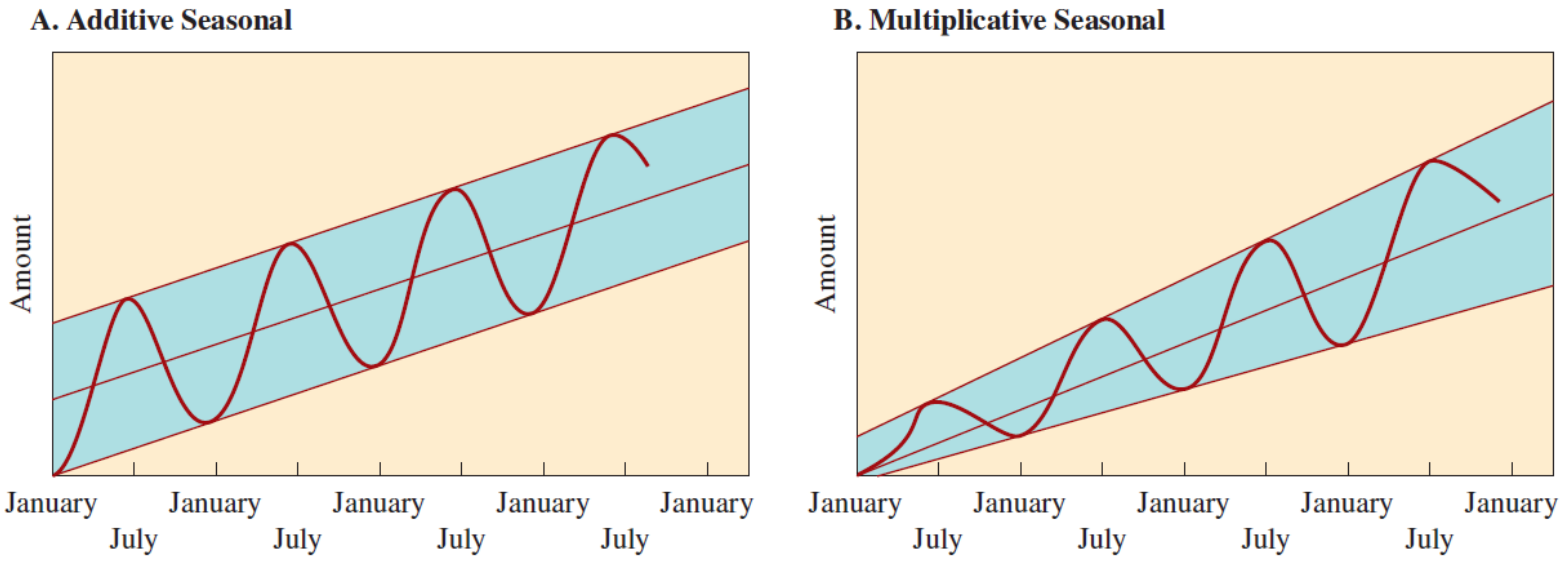


Exhibit 18.9

Example 18.3: Simple Proportion

- In past years, firm sold an average of 1,000 units each year
  - 200 in spring
  - 350 in summer
  - 300 in fall
  - 150 in winter
- Find the seasonal factors
- Using those factors, if we expected demand for next year to be 1,100 units, compute demand per period

Example 18.3: Finding Seasonal Factors

	Past Sales	Average Sales for Each Season (1,000/4)	Seasonal Factor
Spring	200	250	200/250 = 0.8
Summer	350	250	350/250 = 1.4
Fall	300	250	300/250 = 1.2
Winter	150	250	150/250 = 0.6
Total	1,000		

Example 18.3: Forecast for Next Year

	Expected Demand for Next Year	Average Sales for Each Season (1,100/4)		Seasonal Factor		Next Year's Seasonal Forecast
Spring		275	×	0.8	=	220
Summer		275	×	1.4	=	385
Fall		275	×	1.2	=	330
Winter		275	×	0.6	=	165
Total	1,100					

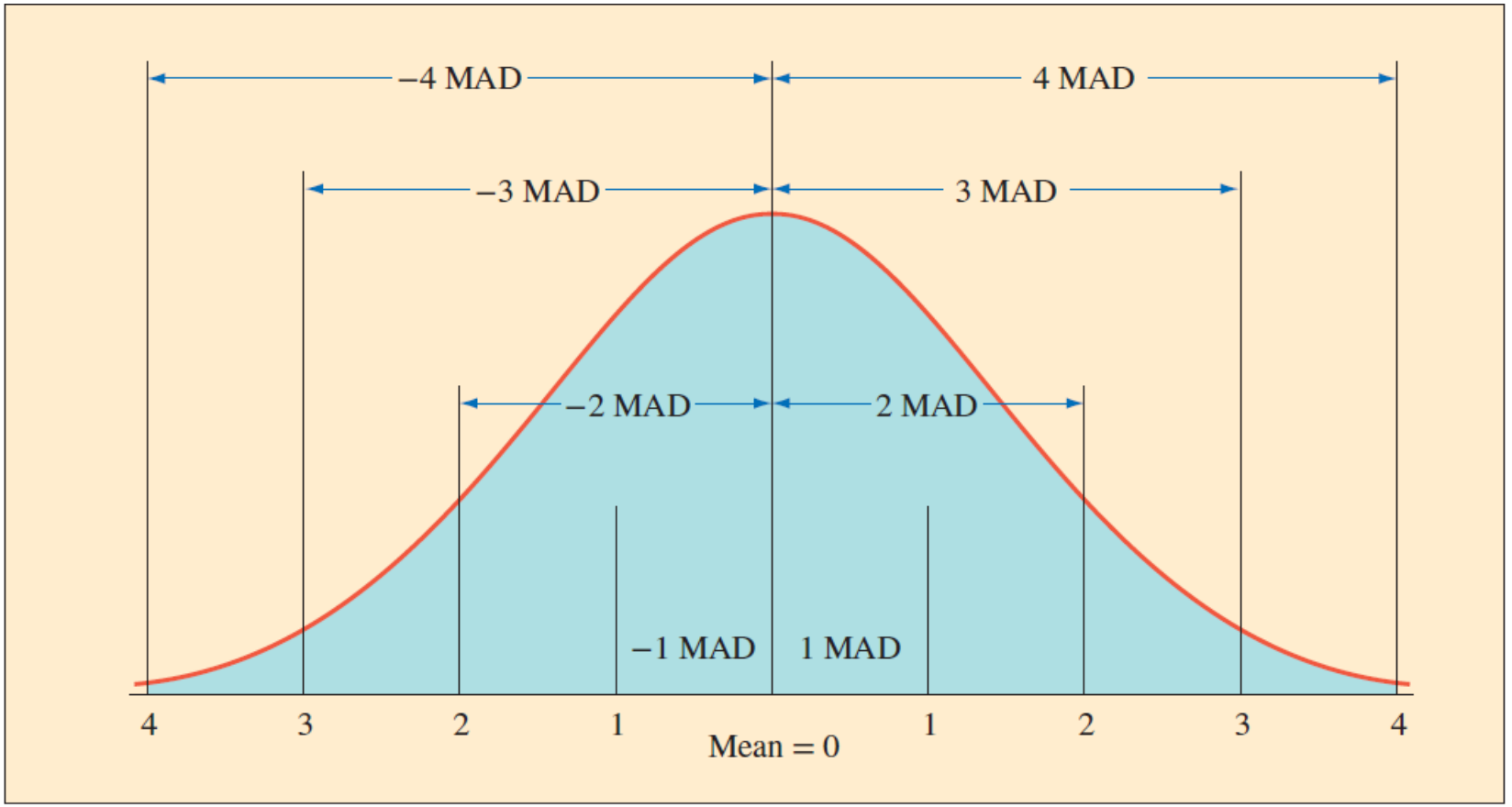
Forecast Errors

- Forecast error is the difference between the forecast value and what actually occurred
- Can come from a variety of sources
- All forecasts contain some level of error
- Sources of error
  - **Bias**: when a consistent mistake is made
  - **Random**: errors that are not explained by the model being used

Measures of Error

- Mean absolute deviation (MAD)
  - $MAD = \frac{\sum|A_t - F_t|}{n}$
  - Ideally, MAD will be zero (no forecasting error)
  - Larger values of MAD indicate a less accurate model
- Mean absolute percent error (MAPE)
  - $MAPE = \frac{MAD}{Average\ demand}$
  - Scales the forecast error to the magnitude of demand
- Tracking signal
  - $TS = \frac{Running\ sum\ of\ forecast\ errors}{MAD}$
  - Indicates whether forecast errors are accumulating over time (either positive or negative errors)

A Normal Distribution with Mean = 0 and MAD = 1



Summary

- Strategic forecasts are longer term and usually involve forecasting demand for a group of products
- Tactical forecasts would cover only a short period of time
- Demand can be broken down or "decomposed" into basic elements, such as trend, seasonality, and random variation
- Four different time series models are evaluated
  - (1) simple moving average, (2) weighted moving average, (3) exponential smoothing, and (4) linear regression
- The quality of a forecast is measured based on its error
- Qualitative techniques depend more on judgment or the opinions of experts
  - These techniques typically involve a structured process so that experience can be acquired and accuracy assessed

Material Requirements Planning (MRP) and ERP

14

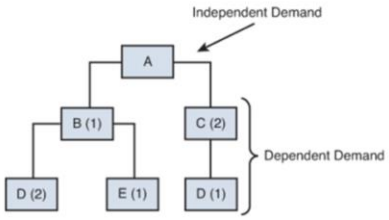
LO 14.1 Develop a product structure
LO 14.2 Build a gross requirements plan
LO 14.3 Describe MRP II
LO 14.4 Describe closed-loop MRP
LO 14.5 Describe ERP

PowerPoint presentation to accompany
Operations Management by Heizer and Render

PowerPoint slides by Jeff Heyl

Dependent Demand

- For any product for which a schedule can be established, dependent demand techniques should be used.
- **Dependent demand** is the **demand** for component parts, raw materials, or sub-assemblies. This **demand** does not occur until there is **demand** for a parent item, which is typically a product



The **dependent demand technique** used in a production environment is called material requirements planning (MRP).

Dependent demand: the need for any one item is a direct result of the need for some other item

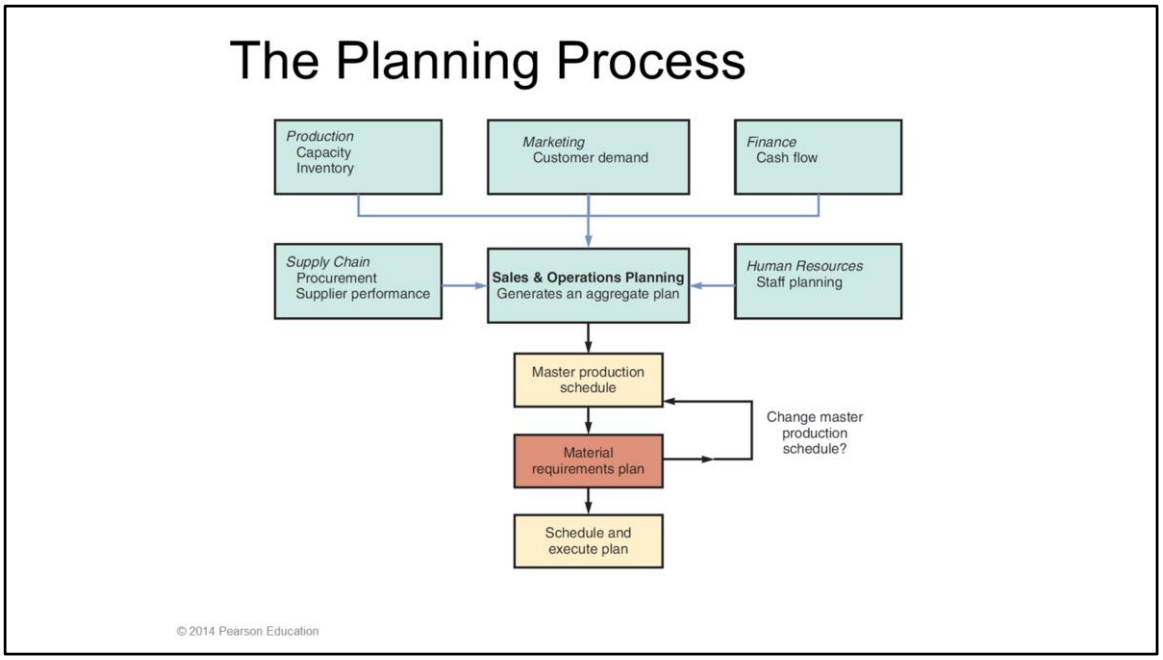
- Usually a higher-level item of which it is part
- If an aircraft company plans on producing 4 planes per month, then it will need 8 engine (2 per plane)

When an organization receives an order or makes a forecast for the final product, quantities for all components can be computed. All components are dependent items. The Boeing Aircraft operations manager who schedules production of one plane per week, for example, knows the requirements down to the last rivet.

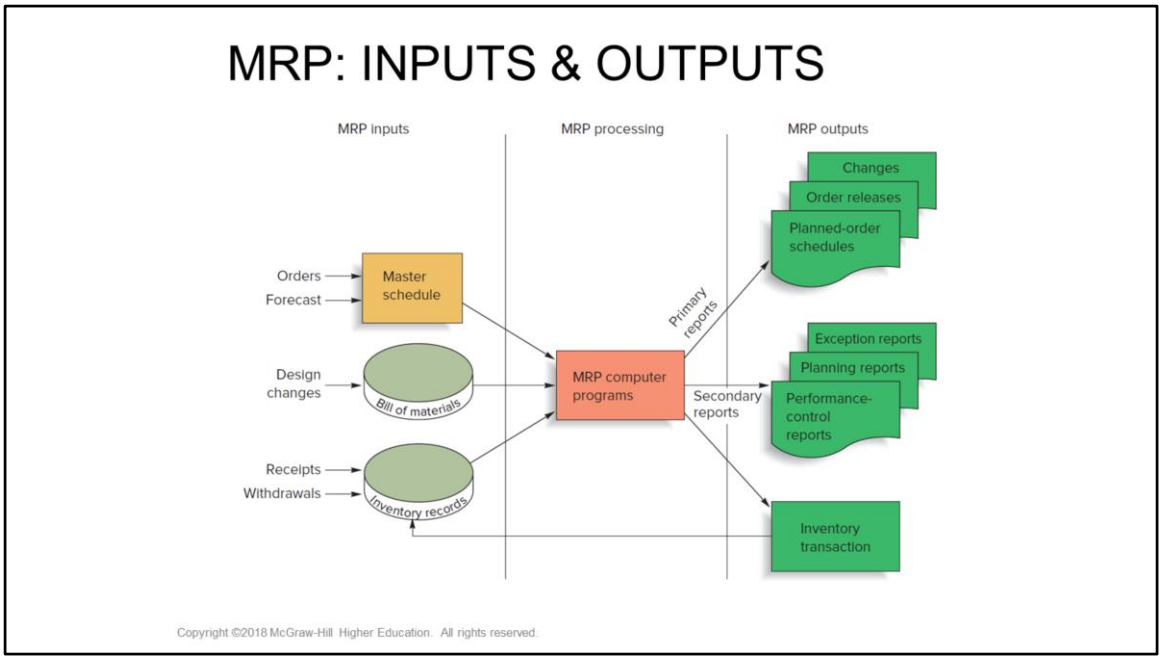
What is MRP?

- Material requirements planning (MRP) is a computer-based inventory management system.
- Organizations use MRP systems to estimate quantities of raw materials and schedule deliveries.
- MRP is designed to answer three questions: *What is needed? How much is needed? When is it needed?"*

Material requirements planning (MRP) is a methodology used for planning the production of assembled products such as smartphones, automobiles, kitchen tables, and a whole host of other products that are assembled. Some items are produced repetitively while others are produced in batches
The process begins with a master production schedule/master schedule



A **master production schedule/master schedule** specifies what is to be made (e.g., the number of finished products or items) and when. The schedule must be in accordance with an aggregate plan. The plan, developed by the sales and operations planning team, includes a variety of inputs, including: *financial data, customer demand, engineering capabilities, labor availability, inventory fluctuations, supplier performance, and other considerations.*
Each of these inputs contributes in its own way to the aggregate plan. The aggregate plan sets the overall level of output in broad terms (e.g., product families, standard hours, or rand volume).



The **primary inputs** of MRP are a *bill of materials*, which tells the composition of a finished product; *a master schedule*, which tells how much finished product is desired and when; and an *inventory records file*, which tells how much inventory is on hand or on order. The planner processes this information to determine the net requirements for each period of the planning horizon. **Outputs** from the process include *planned-order schedules,* schedule indicating the amount and timing of future orders; *order releases,* authorizing the execution of planned orders; *changes,* to planned orders; *performance-control reports,* evaluate system operation; *planning reports* to determine inventory requirements over time*, and exception reports,* used to point out discrepancies, such as late or overdue orders.

MRP Inputs: Master Schedule

- States which end items are to be produced, when these are needed, and in what quantities
- The master schedule should cover a period that is at least equivalent to the cumulative lead time
  - Cumulative lead time
  - The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of the final assembly

The master production schedule tells us how to satisfy demand by specifying what items to make and when.
It is important, though, that the master schedule cover the **cumulative lead time** necessary to produce the end items (lead times include move and wait times in addition to setup and run times.). The reason the master schedule time horizon covers the longest cumulative lead time is because you want to plan far enough in advance to handle any problems that may occur. You want that visibility into the future to avoid any foreseeable problems. If your cumulative lead time is six months, but you are planning ahead for only three months, you may not be able to react to issues or problems that arise.

Aggregate Production Plan

Aggregate Plan
(Shows the total quantity of amplifiers)

Months	January				February			
	1,500				1,200			

Master Production Schedule
(Shows the specific type and quantity of amplifier to be produced)

Weeks	1	2	3	4	5	6	7	8
240-watt amplifier	100		100		100		100	
150-watt amplifier		500		500		450		450
75-watt amplifier			300				100	

The **aggregate plan** is established in gross terms such as families of products or tons of steel

The **master production schedule** is established in terms of specific products.

Figure Description

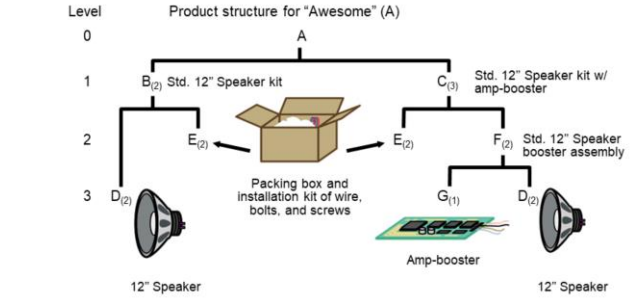
The Figure shows the master production schedules for three stereo models that flow from the aggregate plan for a family of stereo amplifiers

Bill of Materials(BOM)

- List of components, ingredients, and materials needed to make product
- Provides product structure
  - Items above given level are called parents
  - Items below given level are called children

A **bill of materials (BOM)** contains a listing of all of the assemblies, subassemblies, parts, part costs, and raw materials that are needed to produce *one* unit of a finished product. Thus, each finished product has its own bill of materials.
The listing in the bill of materials is hierarchical; it shows the quantity of each item needed to complete one unit of its parent item

BOM Example

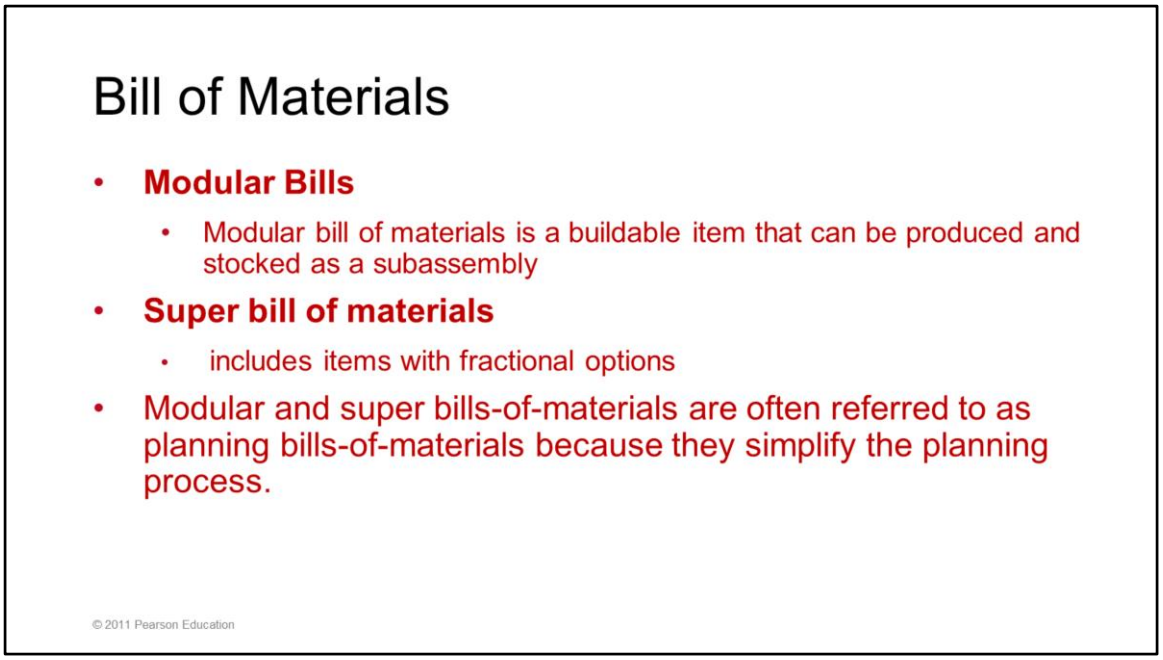


Part B: 2 x number of As = (2)(50) =100
Part C: 3 x number of As = (3)(50) =150
Part D: 2 x number of Bs + 2 x number of Fs = (2)(100) + (2)(300) =800
Part E: 2 x number of Bs + 2 x number of Cs =(2)(100) + (2)(150) =500
Part F: 2 x number of Cs = (2)(150) = 300
Part G: 1 x number of Fs = (1)(300) = 300

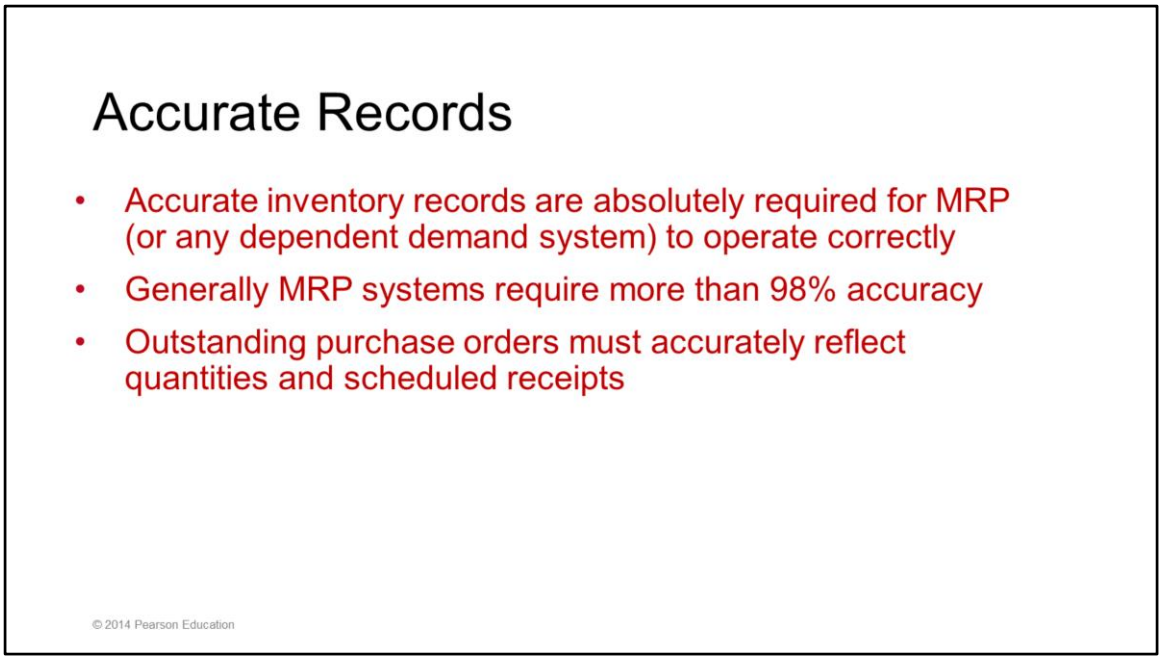
Example: Developing a Product Structure and Gross Requirements

This structure has **four levels**: 0, 1, 2, and 3. There are **four parents**: A, B, C, and F. Each parent item has at least one level below it. Items B, C, D, E, F, and G are components because each item has **at least one level above it**. In this structure, B, C, and F are both parents and components. The number in parentheses indicates how many units of that particular item are needed to make the item immediately above it. Thus, $B_{(2)}$ means that it takes two units of B for every unit of A, and $F_{(2)}$ means that it takes two units of F for every unit of C.

Now that we have developed the product structure, we can determine the number of units of each item required to satisfy demand for a new order of 50 Awesome speaker kits. We "explode" the requirements as shown in the calculation above.



A **modular bill-of-materials** - It is particularly advantageous to schedule subassembly modules when same subassemblies appear in different end items. Using a modular bill-of-materials simplifies the scheduling and control and also makes it easier to forecast the use of different modules.
A **super bill-of-materials** - A super bill can specify a fraction, e.g., 0.3 of a part. What that means is that 30 percent of the units produced contain that part and 70 percent do not. Modular and super bills-of-materials are often referred to as planning bills-of-materials because they simplify the planning process.



After the BOM information is accessed, the next information the MRP system requires to complete the planning job is the inventory records.
There are **two types of inventory records** for this discussion: on-hand inventory and on-order inventory.
The importance of data accuracy becomes more critical due to data dependency. The BOM records must be impeccable and inventory records must be pristine.
Minimally acceptable thresholds for this accuracy require BOM accuracy to be at 98%. This means that 98% of the BOMs are perfect.

MRP Management

- MRP is a dynamic system
- System nervousness can result from too many changes
- Two tools are particularly helpful when trying to reduce MRP system nervousness
  - Time fences put limits on replanning
  - Pegging links each item to its parent allowing effective analysis of changes

The inputs to MRP (the master schedule, BOM, lead times, purchasing, and inventory) frequently change. These frequent changes generate what is called system nervousness and can create havoc in purchasing and production departments if implemented. OM personnel reduce such nervousness by evaluating the need and impact of changes prior to disseminating requests to other departments **by using two tools: Time fences & Pegging**.

Time fences allow a segment of the master schedule to be designated as "not to be rescheduled."

Pegging means tracing upward in the BOM from the component to the parent item. By pegging upward, the production planner can determine the cause for the requirement and make a judgment about the necessity for a change in the schedule.

Finite Capacity Scheduling

- MRP systems do not consider capacity during normal planning cycles
- Finite capacity scheduling (FCS) recognizes actual capacity limits
- By merging MRP and FCS, a finite schedule is created with feasible capacities which facilitates rapid material movement

MRP is considered an *infinite* scheduling technique.
Infinite scheduling produces a schedule without any consideration for each resource's capacity or the other batches to be scheduled. The assumption is that each resource has infinite capacity.

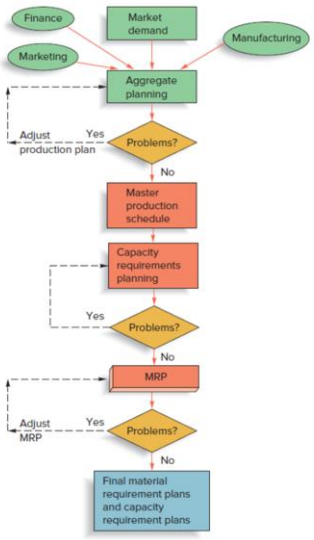
Extensions of MRP

- MRP II
- Closed-Loop MRP
  - MRP system provides input to the capacity plan, MPS, and production planning process
- Capacity Planning
  - MRP system generates a load report which details capacity requirements
  - This is used to drive the capacity planning process
  - Changes pass back through the MRP system for rescheduling

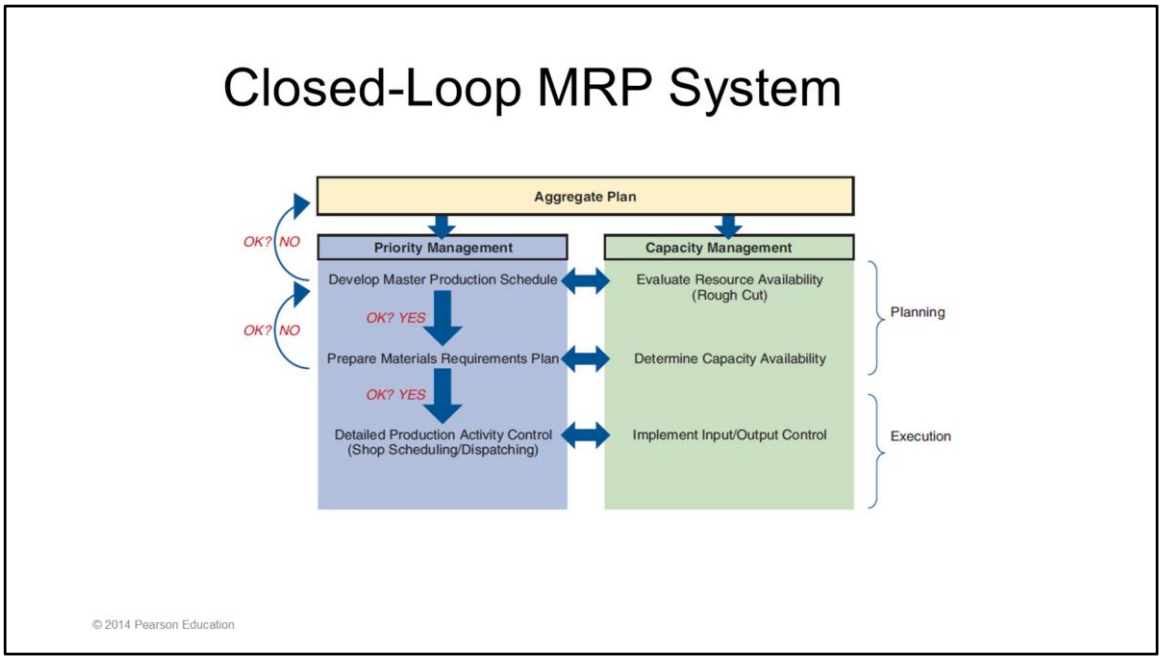
The 3 extensions of MRP will be reviewed in more details in the next 3 slides.

MRP II

- Generally called MRP II or Material Resource Planning
- It evolved to support other manufacturing functions beyond material planning, inventory control and BOM control.
- These extensions included the addition of transaction processing software to support the purchasing, inventory and financial functions of the firm



Through these extensions MRP II can support Master Planning, Capacity Requirements Planning and Production Activity Control. The MRP II system, is a closed loop MRP system, with additional features to cover **business** and **financia**l planning (not just **manufacturing**), as shown in the Figure
Most MRP II systems have the capability of performing simulation, enabling managers to answer a variety of what-if questions so they can gain a better appreciation of available options and their consequences.



A Closed-loop MRP system - provides feedback to the *capacity plan, master production schedule, and production plan* so planning can be kept valid at all times. Nearly all commercial MRP systems are closed-loop.

Capacity Planning

- Feedback from the MRP system
- Load reports show resource requirements for work centers
- Work can be moved between work centers to smooth the load or bring it within capacity

Capacity requirements planning is the process of determining short-range capacity requirements. Closed-loop MRP systems evaluate a proposed material plan relative to available capacity. If a proposed plan is not feasible, it must be revised.

Key outputs of capacity planning include load reports for each work center. When variances (underloads or overloads) are projected, managers might consider smoothing the load and minimizing the impact of changed lead time by: *Overlapping, Operations splitting and Order splitting,* or *lot splitting*

Smoothing Tactics

1. Overlapping
   - Sends part of the work to following operations before the entire lot is complete
   - Reduces lead time
2. Operations splitting
   - Sends the lot to two different machines for the same operation
   - Shorter throughput time but increased setup costs
3. Order or lot splitting
   - Breaking up the order into smaller lots and running part earlier (or later) in the schedule

Overlapping is a method that processes part of the lot on the work center performing the second operation, while the rest of the lot is still in the work center in the first operation. Overlapping reduces lead time in a way similar to parallel processing.

Operations Splitting: Throughput time decreases as only part of the lot is processed on one machine.

Lot Splitting /Order Splitting: A lot (or order) is split, and a part of it is run ahead of schedule in a period where there is available capacity.

MRP in Services

- Some services or service items are directly linked to demand for other services
- These can be treated as dependent demand services or items
  - Restaurants
  - Hospitals
  - Hotels

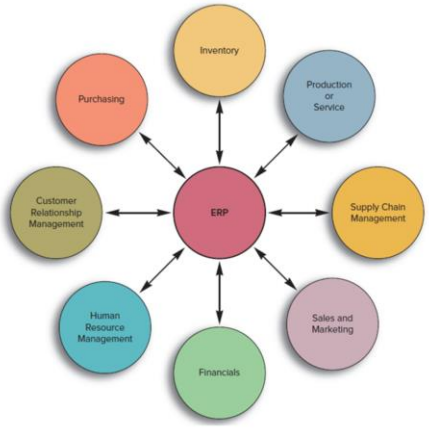
MRP has applications in services as well as in manufacturing. These applications may involve material goods that form a part of the product–service package, or they may involve mainly service components.
An example of a product–service package is a food catering service, particularly in instances that require preparing and serving meals for large numbers of people. To estimate quantities and costs of an order, the food manager would have to determine the quantities of the ingredients for each recipe on the menu (i.e., a bill of materials), which would then be combined with the number of each meal to be prepared to obtain a material requirements plan for the event.

Enterprise Resource Planning (ERP)

- An extension of the MRP system to tie in customers and suppliers
  - Allows automation and integration of many business processes
  - Shares common data bases and business practices
  - Produces information in real time
- Coordinates business from supplier evaluation to customer invoicing

A typical ERP system is made up of functionally oriented and tightly integrated modules. All the modules of the system use a common database that is updated in real time.
The modules relate to the functional areas of business organizations. For example, there are modules for accounting/finance, HR, Supply Chain Management, product planning, purchasing, Customer RelationshipManagement, inventory management, distribution, sales and marketing. Organizations can select the modules that best serve their needs and budgets

Key connections to the ERP system



Accounting/Finance: A central component of most ERP systems. It provides a range of financial reports, including general ledger, accounts payable, accounts receivable, payroll, income statements, and balance sheets

Marketing: Supports lead generation, target marketing, direct mail, and sales

Human Resources: Maintains a complete data base of employee information such as date of hire, salary, contact information, performance evaluations, and other pertinent information

Purchasing: Facilitates vendor selection, price negotiation, making purchasing decisions, and bill payment

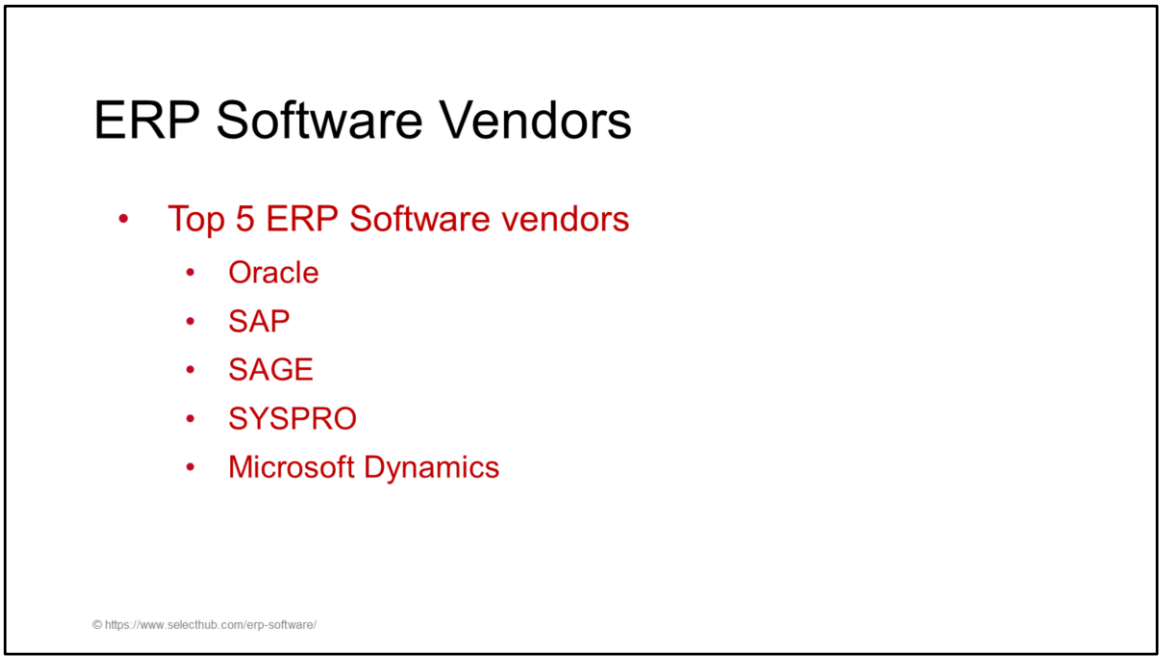
Production Planning: Integrates information on forecasts, orders, production capacity, on-hand inventory quantities, bills of material, work in process, schedules, and production lead times

Inventory Management: Identifies inventory requirements, inventory availability, replenishment rules, and inventory tracking

Distribution: Contains information on third-party shippers, shipping and delivery schedules, delivery tracking

Sales: Information on orders, invoices, order tracking, and shipping

Supply Chain Management: Facilitates supplier and customer management, supply chain visibility, and event management



Listed above are the Top ERP 5 software vendors

Advantages of ERP Systems

- Provides integration of the supply chain, production, and administration
- Creates commonality of databases
- Can incorporate improved best processes
- Increases communication and collaboration between business units and sites
- Has an off-the-shelf software database
- May provide a strategic advantage

Deciding whether or not your business should take on an ERP software can be an overwhelming decision, listed above and on the next slide are factors (advantages and disadvantages) to consider before implementing ERP software

Disadvantages of ERP Systems

- Is very expensive to purchase and even more so to customize
- Implementation may require major changes in the company and its processes
- Is so complex that many companies cannot adjust to it
- Involves an ongoing, possibly never completed, process for implementation
- Expertise is limited with ongoing staffing problems

It's equally as important to understand the disadvantages of this type of software to make sure ERP is the right system for the organization. The five most common disadvantages that organizations have reported after implementation are listed above.

ERP in the Service Sector

- ERP systems have been developed for health care, government, retail stores, hotels, and financial services
- Also called efficient consumer response (ECR) systems
- Objective is to tie sales to buying, inventory, logistics, and production

In the service industry, an enterprise resource planning (ERP) system is a vital tool as many moving parts, must work in sync every day to ensure that the organization operates at its optimum level.
Listed below are five ways ERP streamlines hotel and resort operations:

- Room booking system;
- Guest management;
- Front-desk efficiency;
- Inventory management; and
- Housekeeping, laundry, and maintenance.

Summary

- Material requirements planning (MRP) schedules production and inventory when demand is dependent.
- In addition to material planning, ERP systems integrate organizational needs such as: accounting/finance, HR, Supply Chain Management, Product Planning, Purchasing, Customer Relationship Management, Inventory Management, Distribution, Sales and Marketing
- When deciding on software selection it comes down to what your needs are
  - Take into consideration both the advantages and disadvantages.

CHAPTER 23: THEORY OF CONSTRAINTS

LO23–1: Explain the Theory of Constraints (TOC).

LO23–2: Analyze bottleneck resources and apply TOC principles to controlling a process.

LO23–3: Evaluate bottleneck scheduling problems by applying TOC principles.

ELI GOLDRATT'S THEORY OF CONSTRAINTS

- Goldratt contends that manufacturers were not doing a good job in scheduling and in controlling their resources and inventories
- Goldratt developed software that scheduled jobs through manufacturing processes
  - It takes into account limited facilities, machines, personnel, tools, materials, and any other constraints
  - This was called optimized production technology (OPT)
- Scheduling logic was based on the separation of bottleneck and nonbottleneck operations

Goldratt's Rules of Production Scheduling

1. Do not balance capacity, balance the flow
2. The level utilization of a nonbottleneck resource is not determined by its own potential but by some other constraint in the system
3. Utilization and activation of a resource are not the same
4. An hour lost at a bottleneck is an hour lost for the entire system
5. An hour saved at a nonbottleneck is a mirage

Goldratt's Rules of Production Scheduling

Continued

6. Bottlenecks govern both throughput and inventory in the system
7. Transfer batch may not, and many times should not, be equal to the process batch
8. A process batch should be variable both along its route and in time
9. Priorities can be set only by examining the system's constraints, and lead time is a derivative of the schedule

Goldratt's Theory of Constraints (TOC)

1. Identify the system constraints
2. Decide how to exploit the system constraints
3. Subordinate everything else to that decision
4. Elevate the system constraints
5. If, in the previous steps, the constraints have been broken, go back to step 1, but do not let inertia become the system constraint

Unbalanced Capacity

- *Unbalanced capacity* is better!
- Synchronous manufacturing views constant workstation capacity as a bad decision
  - Random variations must be handled using inventory
  - When one process takes longer than the average, the time can not be made up

Bottlenecks, Capacity-Constrained Resources and Synchronous Manufacturing

- **Capacity**: the available time for production
- **Bottleneck**: what happens if capacity is less than demand placed on resource
- **Nonbottleneck**: what happens when capacity is greater than demand placed on resource
- **Capacity-constrained resource (CCR)**: a resource where the capacity is close to demand on the resource

Basic Manufacturing Building Blocks

- All manufacturing processes and flows can be simplified to four basic configurations

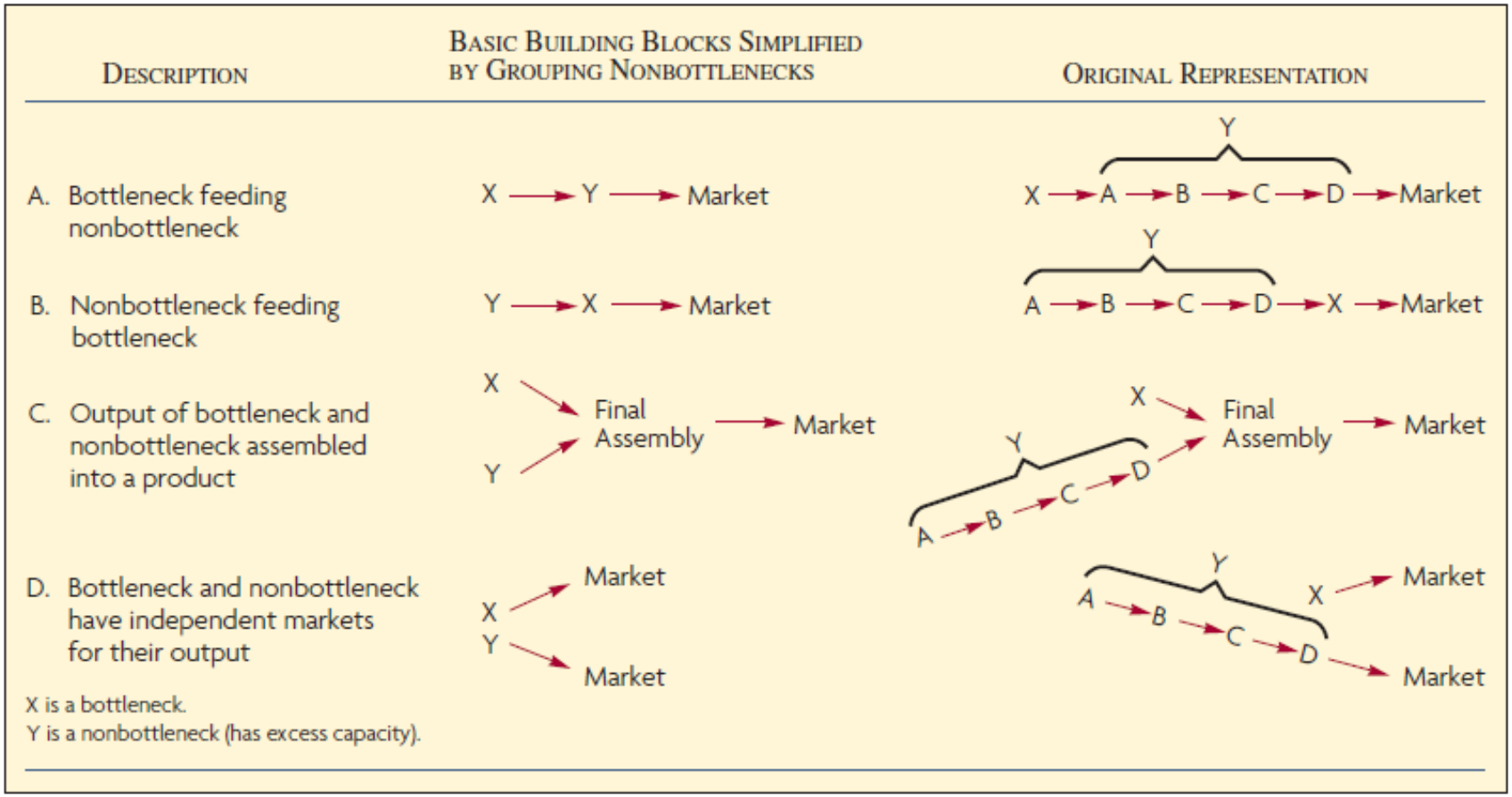


Exhibit 23.6

Methods for Synchronous Control

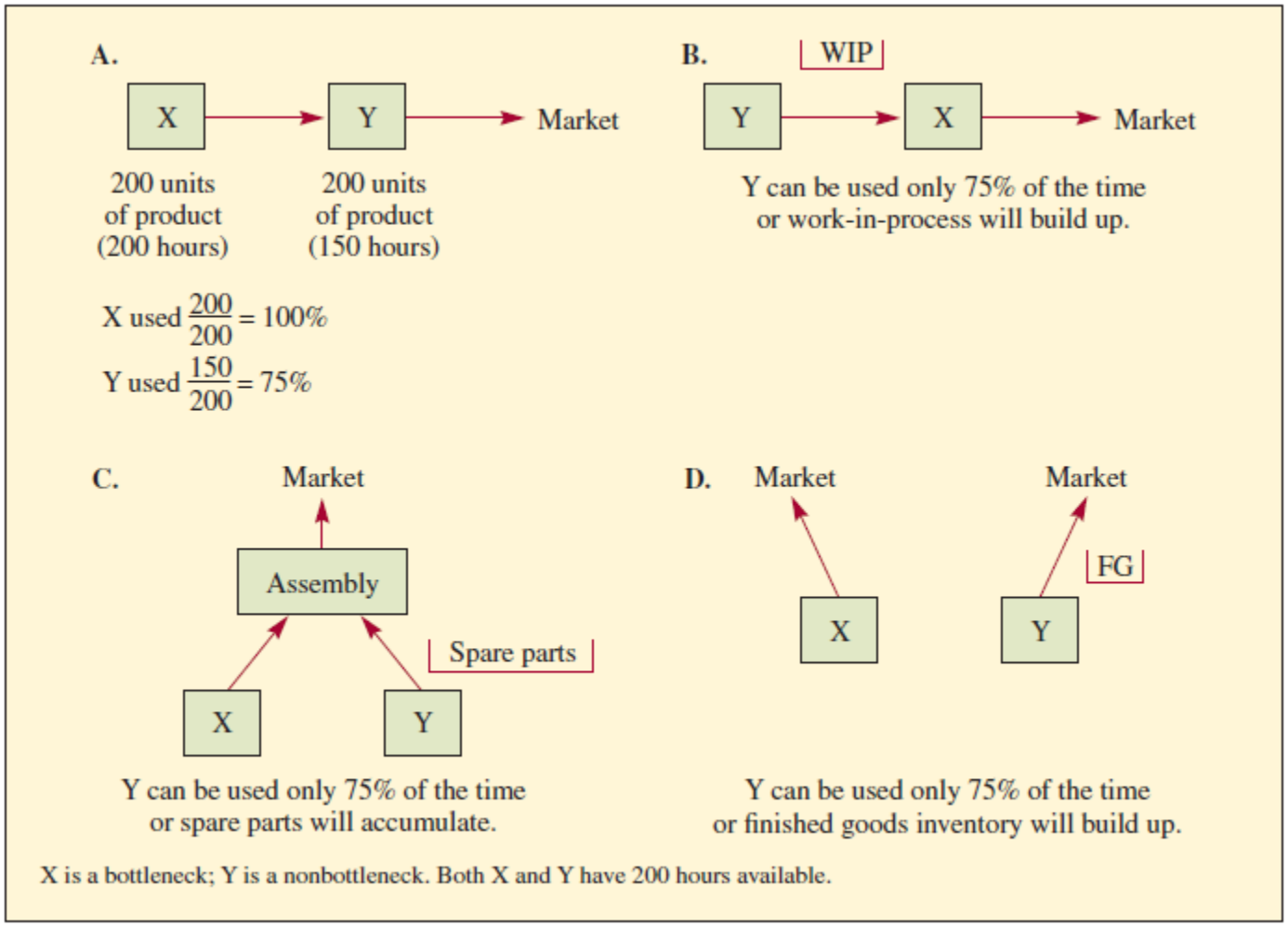


Exhibit 23.7

Time Components

1. **Setup time**: the time that a part spends waiting for a resource to be set up to work on this same part
2. **Process time**: the time that the part is being processed
3. **Queue time**: the time that a part waits for a resource while the resource is busy with something else
4. **Wait time**: the time that a part waits not for a resource but for another part so that they can be assembled together
5. **Idle time**: the unused time that represents the cycle time less the sum of the setup time, processing time, queue time, and wait time

Finding the Bottleneck

1. Run a capacity resource profile
   - Obtained by looking at the loads placed on each resource by the products that are scheduled through them
2. Use your knowledge of the particular plant
   - Look at the system in operation
   - Talk with supervisors and workers

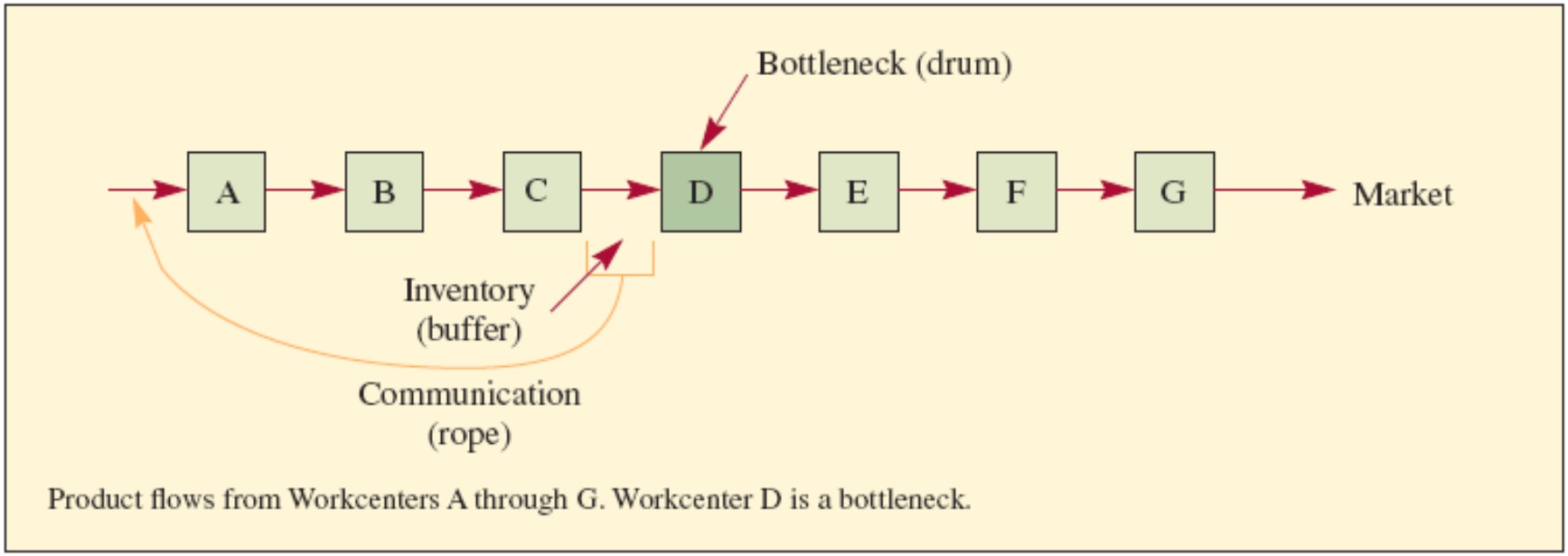
Saving Time

- Bottlenecks govern both throughput and inventory in the system
- An hour saved at the bottleneck adds an extra hour to the entire production system – Time is very valuable
- An hour saved at a nonbottleneck is a mirage and only adds an hour to its idle time

Drum, Buffer, Rope

- Every production system needs some control point or points to control the flow
- If the system contains a bottleneck, it is the best place for control
- This control point is called the drum
  - It strikes the beat that the rest of the system uses to function
- If there is no bottleneck, the next-best place to set the drum would be a capacity- constrained resource

Linear Flow of Product with a Bottleneck



Product flows from Workcenters A through G. Workcenter D is a bottleneck.

Exhibit 23.9

Example 23.1: What to Produce?

- Three products are sold in the market
  - A, R50
  - B, R75
  - C, R60
- The market will take all that can be supplied
- Three workcenters (X, Y, and Z) process the three products
  - Times given on next slide
- Raw materials, parts, and components are added at each workcenter to produce each product
  - Shown on next slide
- What should be produced?

Example 23.1: Data

Product	Limiting Resource	Time Required	Number Produced per Hour	Selling Price	Sales Revenue per Hour
A	Y	10 min	6	$50	$300
B	X	6 min	10	75	750
C	Z	5 min	12	60	720

Example 23.1: Prices and Production Requirements for Three Products and Workcenters

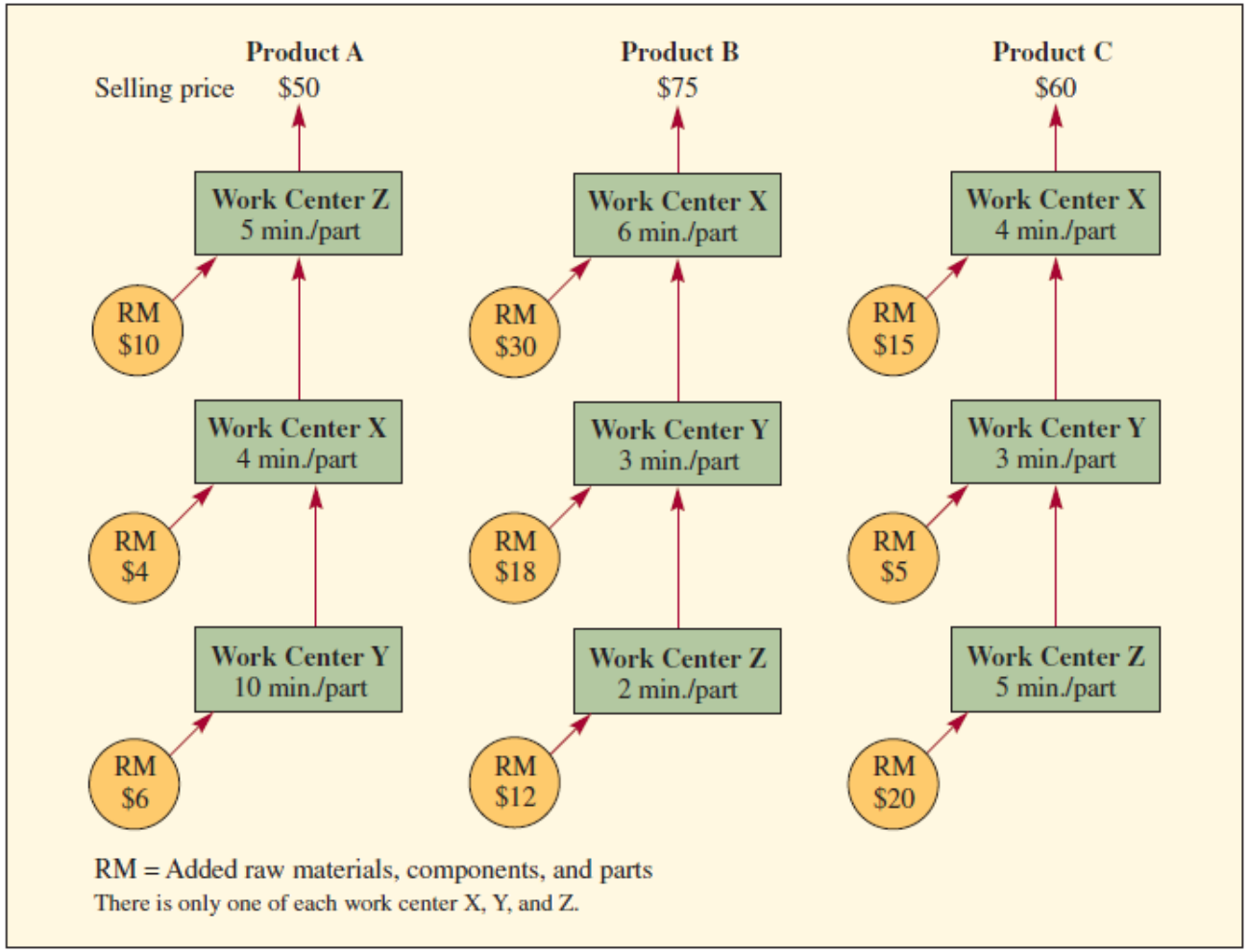


Exhibit 23.14

Example 23.1: Solution

- Three different objectives could exist that lead to different conclusions
  1. Maximize sales revenue because marketing personnel are paid commissions based on total revenue
  2. Maximize per unit gross profit
  3. Maximize total gross profit
- In this example, we use gross profit as the objective and provide a solution
- Other objectives can be worked out similarly

Example 23.1: Objective 3 – Maximize Total Gross Profit

- We can solve this problem by finding either
  - Total gross profit for the period
  - Rate at which profit is generated
- We use rate to solve the problem both because it is easier and because it is a more appropriate measure
  - We use profit per hour as the rate
- Note that each product has a different workcenter that limits its output
  - The rate at which the product is made is then based on this bottleneck workcenter

Profit per Hour Calculations

(1) Product	(2) Limiting Work Center	(3) Processing Time per Unit (Minutes)	(4) Product Output Rate (per Hour)	(5) Selling Price	(6) Raw Material Cost	(7) Profit per Unit	(8) Profit per Hour (4) × (7)
A	Y	10	6	$50	$20	$30	$180
B	X	6	10	75	60	15	150
C	Z	5	12	60	40	20	240

- It is clear that product C provides the highest profit per hour
- In order to maximize total gross profit, the firm should produce as much of the C as possible

Summary

- TOC is an alternative way to think about improving processes
- It is essential to concentrate on system limitations imposed by capacity-constrained resources
  - To do this, the firm must simultaneously increase throughput, reduce inventory, and reduce operating expenses
- Maintain perfectly balanced capacity leads to many problems
- Managing the flow through the bottlenecks is essential to the TOC synchronous manufacturing approach.
- Bottlenecks are identified by calculating the expected utilization (percentage of capacity used) for each resource
- Saving time on a bottleneck resource is the only way to increase throughput
- Synchronous manufacturing is flexible and focused on maximizing flow through the system while minimizing cost
- TOC can be used to schedule production

CHAPTER 12: QUALITY

LO12–1: Explain the scope of total quality management in a firm.

LO12–2: Understand the Six Sigma approach to improving quality and productivity.

LO12–3: Illustrate globally recognized quality benchmarks.

Total Quality Management (TQM)

- **Total quality management**: managing the entire organization so that it excels on all dimensions of products and services that are important to the customer
- Two fundamental operational goals
  1. Careful design of the product or service
  2. Ensuring that the organization's systems can consistently produce the design
- Can only be achieved if the entire organization is oriented toward them
  - Hence, the term *total* quality management

The Quality Gurus Compared

	Crosby	Deming	Juran
Definition of quality	Conformance to requirements	A predictable degree of uniformity and dependability at low cost and suited to the market	Fitness for use (satisfies customer's needs)
Degree of senior management responsibility	Responsible for quality	Responsible for 94% of quality problems	Less than 20% of quality problems are due to workers
Performance standard/motivation	Zero defects	Quality has many "scales"; use statistics to measure performance in all areas; critical of zero defects	Avoid campaigns to do perfect work
General approach	Prevention, not inspection	Reduce variability by continuous improvement; cease mass inspection	General management approach to quality, especially human elements
Structure	14 steps to quality improvement	14 points for management	10 steps to quality improvement
Statistical process control (SPC)	Rejects statistically acceptable levels of quality [wants 100% perfect quality]	Statistical methods of quality control must be used	Recommends SPC but warns that it can lead to tool-driver approach

Exhibit 12.1

The Quality Gurus Compared Continued

	Crosby	Deming	Juran
Structure	14 steps to quality improvement	14 points for management	10 steps to quality improvement
Statistical process control (SPC)	Rejects statistically acceptable levels of quality [wants 100% perfect quality]	Statistical methods of quality control must be used	Recommends SPC but warns that it can lead to tool-driver approach
Improvement basis	A process, not a program; improvement goals	Continuous to reduce variation; eliminate goals without methods	Project-by-project team approach; set goals
Teamwork	Quality improvement teams; quality councils	Employee participation in decision making; break down barriers between departments	Team and quality circle approach
Costs of quality	Cost of nonconformance; quality is free	No optimum; continuous improvement	Quality is not free; there is not an optimum
Purchasing and goods received	State requirements; supplier is extension of business; most faults due to purchasers themselves	Inspection too late; sampling allows defects to enter system; statistical evidence and control charts required	Problems are complex; carry out formal surveys
Vendor rating	Yes, quality audits useless	No, critical of most systems	Yes, but help supplier improve

Exhibit 12.1

Quality Specifications

- **Design quality:** the degree to which quality characteristics are designed into the product.
- **Conformance quality:** Degree to which the product or service design specifications are met
- Quality of design and Quality of conformance provide the fundamental basis for managing processes to produce quality products.
- Good quality can be attained only when both, quality of design and quality of conformance are good.

Dimensions of Product Quality

Dimensions of Product Quality
Performance this includes the basic operating characteristic of a product
Features these are the “extra” items (bells and whistles, secondary characteristics) added to the basic feature
Reliability/durability involves the consistency of performance over time, probability of failing, useful life
Serviceability includes the ease of repair, the speed of repair
Aesthetics the sensory characteristics (sound, feel, look, and so on)
Perceived quality Past performance and reputation
Safety refers to assurance that the customer will not suffer injury or harm from the product

Dimensions of Service Quality

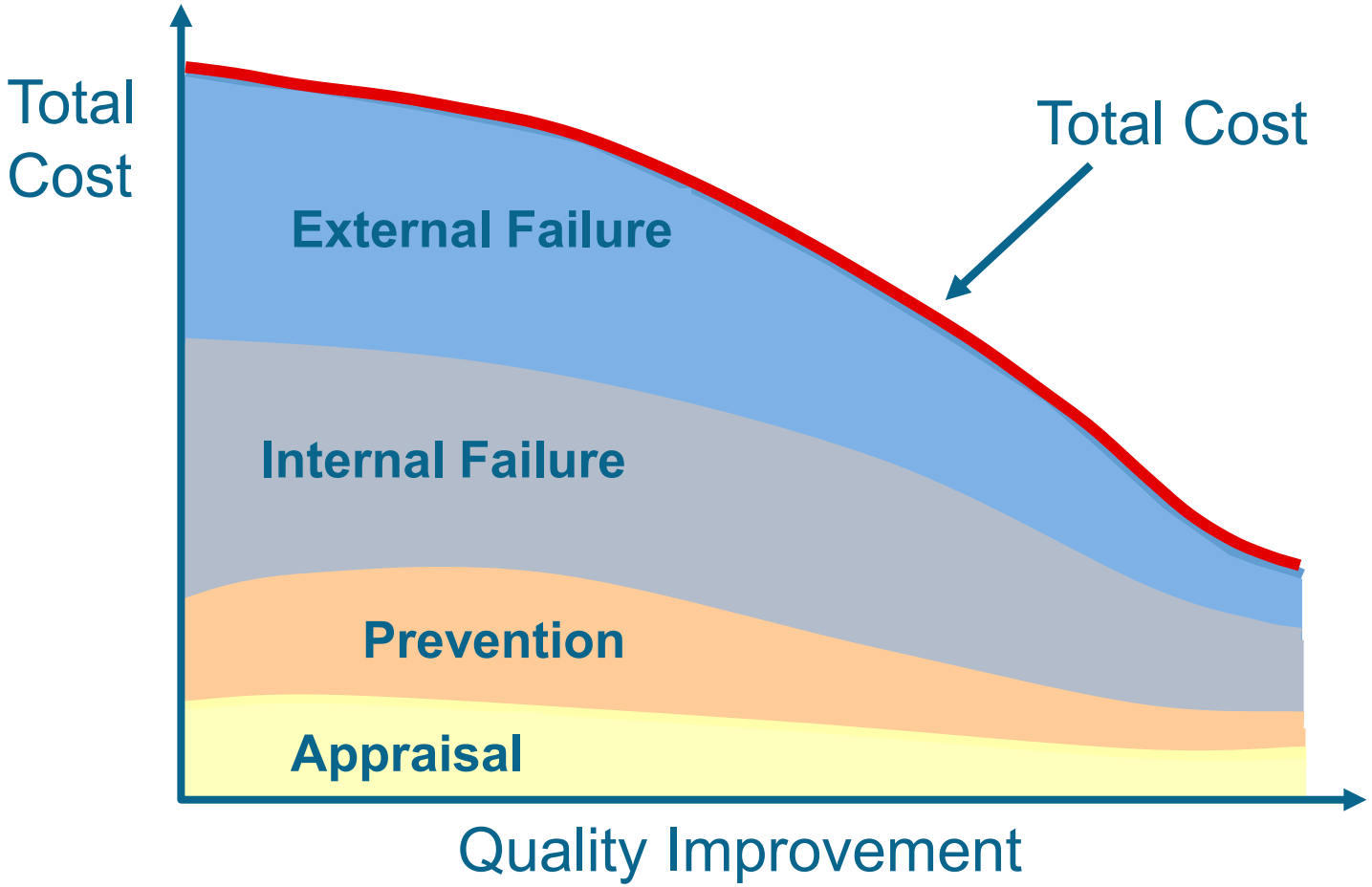
- Service quality is more difficult to measure than the quality of goods

- Service quality perceptions depend on
  - Intangible differences between products
  - Intangible expectations customers have of those products

Dimensions of Service Quality

Dimensions of Service Quality
Reliability involves consistency of performance and dependability. It means that the company performs the service right the first time and that it honours its promises.
Responsiveness It involves timeliness of service, readiness of employees
Competence possession of the required skills and knowledge to perform the service.
Access involves approachability and ease of contact.
Courtesy involves politeness, respect, consideration, friendliness of contact personnel
Communication keeping customers informed in language they can understand and listening to them.
Credibility involves trustworthiness, believability, and honesty.
Security is the freedom from danger, risk, or doubt.
Understanding/knowing the customer involves making the effort to understand the customer's needs.
Tangibles include the physical evidence of the service.

Quality Costs



Quality Costs

- **Appraisal costs**: costs of the inspection and testing to ensure that the product or process is acceptable
- **Prevention costs**: sum of all the costs to prevent defects
- **Internal failure costs**: costs for defects incurred within the system
- **External failure costs**: costs for defects that pass through the system

Six Sigma

- A philosophy and set of methods companies use to eliminate defects in their products and processes
- Seeks to reduce variation in the processes that lead to product defects
- The name, “Six Sigma,” refers to the goal of no more than 3.4 defects per million units
- DPMO is defects per million opportunities
- $$DPMO = \frac{Number\ of\ defects}{Number\ opportunities\ for\ errors\ per\ unit \times Number\ units}$$

DMAIC Cycle

Define - identify customers and their priorities

Measure - determine how to measure the process and how it is performing

Analyze - determine the most likely causes of defects

Improve - identify means to remove the causes of defects

Control - determine how to maintain the improvements

Six Sigma Analytical Tools

1. Flowchart
2. Run chart
3. Pareto chart
4. Checksheet
5. Cause-and-effect diagram
6. Opportunity flow diagram
7. Process control chart

Flowchart (Define)

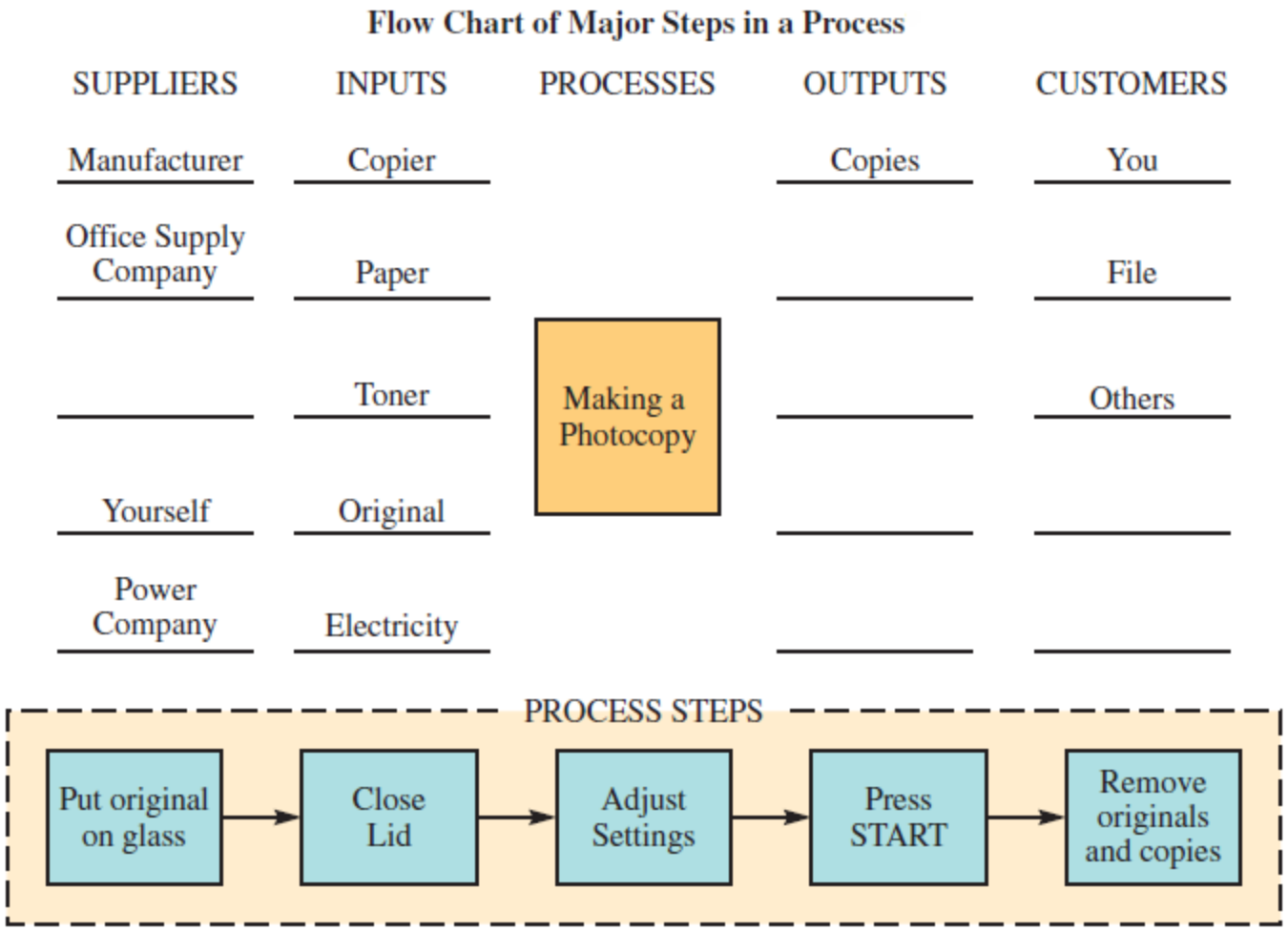


Exhibit 12.5

Run Chart (Define)

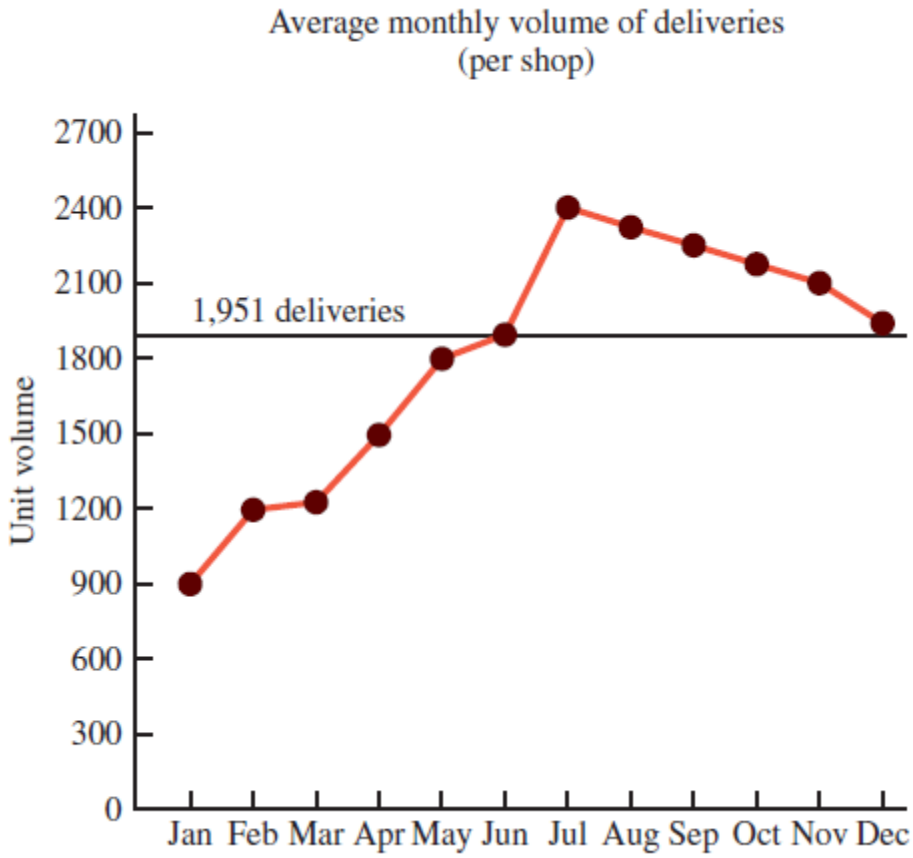


Exhibit 12.5

Checksheet (Define)

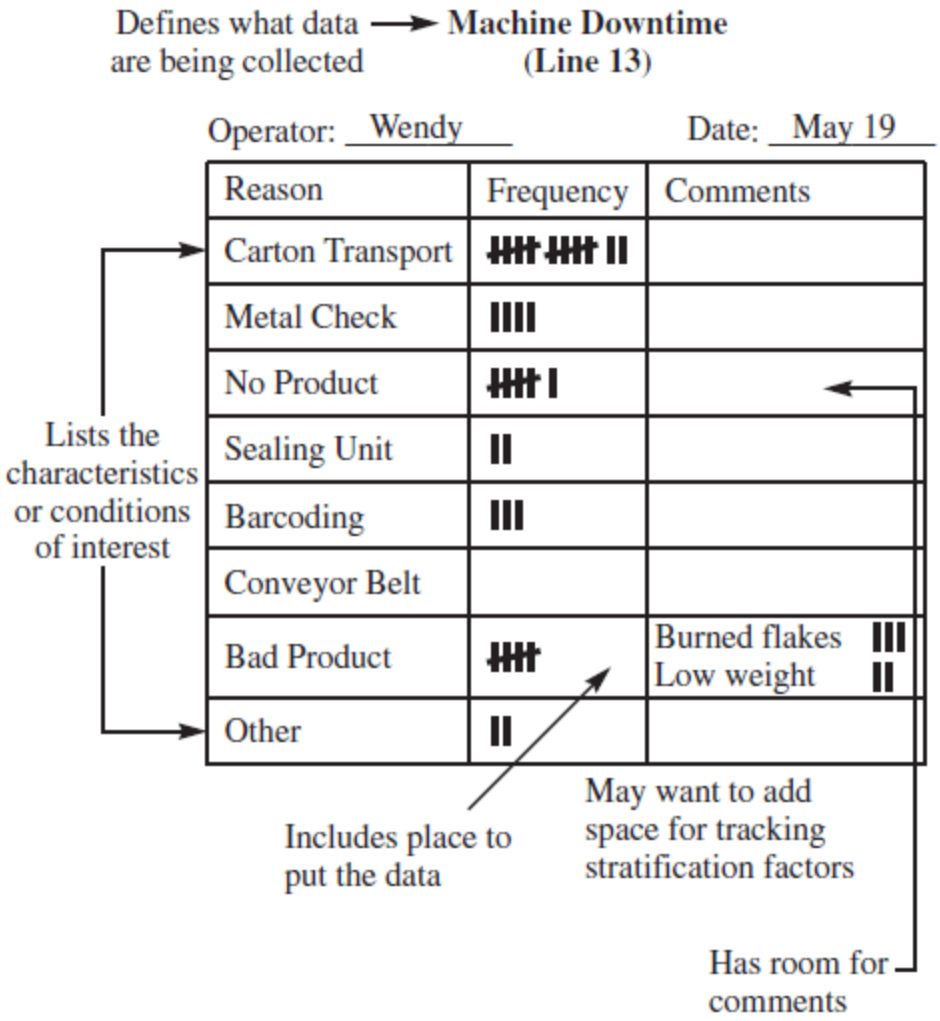


Exhibit 12.5

Pareto Chart (Measure)

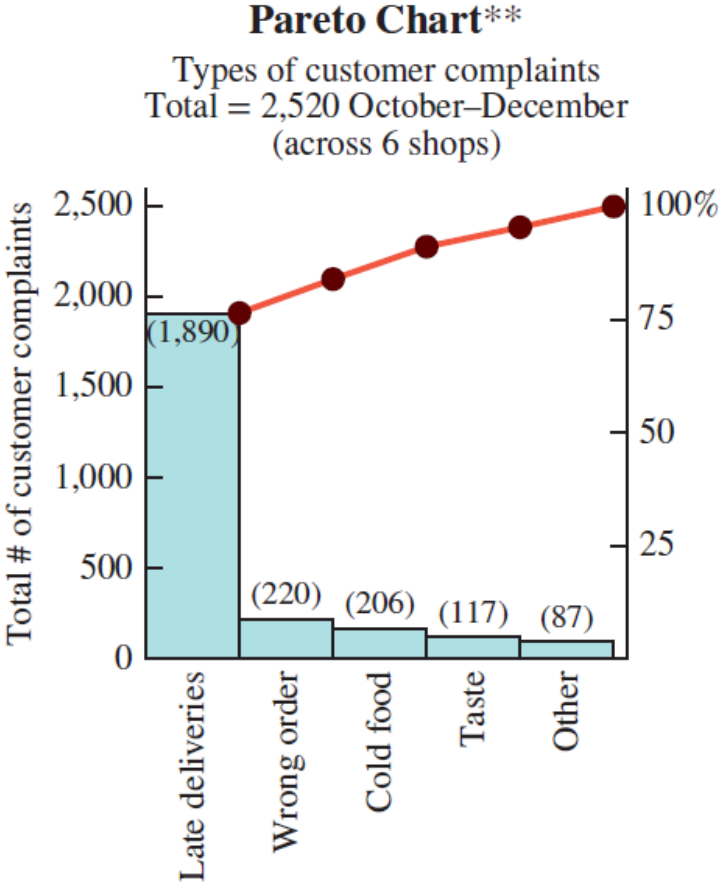


Illustration note: Delivery time was defined by the total time from when the order was placed to when the customer received it.

Cause-and-Effect Diagram (Analyse)

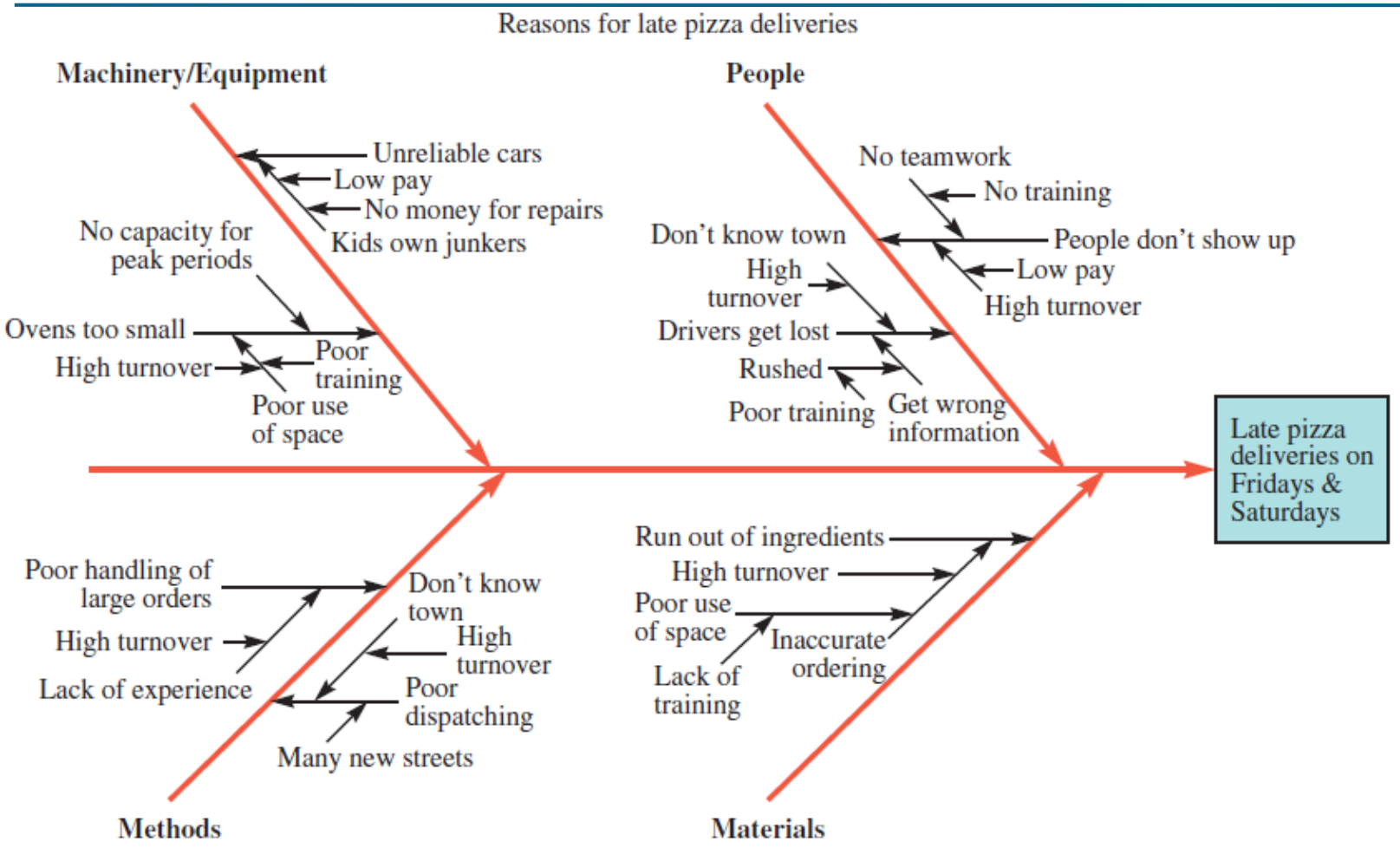


Exhibit 12.5

Opportunity Flow Diagram (Improve)

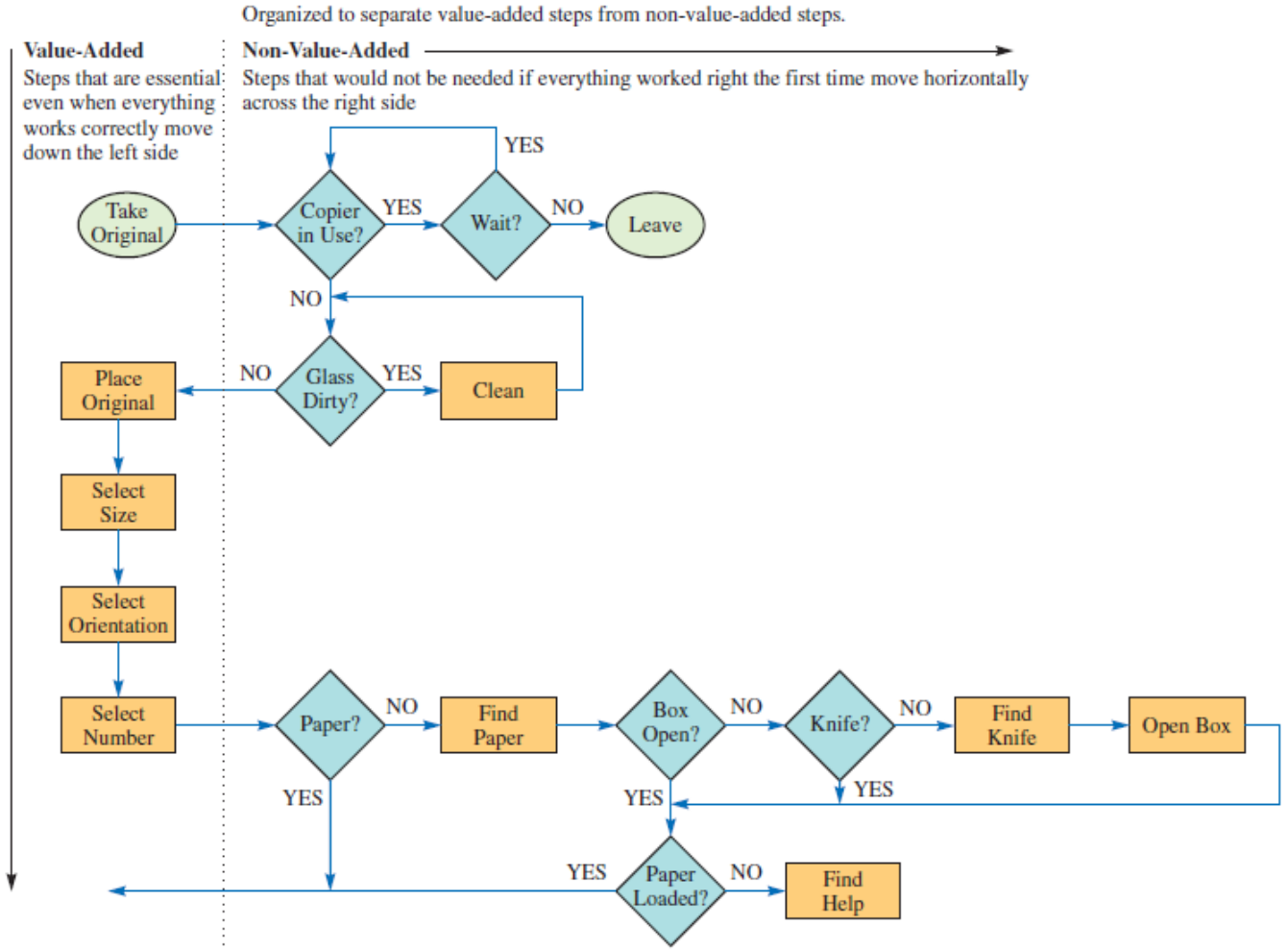


Exhibit 12.5

Process Control Chart (Control)

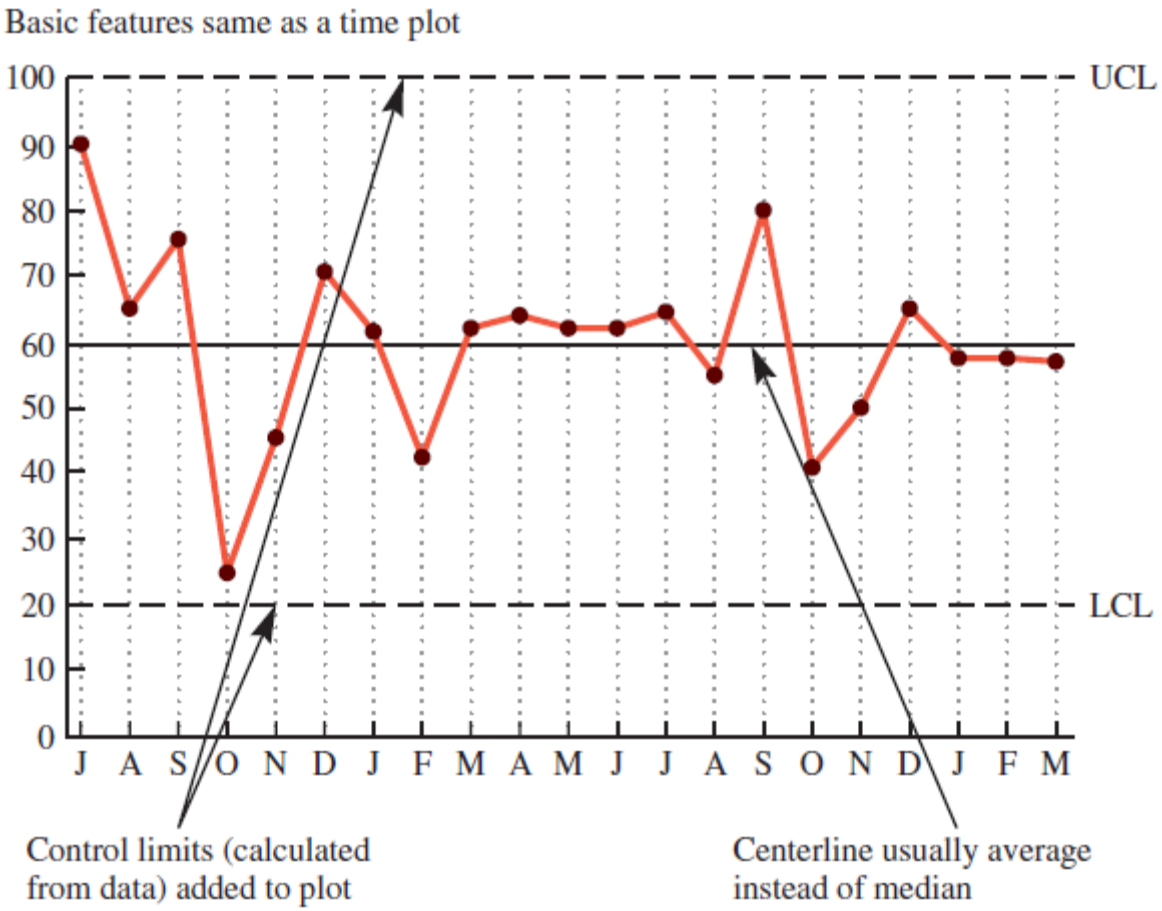


Exhibit 12.5

The Shingo System: Fail-Safe Design

- Shingo's argument:
  - SQC methods do not prevent defects
  - Defects arise when people make errors
  - Defects can be prevented by providing workers with feedback on errors
    1. Successive check
    2. Self-check
    3. Source inspection
- Poka-yoke includes:
  - Checklists
  - Special tooling that prevents workers from making errors

ISO 9000 and ISO 14000

- Series of international standards agreed upon by the International Organization for Standardization (ISO)
  - Adopted in 1987
  - Used in more than 160 countries
- A prerequisite for global competition?
- ISO 9000 an international reference for quality; ISO 14000 primarily concerned with environmental management

Seven Quality Management Principles ISO 9000 Based On

1. Customer focus
2. Leadership
3. Involvement of people
4. Process approach
5. Continual improvement
6. Factual approach to decision making
7. Mutually beneficial supplier relationships

Three Forms of ISO Certification

1. **First party**: a firm audits itself against ISO 9000 standards
2. **Second party**: a customer audits its supplier
3. **Third party**: a "qualified" national or international standards or certifying agency serves as auditor

The South African Excellence Model

- The South African Excellence Model (SAEM) was developed to help companies to deal with the issue of performance excellence
- The model provides a diagnostic self-assessment tool that allows organizations identify their strengths and areas for improvement
- It scores business performance against internationally recognized criteria for performance excellence
- The model has 11 criteria which have been customized to better represent South African needs.

Ladzani, W., 2016. “Benchmarking the South African Excellence Model against worldclass best practice business Excellence Models. Environmental Economics, 7(4), pp. 8-19.

Criteria

1. Leadership
2. Policy and strategy
3. Customer and market focus
4. People management
5. Resources and information management;
6. Processes
7. Impact on society
8. Customer satisfaction
9. People satisfaction
10. Supplier and partnership performance
11. Business results.

1. Customer focus (3)
2. Leadership (1)
3. Involvement of people (4, 9)
4. Process approach (6)
5. Continual improvement (8, 11)
6. Factual approach to decision making (5)
7. Mutually beneficial supplier relationships (10,11)

Ladzani, W., 2016. “Benchmarking the South African Excellence Model against worldclass best practice business Excellence Models. Environmental Economics, 7(4), pp. 8-19.

Summary

- TQM is a comprehensive approach to quality
  - Two goals: design of the produce/service and ensuring consistency
- Quality specifications are fundamental to a sound quality program
- Processes are designed so design specifications are met when the product is produced or the service delivered
- Costs related to quality may be difficult to measure
- Six Sigma projects follow five steps: (1) define, (2) measure, (3) analyze, (4) improve, and (5) control
- Often, fail-safe procedures can be included in a process that guarantees a very high level of quality
- The International Organization for Standardization (ISO) has developed specifications that define best-quality practices
  - The two most accepted specifications are ISO 9000 and ISO 14000